HERRERA

FINAL TECHNICAL MEMORANDUM

Date: June 24, 2022

To: Kira Glover-Cutter, Oregon Department of Transportation (kira.m.glover-cutter@gmail.com)

Copy to: Paul Wirfs, Oregon Department of Transportation (paul.r.wirfs@odot.oregon.gov)

From: John Lenth, Herrera
Sam Nilsson, Herrera
Dylan Ahearn, Herrera

Subject: Stormwater Technology Testing Center Pooled Fund Final Report

EXECUTIVE SUMMARY

The specific aim of this pooled fund project was to provide partial support for calibration of the Stormwater Technology Testing Center (STTC) for future full scale operation. Proper calibration is essential to assure fair, repeatable, and defensible results when measuring maintainability. Main deliverables include: 1) database structure design and website for future STTC users, 2) development of the technology selection process, standard operating procedures, administrative plans, and the maintainability evaluation protocol, 3) configuration of monitoring and control software, and 4) verification through a nearly completed pilot study of facility operation with an installed Stormwater Control Measure. By properly calibrating the STTC together with development of maintainability protocols and established business rules this center can provide designers, owners, and permittees of stormwater treatment technologies with an independent and credible technology assessment that can be systematically compared. Additionally, this facility will enable future research in a controlled setting for institutions nationwide.

CONTENTS

TABLES

FIGURES

INTRODUCTION

Under evolving National Pollution Discharge Elimination System (NPDES) permit requirements, municipalities and private businesses are being held to increasingly stringent standards for the quality of stormwater discharges into the environment. Stormwater control measures (SCMs) are playing a central role in helping permittees meet those standards. Since the early 1990's, technological advances in SCMs have been phenomenal. Once limited to a small number and type of system, the choices now are abundant – though sometimes with mixed results regarding promised performance. To compound the challenge of selecting appropriate SCMs, available data on pollutant removal performance can be limited.

To fill this data gap, several statewide and regional testing and verification programs have been established to obtain data on the pollutant removal performance of emerging SCMs using standardized protocols for controlled laboratory and/or field testing. Examples of these protocols include the Technology Assessment Protocol - Ecology (TAPE), the Technology Acceptance Reciprocity Protocol, and the Laboratory Protocol to Assess Total Suspended Solids Removal by a Filtration Manufactured Treatment Device. While these protocols have provided valuable data for quantifying the pollutant removal performance of SCMs, none of the protocols have specifically focused on quantifying the associated maintenance requirements. For those responsible for the long-term performance of SCMs, information on their maintenance requirements and lifecycle costs is vital.

Recognizing this need, the Oregon Department of Transportation (ODOT) worked collaboratively with numerous public stakeholders in Oregon and Washington to design and construct the Stormwater Technology Testing Center (STTC), a dedicated testing facility located in Portland, OR for evaluating emerging SCMs. The primary goal of testing at the STTC is to evaluate maintenance requirements for these systems based on an established protocol. A secondary goal is to evaluate the pollutant removal performance of SCMs in accordance with the TAPE program.

Construction of the STTC was completed in 2016 and ODOT is now implementing a Pilot Study at the facility with support from Herrera. Leading up to the facility's construction and through the current phase of the pilot study's implementation, Herrera has also worked with ODOT to develop a variety of guidance documentation to support the facility's long-term operation.

A portion of the funding for the STTC's development was obtained through the Transportation Pooled Fund (TPF) Program (Pooled Fund TPF5-355) that is administered by the Federal Highway Administration. This memorandum provides a status update on work that was performed using the TPF to satisfy associated reporting requirements. This memorandum specifically summarizes the following information towards that purpose:

- STTC location and components
- Guidance documentation that has been prepared to support long-term operations
- Status update on the Pilot Study

STTC Location and Components

The STTC was constructed at the Oregon Department of Transportation East Portland Maintenance Yard (Yard) at 5315 Northeast 101st Avenue near Interstate 205 (I-205) and the Columbia Slough in Portland, Oregon (Figure 1). At this location, the STTC occupies a 50-foot by 200-foot fenced area on the western edge of the Yard near the top of the highway embankment for I-205. This area was strategically selected because of its secure location on ODOT private property and proximity to a 7-foot diameter storm drain that provides stormwater needed for testing at the STTC.

As shown in Figure 2, there are three major physical components associated with the STTC:

- Wet Well
- Control Center
- Test Bays

During runoff events used for SCM testing, stormwater from the 7-foot diameter storm drain is diverted to an existing 6-foot diameter wet well through a 3-foot diversion structure (Figure 3). Within this wet well, stormwater is continuously mixed with an air-operated double diaphragm (AODD) pump (Figure 4) to keep suspended solids from settling and pumped through suction tubes using AODD pumps to one of three test bays for SCMs undergoing testing. Stormwater can also be delivered to the test bays using gravity flow under an alternative operating configuration at the STTC. However, to provide maximum control over the test conditions, the default procedure for testing involves the use of the AODD pumps for delivery of this stormwater.

Figure 1. Vicinity map for the Stormwater Technology Testing Center

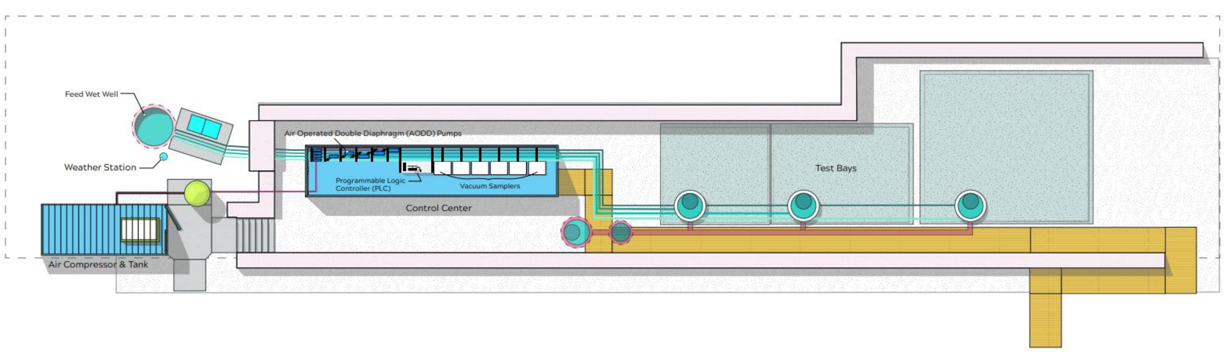

Figure 2. Plan view of major physical components for the Stormwater Technology Testing Center

HERRERA

	
Figure 3. Diversion Structure	**Figure 4. Air-Operated Double Diaphragm Pump**
	
Figure 5. Programmable Logic Controller	**Figure 6. Control Center**
	
Figure 7. Vacuum Auto Samplers	**Figure 8. Test Bays**

The pump discharge rates are regulated by air valves that are controlled by programmable logic controllers (PLCs) (Figure 5). The STTC can provide stormwater to a treatment test bay at controlled discharge rates from 10 to 125 gallons per minute. The AODD pumps (one for mixing and three for delivery of stormwater to the treatment test bays), automated samplers, and facility controller/datalogger are stored in a secure shipping container on-site (hereafter referred to as the control center, see Figure 6). A separate control room also provides storage for surplus materials and ice for sample handling and delivery. Stormwater from the intake wet well is pumped into the control center using suction tubing and out to each of the three treatment test bays through pump discharge tubing.

Three vacuum auto samplers (Figure 7) located within the control center collect influent samples at each of the raw influent stormwater pipes at the test bay for quantifying pollutant concentrations in stormwater that is being delivered to the treatment test bays. Three additional vacuum auto samplers located in the control center collect effluent samples from the outlets of the SCMs installed in each of the test bays to quantify pollutant removal.

The PLC and a Supervisory Control and Data Acquisition (SCADA) system control and log all events and data from the four pumps that drive the system and the six auto samplers. The SCADA system has a graphical user interface allowing for system monitoring and control that is accessible remotely through an internet connection.

SCMs to be tested at the STTC can be placed on one of three gravel test bays (Figure 7) or set up to 4 feet below grade within the test bays. Each bay occupies an area of approximately 16 feet by 18 feet for SCM placement. This will provide room for SCMs with varying physical configurations, including those that are contained in circular manhole structures or in rectangular vaults.

Because stormwater flow will be precisely controlled with the AODD pumps, flow metering is managed by the SCADA system and the AODD pumps. This greatly simplifies the equipment requirements for the STTC while providing precision control of flow to the test bays.

Treated effluent from the SCMs is discharged to an existing below-ground vault located just inside the ODOT East Portland Maintenance Yard adjacent to the STTC. This water then flows to Columbia Slough through existing storm drainage pipes.

Guidance Documentation

As described in the Introduction, a variety of guidance documentation has been developed to support the facility's long-term operation. This documentation generally falls within the following categories:

Technical documentation that describes the procedures that will be used for data collection, analysis, and reporting at the STTC. Also included in this category is documentation to describe standard operating procedures (SOPs) for basic facility operations and maintenance at the facility.

Administrative documentation to support the long-term self-sustaining operation of the STTC. This documentation includes guidance on staffing, communication, advertising, and financial requirements for successful operation of the facility.

Procedural documentation that establishes guidelines and protocols for selecting SCMs for testing and releasing associated results upon completion of the testing.

The specific documentation that was produced in each these categories is identified below. To request this documentation please contact the Oregon Department of Transportation.

- **Technical Documentation**
  - Maintainability Evaluation Protocol
  - Quality Assurance Project Plan
  - Standard Operating Procedure – Startup and Shutdown
  - Standard Operating Procedure – Pump Calibration
  - Standard Operating Procedure – Testing Setup
  - Standard Operating Procedure – Equipment Maintenance
  - Template for computing lifecycle costs
  - Facility plans
- **Administrative Documentation**
  - Advertising and Promotions Plan
  - Communication Plan
  - Financial Control Plan
  - Health and Safety Plan
  - Organization, Management, and Staffing Plan
- **Procedural Documentation**
  - Procedure for release of results from STTC testing

- Protocol for release of testing results
- Protocol for submitting and selecting technologies for testing

Status update on the Pilot Study

In the Fall of 2021, ODOT partnered with a SCM manufacturer and Herrera to conduct a Pilot Study at the STTC. SCMs provided by the manufacturer for the pilot study were installed at the STTC on August 19, 2021. Herrera is now overseeing the collection of stormwater samples following sampling protocols and technical documentation that has been developed for the STTC as described above. The specific goals of the Pilot Study are as follows:

- Complete the configuration and testing of equipment and software at the STTC.
- Refine existing SOPs to guide the long-term operation of the STTC and update existing technical guidance documents for assessing the performance and lifecycle maintenance costs of SCMs.
- Collect relevant data on the performance and maintenance requirements of the test SCMs installed at the STTC facility to support the associated manufacture's research and marketing efforts.

It is anticipated that the Pilot Study will conclude in the Fall of 2022. At that point, the STTC will be fully operational and ongoing testing of both proprietary and nonproprietary SCMs will commence. Costs for this testing will be borne by the SCM manufacturers. Additional funding support for the STTC will also be obtained via membership contributions from "partner organizations" including local municipalities, counties, special districts, and federal or state agencies. ODOT will oversee business and administrative functions for STTC while the actual testing and subsequent data analysis and reporting functions will be managed by Herrera. A Board of directors with representatives from local, state, and federal agencies will also provide high-level input on the STTC's mission and strategic direction. The ultimate goal will be to ensure the STTC is self-sustaining and serving as a national information resource for the professional stormwater community.

The following subsection provide more information on the following topics related to the Pilot Study:

- Monitored events
- Influent chemistry
- Issues and troubleshooting
- Major conclusions

Monitoring Events

To date, 13 storm events have been sampled since the SCMs for the Pilot Study were installed (Table 1). Over the course of this sampling, the facility has generally performed as designed and qualifying storm events were sampled in quick succession except in several instances where maintenance or troubleshooting needs halted sampling efforts (see description below). SOPs for monitoring and maintenance procedures at the STTC that were developed prior to initiating the Pilot Study are now being continuously updated based on lessons learned.

Table 1. Samples Storm Events for the STTC Pilot Study

Technology Tested	Date
Technology 1—Cartridge Filter Vault	10/29/2021
	11/4/2021
	11/11/2021
	12/6/2021
	12/11/2021
	12/15/2021
	1/13/2022
	1/19/2022
Technology 2—Media Filter	3/14/2022
	5/2/2022
	5/5/2022
	5/12/2022
	6/4/2022

Influent Chemistry

Chemistry of the composite stormwater samples collected at the influent stations for the SCMs that were installed for the Pilot Study are presented below in Table 2. Influent stations for these SCMs are located directly at the base of the influent pipe invert within the respective technologies and represent concentrations that are delivered to the test bays (Figure 8).

Concentrations measured in all influent samples met applicable targets that have been established by the TAPE program (Ecology 2018) for SCM performance certifications. Particle size distribution (PSD) has met the TAPE influent criteria of majority silt or finer for all samples collected (n=7). The D50 (the particle size at which 50 percent by weight is finer) for each event has ranged from 5 to 25 microns. This range of D50 is relatively fine and lower than the ideal range of 30 to 60 microns. Efforts to identify and remedy the fine PSD are detailed below.

Table 2. STTC Influent Concentrations

Parameter (Unit)	TAPE Range[a]	Minimum	Median	Maximum	N[b]
TSS (mg/L)	20 – 200	35	85.5	142	12
SSC (mg/L)	None	45.8	92.7	128.6	8
Copper, Total (µg/L)	None	27.1	30.1	33.7	5
Copper, Dissolved (µg/L)	5 – 20	6.98	9.45	12.8	4
Zinc, Total (µg/L)	None	121	184	202	5
Zinc, Dissolved (µg/L)	20 – 300	33.3	47.1	73.5	4
Total Kjeldahl N (mg/L)	None	1.14	1.42	1.64	7
Nitrate+Nitrite (mg/L)	None	0.292	0.386	2.1	7
Total Nitrogen (mg/L)	None	1.43	1.78	2.41	4
Orthophosphate (mg/L)	None	0.01	0.019	0.03	7
Dissolved Phosphorus[b] (mg/L)	None	0.014	0.023	0.042	5
Total Phosphorus (mg/L)	0.1 – 0.5	0.209	0.263	0.352	8
6PPD-quinone (µg/L)	None	0.635	0.635	0.635	1

[a] Ecology 2018

[b] Results for the June 4, 2022, monitoring event have not yet been reported.

[c] One sample reported as non-detect at a reporting limit of 0.02 mg/L was not used in calculation of summary statistics.

TSS: Total Suspended Solids

SSC: Suspended Sediment Concentration

mg/L: milligrams per liter

µg/L: micrograms per liter

Issues and Troubleshooting

Over the course of pilot testing, several issues were encountered that impacted either Pilot Testing schedule or facility operation.

Influent Particle Size Distribution

As discussed above in the Influent Chemistry subsection, influent PSD met applicable TAPE targets but has consistently exhibited D50s below the ideal range of 30 to 60 microns. This fine sediment typically means that treatment technologies will clog and require maintenance more frequently. Since one of the main purposes of the STTC is to determine maintenance requirements and lifecycle costs, identifying a method to increase PSD at the STTC is a high priority.

Samples collected from the main 7-foot storm sewer pipe and settled sediment in the wet well indicate that coarser solids are likely settling out before reaching the test bays. The diversion structure, wet well sump, and flexible suction hose connecting the wet well to the pump house are all likely low energy environments where coarse sediment settles. In addition, once the wet well level is in equilibrium with the water level in the main storm sewer pipe, the velocity in the entire diversion structure and wet well is essentially zero. When the pump is turned on to start the test event, velocity through the diversion structure and wet well increases but remains very low relative to the diameter of the diversion structure which favors coarse sediment settling.

In Spring 2022, the wet well and diversion structure were cleaned with a vac-truck which led to a median D50 increase from 8 microns (n= 4) to 17 microns (n=3). The wet well recirculation pump intakes and outlet were reconfigured to increase energy within the wet well and remobilize settled sediment more efficiently. Increasing the frequency of wet well maintenance, continuing improvements to the recirculation pump, and opening the gravity lines during test events to increase system velocities have been recently implemented. More PSD data is necessary to evaluate the impact of these changes.

PLC–SCADA Communications, Firewall, and Server Maintenance

The pumphouse server went offline due to a malfunctioning firewall in late Winter 2022. The communications between the PLC and SCADA system were offline and the site was not operable until this issue was resolved. Due to privacy concerns and uncertainty over IT-related maintenance duties, no events could be targeted for approximately two months.

A virtual private network (VPN) was set up to allow STTC operators remote access to the pumphouse computer and SCADA system. This VPN is functioning as intended, but due to the frequency of minor on-site troubleshooting, no events have been targeted using the VPN control of the facility. SOPs for pre- and post-storm remote set-up will be refined as this functionality is further tested through the end of the Pilot Study.

PLC and SCADA Programming Bugs

Several bugs have been identified in the PLC or SCADA application (VTSCADA) programming or configuration. When the water level within a treatment technology reaches bypass, the STTC is designed to lower pump discharge rate (or “truncate the hydrograph”) to maintain a water level below the bypass. Due to a bug in the PLC programming, at least one pump is currently increasing pump discharge when bypass is reached. Once this bug was identified, no events were monitored with discharge peaks greater than 75 percent of the technology’s designed flow rate. Actual facility response times and performance in truncating the hydrograph have not been fully tested.

Additional minor bugs identified include pump command flow dropping to 0 gallons per minute for a few seconds in the middle of a test hydrograph, sampler aliquot count increasing on the incorrect sampler, and wrap around errors in sampler pacing volumes above an undefined threshold.

The original programmer of the STTC PLC will be contracted to fix these bugs before regular sampling is resumed in Fall 2022. Long-term technical and programming support still needs to be identified for the STTC.

Miscellaneous Troubleshooting and Maintenance

Additional miscellaneous equipment troubleshooting has included:

- Vacuum samplers could not fully pinch the dosing chamber to create a vacuum and pull sample volume. The samplers' air handlers were malfunctioning and had to be replaced.
- One pump failed during the peak of a hydrograph. The cause was not identified, but the issue has not repeated after reconfiguring pump time-out settings.
- Vacuum samplers PLC-controlled program reached maximum sample number halted sampling. Until a permanent fix is identified, sampler programs are restarted regularly.

Major Conclusions

The specific goals of the Pilot Study are anticipated to be met by its conclusion. Despite a few issues and potential modifications, most equipment and functionality of the STTC has already been tested. SOPs were developed at the start of the Pilot Study and have been continuously updated as procedures are refined, and the data collected during monitoring events have for the most part been useful to the SCM manufacturer. Continued modifications and testing of equipment and programming at the STTC will likely continue to a lesser extent past the conclusion of the Pilot Study. Likewise, SOPs will continue to be refined as these modifications are implemented and as operators become more experienced with the facility.

TPF Partners and Technical Advisory Committee

The scope of work for this pooled fund was completed by Herrera. TPF contributing partners included Pennsylvania, Washington, and California Departments of Transportation as well as the Port of Portland. The Technical Advisory Committee (TAC) evolved as the project progressed and included individuals from each contributing partner. The final TAC Meeting included:
Paul Wirfs (Oregon Department of Transportation)
Kira Glover-Cutter (Oregon Department of Transportation)
Doug Howie (Washington Department of Ecology)
Daryl St. Clair (Pennsylvania Department of Transportation)
Rich Hineman (Pennsylvania Department of Transportation)
Bhaskar Joshi (California Department of Transportation)
Alex Nguyen (Washington Department of Transportation)
Nich Hehemann (Washington Department of Transportation)
Josh Gualco (Washington Department of Transportation)
Elsa Pond (Washington Department of Transportation)
Tony Bush (Washington Department of Transportation)
Cory Engel (Oregon Department of Transportation)
John Lenth (Herrera)
Dylan Ahearn (Herrera)