DATE: March 9, 2000

TO: Office of Water Program Engineers

THROUGH: E. H. Bartsch, P.E., Director, Division of Water Supply Engineering

FROM: Robert B. Taylor, P.E., Director, Division of Water Supply Engineering

SUBJECT: Water - Design Equipment - Cartridge Filtration

I. General

Cartridge filtration has been demonstrated to be an acceptable equivalent substitute for conventional filtration treatment in complying with the Surface Water Treatment Rule (SWTR) for certain Groundwater's Under the Direct Influence of Surface Water (GWUDISW). This treatment option is available only for low turbidity raw waters characterized by infrequent and minor changes in turbidity. Cartridge filtration systems typically utilize ceramic or disposable polypropylene, microporous filter elements in pressurized stainless steel housings. Typical designs include two-stage filtration, with a larger pore size pre-filter followed by a final filter (pore size 0.2 to 1.0 μ). The need to verify the integrity of the cartridges and end seals require the provision of a continuous monitoring particle counter or particle monitor and turbidimeter.

II. OWP Experience

There have been a number of successful full-scale **pilot tests** of cartridge filtration systems in Virginia. Each of these pilot tests has involved modified **Harmsco** two-stage cartridge filtration units. Of those previously pilot tested, some are now in full operation with provisional operation permits.

Other manufacturers of cartridge filtration equipment have expressed interest in pilot testing their equipment in the State; however, no firm agreement with a waterworks with a GWUDISW source has been reached to date. Other equipment suppliers with comparable equipment should be encouraged to provide evidence to justify their suitability in addressing GWUDISW problems.

III. Raw Water Quality Criteria

To be considered treatable by cartridge filtration, raw water must meet the following criteria or be pre-treated accordingly:

A. The water applied to the cartridge filter must not contain color in excess of 15 CU.

B. The water applied to the cartridge filter must not be subject to rapid or wide fluctuations in turbidity. The turbidity level must not exceed 10 NTUs.

C. The water source must be fully characterized with respect to the presence of algae, iron, and/or manganese, as each of these contaminants can interfere with efficient cartridge filtration.

Pilot testing is required when algae is present in the raw water and when iron and/or manganese concentrations exceed their respective SMCLs. Pilot testing to establish **pre-treatment** requirements to reduce color and/or turbidity to an acceptable level(s) may be required. Chlorination ahead of cartridge filters is recommended to control slime growth. The use of calcium hypochlorite is discouraged due to the observed tendency of the "filler" in this chlorine compound to enhance clogging of the cartridge elements.

IV. Log Removal Credits / Disinfection Requirements

The log removal credits for approved cartridge filtration units is 2 for *Giardia* and *Cryptosporidium*, and 0 for viruses. Disinfection facilities shall be designed to achieve the additionally required 1-log removal/inactivation of *Giardia* and 4-log removal/inactivation of viruses.

V. Equipment Requirements - General

A. Pore size

The issue of **nominal vs. absolute rated filter cartridges** has been carefully considered. There appears to be no industry standard by which to compare different manufacturers' cartridges; therefore, the manufacturers' rating claims must be considered with a degree of skepticism. This guidance can not establish a prescriptive rating for cartridges. Rather, **performance based criteria for filter cartridges** has been established, to be verified by appropriate pilot testing as prescribed in **VIII.** below.

B. Cartridges

The **integrity of the filter cartridge** is a primary concern. It is equally as important to insure that no untreated source water bypasses the cartridge. The potential exists for bypassing around the cartridge end seals. Voids have been found in the sealing O-rings of certain cartridges; therefore, close visual inspection of all cartridges and their seals must be made prior to installation.

C. Configuration

A system design proposing the stacking of cartridges shall not be approved due to the increased probability of leaking around cartridge end seals.

D. Housings

All multiple cartridge filter housings shall be ASME certified. Non-ASME certified housings have been observed to undergo excessive deflection during pressurization, resulting in unseating of cartridge element end seals, and untreated raw water being bypassed. All Harmsco Hurricane single cartridge housings **shall be modified** to prevent bypassing of untreated water, by discarding the plastic nut connecting the top of the cartridge to the top plate, and by replacing it with a standard PVC pipe plug in the top of the filter cartridge.

E. Instrumentation/Alarms

Minimum process monitoring shall include continuous product water monitoring, using either a particle counter or particle monitor, and continuous source and product water turbidity monitoring. A provision that would allow particle counting or particle monitoring of raw water grab samples is desirable and encouraged. The source water turbidimeter shall be capable of both initiating an alarm function and bypassing the source water to waste at a source water turbidity set point. The product water turbidimeter and particle counter, or particle monitor, shall be capable of initiating an alarm function and discharging product water to waste at appropriate set points. Alarms shall be reported to a location continuously manned during treatment system operation periods.

It should be noted that intermittent system operation (frequent shutdowns and start-ups) tend to entrain air bubbles in the product water which in turn appear as contaminants in particle counting/monitoring and turbidity monitoring. Constant flow systems are preferred, where feasible, as the problem of entrained air is minimized.

VI. Operator Requirements

The class operator and attendance requirements will be in accordance with 12 VAC 5-590-460 of the *Waterworks Regulations*. A minimum of a Class IV waterworks operator will be required to give attendance at the system each day of operation for sufficient time to perform necessary monitoring and process evaluation and to make any process and instrumentation adjustments deemed

necessary. Should chemical pre-treatment of the raw water be necessary, a minimum of a Class III waterworks operator will be required.

VII. Operations Guidelines

A. Flow Rating

Experience indicates that the flow ratings applied to the Harmsco cartridges by the manufacturer are greatly exaggerated. In order to achieve optimum filter runs and system performance, and to prevent permanent cartridge plugging, **a maximum flux rate of 0.2 gpm/ft^2** shall be adhered to.

B. Flushing/Washing Cartridges

Although the manufacturer suggests that cartridge life may be extended with cleaning by flushing with a garden hose, experience indicates that little, if any, benefit is realized from this procedure. Harmsco qualifies this matter by indicating that it is generally not possible to clean cartridges when filtering applications are addressing $\leq$ 1μ size particle removal. Spent cartridges shall not be reused.

C. Pressure Differential

In order to protect the cartridge(s) from structural damage, it is critical that the pressure differential across the cartridge(s) be maintained below the manufacturer's recommendation. A reasonable upper limit has been found to be a 20 psi differential for the final filter. Permanent deformation and damage to cartridges has been observed when an excessive pressure differential is allowed to develop (due to excessively dirty cartridge). Therefore, cartridge replacement shall be undertaken prior to the pressure differential reaching 20 psi, unless a higher allowable pressure differential has been substantiated during pilot testing. A minimum replacement frequency for cartridges in low turbidity applications was not felt necessary, since particle counter or particle monitor and turbidity sensing equipment will be relied upon to monitor finished product water quality.

D. Filter to Waste

As with conventional filtration systems, cartridges ripen or mature with usage. It should be expected that a newly installed cartridge would shed fibers into the product water. This will normally result in elevated particle counts, and possibly an elevated turbidity level, of product water in the initial stages following cartridge installation or replacement. Provisions for filtration to waste following cartridge replacement shall be made.

Experience indicates that filter to waste duration varies with the particular raw water, and may be dependent upon seasonal variations in raw water quality. Data is not sufficient to establish a universal filter to waste duration. This will be a site-specific issue and should be addressed during pilot testing and/or during the system's provisional operating period.

E. O-ring Integrity/Seating

It should be restated that certain O-rings have been found with manufacturing flaws that compromise the integrity of the treatment system. A close visual inspection of all cartridges, especially O-rings, prior to installation is critical to eliminate this potential integrity breach.

The importance of proper seating of the cartridge seals can not be overstated. Experience gained in pilot testing and full-scale operation of housings containing multiple cartridges and standpipes for cartridge mounting, indicates that the cartridge retainer nuts must be tightened to a minimum torque of 20 ft-lbs. This will necessitate that a torque wrench be a basic operational tool for this type system.

VIII. Pilot Testing Guidelines & Waivers

A. Harmsco Waivers

OWP experience with Harmsco cartridge filtration systems is such that initial pilot testing may be waived for Harmsco systems utilizing ASME certified housings, or Harmsco Hurricane housings modified as detailed in **V.** above, using 5µ or less nominal pre-filter and 0.35µ nominal final filter Polyester-Plus™ cartridges, provided that these future proposed applications include similar raw waters to those previously piloted, and that all other criteria contained herein is adhered to.

B. Similar Waters

Similar water is water with similar physical and chemical characteristics to those previously pilot tested; i.e., no excessive iron, manganese, algae, etc. Variations in pH, alkalinity, hardness, etc. from waters previously piloted should not normally be considered criteria to declare the waters dissimilar.

Raw waters which exhibit the presence of algae and/or iron or manganese exceeding the respective SMCL, but similar to raw waters previously pilot tested in all other respects, will not necessarily require cyst and turbidity challenges as part of the required pilot test.

A summary of the chemical and bacteriological characteristics of those waters previously pilot tested is attached (Attachment C). Proposals for systems, other than Harmsco and where insufficient evidence of SWTR compliance exists, will require pilot testing. Attached is a suggested pilot testing protocol (Attachment A). Pilot testing of a full-scale system will be considered if proposed. In most instances, this can significantly reduce costs. A provisional waterworks operation permit can not be issued until the proposed system is shown by pilot testing to be capable of compliance with the SWTR, assuming technical plans and specifications have been evaluated and approved by OWP.

C. Challenge Testing

Challenge testing of cartridge filtration systems must be carefully planned, and must be conducted only by qualified personnel. Turbidity challenges should be performed using graded test dust. This allows the application of known size particles, which permits a relatively accurate characterization of the system's turbidity removal efficiency. Cyst challenge testing expertise is of extreme importance due to the technically sensitive nature of this procedure. Few analytical testing laboratories are qualified and experienced in this testing. OWP shall be consulted for input on the selection of a suitable laboratory.

D. NSF

A reference source that may be useful in the development of a cartridge filtration pilot testing protocol is the Environmental Technology Verification (ETV) protocol titled "Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants", prepared by the National Sanitation Foundation (NSF) and dated May 14, 1999. Chapter 4 of the protocol addresses cartridge filtration and is titled "NSF Equipment Verification Testing Plan - Bag Filters and Cartridge Filters for the Removal of Microbiological and Particulate Contaminants". This testing protocol may be accessed through the EPA website at the following address: http://www.epa.gov/etv

IX. Full-Scale Demonstration Testing

Following approval of engineering plans and specifications, equipment installation, and final inspection of a newly installed cartridge filtration system by OWP, a provisional waterworks operation permit will be issued in accordance with 12 VAC 5-590-290 of the *Waterworks Regulations*. This permit will be issued with an expiration date of at least 12 months but not more than 18 months following its effective date. During this provisional period, certain special monitoring conditions will apply (See Attachment B). In addition, a final report of

all findings, prepared by a Virginia licensed Professional Engineer or other appropriately qualified professional, shall be submitted to OWP for review. Final operation permit issuance will be contingent upon the satisfactory demonstration, during this provisional period, that the system can consistently achieve SWTR and Interim Enhanced Surface Water Treatment Rule (IESWTR) compliance.

TABLE 1

MONITORING PROTOCOL FOR CARTRIDGE FILTRATION

Parameter	Sampling Points	Frequency	Method
Turbidity	Feed/Product	Continuous	On-Line Monitor
Particles (> 2μ)	Feed/Product	Continuous	On-Line Monitor
Coliform (Total)	Feed/Product	Weekly	Grab
Coliform (Fecal)	Feed/Product	Weekly	Grab
HPC	Feed/Product	Weekly	Grab
Temperature	Feed	Daily	Grab
Iron	Feed	Once	Grab
Manganese	Feed	Once	Grab
Hardness	Feed	Once	Grab
Alkalinity	Feed	Once	Grab
pH	Feed/Product	Daily	Grab
TOC	Feed/Product	Once	Grab
Pressure Differential	Pilot	Continuous	Gauge/Recorder
Influent Flow	Pilot	Daily	Gauge-GPM & GPD
Product Flow	Pilot	Daily	Gauge-GPM & GPD
Waste Volume	Pilot	Each Backwash*	Calculation

* Or cartridge change

Attachment A

PROTOCOL TO TEST CARTRIDGE FILTRATION EQUIPMENT

I. INTRODUCTION

This document presents the methodology and schedule for the testing of filters at the Town of _____ waterworks. The filters are to be tested to meet the criteria set forth in the Surface Water Treatment Rule (SWTR) and Interim Enhanced Surface Water Treatment Rule (IESWTR).

II. OBJECTIVES

The objective of the testing program is to evaluate the performance of a micro-filtration unit in removing turbidity, *Giardia*, and *Cryptosporidium* from the water and to generate probable filter run times to develop typical operating costs.

III. INVESTIGATIONS

The water will be inoculated with known concentrations of inactivated *Giardia* cysts and *Cryptosporidium* oocysts. A minimum of one (1) biological trial and one (1) turbidity trial will be conducted.

The well water will be dirtied with ISO Fine Dust to evaluate the capacity of the filtration as well as the turbidimeter sensitivity.

IV. TESTING

A. Setup

A prototype (pre and final) filter system will be installed in the well house for the purpose of this evaluation. Flux rate will be less than 0.2 gpm/ft^2 of filter media.

B. Finished Water Quality Goals

Turbidity	0.1 – 0.2 NTU
Iron	< 0.3 mg/l
Manganese	< 0.5 mg/l
Giardia and *Cryptosporidium* removal	99.9% (3 log)

C. Plant Operating Conditions

All water used in this testing process will be piped to waste.

Flow Rate = ____ GPM
Pre-filter of 5.0μ nominal opening
Final filter of 0.35μ nominal opening
Disinfection will occur prior to filtration

Turbidimeters are to be connected to an automatic waste valve. If either raw or filtered water exceed preset turbidity values, flow will be valved to waste instead of distribution. The particle counter may also be used to trigger the automatic waste valve. Pressure differential across filtration > 20 psi will shut down well pump as will a no flow situation.

D. Chemicals to be used: Oxidant/Disinfectant – Sodium Hypochlorite

E. Monitoring Requirements

Hach Model 1720C and/or 1720D, Low Range Turbidimeter units "or equal" will be installed on the raw water side of the filtration system and on the finished water side.

Hach Model 1900 WPC particle counter "or equal" will be installed on the finished water side of the filtration system.

The raw waterside will be monitored by a temporary installation of a Hach Model 1900 WPC "or equal" for the duration of the test period.

Cartridge integrity will be monitored by pre and post filtration turbidity monitoring, pre and post filtration particle counting, and pressure measurements on both sides of the filtration equipment.

Other biological, chemical, and physical analyses as required by Table 1. (Attached)

F. Methodology

Inactivated cysts in a known concentration will be introduced into the well water prior to the turbidimeter and particle counter port. This mixture will flow through the filter system and be evaluated by the turbidimeter and particle counter on the downstream side.

A minimum of one (1) spike with identified samples of inactivated *Giardia* cysts and *Cryptosporidium* oocysts will be used.

Two (2) capture filters of 1μ absolute pore size will be used for the spike and for one hour after the spike.

The capture filters will be analyzed to determine the quantity of cysts which pass through the filters under test.

Turbidity spiking will be performed using dust in predetermined concentrations to evaluate turbidity removal of the filtration system, automatic waste valve operation, and turbidity monitoring. A minimum of one (1) turbidity evaluation will be performed. Near the end of the test period, raw water turbidity will be increased in steps to determine capacity of filters to remove turbidity. The expected maximum feed of turbidity is in the range of 30 NTUs from ISO Fine Test Dust.

V. SAFETY AND HYGIENE

Special hygiene practices MUST be observed during this evaluation. Although the cysts used for this evaluation are inactivated, there exists the possibility of contamination. When the filter media is removed from the filter housing, water must first be drained to a

level below that of the filter media in order to not contaminate the clean side of the filter housing. Following the removal of the old filter media, the area must be disinfected with an appropriate disinfection agent. After area disinfection, personnel disinfection will be performed. Only then can the package containing the new filter media be opened.

VI. FILTER MEDIA REPLACEMENT PROCEDURE

NOTE: Rubber gloves, rubber apron, boots, and face protection are required for this task.

The following procedure is to be followed whenever filter media replacement is performed:

A. De-energize well pump
B. Close filter inflow valve
C. Close filter outflow valve
D. Open vent on top of filter housing
E. Open drain located on bottom of filter housing
F. Open outflow pipe drain
G. When water ceases to flow from steps E & F, the filter housing may be opened
H. Remove filter media. Dispose in sealed trash bags.
I. Disinfect area where drain water was present
J. Disinfect person handling filter media, drain water, etc.
K. Replace filter media
L. Close filter housing
M. Close outflow pipe drain
N. Close vent on top of filter housing
O. Open outflow valve
P. Open inflow valve
Q. Energize pipe by starting pump
R. Vent may need to be used to remove airlock from filter

SCHEDULE FOR EVALUATION

DAY	OBJECTIVE
One	Specific yield, raw water base turbidity, hardness, complete chemical and other tests as deemed necessary
Two	Set up turbidity evaluation
Three	Turbidity removal evaluation
Four	*Giardia* and *Cryptosporidium* evaluation
DAY	OBJECTIVE
Five thru Thirty	Biological and chemical analyses along with maximum turbidity removal as per Table 1 (Attached)
Thirty-One	Return system to normal operation

Attachment B

Town of _____
Waterworks Operation Permit No. 0000000
Special Conditions

1. The Town of _____ shall implement a monitoring program for the Well water treatment plant to demonstrate plant performance and compliance with Surface Water Treatment Rule criteria. The monitoring program shall include the following parameters, sampling locations, and sampling frequencies in addition to any required operational monitoring:

PARAMETER	SAMPLING LOCATION	SAMPLING FREQUENCY
Flow	Raw Water Finished Water	Daily
Temperature	Raw Water	Daily
pH	Raw Water Finished Water	Daily
Coliform (MPN)	Raw Water Finished Water	Semi-Monthly (grab)
Particle Count (> 2μ)	Raw Water Finished Water	Hourly (30 Continuous Days) Continuous
Turbidity	Raw Water Finished Water	Continuous
Pressure Differential	Filter, each	Daily (gauge)
Chlorine Residual	Entry Point	Daily
Plant Service Hours		Daily

* Raw Water refers to feed water ** Finished Water refers to filtrate

2. The monitoring program shall continue for a period of 12 consecutive months, beginning with the effective date of the permit.

3. Upon completion of this monitoring program, a final written report shall be submitted to this Department. This report shall be prepared by or under the supervision of a Virginia licensed Professional Engineer or by other appropriately qualified professional and shall include all monitoring, observations, and any related factors influencing treatment plant performance and conclusions and recommendations. This report shall be submitted to the Department within 30 days following the end of the monitoring period.

Attachment C

Chemical & Bacteriological Characteristics Of Groundwater's Previously Pilot Tested

	Town of Shenandoah	Boiling Springs Elem. School	Town of Timberville	Leisure Living Mobile Home Park
Alkalinity (Total)	178.5	88.4	304.4	313.5
Alkalinity (Bicarbonate)	166.8	88.4	277.2	313.5
Corrosion Index	12.54	11.93	13.3	12.28
Chloride	2.0	5.0	7.2	30.0
Color (APHA)	8.0	<5.0	<5	<5
Turbidity (NTU)	8.6	3.2	1.6	0.96
Sulfate	2.1	15.4	12.6	13.7
TDS (Volatile)	185	16	63	67
TDS (Fixed)	31	107	285	307
Silica (as SiO_2)	13.5	7.7	11.2	8.6
Fluoride	0.14	<0.2	<0.2	<0.2
Nitrate	0.79	0.25	5.17	2.44
Total Hardness	190	95	295	340
Ca. Hardness	110	79.3	211	210
pH	6.98	8.08	8.49	7.46
Langlier Index	0.504	-0.099	1.23	0.209
Aluminum	0.27	<0.2	<0.2	<0.1
Iron	0.29	<0.2	<0.2	<0.1
Manganese	<0.01	<0.01	<0.01	<0.01
Magnesium	18	-	-	27
Copper	0.01	<0.2	<0.2	0.02
Sodium	1	<5	<5	14
Total MPN Geo. Mean	0	108	57.46	11.37
Fecal MPN Geo. Mean	0	23	1.85	1.41
Total MPN > 100 Per 100 ml (No. / No. Samples)	0 / 23	12 / 23	11 / 27	6 / 25
MPA Results	Unconfirmed Giardia	-	-	-