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Evaluating the Performance of Contech's StormFilter with ZPG Media Under the
City of Portland's 2016 Stormwater Management Manual Requirements for
Manufactured Stormwater Treatment Technologies

BY

Mawj Khammas

A research project report submitted in partial fulfillment
of the requirement for the degree of

MASTER OF SCIENCE
IN
CIVIL AND ENVIRONMENTAL ENGINEERING

Project Advisor:
Dr. William Fish

Portland State University
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- Dr. William Fish provided guidance and advice
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- The Civil and Environmental Engineering department at Portland State University has supported my work
- My mother and my family

ABSTRACT

Stormwater runoff is the water generated from excess rainfall or snowmelt that flows over impervious surfaces such as paved roads, parking lots, and on roofs, it often carries a variety of pollutants that adversely affect water quality in that region. Portland is a well-developed city; the majority of the streets are paved and impervious and will consequently generate a tremendous amount of stormwater this creates the necessity for management to help preserve and mimic natural hydrologic cycle through improving water quality. The StormFilter® with ZPG media, manufactured by CONTECH, is a manufactured stormwater treatment technology(MSTT) in which zeolite, perlite, and granular activated carbon are used. The device has a current Routine Use Level Designation (GULD) for basic treatment from the Washington State Department of Ecology (WA DOE) under the Technology Assessment Protocol-Ecology (TAPE). Storm data from two different sites were used to evaluate the performance of The StormFilter-ZPG with respect to Portland's pollution reduction requirements, as prescribed in the 2016 Stormwater Management Manual (SWMM). The results of the evaluation suggest approving the device for use in the City of Portland at the TAPE-approved flow rate of 1 gpm/ft².

TABLE OF CONTENTS

1.0	INTRODUCTION.....	1
2.0	STORMWATER POLLUTION OVERVIEW	3
2.1	STORMWATER POLLUTANTS	4
	Total Suspended Solids (TSS)	4
	Heavy metals.....	5
	Chlorides	5
	Nutrients.....	5
	Polycyclic Aromatic Hydrocarbons (PAHs)	6
	Biochemical Oxygen Demand (BOD5)	6
	Pathogens	6
3.0	LAND COVER EFFECT ON GENERATED STORMWATER RUNOFF	10
4.0	SOURCES OF URBAN STORMWATER CONTAMINANTS.....	12
	Activity Related	12
	Land Related.....	12
	Atmospheric Deposition.....	13
	Behavior Related	13
5.0	TECHNOLOGY ASSESSMENT PROTOCOL- ECOLOGY (TAPE).....	15
6.0	STORMFILTER-ZPG MEDIA THIRD PARTY EVALUATION PROCESS	18
7.0	STORMFILTER-ZPG MEDIA BACKGROUND	20
8.0	TECHNOLOGY DESCRIPTION.....	21
9.0	STORMFILTERS - ZPG MEDIA SIZING PROTOCOL	25
10.0	ANTICIPATED LONG-TERM PERFORMANCE AND MAINTENANCE.....	27
11.0	PERFORMANCE TEST SITES DESCRIPTION.....	29
	11.1 HERITAGE MARKETPLACE.....	29
	11.2 LAKE STEVENS	30
12.0	STORMFILTER - ZPG MEDIA TESTING PERFORMANCE	32
13.0	REVIEW& EVALUATION FINDINGS.....	36
14.0	CONCLUSION	38

15.0	REFERENCES.....	39
16.0	APPENDIX – MORE ADDITIONAL INFORMATION.....	41
16.1	FINAL REPORT SUBMITTED TO THE CITY OF PORTLAND.....	41
16.2	TECHNICAL INTERVIEW QUESTIONS.....	50

LIST OF TABLES

Table 1: Effect of water Quality impairment on habitat 8

Table 2: Common Urban Stormwater contaminants (EPA. 2015). 9

Table 3: Median Event Mean concentration of main stormwater pollutants for different Urban Land Uses (US EPA 1983). 11

Table 4: TAPE Basic & Dissolved metals Treatment criteria (Howie. 2011). 16

Table 5: TAPE Phosphorus, oil and pretreatment removal criteria (Howie. 2011). 16

Table 6: Comparison in TSS removal between WA (DOE) goals and Portland’s requirements. 17

Table 7: CONTECH stormFilter-ZPG media GULD revision history (GULD for CONTECH .2017). 20

Table 8: Sizing estimates for StormFilter with ZPG media use in City of Portland (CONTECH. 2016). 25

Table 9: Approved GULD rates per cartridge at 1 GPM/FT (CONTECH. 2016). 26

Table 10: Best annual plan for maintenance activities. (CONTECH. 2016). 27

Table 11: StormFilter maintenance activities (CONTECH. 2016). 28

Table 12: Sediment size comparison between the two sites (CONTECH application. 2016). 31

Table 13: Qualified storms with aggregate TSS load reduction (CONTECH application. 2016) 33

Table 14: Efficiency Calculations Submitted by Stormwater Management, Inc. as part of the WA DOE TAPE Technical Evaluation Report (TER) for the StormFilter with ZPG (2004a). 34

Table 15: WA TAPE Goals vs. Portland Requirements vs. TAPE Testing Results for the StormFilter with ZPG 36

LIST OF FIGURES

Figure 1: Urban runoff pollution sources and impacts (Tsihrintzis and Hamid, 1997).....	4
Figure 2:Urban stormwater runoff non -point pollution sources (Petrucci et al. 2014)	14
Figure 3: City of Portland review process and timeline (SWMM. 2016).....	19
Figure 4: Cartridges in empty vault	22
Figure 5: Water is high, float not risen yet	22
Figure 6: Float is up, water is passing through the underdrain system.....	23
Figure 7: Water level has dropped, siphon begins to collapse, air scouring outside of the cartridge media	23
Figure 8: Sediment falling to the bottom of the cartridge as a reaction to the collapsing siphon.	24
Figure 9: Remaining water drains, imperfect seal at the base of the float.....	24
Figure 10: Aerial view of the Heritage Marketplace StormFilter site (CONTECH product evaluation. 2006)	30
Figure 11: Aerial view of the Lake Stevens North StormFilter site (CONTECH product evaluation. 2006).	31
Figure 12: The graph compares the City of Portland’s treatment criteria against the performance of the ZPG-filter. Most of the storm effluent concentrations lie below Portland’s criteria.....	35

1.0 INTRODUCTION

Stormwater runoff represents a significant non-point source (NPS) of contamination to water bodies. From the onset of a rain event, rain can either infiltrate the soil, evaporate or migrate above different surfaces carrying various contaminants until it reaches receiving water bodies (Tsihrintzis and Hamid, 1997) as shown in Figure 1. Polluted stormwater could adversely affect groundwater as well as surface water and cause degradation in species and fish mortality and most importantly affect human health. A report in early Nineties revealed that in the U.S. stormwater runoff is ranked as the second largest source of pollution in lakes and estuaries and as the third largest source of pollution in rivers (Lee and Jones-Lee, 1994). The Clean Water Act (CWA), created in 1972 set basic regulations for discharging pollutants into surface water bodies in the United States. Under this law, all municipal, industrial and commercial sources that discharge wastewater or stormwater from point source must get a National Pollutant Discharge Elimination System (NPDES) permit to regulate water quality in surface waters. The NPDES stormwater program regulates stormwater discharge to prevent stormwater runoff from washing harmful pollutants into local surface water. The city of Portland has established NPDES under the CWA. The Oregon Department of Environmental Quality issued the first permit for the city in 1995. The license is formally called the Phase I, National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Discharge Permit. DEQ renewed it for a second term in 2004. Finally, the final third-term permit was issued on January 31, 2011, and expired on January 30th, 2016 and has been organizationally extended by the DEQ. The city of Portland has issued a manual, the stormwater management manual (SWMM) that contains all the city's stormwater pollution management strategies. An essential part of the SWMM is Appendix B which has all the rules and requirements needed from any vendor who intends to present their technology to the city of Portland. Each vendor must follow Appendix B to ensure and to prove that their device is capable

of meeting Portland's requirements and guidelines. Washington State has also developed a stormwater management plan (2008) that is used statewide called Technology Assessment Protocol Ecology (TAPE) (Howie, 2011). In this report, I will discuss my review and evaluation of a manufactured stormwater treatment technology (MMST) made by a company called CONTECH, which has been awarded General Use Level Designation (GULD) under TAPE process from Washington State Department of Ecology (WA DOE). The device is called StormFilter- ZPG media, in which zeolite, perlite, and granular activated carbon are used to trap total suspended solids (TSS) in particular. TSS is given a top priority because it is considered a tracer and evidence for the presence of various other contaminants such as metals, oil and grease, agricultural chemicals, nutrients, hydrocarbons, debris and litter and pathogens. Removal of TSS implies the removal of the associated pollutants. The device was formally approved, in 2002, by the City of Portland, and has been successfully applied in many public and private sites to meet water quality requirements for stormwater, generated runoff. The vendor has reapplied to the City of Portland to get approval for MSTT, under SWMM Appendix B, and my evaluation was done as a part of third party reviewal by Portland State University (PSU).

2.0 STORMWATER POLLUTION OVERVIEW

Stormwater contaminants vary from one place to another depending on many factors such as surface type, land use, and human activities. In addition, different surfaces generate different stormwater content. For instance, surfaces with depressions more easily retain pollutants than a relatively smooth surface. Rough surfaces such as asphalt tend to produce higher contaminant concentrations in the runoff rather than concrete surfaces, because more pollutant will get attached into the asphalt during periods of dry weather hence higher contaminant availability for wash-off (Liu et al. 2014). So, choosing the most effective stormwater treatment design is very crucial in preventing or minimizing stormwater deterioration. Land use and human activities such as construction sites have a significant impact on the amount and variety of pollutants that are added to the runoff. Furthermore, other factors like geographic, meteorological and geologic characteristic of the particular area will affect human activities. (Figure 1) below represents urban runoff contamination sources and different impacts on water bodies and other aspects such as human health, fish mortality and species diversity.

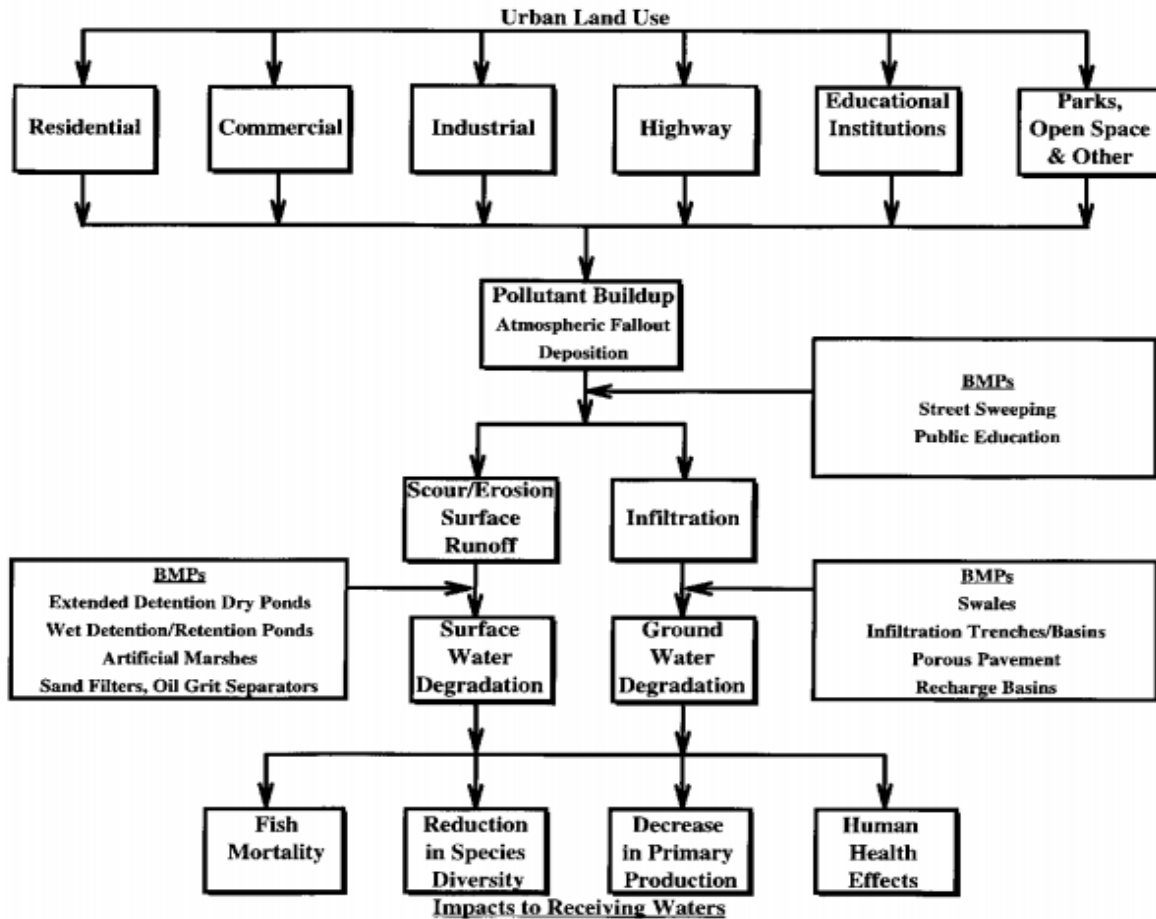


Figure 1: Urban runoff pollution sources and impacts (Tsihrintzis and Hamid, 1997).

2.1 Stormwater Pollutants

The following contaminants are typically found in urban stormwater:

Total Suspended Solids (TSS)

They are considered the main target of removal in any treatment technology. Street dust is the main source of TSS in stormwater and the main cause of its turbidity. Also, more dangerous pollutants tend to adhere to fine TSS particles posing additional contamination problems.

Heavy metals

Industrial and commercial land use represent the largest source of heavy metal contribution to the runoff. However, runoff originating from vehicles and traffic related deposits contains the most toxic pollutants like lead deposits from leaded fuel, oxides of lead and zinc from tire wear, copper, and nickel. Certain heavy metals (e.g., copper, lead and zinc) are more soluble in water than others and may cause serious toxic effects at levels exceeding threshold values (Novotny et al. 2008).

Chlorides

Salt is applied in winter in many parts of the U.S. to prevent snow from adhering to the pavement, hence creating slippery conditions and unsafe driving roads. The primary agent used for deicing is rock salt (NaCl). The annual usage of NaCl for this purpose has been increasing dramatically from 163,000 tons in 1940 to 23 million ton in 2005 according to United States Geological Survey (USGS). Salts can either wash off to receiving waters through runoff or percolate to groundwater.

Nutrients

Urban stormwater runoff may carry elevated concentrations of phosphorus (P), and nitrogen (N), compounds that can leach in to receiving water bodies and cause eutrophication. The main source of these nutrients is agricultural runoff where soil amendments and fertilizers are used. In urban areas, the main source of nutrients is industrial discharge, detergents, animal waste and fertilizers (Zahraa.2013). Most of the stormwater runoff P load is particulate, while available algal P comes from mainly soluble P and only 20% of the particulate P. Therefore, about 80% of the stormwater particulate P doesn't support algal growth (Lee and Lee. 2005).

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons a ubiquitous organic compound released by both natural combustion processes and anthropogenic activities. Many PAHs have been identified as known or suspected human carcinogens. The United States Environmental Protection Agency (US EPA) lists PAHs as one of the compounds most likely to be associated with Tier 1 impacted aquatic sediments, where "adverse effects on aquatic life or human health are probable" (Alison et al. 2010). The main human source of PAHs is truck and automobile exhaust, emitted into the atmosphere. These PAHs scrubbed by rainfall and constitute vital source of runoff contamination and hydrocarbon build-up and accumulation (Tsihrintzis and Hamid. 1997). It is estimated that 70% of the total PAHs found in receiving waters are related to urbanization and traffic density represented in highway runoff.

Biochemical Oxygen Demand (BOD₅)

BOD₅ is a water pollutant as well as a useful indicator of other contamination. The conventional sources of BOD₅ is usually from vegetation, litter and garbage and animal waste. Elevated BOD will induce higher oxygen demand and can drive water bodies to anoxic or anaerobic conditions due to oxygen depletion. Under anaerobic conditions, metals and nutrients are released from sediments faster than they should be. A typical BOD₅ concentration of 12 mg/L was observed in stormwater discharge from nationwide urban runoff program NURP, EPA.

Pathogens

Pathogens include viruses, bacteria and protozoa. In general, coliform bacteria are used as an indicator for the presence of other pathogens in water. Some studies have shown elevated levels

of coliform bacteria in stormwater, especially in dry weather flow. The most important source of pathogens is septic systems and illicit connections from toilets to storm sewer pipes. Determinations regarding pathogen impairment are based on the comparison between fecal indicator bacteria (FIB) such as *Escherichia coli* (*E. coli*), enterococci or fecal coliform concentrations to similar water body standards and classifications (Urban Water Resources Research Council. 2014).

All the mentioned stormwater contaminants and others cause numerous complications affecting water quality, water quantity, public health, aesthetic appearance of urban waterways and aquatic habitat and biological resources. The most adverse impact of urban stormwater on receiving waters is the alteration of species distribution, degradation of native species with the growing of pollutant tolerant and less sensitive species. (Table 1), emphasize water quality parameters that have a significant effect on habitat (EPA.2014)

Table 1: Effect of water Quality impairment on habitat

Water Quality Parameter	Habitat Effect
Bacteria	Contamination
Heavy metals	Alteration of species distribution
Toxic organics	Alteration of species distribution
Nutrients	Eutrophication, algal blooms
Sediment	Decreased spawning areas
BOD	Reduced dissolved oxygen levels
Temperature	Reduced dissolved oxygen levels
pH	Alteration of species distribution

Contaminants commonly found in urban stormwater runoff and their source are summarized in (Table 2).

Table 2: Common Urban Stormwater contaminants (EPA. 2015).

Contaminant	Contaminant Sources
Sediment and Floatables	Streets, lawns, driveways, roads, construction activities, atmospheric deposition, drainage channel erosion
Pesticides and Herbicides	Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil wash-off
Organic Materials	Residential lawns and gardens, commercial landscaping, animal wastes
Metals	Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, corroding metal surfaces, combustion processes
Oil and Grease/ Hydrocarbons	Roads, driveways, parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains
Bacteria and Viruses	Lawns, roads, leaky sanitary sewer lines, sanitary sewer cross-connections, animal waste, septic systems
Nitrogen and Phosphorus	Lawn fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents

3.0 LAND COVER EFFECT ON GENERATED STORMWATER RUNOFF

The pollutants mentioned found in general, but different surfaces will yield different ranges of contaminants. Also, runoff generated from urban and non-urban sites is entirely different. Since the inception of water quality act in 1965, many intensive types of research and studies have been done in the urban stormwater field to characterize its nature to apply the most suitable Best Management Practices (BMPs). EPA's Nationwide Urban Runoff Program (NURP); did a comprehensive study between 1978 and 1983 of urban runoff characteristics and the effect of land use on the type of the runoff. Sampling was conducted for 28 NURP projects which included 81 specific sites and more than 2,300 different storm events. (Table 3), lists the median event mean concentration (EMCs) for ten general NURP pollutants for various land use categories. It shows that, for urban sites, pollutant concentrations do not significantly vary with land use categories. However, a significant difference is found between urban and non-urban areas (US EPA 1983).

Table 3: Median Event Mean concentration of main stormwater pollutants for different Urban Land Uses (US EPA 1983).

Pollutant	Units	Residential		Mixed		Commercial		Open/ Non-Urban	
		Median	COV	Median	COV	Median	COV	Median	COV
BOD	mg/l	10	0.41	7.8	0.52	9.3	0.31	--	--
COD	mg/l	73	0.55	65	0.58	57	0.39	40	0.78
TSS	mg/l	101	0.96	67	1.14	69	0.85	70	2.92
Total Lead	µg/l	144	0.75	114	1.35	104	0.68	30	1.52
Total Copper	µg/l	33	0.99	27	1.32	29	0.81	--	--
Total Zinc	µg/l	135	0.84	154	0.78	226	1.07	195	0.66
Total Kjeldahl Nitrogen	µg/l	1900	0.73	1288	0.50	1179	0.43	965	1.00
Nitrate + Nitrite	µg/l	736	0.83	558	0.67	572	0.48	543	0.91
Total Phosphorus	µg/l	383	0.69	263	0.75	201	0.67	121	1.66
Soluble Phosphorus	µg/l	143	0.46	56	0.75	80	0.71	26	2.11

COV: Coefficient of variation

4.0 SOURCES OF URBAN STORMWATER CONTAMINANTS

In general, nonpoint sources of urban stormwater pollutants can be divided into activity- related, land- related, behavior- related and atmospheric deposition (Petrucci et al. 2014). Knowing the source of stormwater is a useful way to predict and to expect which pollutants could be present.

Activity Related

The main human activities that generate a tremendous amount of pollutants are road transport emissions, railway transport emissions and domestic heating (Petrucci et al. 2014). Coal and wood are considered the more pollution-causing type of fuels, although their use is limited in the urban area. Specific studies on particular catchment have shown that human activities are the cause of copper (Cu) and polycyclic aromatic hydrocarbons (PAHs) contamination, through brake pad wear and tire wear respectively (Petrucci et al. 2014)

Land Related

Building roofs imperviousness and infrastructure generate runoff. They can add a substantial number of contaminants to stormwater depending on the material of manufacture. For instance, infrastructure materials such as train and tramway catenaries, guardrails, urban lights road panels and markings are considered significant metal sources, a result of a particular study has shown that land cover materials are responsible for lead (Pb) and zinc (Zn) Pollution (Petrucci et al. 2014)

Atmospheric Deposition

Fraction of the land-emitted pollutants is transferred to the atmosphere, pollutants from various sources are mixed, finally, some atmospheric pollutants can re-enter the land and pass through urban runoff either through wet deposition, dry deposition or a combination of a set of processes.

Behavior Related

The emission of some pollutants is strongly related to individual human or institutional behavioral activities, such as the usage of pesticides, biocides, fertilizers or other chemicals. Assessing and controlling these emissions is very complicated, so strong knowledge of local traditions, regulations, and practice, social and economic conditions must be determined (Petrucci et al. 2014).

(Figure 2) below summarizes the Non-point contamination sources.

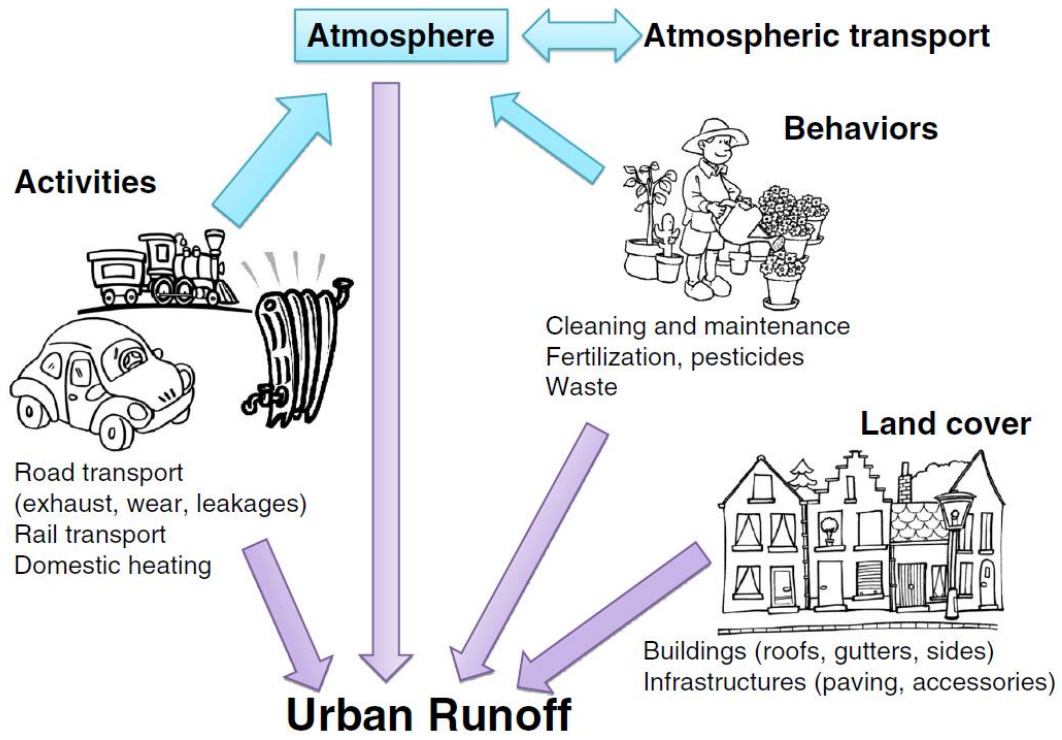


Figure 2:Urban stormwater runoff non -point pollution sources (Petrucci et al. 2014)

5.0 TECHNOLOGY ASSESSMENT PROTOCOL- ECOLOGY (TAPE)

TAPE is a Washington State protocol that provides certification for emerging stormwater treatment technologies, corresponding to one or more of the five performance goals (Table 4), (Table 5) and the design criteria and performance goals for stormwater treatment facilities. Ecology evaluates the technology to assign the use level designation that determines the number of installations that maybe installed in Washington and the monitoring requirement needed for them to obtain additional performance data. There are two categories of use level designation. Ecology will place any technology under one of two application levels.

- Pilot use level designation (PULD), when there are sufficient lab data indicates that the technology's performance meets TAPE.
- Conditional use level designation (CULD), when there is a field data in addition to lab data that indicates the technologies' performance will more likely meet TAPE goals.

The PULD and CULD allow the device to be installed and operated in the state of Washington to gather more performance and monitoring data as a preparation for the final general use level designation (GULD) certification (Howie. 2011). TAPE certification is given when the new technology has successfully met TAPE performance goals when properly installed, operated and maintained. Several states and local jurisdiction use TAPE certification to determine whether the new technology can or cannot be installed within their jurisdiction.

Table 4: TAPE Basic & Dissolved metals Treatment criteria (Howie. 2011).


Performance Goal	Influent Range	Criteria ^a
Basic Treatment	20-100 mg/L TSS	Effluent goal \leq 20 mg/L TSS
	100-200 mg/L TSS	\geq 80% TSS removal
	> 200 mg/L TSS	> 80% TSS removal
Dissolved Metals Treatment	Dissolved copper 0.005 - 0.02 mg/L	Must meet basic treatment goal and better than basic treatment currently defined as >30% dissolved copper removal
	Dissolved zinc 0.02 - 0.3 mg/L	Must meet basic treatment goal and better than basic treatment currently defined as > 60% dissolved zinc removal

Table 5: TAPE Phosphorus, oil and pretreatment removal criteria (Howie. 2011).

Performance Goal	Influent Range	Criteria ^a
Phosphorus Treatment	Total phosphorus (TP) 0.1 to 0.5 mg/L	Must meet basic treatment goal and exhibit \geq 50% TP removal
Oil Treatment	Total petroleum hydrocarbon (TPH) > 10 mg/L	1) No ongoing or recurring visible sheen in effluent 2) Daily average effluent TPH concentration < 10 mg/L 3) Maximum effluent TPH concentration of 15 mg/L for a discrete (grab) sample
Pretreatment ^b	50-100 mg/L TSS	\leq 50 mg/L TSS
	\geq 200 mg/L TSS	\geq 50% TSS removal
<p>a. See TAPE Technical Guidance Manual for further details.</p> <p>b. Pretreatment technologies generally apply to (1) project sites using infiltration treatment and (2) treatment systems where pretreatment is needed to ensure and extend performance of the downstream basic or dissolved metals treatment facilities.</p> <p>mg/L - milligrams per liter TP - total phosphorus TPH - total petroleum hydrocarbons TSS - total suspended solids</p>		

StormFilter-ZPG media, which is evaluated in this paper, has been awarded GULD for basic treatment, removal of TSS. However, a sufficient knowledge of Portland’s TSS removal requirements is still essential for the City of Portland to assess the usage of any technology in the area. Because of the difference in Portland and Washington requirements, it is vital to investigate any technology before implementing and using in Portland regardless of the similarities between the two cities regarding climate and geographic land cover (Zahraa. 2013). Table 6, illustrates the differences in TSS removal in both, and as can be seen, Washington Department of Ecology WA (DOE) has stricter rules. In general, if the device was accepted in the state of Washington under TAPE process, and was awarded GULD, it will probably be accepted in Portland after review and third-party evaluation from Portland State University. The assessment process involves many stages that will be covered in the following pages.

Table 6: Comparison in TSS removal between WA (DOE) goals and Portland’s requirements.

	<u>WA TAPE goals</u>	<u>Portland requirement</u>
<p style="text-align: center;">TSS</p>	<ul style="list-style-type: none"> - 80% removal with influent concentration 100-200 mg/L - < 20mg/L effluent if influent concentration < 100 mg/L 	<ul style="list-style-type: none"> - 70% removal if influent concentration is > 70 mg/L - < 20mg/L with influent <100 mg/L

6.0 STORMFILTER-ZPG MEDIA THIRD PARTY EVALUATION PROCESS

The assessment process involved:

1. The vendor's (CONTECH) public presentation, in which they discussed their technology, long time performance and maintenance.
2. Technical interview that is not open to the public and consists of answering questions that were submitted to them two weeks prior, based on a preliminary review of the submitted materials. The questions were prepared by myself after being revised from Dr. William Fish, both representing the third party, and from other team members from the city representing the review committee.
3. A deep study of their material, TAPE and GULD findings of fact, technology evaluation engineering report (TEER) and Portland's storm water management manual SWMM, especially chapter 2, section 2.4.8., all were used to construct a third-party evaluation report. The report analyzed all the qualified storm criteria and the average pollutant reduction and loading rate. Eventually, a recommendation was made based on the review process, and the report submitted to the city for corrections and editing before publishing the final report. Both the final draft and the technical presentation questions are in the Appendix for reference.

(Figure 3) below, summarizes the MSTT reviewing process and timeline for all three parties: PSU, vendor and the City of Portland represented by the BES.

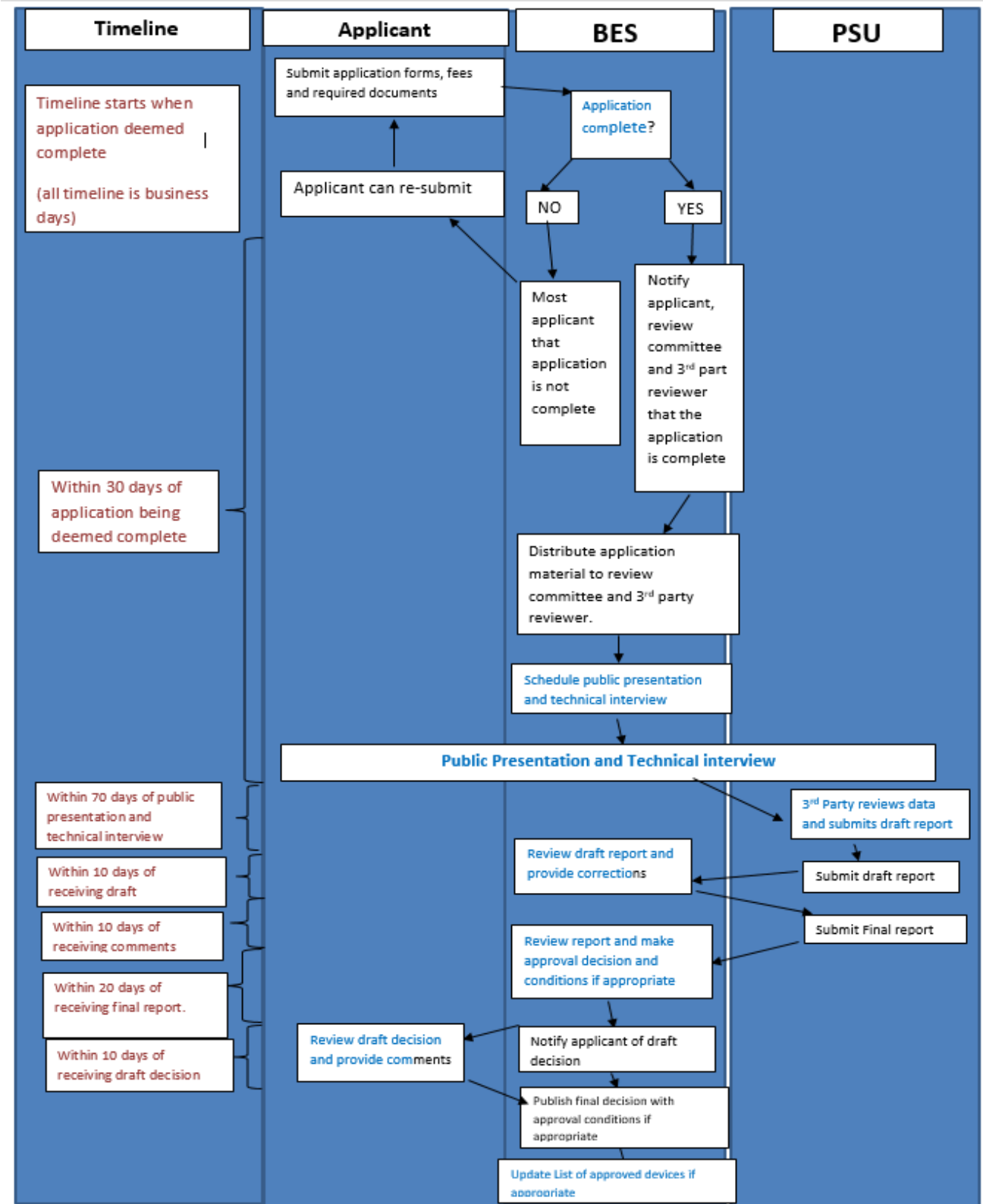


Figure 3: City of Portland review process and timeline (SWMM. 2016)

7.0 STORMFILTER-ZPG MEDIA BACKGROUND

The device was formally approved in 2002 by the City of Portland and has been successfully applied in many public and private sites to meet water quality requirements for stormwater runoff. In addition, it was awarded GULD certification for Basic Treatment by the Washington Department of Ecology in January 2005 under the TAPE process. Since then, GULD was expanded to include other changes and modifications due to Ecology's sizing requirements ([ftp://ftp02.portlandoregon.gov/BES/SWMM PSU COP](ftp://ftp02.portlandoregon.gov/BES/SWMM_PSU_COP)). The most recent update of GULD certification was in April 2017 (GULD for CONTECH .2017) (Table 7). According to 2014 City of Portland Stormwater Management Manual (SWMM), all approved technologies have a three-year expiration date, after which they must resubmit their information to the city for re-approval. In January 2017 Contech Stormfilter resubmitted their application to the city at the previously approved water quality and flow rates of 2005.

Table 7: CONTECH stormFilter-ZPG media GULD revision history (GULD for CONTECH .2017).

Date	Revision
Jan 2005	Original Use Level Designation
Dec 2007	Revision
May 2012	Maintenance requirements updated
November 2012	Design Storm and Maintenance requirements updated
January 2013	Updated format to match Ecology standard format
September 2014	Added Peak Diversion StormFilter Alternate Configuration
November 2016	Revised Contech contact information
April 2017	Revised sizing language to note sizing based on Off-line calculations

8.0 TECHNOLOGY DESCRIPTION

The StormFilter is an inline, media-filled cartridge system that removes pollutants from stormwater runoff. The system is contained in a precast concrete vault that can be designed in multiple configurations and sizes. Each filter is designed to treat a specific flow rate, which can be controlled through a calibrated reducer disk at the base of the cartridge. StormFilters may include an internal bypass in case flow rates exceed the capacity of the cartridges. In case the site generates a flow that exceeds the internal bypass capacity, a peak diversion configuration must be used, which integrates the diversion weir with the filter bay into the same vault structure.

The StormFilter® with ZPG, which is the subject of this review, is expressly designed to remove Total Suspended Solids (TSS) from stormwater runoff. The media is comprised of zeolite, perlite, and granular activated carbon (GAC). The outer layer is 100% perlite; the inner layer is a mixture of 90% Zeolite and 10% GAC. Many physical processes contribute to the treatment of the stormwater: filtration, by trapping the suspended particles in the ZPG media, ion exchange, adsorption and precipitation for larger particles. Cartridges are housed in a vault and receive stormwater horizontally through the inlet pipe. Stormwater passes through the filtration media (ZPG) and begins filling the cartridge's center tube. When water reaches the top of the cartridge, the float valve opens, and filtered water can drain at the design flow rate. Treated water is then released out of the system through the under-drain manifold. When the water level outside the cartridge moves toward the base of the hood, air will rush through the scrubbing regulators, releasing the water column and breaking the siphon as shown in Figure 4 through Figure 9). The chaotic bubbling movement disturbs the filter media surface, triggering trapped sediment to sink to the vault floor. This surface cleaning mechanism helps restore the permeability of the filter surface between storm events.



Figure 4: Cartridges in empty vault

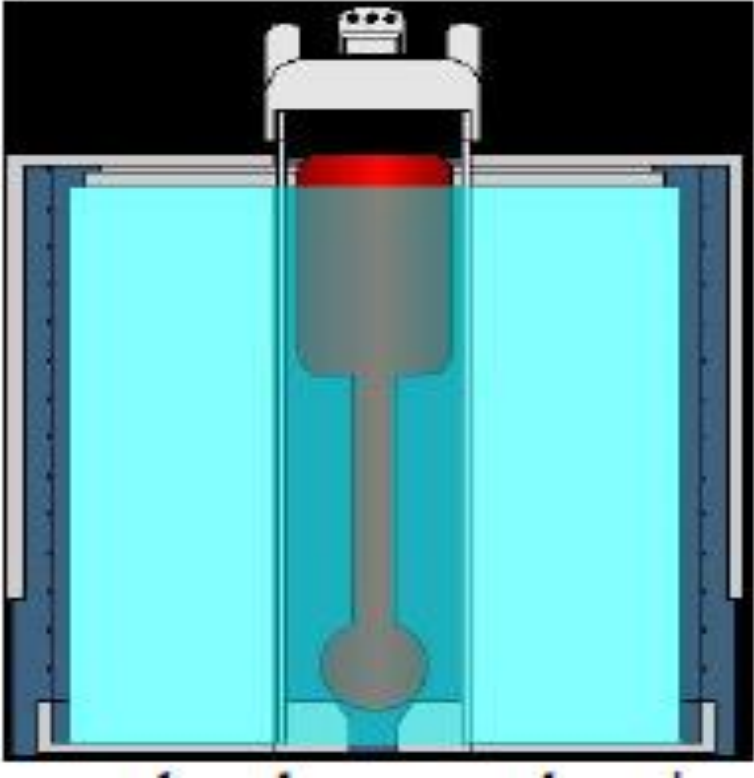


Figure 5: Water is high, float not risen yet

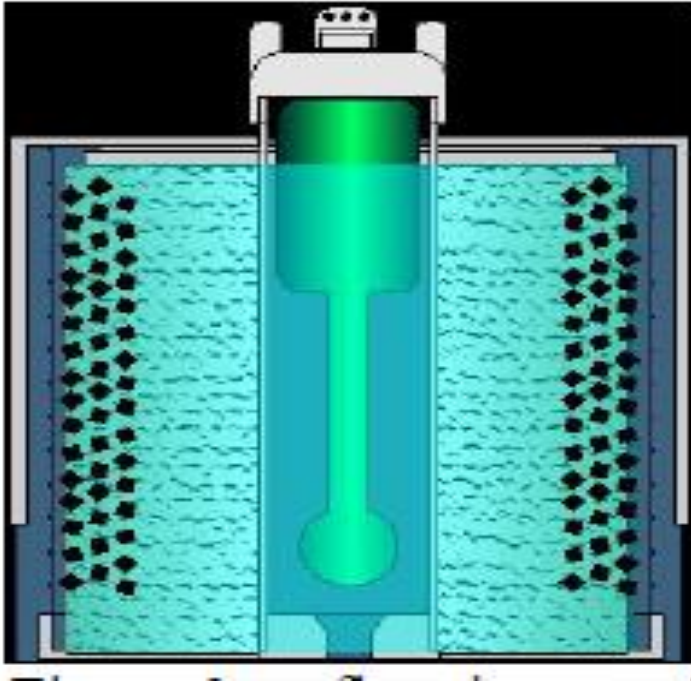


Figure 6: Float is up, water is passing through the underdrain system

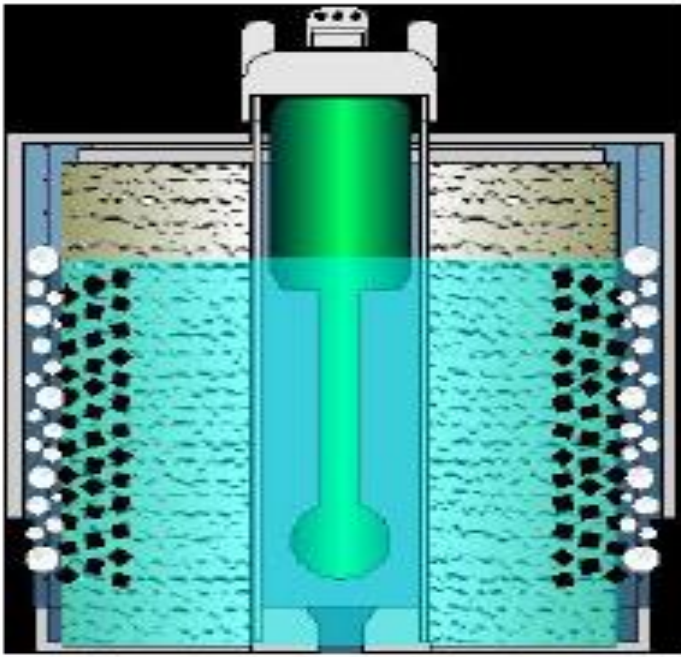


Figure 7: Water level has dropped, siphon begins to collapse, air scouring outside of the cartridge media

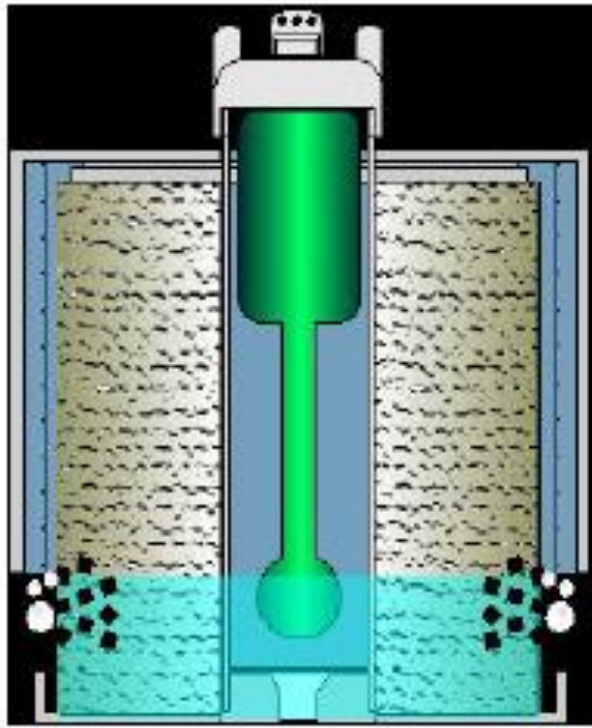


Figure 8: Sediment falling to the bottom of the cartridge as a reaction to the collapsing siphon

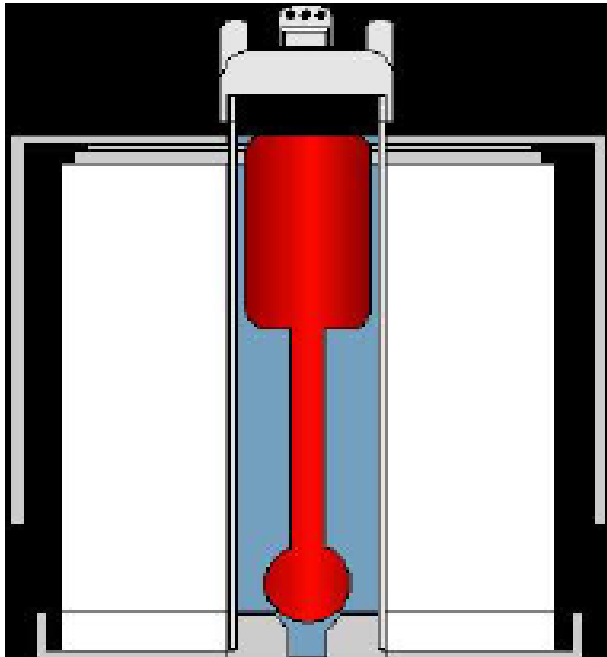


Figure 9: Remaining water drains, imperfect seal at the base of the float

9.0 STORMFILTERS - ZPG MEDIA SIZING PROTOCOL

CONTECH did not provide a specific sizing table for the City of Portland. However, during the technical interview with the City of Portland, the applicant provided the following a sizing table estimates (Table 8). During the performance approach, the Santa Barbara Urban Hydrograph method (SBUH) was used to determine the flow rate at which almost 90% of the average annual stormwater runoff is treated. GULD was originally approved and awarded for an 18” cartridge for both single- event runoff modeling with 2 gpm/sf and continuous simulation runoff modeling with 1 gpm/sf. However, due to the large incompatibility in site’s runoff values that showed a dramatic peak in the flow rate resulted from SBUH modeling compared with flow generated by the off-line-15-min flow rate generated by Western Washington Hydrology Model (WWHM), Ecology amended the GULD to require more cartridges height and eliminated the single event modeling in favor of the continuous, primarily using WWHM. (Table 9) below summarizes all the approved cartridge flow rate and height.

CONTECH is seeking to maintain approval for basic treatment for 2 gpm/sf although Ecology is no longer approving that flow with single- event modeling. The applicant provided an example of the PDX Airport showing the equivalency between the two methods and stated explicitly during the interview that the two systems will have similar TSS removal independent of particle size.

Table 8: Sizing estimates for StormFilter with ZPG media use in City of Portland (CONTECH. 2016).

Cartridge Flow Rates		Flow Rate (gpm/cartridge)	
		2 gpm/ft ²	1 gpm/ft ²
StormFilter	12"	10	5
	18"	15	7.5
	27"	22.5	11.3

Table 9: Approved GULD rates per cartridge at 1 GPM/FT (CONTECH, 2016).

Effective Cartridge Height (inches)	12	18	27
Cartridge Flow Rate (gpm/cartridge)	5	7.5	11.3

10.0 ANTICIPATED LONG-TERM PERFORMANCE AND MAINTENANCE

StormFilter-ZPG media system is designed to trap TSS and other particles through its porous media, so as particles fill the filter's openings, the flow decreases, eventually requiring a cartridge replacement. In general, annual replacement is required for most sites. However, some locations such as active construction sites, typically they require additional maintenance and replacement due to heavy sediment loadings. There are two types of maintenance, minor and major. Minor maintenance usually occurs late in the rainy season and involves the cleanup and removal of vegetation and debris in addition to the determination of the date of major maintenance. During major maintenance, which occurs in late summer or early fall, cartridge replacement and sediment removal occur. (Table 10) shows the optimum time of the year for maintenance activities to take place in the Pacific Northwest.

Table 10: Best annual plan for maintenance activities. (CONTECH, 2016)

WET			WET			DRY			WET		
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
		X	X	X	X	XX	XX	XX	XX		

X = Minor maintenance inspection during one of these months.

XX= Major maintenance during one of these months.

Indications for the need of maintenance include:

- Decreased flow of the effluent below the design flow rate.
- Accumulated vault sediment depths exceed an average of 2 inches.
- Accumulated sediment depths on the tops of the cartridges exceed an average of 0.5 inches.
- Standing water remains in the vault between rain events.
- Bypass occurs during storms smaller than the designed storm.

(Table 11) summarizes the activities associated with StormFilter maintenance

Table 11: StormFilter maintenance activities (CONTECH. 2016)

Facility Component Requiring Maintenance	Maintenance Activity	When Maintenance Activity Is Required/Action taken	Expected Facility Performance After Maintaining
StormFilter Cartridges and Vault	Inspection/Minor Maintenance: Trash and Debris Removal	When large amounts of floatable objects or other trash is present in the filter.	No change
StormFilter Cartridges and Vault	Major Maintenance: Cartridge Replacement and Sediment Removal	Yearly or every other year, or when sediment accumulation in cartridge bay of vault 6" or more.	New media is able to effectively treat stormwater.
Drainage System Piping	Flushing With Water	If drainage system is obstructed by debris or sediment.	Outflow is not restricted.

11.0 PERFORMANCE TEST SITES DESCRIPTION

StormFilter with ZPG media received Washington GULD approval in January 2005, based on a field study conducted at five locations, but the results of only two, site A (Heritage Marketplace Field Evaluation) and site E (Lake Stevens Field Evaluation) were taken because they were the only testing locations using ZPG media. The sites used for the study were chosen based on their suitability for a long-time monitoring project. Historical maintenance records and preliminary site surveys were conducted to confirm the suitability of the sites for TSS performance evaluation. A brief description of the stormFilter-ZPG installed at each location is described below.

11.1 Heritage Marketplace

The Heritage Marketplace StormFilter system was installed in a parking lot area, close to a large grocery store with many smaller businesses with high traffic density during normal business hours. The StormFilter installed at Heritage Marketplace consists of vault housing 23 cartridges, with dimensions of 2.4-m x 4.9-m (8-ft x 16- ft). Each cartridge operated at a filtration rate of 7.5-gpm (28 L/min), yielding a peak operation rate of 640 L/min which is approximately 5% less than the 680 L/min, peak system operation rate recommended for the site based upon the sizing standards specified by Ecology. The StormFilter system treats runoff from 16,000-m³ (4.0-ac), primarily from impervious surfaces such as parking lots. Main sources of pollutants in this drainage area include trash, metals, solids, and automobile waste, site maintenance events, seasonal activities, and atmospheric fallout. Filtered runoff is discharged directly into an on-site infiltration gallery (CONTECH product evaluation. 2006). (Figure 10) below shows the location of the installed stormFilter.



Figure 10: Aerial view of the Heritage Marketplace StormFilter site (CONTECH product evaluation. 2006)

11.2 Lake Stevens

The Lake Stevens StormFilter system was placed by the side of Lake Stevens, east of South Lake Stevens Road in the vicinity of the north end of the bridge deck. The drainage area is 1,200 m³ (0.29 ac) of 100% impervious arterial-road bridge decking and adjacent roadway. Primary sources of pollutants in this area include solids, metals, trash, and debris from automobiles, maintenance activities, and atmospheric fallout. Filtered runoff is discharged directly into the adjacent lake (CONTECH product evaluation. 2006). The StormFilter installed at Lake Stevens consists of vault housing ten cartridges, with dimensions of 1.8-m x 3.7-m (6-ftx12-ft). Each cartridge operated at a filtration rate of 7.5-gpm (28 L/min), yielding a peak operation rate of 280 L/min which is approximately 10% less than the 320 L/min, peak system operation rate is recommended for the site based upon the sizing standards specified by Ecology. (Figure 11) below shows the location of Lake Stevens stomFilter site.



Figure 11: Aerial view of the Lake Stevens North StormFilter site (CONTECH product evaluation, 2006).

The two selected sites are entirely different. The Heritage site is a parking lot of a shopping mall, (Heritage site) with a low concentration of coarse sediments, mainly because stormwater moves like a thin sheet of flow across the pavement. The bridge site, (Lake Stevens) has a daily traffic of 10,000 vehicles/day with a much coarser influent sediment. A comparison between the characteristics of the two sites is provided in (Table 12).

Table 12: Sediment size comparison between the two sites (CONTECH application, 2016)

	LAKE STEVENS	HERITAGE
Sediment % > 100 microns	35%	12%
Sediment % > 500 microns	15%	4%
TSS % > 500 microns ^a	10%	11%
TSS median ^a	89 mg/L	52 mg/L

a. Of all sampled storms

12.0 STORMFILTER - ZPG MEDIA TESTING PERFORMANCE

CONTECH sampled 32 storms between April 2003 to March 2004. However, only 22 storms met TAPE requirements in the October 2002 version of the Guidance for Evaluating Emerging Stormwater Treatment Technologies. TAPE minimum criteria for the sampled storm are:

- Minimum storm depth – 0.15 inches;
- Minimum storm runoff duration - one hour;
- Antecedent condition – not more than 0.06 inches during the 6 hours preceding the sampled storm;
- For TSS, 12 to 35 events are tested, the specific minimum number dependent upon the coefficient of variation observed at the test sites.

The guidelines are:

- For each sampled storm, at least ten aliquots are retrieved to produce the flow- weighted composite sample;
- The aliquots are obtained over at least 75% of the volume of the sampled storm. The qualified storms and other event characteristics are summarized in (Table 13) below.

Table 13: Qualified storms with aggregate TSS load reduction (CONTECH application, 2016)

Qualifying Event ID	Normalized, Sampled Influent Volume gal/cartridge	TSS-WA EMCs by Category					
		ALL		Inf EMC < 100		Inf EMC > 100	
		Influent mg/L	Effluent mg/L	Influent mg/L	Effluent mg/L	Influent mg/L	Effluent mg/L
HMP050303	842	66.4	28.3	66.4	28.3	NA	NA
HMP050703	1033	519	23	NA	NA	519	23
LSN051503	123	120	29	NA	NA	120	29
HMP090703	270	378	37.2	NA	NA	378	37.2
HMP090903	428	76.9	16	76.9	16	NA	NA
HMP091603B	363	96.9	31.2	96.9	31.2	NA	NA
LSN091603	250	99	21	99	21	NA	NA
HMP100603	433	117	41.1	NA	NA	117	41.1
LSN100603	158	83	22	83	22	NA	NA
HMP100903A	307	83.6	40.4	83.6	40.4	NA	NA
HMP101103	481	7.53	4.86	7.53	4.86	NA	NA
HMP102203	463	22.1	9.59	22.1	9.59	NA	NA
LSN102203	330	95	11	95	11	NA	NA
HMP111003	332	30.6	22.3	30.6	22.3	NA	NA
LSN111003	1112	26	10	26	10	NA	NA
HMP111503	540	6.85	6.16	6.85	6.16	NA	NA
LSN120203	465	264	32.6	NA	NA	264	32.6
HMP121003	710	28	17.2	28	17.2	NA	NA
HMP121603	540	45.9	18.8	45.9	18.8	NA	NA
LSN012204	268	54	46	54	46	NA	NA
LSN012904	473	170	48	NA	NA	170	48
LSN030604	170	120	26	NA	NA	120	26
Average EMC (mg/L):		114	25	55	20	241	34
Aggregate Pollutant Load Reduction%:		82		61		89	

Seven of the qualified storms had an influent TSS exceeding 100 mg/L, reaching 519 mg/L. For this range of TSS, the average influent and effluent concentrations and aggregate pollutant load reduction are 241 mg/L, 34 mg/L, and 89% respectively. Two out of the previous seven storm events had an influent TSS exceeding Ecology’s guidelines of 300 mg/L, so by eliminating those storms, all the numbers will change, yielding an average influent and effluent concentrations and aggregate pollutant reduction of 158mg/L, 35mg/L, and 78%, respectively. The remaining 15

qualified storms had influent TSS less than 100 mg/L reaching 6.85 mg/L, so the average influent and effluent concentrations and aggregate pollutant load reduction are 55mg/L, 20 mg/L, and 61% respectively. Six out of the 15 events have TSS concentrations below Ecology's guidelines of 33 mg/L. So, by excluding them, the concentrations and the pollutant load reductions have changed to be 78 mg/L, 26 mg/L and 67% for the average influent and effluent TSS and the pollutant load reduction respectively.

CONTECH explained in their application that none of the methods used to measure the performance goal of the stormfilter are applicable at an influent concentration below 100 mg/L. However, there is a simpler approach that involves determining the number of storms with influent TSS less than 100 mg/L that had an effluent TSS at or near 20 mg/L. In addition, they provided the table below, (Table 14), summarizes the annual average TSS- removal efficiency of the stormfilters during TAPE testing period.

Table 14: Efficiency Calculations Submitted by Stormwater Management, Inc. as part of the WA DOE TAPE Technical Evaluation Report (TER) for the StormFilter with ZPG (2004a).

<i>Influent TSS-WA EMC (mg/L)</i>	
<i>< 100</i>	<i>> 100</i>
<i>Approximately 70% of the qualifying events fall into this category. Of these, approximately half demonstrate effluent EMCs less than 20 mg/L. An arithmetic average of effluent EMCs under this category yields an annual average effluent TSS-WA EMC of 20 mg/L (n=15).</i>	<i>Only the aggregate pollutant loading reduction calculation (Method #2) recommended by WADOE (2002) produces a singular performance value on an annual average basis. The resulting performance for this category is an annual average removal of 89% (n=7).</i>

As seen in (Table 14), for TSS < 100 the average effluent was less than 20 mg/L. Moreover, for TSS > 100 mg/L the aggregate removal reduction was 89%, which indicates that the StormFilter met the WA TAPE requirements for TSS removal.

The following graph, generated by the author, presents a comparison of the City of Portland's treatment requirements with the performance of the StormFilter with ZPG for the 22 qualifying storms. Most of the effluent concentrations meet Portland's treatment standard, but there are some exceedances.

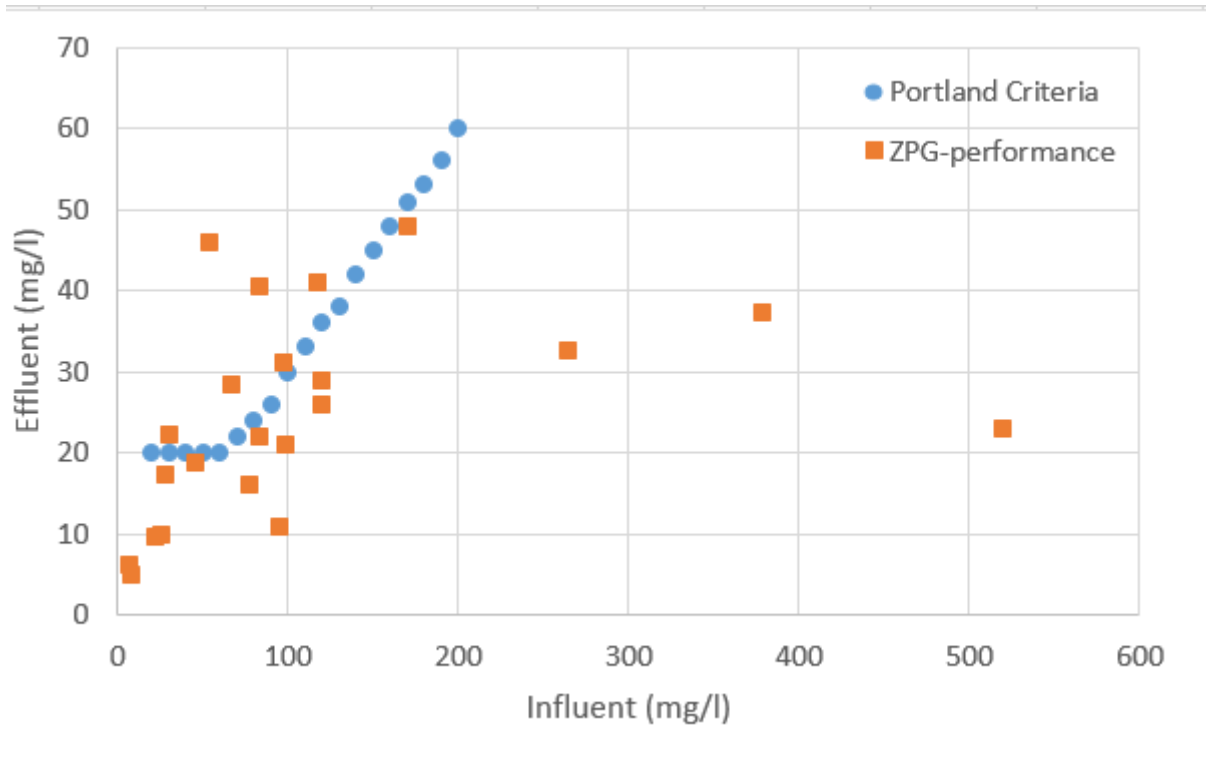


Figure 12: The graph compares the City of Portland's treatment criteria against the performance of the ZPG-filter. Most of the storm effluent concentrations lie below Portland's criteria.

13.0 REVIEW & EVALUATION FINDINGS

The City of Portland's SWMM requirements for TSS removal are slightly different from TAPE requirements, and according to (Table 14) above, StormFilter (ZPG) meets them all. However, (Table 14) is biased for two reasons:

1. For influent TSS < 100 mg/L, all storms even the ones that are below 33 mg/L. were used, (Table 13). There were storms with an influent as low as 6.85 mg/L, in which their effluent did not change much to be 6.16 mg/L. So, including these low effluent concentrations will indeed yield a low arithmetic average of effluent EMCs of 20 mg/L.
2. For influent TSS > 100 mg/L, all storms, even the ones that were above 300 mg/L, were used, (Table 13). There were storms with an influent as high as 519 mg/L, in which their effluent decreased dramatically after filtration, reaching 23 mg/L. Including these high pollutant reductions in the calculations will yield a high removal efficiency of 89%.

The following table compares WA TAPE's treatment goals, Portland's treatment requirements, and a summary of the TAPE performance information presented in the previous section.

Table 15: WA TAPE Goals vs. Portland Requirements vs. TAPE Testing Results for the StormFilter with ZPG

	WA TAPE Goals	Portland Requirement	ZPG Filter Performance
TSS Removal	80% removal with influent concentration 100-200 mg/L <20 mg/L if influent concentration <100 mg/L	70% removal if influent concentration is >70 mg/L <20 mg/L with influent <100 mg/L	<u>TER Submittal</u> 89% removal for influent concentration >100mg/L; <20 mg/L for influent < 100mg/L. <u>WA DOE Findings of Fact</u> 78% removal for influent concentration > 100 mg/L (excluding storms exceeding Ecology guideline of 300 mg/L). 26% mg/L for influent < 100 mg/L (excluding storms below Ecology guideline of 33 mg/L).

As shown in Table 15, when the six storms with influent concentrations < 33 mg/L were excluded from the data analysis, ZPG filter performance (26 mg/L) exceeded the < 20 mg/L TAPE criterion for storms with influent concentrations < 100 mg/L. However, in the 2005 Findings of Fact, the WA DOE Technical Review Committee relied upon the weight of evidence and best professional judgment for approving the Stormfilter with ZPG filter media. Other factors used in the decision to support the Stormfilter included:

- Results of data analysis in aggregate;
- Data analysis with events near the Stormfilter design flow rate more heavily weighted;
- During sub-design flow rate periods, different cartridges within the Stormfilter vault may be operating at different flow rates (some with open float valves while others are closed and running at a "trickle" flow rate;
- Laboratory testing of silica product resulted in 87% TSS removal at 100% design flow rate; and
- Additional testing at three sites, (The I-5 Lake Union, Greenville Yards (New Jersey) and Ski Run Marina (Lake Tahoe) facilities show consistent TSS removals in the 75 to 85% range. Showed consistent TSS removals between 75% and 85%.

14.0 CONCLUSION

The results of the TAPE evaluation and review of additional submittal information suggests the StormFilter generally meets Portland's treatment standard for TSS removal. Consistent with the WA DOE approval, the recommendation was to approve the device for use in the City of Portland at the TAPE-approved flow rate of 1 gpm/ft³. Using the cartridge flow rates provided in Table 9, a Portland-specific sizing table should be developed to assist designers with preliminary sizing and cost estimates based on Portland's design storm and sizing methods.

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16.0 APPENDIX – MORE ADDITIONAL INFORMATION

16.1 Final report submitted to the City of Portland.

Evaluating the performance of Contech’s StormFilter with ZPG Media under the City of Portland’s 2016 Stormwater Management Manual requirements for manufactured stormwater treatment technologies

Prepared by: Mawj Khammas

 6/27/17

Reviewed by: William Fish, Ph.D.

 6/27/17

Document Milestone	Deadline/Date
Draft Report submitted to the city	5/23/2017
Comments submitted by city	6/8/2017
Final submitted to city	6/27/2017

Report Objective

Review the reported performance of the StormFilter® with ZPG media with respect to Portland’s pollution reduction requirements, as prescribed in the 2016 Stormwater Management Manual (SWMM).

The 2016 SWMM pollution reduction requirements are:

- 70% removal of total suspended solids (TSS) from 90% of the average annual runoff.
- In watersheds that have established total maximum daily loads (TMDLs) or that are on Oregon Department of Environmental quality 303(d) list of impaired waters, stormwater management facilities must be capable of reducing the pollutant(s) of concern.
- Have a current General Use Level Designation (GULD) for Basic Treatment, from the Washington State Department of Ecology (WA DOE) under the Technology Assessment Protocol-Ecology (TAPE), prior to application and review by the City of Portland.

The City of Portland reviews manufactured stormwater treatment technologies under the submittal and review criteria in Chapter 2 of the SWMM.

Description of the Manufactured Stormwater Treatment Technology

The StormFilter is an inline, media-filled cartridge system which removes pollutants from stormwater runoff. The system is housed in a precast concrete vault that can be designed in multiple configurations and sizes. Each filter is designed to treat a specific flow rate, which can be controlled through a calibrated reducer disk placed at the base of the cartridge. StormFilters may include an internal bypass in case flow rates exceed the capacity of the cartridges. In case the site generates flow that exceeds the internal bypass capacity, a peak diversion configuration must be used which integrates the diversion weir with the filter bay into the same vault structure. The StormFilter® with ZPG, which is the subject of this review, is specifically designed to remove Total Suspended Solids (TSS) from stormwater runoff. The media is comprised of zeolite, perlite, and granular activated carbon (GAC). The outer layer is 100% perlite; the inner layer is a mixture of 90% Zeolite and 10% GAC. A number of physical processes contribute to treatment of the stormwater: filtration, by trapping the suspended particles in the ZPG media, ion exchange, adsorption and precipitation for larger particles. Cartridges are housed in a vault and receive stormwater horizontally through the inlet pipe. Stormwater passes through the filtration media (ZPG) and begins filling the cartridge's center tube. When water reaches the top of the cartridge, the float valve opens, and filtered water can drain at the design flow rate. Filtered water then discharges out of the system through the under-drain manifold. When the water level outside the cartridge approaches the bottom of the hood, air rushes through the scrubbing regulators, releasing the water column and breaking the siphon. The turbulent bubbling action agitates the surface of the filter media, promoting trapped sediment to drop to the vault floor. This patented surface cleaning mechanism helps restore the permeability of the filter surface between storm events.

StormFilters - ZPG media sizing protocol

The applicant's submittal to the City of Portland didn't include a Portland-specific sizing table. The applicant provided the following reference table, which is based on the 1gpm/sf2 approved by the WA DOE TAPE program (Table 1).

Table 1. Approved GULD rates per cartridge at 1 GPM/FT²

Effective Cartridge Height (inches)	12	18	27
Cartridge Flow Rate (gpm/cartridge)	5	7.5	11.3

Summary of StormFilter - ZPG media performance data

The StormFilter with ZPG media received WA DOE GULD for Basic Treatment approval in January 2005, based on field studies conducted at two sites, Site A (Heritage Marketplace), and Site E (Lake Stevens). CONTECH sampled 32 storms between April 2003 and March 2004. Out of those 32 storms, 22 storms met the TAPE requirements provided by Ecology in the October 2002 version of the Guidance for Evaluating Emerging Stormwater Treatment Technologies. The TAPE minimum criteria for the sampled storms were:

Minimum storm depth – 0.15 inches;

Minimum storm runoff duration - one hour;

Antecedent condition – not more than 0.06 inches during the 6 hours preceding the sampled storm;

With respect to TSS, 12 to 35 events are sampled, the specific minimum number dependent upon the Coefficient of Variation observed at the test sites.

The guidelines were:

For each sampled storm, at least 10 aliquots are retrieved to produce the flow weighted composite sample;

The aliquots are obtained over at least 75% of the volume of the sampled storm.

The qualified storms are listed in the Table 2, below.

Table 2. Qualified storms with aggregate TSS load reduction

Qualifying Event ID	Normalized, Sampled Influent Volume gal/cartridge	TSS-WA EMCs by Category					
		ALL		Inf EMC < 100		Inf EMC > 100	
		Influent mg/L	Effluent mg/L	Influent mg/L	Effluent mg/L	Influent mg/L	Effluent mg/L
HMP050303	842	66.4	28.3	66.4	28.3	NA	NA
HMP050703	1033	519	23	NA	NA	519	23
LSN051503	123	120	29	NA	NA	120	29
HMP090703	270	378	37.2	NA	NA	378	37.2
HMP090903	428	76.9	16	76.9	16	NA	NA
HMP091603B	363	96.9	31.2	96.9	31.2	NA	NA
LSN091603	250	99	21	99	21	NA	NA
HMP100603	433	117	41.1	NA	NA	117	41.1
LSN100603	158	83	22	83	22	NA	NA
HMP100903A	307	83.6	40.4	83.6	40.4	NA	NA
HMP101103	481	7.53	4.86	7.53	4.86	NA	NA
HMP102203	463	22.1	9.59	22.1	9.59	NA	NA
LSN102203	330	95	11	95	11	NA	NA
HMP111003	332	30.6	22.3	30.6	22.3	NA	NA
LSN111003	1112	26	10	26	10	NA	NA
HMP111503	540	6.85	6.16	6.85	6.16	NA	NA
LSN120203	465	264	32.6	NA	NA	264	32.6
HMP121003	710	28	17.2	28	17.2	NA	NA
HMP121603	540	45.9	18.8	45.9	18.8	NA	NA
LSN012204	268	54	46	54	46	NA	NA
LSN012904	473	170	48	NA	NA	170	48
LSN030604	170	120	26	NA	NA	120	26
Average EMC (mg/L):		114	25	55	20	241	34
Aggregate Pollutant Load Reduction%:		82		61		89	

The characteristics of the two sites were quite different. The Heritage site is a parking lot at a shopping mall, with low concentrations of coarse sediments. The Lake Stevens site is a bridge with a daily traffic count of 10,000 vehicles/day and much coarser influent sediment. A comparison of the characteristics of the two sites is provided below in Table 3.

Table 3. Sediment size comparison between the two sites

	LAKE STEVENS	HERITAGE
Sediment % > 100 microns	35%	12%
Sediment % > 500 microns	15%	4%
TSS % > 500 microns ^a	10%	11%
TSS median ^a	89 mg/L	52 mg/L

a. Of all sampled storms

Total Suspended Solid (TSS) Removal

The following is the TAPE performance goal taken from the Department of Ecology’s 2001 Stormwater Manual for Western Washington.

Ecology’s basic treatment menu facility choices are intended to achieve a goal of 80 percent removal of total suspended solids for influent concentrations that are greater than 100 mg/L, but less than 200 mg/L. For influent concentrations, greater than 200 mg/L, a higher treatment goal may be appropriate. For influent concentrations, less than 100 mg/L, the facilities are intended to achieve an effluent goal of 20 mg/L total suspended solids. Flows in excess of the water quality design flow or volume can be bypassed around the facility. The performance goal applies:

- to stormwater with a typical particle size distribution;
- on an annual average basis to the entire discharge volume (treated plus bypassed); and,
- to the water quality design storm volume or flow rate. (Ecology, 2001-Ch.4, Vol.V).

The table below, included in the TAPE technical submittal by the company’s consultant, summarizes the annual average TSS-removal efficiency of the StormFilter with ZPG during the TAPE testing period.

Table 4. Efficiency Calculations Submitted by Stormwater Management, Inc. with the WA DOE TAPE Technical Evaluation Report (TER) for the StormFilter with ZPG (2004a).

<i>Influent TSS-WA EMC (mg/L)</i>	
<i>< 100</i>	<i>> 100</i>
<i>Approximately 70% of the qualifying events fall into this category. Of these, approximately half demonstrate effluent EMCs less than 20 mg/L. An arithmetic average of effluent EMCs under this category yields an annual average effluent TSS-WA EMC of 20 mg/L (n=15).</i>	<i>Only the aggregate pollutant loading reduction calculation (Method #2) recommended by WADOE (2002) produces a singular performance value on an annual average basis. The resulting performance for this category is an annual average removal of 89% (n=7).</i>

The results summarized in Table 4, using arithmetic averages of effluent EMC's, indicates the StormFilter met the WA TAPE requirements for TSS removal.

The following information is taken directly from WA DOE's' Findings of Fact in the General Use Designation for Basic (TSS) Treatment for the StormFilter with ZPG Media (April 2017; based on 1 gpm/sf of media surface area). The information forms the technical basis for WA DOE's approval of the device.

- Of the 32 sampling events, 22 met TAPE required storm event conditions with an average influent concentration of 114 mg/L, average effluent concentration of 25 mg/L and an aggregate pollutant reduction of 82%.
- Seven of the qualified storms had an influent TSS exceeding 100 mg/L, reaching 519 mg/L. For this range of TSS, the average influent and effluent concentration and aggregate pollutant load reduction are 241 mg/L, 34 mg/L and 89% respectively. Two out of the previous 7 storm events had an influent TSS exceeding Ecology's guidelines of 300 mg/L. Eliminating those 2 storms yields average influent and effluent concentrations and an aggregate pollutant reduction of 158mg/L, 35mg/L and 78%, respectively.
- The remaining 15 qualified storms had influent TSS less than 100 mg/L, reaching 6.85 mg/L. The average influent and effluent concentrations and aggregate pollutant load reduction were 55mg/L, 20 mg/L and 61% respectively. Six out of the 15 events have TSS concentrations below Ecology's guidelines of 33 mg/L. Excluding those six storms results in average influent

and effluent concentrations and an aggregate pollutant load reduction of 78 mg/L, 26 mg/L, and 67%, respectively.

The following graph, generated by the author, presents a comparison of the City of Portland's treatment requirements with the performance of the StormFilter with ZPG for the 22 qualifying storms. Most of the effluent concentrations meet Portland's treatment standard, but there are some exceedances.

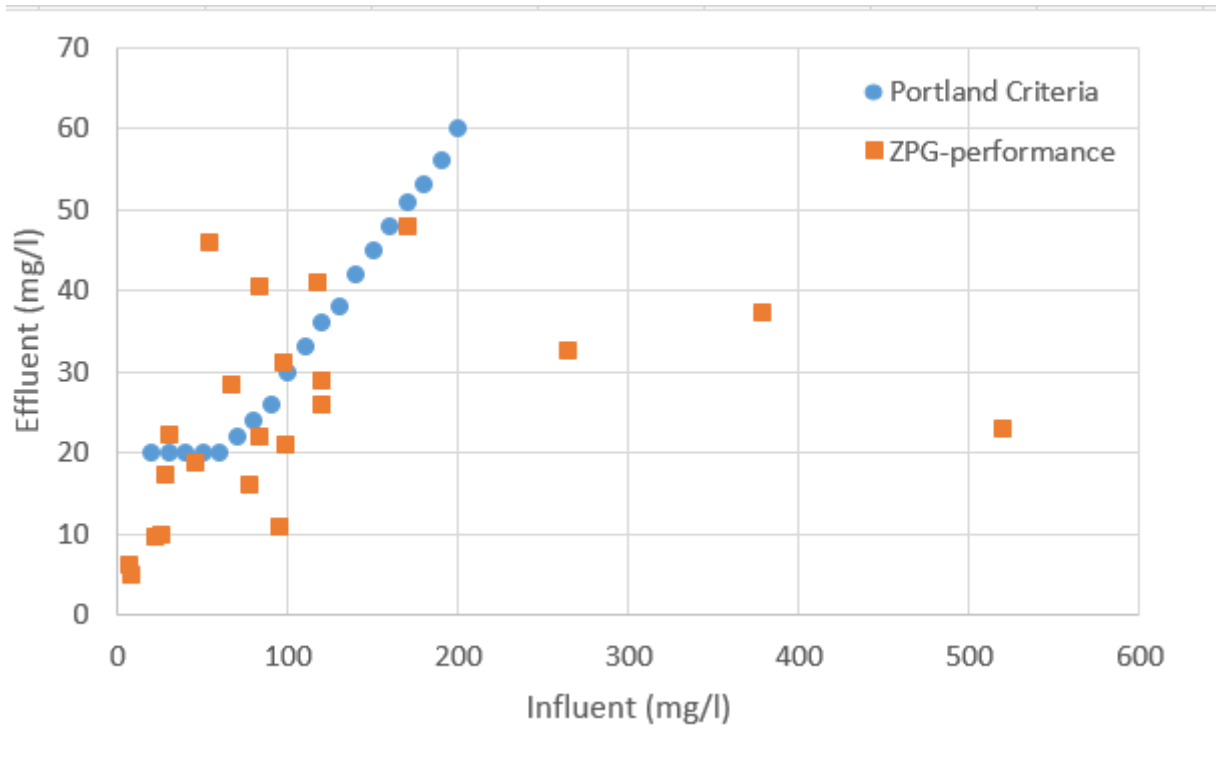


Figure 1. The graph compares the City of Portland's treatment criteria against the performance of the ZPG-filter. Most of the storm effluent concentrations lie below Portland's criteria.

Review of Findings

The following table compares WA TAPE’s treatment goals, Portland’s treatment requirements, and a summary of the TAPE performance information presented in the previous section.

	WA TAPE Goals	Portland Requirement	ZPG Filter Performance
TSS Removal	80% removal with influent concentration 100-200 mg/L <20 mg/L if influent concentration <100 mg/L	70% removal if influent concentration is >70 mg/L <20 mg/L with influent <100 mg/L	<u>TER Submittal</u> 89% removal for influent concentration >100mg/L; <20 mg/L for influent < 100mg/L. <u>WA DOE Findings of Fact</u> 78% removal for influent concentration > 100 mg/L (excluding storms exceeding Ecology guideline of 300 mg/L). 26% mg/L for influent < 100 mg/L (excluding storms below Ecology guideline of 33 mg/L).

Table 5. WA TAPE Goals vs. Portland Requirements vs. TAPE Testing Results for the StormFilter with ZPG

As displayed in Table 5, when the six storms with influent concentrations < 33 mg/L were excluded from the data analysis, ZPG filter performance (26 mg/L) exceeded the < 20 mg/L TAPE criterion for storms with influent concentrations < 100 mg/L. However, in the 2005 Findings of Fact the WA DOE Technical Review Committee relied upon weight of evidence and best professional judgement for approving the Stormfilter with ZPG filter media. Other factors used in the decision to approve the Stormfilter included:

- Results of data analysis in aggregate;
- Data analysis with events near the Stormfilter design flow rate more heavily weighted;
- During sub-design flow rate periods, different cartridges within the Stormfilter vault may be operating at different flow rates (some with open float valves while others are closed and operating at a “trickle” flow rate);
- Laboratory testing of silica product resulted in 87% TSS removal at 100% design flow rate; and

- Additional testing at three sites showed consistent TSS removals between 75% and 85%.

Anticipated Long-term Performance and Maintenance

The system is designed to trap TSS and other particles through its porous media, and as particles fill filter's openings the flow decreases to eventually calling the need for a cartridge replacement. In general, annual replacement is required for most sites. However, some locations like active construction sites require additional maintenance and replacement due to heavy sediment loadings. There are two types of maintenance, minor and major. Minor maintenance involves the cleanup and removal of vegetation, debris in addition to the determination of the date of major maintenance. During major maintenance, cartridge replacement and sediment removal occurs. Indications for the need of maintenance include:

- Decreased flow of the effluent below the design flow rate.
- Accumulated vault sediment depths exceed an average of 2 inches.
- Accumulated sediment depths on the tops of the cartridges exceed an average of 0.5 inches.
- Standing water remains in the vault between rain events.
- Bypass occurs during storms smaller than the designed storm.

Conclusions and Recommendations

The results of the TAPE evaluation and review of additional submittal information suggests the StormFilter generally meets Portland's treatment standard for TSS removal. Consistent with the WA DOE approval, the recommendation is to approve the device for use in the City of Portland at the TAPE-approved flow rate of 1 gpm/sf². Using the cartridge flow rates provided in Table 1, a Portland-specific sizing table should be developed to assist designers with preliminary sizing and cost estimates based on Portland's design storm and sizing methods.

References

City of Portland. 2016. Stormwater Management Manual, Appendix B: Manufactured Stormwater Treatment Technologies. City of Portland Bureau of Environmental Services, Portland, Oregon.

CONTECH Engineered Solution. (2016). “Stormwater Treatment for the Most Challenging Pollutants”, <<http://www.conteches.com/products/stormwater-management/treatment/stormwater-management-stormfilter>> (accessed March 20th, 2017).

Ecology. 2008. Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol-Ecology (TAPE). Publication No. 02-10-037, Washington State Department of Ecology, Olympia, Washington.

StormFilter with ZPG Media. 2016. Re-Application letter to City of Portland BES. CONTECH, Portland, Oregon. December 21st, 2016.

16.2 Technical Interview Questions

PORTLAND’S POLLUTION REDUCTION REQUIREMENTS (TAPE RESULTS)

1. Please provide sizing table for Portland reflecting the Washington DOE GULD-approved rate of 1 gpm/sf of filter. There are several references to the 2 gpm/sf flow rates for which Contech seeks to maintain approval. "Ecology" no longer awards Basic treatment certification for 2 gpm/sf flow rates, based on the exclusion of single-event modeling. The application explains the "equivalency" between a specific flow rate of 2 gpm/sf with the conservative BES (SBUH) model and the Ecology (WWHM) model 1 gpm/sf design flows. Please explain.
2. The PDX Airport example attempts to demonstrate that an equally-sized system can be used for either the SBUH or WWHM flows. Is it accurate to say that under both of these modeled scenarios, the stated system achieves the same level of TSS removal? If so, why not state this explicitly? If not, is it valid to claim a system equivalency?
3. Page 6 of the November 2016 StormFilter GULD indicates that some storms included in Table 2 of The TEER were not qualifying storms due to TSS influent concentrations being either too low (< 33 mg/L) or too high (> 300 mg/L). When storms with influent concentrations either too low or too high were excluded from system performance calculations, pollutant load reductions did not meet pollutant load reduction goals as noted in pages 6 & 7 of the November 2016 GULD (pages 172 & 173 of the submittal). Please discuss why storms that did not qualify based on influent TSS concentrations were used in the original pollutant load reduction calculations. In addition, please discuss why Ecology issued a GULD for the StormFilter when the system did not meet pollution load reduction goals if non-qualifying storms were excluded from the calculations.

DESIGN

4. What design changes, if any, have been implemented with the StormFilter / ZPG media since its initial City of Portland approval in 2002?
5. The original TEER is from 2004. What kind of feedback have you received from customers, both positive and negative, regarding system performance and what design upgrades and modifications have you made in response to customer feedback, if any?
6. Provide documentation confirming H-20 traffic rating, specified frictional resistance, and ADA compliance for the configurations used in the public right-of-way and pedestrian corridors (curb type and vault type grate covers, lids, pre-cast vault, etc.).
7. The calibrated reducer disk placed at the base of the cartridge is responsible for controlling the individual flow rate in each cartridge. The maximum flow rate through each cartridge can be adjusted between 5 and 15 gpm, (Technical Evaluation Report, page 18). Explain and give more details about how it is managed and the possibility for failure in the disk and the consequences?
8. Is the internal bypass capacity for each filter mentioned anywhere (besides the individual details found on the website)? Can external bypass be provided if needed? Similar question for hydraulic head needed for each cartridge size.

MAINTENANCE

9. The brochure mentions a Sorbent Hood Cover. How does it compare with the standard cover for replacement cost and maintenance frequency? Does it have an "expiration date" beyond which it might deteriorate if installed in a location that has a long maintenance cycle (3 to 5 years)?
10. Are the individual cartridges labeled with media type and unit height, so the details can be easily noted during inspection (without making confined space entry), to facilitate ordering the correct replacements?
11. Explain appropriate ways of disposing sediments collected during maintenance from construction sites or others that might have high heavy metal levels, municipal landfill disposal may not be an option.

12. In general, minor maintenance activities will occur late in the rainy season, but in case of a flood due to snow melt, such as what happened in Portland last January, should an inspection or minor maintenance have performed on the units mid-season?
13. When a facility requires media replacement, does it need to be ordered specifically for that installation or can the agency order in bulk and store the media for subsequent uses? Does the media have a shelf life before it begins to degrade?

INITIAL & ANNUAL MAINTENANCE COSTS

14. Provide information on typical cost per model unit, installed.
15. Based on the recommended major and minor maintenance / inspection. Please provide detailed information about the cost of replacing or cleaning cartridges or other unit media.

DISCUSSION:

16. Provide input on the City of Seattle's proposal to move to a solids-loading basis for system sizing and maintenance. It's our understanding Seattle's proposal stems from the results of a Seattle field evaluation of the performance of a group of StormFilter installations.