Report

Pilot Study Report
Iron and Manganese Removal
Well No. 8 and Well No. 20
Dennis Water District
Dennis, Massachusetts

Prepared for:
Board of Water Commissioners
Dennis Water District
80 Old Bass River Road
South Dennis, Massachusetts 02660

Prepared by:
Earth Tech, Inc.
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June 2007

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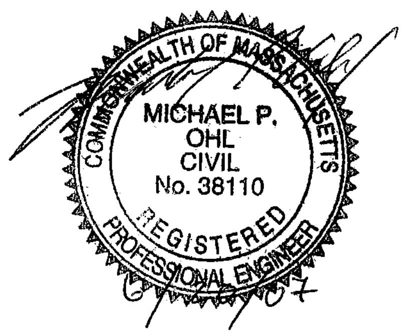

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June 20, 2007

Mr. David Larkowski
Dennis Water District
80 Old Bass River Road
P.O. Box 2000
South Dennis, MA 02660

Subject: Pilot Study Report
Iron and Manganese Removal
Well No. 8 and Well No. 20

Dear Mr. Larkowski:

We are pleased to submit six (6) copies of our Pilot Study Report presenting the findings of the pilot testing of pressure filtration using Hungerford & Terry's GreensandPlus media and Layne Christensen's LayneOx media for the removal of iron and manganese at Well No. 8 and Well No. 20. This report includes our recommendation for which process to utilize in the full-scale water treatment facility design. We have provided a description of the facilities with a proposed floor plan and our opinion of probable construction costs.

We have also transmitted this report to the Massachusetts Department of Environmental Protection Southeast Regional office for their review and approval.

If you have any questions or comments regarding this report, please contact Kristen at 978-371-4099 or Mike at 978-371-4075 at your earliest convenience.

Very truly yours,

Earth Tech, Inc.

Kristen M. Berger, P.E.
Project Engineer

Michael P. Ohl, P.E.
Project Manager

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EXECUTIVE SUMMARY

During April and May of 2007, Earth Tech Inc. conducted a pilot study examining the effectiveness of potential treatment for iron and manganese removal at several of the Dennis Water District's groundwater supplies. The District has two separate pressure zones (North Side and South Side) with dedicated sources of groundwater supply within each system. Approximately ten of the District's groundwater supply wells, 5 in each pressure zone, require treatment for the removal of iron and manganese. The current intent is to construct two water treatment facilities, one in each pressure zone, which would be dedicated to treating the wells within that zone. As discussed with the Massachusetts Department of Environmental Protection (DEP), for this pilot study water from two groundwater wells were pilot tested separately, Well No. 20 within the North Side and Well No. 8 within the South Side.

Two separate treatment technologies were evaluated on each well during the study; a multimedia pressure filter with Hungerford and Terry's GreensandPlus media (GreensandPlus system) and a pressure filter with Layne Christensen's LayneOx media (LayneOx system). The primary piloting objective was to demonstrate stable system performance while meeting drinking water treatment objectives for select parameters including iron and manganese. This document provides a summary of the operational and analytical results obtained from the pilot study, which are then used to establish the design parameters for the proposed treatment facilities.

Once optimized, both pilot systems were able to produce their respective water quality treatment objectives by consistently producing finished water with levels less than the SMCLs of 0.3 mg/L of iron (Fe) and 0.05 mg/L of manganese (Mn). However, the GreensandPlus system was able to consistently produced water with better quality over that produced by the LayneOx system.

During the extended filter runs the GreensandPlus system produced approximately 15% more water than the LayneOx system during the extended run at Well No. 20 and the GreensandPlus system produced approximately 34% more water than the LayneOx system during the extended run at Well No. 8. Using the pilot data to estimate filter run times of 96 hours for the GreensandPlus system and 48 hours for the LayneOx system, we calculated the process efficiencies. The GreensandPlus system is 0.37% more efficient than the LayneOx system. This translates to a savings of 10.8 million gallons per year in backwash supply water (assumes operation at 4 mgd non-stop for two facilities).

In addition to water quality and process efficiency, we examined cost components. The GreensandPlus media can be utilized by several manufacturers of pressure filter systems which allows for more competitive bid prices. The LayneOx media is proprietary and can only be used with the pressure filter system manufactured by Layne Christensen Co. While the higher hydraulic loading rate provided by the LayneOx system allows for a slightly smaller building footprint, the difference in footprint is relatively small and does not significantly impact the overall capital cost of the facility. Additionally the capital cost for the LayneOx system is more than that for the GreensandPlus system.

The following decision matrix presents the factors involved in the selection process. Each factor was rated as 1 = Poor or 2 = Good. The factors were weighted as shown. The Relative Score is the Sum of the Factor Ratings times the Factor Weight. The decision matrix shows that the GreensandPlus system is slightly more favorable than the LayneOx system. We have weighted the factors according to the level of importance we feel should be placed on each.

TABLE ES-1
DECISION MATRIX

1 = Poor, 2 = Good

Factor	**Factor Weight**	**GreensandPlus System**	**LayneOx System**
Filtered water meets drinking water standards	10%	2	2
System excels in removing Fe & Mn	10%	2	1
Volume of water treated between backwashes	10%	2	1
Volume of water produced annually	10%	2	1
Higher hydraulic loading rate (smaller footprint)	10%	1	2
Ease of operation and training of staff	10%	2	2
Competitive bidding environment	10%	2	1
Facility capital costs (process & building)	15%	2	2
Operation and maintenance costs	15%	2	2
Relative Score	**100%**	**1.9**	**1.6**

After consideration of all of the factors above, we recommend that the District utilize the GreensandPlus system as the primary treatment process for the removal of iron and manganese at the proposed water treatment facilities.

Some of the pilot testing was performed with a simulated raw water transmission main to mimic chemical addition at the existing corrosion control facilities. The additional detention time allowed for removal of iron and manganese that met or exceeded removals achieved without the transmission main. The field data show that utilizing the District's existing corrosion control facilities for addition of chemicals for pH adjustment and oxidation is feasible for final design. This design provides for additional cost savings since the District will be able to continue to utilize an investment in which they have already made and they will not have to build space for pre-filter chemical feed systems at the new facilities.

The proposed GreensandPlus water treatment facilities will have the design parameters listed in Section 6 of this report. The current intent is to have two facilities, one for each pressure zone. Each facility will be designed for 2,850 gallons per minute (gpm) or approximately 4 million gallons per day (mgd) with six vertical filter vessels 11-feet in diameter. The buildings will be slab-on-grade, pre-engineered metal buildings with standing seam metal roofs approximately 45 feet by 85 feet (3,825 square feet) each. Each facility will have unique site designs and will be equipped with on-site lagoons for residuals handling.

Our estimates of probable project cost are for planning purposes only and should be re-evaluated prior to appropriating funds for the actual construction of each project. The engineering, construction and operational cost are based on individual site-specific projects. The ENR construction cost index at the time of this budget cost estimate was 7939 for June 2007. The opinion of probable construction costs are shown in the following Table ES-2.

TABLE ES-2
OPINION OF PROBABLE CONSTRUCTION COSTS

Item	**Description**	**Cost**
North Side WTP	WTP Construction	$ 3,500,000
	Water Main Construction	$ 900,000
	Subtotal - Construction	$ 4,400,000
South Side WTP	WTP Construction	$ 3,500,000
	Water Main Construction	$ 1,100,000
	Subtotal - Construction	$ 4,600,000
Contingency	20% of Construction Estimate	$ 1,800,000
Engineering	Design/Bidding/Construction	$ 1,100,000
Total		**$ 11,900,000**

Assumptions:
Land already owned by District - no land acquisition costs included.
Water main costs assume public bidding is not required and construction is by the District.
Costs projected to 2008, assuming 3% inflation rate.

Table ES-3 shows the estimated additional operation and maintenance costs.

TABLE ES-3
ESTIMATED ADDITIONAL OPERATION AND MAINTENANCE COSTS

Description	Cost	Frequency
Labor (1 operator)	$80,000	per year
Electricity ($0.22 per kwh)	$180,000	per year
Chemicals	$50,000	per year
Media Replacement	$200,000	every 10 years

Assumptions:
Costs shown are additional to those the District already experiences.
Costs for 16 hours per day operation at 4 mgd.
Costs based on two water treatment facilities.
Labor cost includes fringe benefits.
Chemical costs for sodium hypochlorite only.
Media cost is materials only (no labor or disposal costs).

SECTION 1

Introduction

1. INTRODUCTION

A. OVERVIEW

Several of the District's groundwater supplies have elevated concentrations of iron and/or manganese, above the U.S. Environmental Protection Agency (USEPA) Secondary Maximum Contaminant Level (SMCL). This pilot study is a continuation of the Iron and Manganese Treatment Feasibility Study, dated February 19, 2007, performed by Earth Tech, Inc. The current intent is to construct two water treatment facilities, one in each pressure zone, which will ultimately treat water from ten of the District's wells.

As discussed with the Massachusetts Department of Environmental Protection (DEP) Southeast Region, piloting was conducted on one well within each zone, preferably a well that had historically shown higher levels of iron and manganese. For the North Side, the well with the highest levels of iron and manganese has been Well No. 11. However, this well was being cleaned and redeveloped as part of routine maintenance and was not available during the pilot study. As an alternate, Well No. 20 was used for the North Side pilot study, as it had historically shown high levels of iron and manganese. Recent sampling of Well No. 20 by the District (first quarter of 2007) indicated iron levels of approximately 1.1 mg/L. For the South Side, Well No. 8 was tested since historically it has shown the worst water quality in this zone. Well No. 20 was selected to demonstrate the processes abilities to treat water with higher iron levels, while Well No. 8 was selected to demonstrate the processes abilities to treat water with higher manganese levels.

The processes tested during this pilot study were a multimedia pressure filter with Hungerford and Terry, Inc.'s GreensandPlus media (GreensandPlus system) and a pressure filter with Layne Christensen Company's LayneOx media (LayneOx system). Earth Tech, Inc. operated the GreensandPlus system from April 9 through May 4, 2007. Operators from Layne Christensen Company operated the LayneOx system from April 9 through May 2, 2007 and May 15 through May 18, 2007.

B. OBJECTIVE

The pilot testing objectives were to determine the adequacy and capability of the processes to treat groundwater from Well No. 20 and Well No. 8. Operational parameters affecting full-scale treatment design were determined by evaluation of the following parameters:

- Treated water quality
  - Total Iron concentration in the filtered water (Goal: below 0.3 mg/L)
  - Total Manganese concentration in the filtered water (Goal below 0.05 mg/L)
- Hydraulic loading rates
- Operating run lengths
- Chemical feed requirements
- Waste characteristics

SECTION 2

Raw Water Characteristics

2. RAW WATER CHARACTERISTICS

A. HISTORICAL WATER QUALITY

As shown in Table 2-1 the historical raw water quality of the groundwater well supply sources with elevated concentrations of iron (Fe) and/or manganese (Mn). The full-scale system would treat water from a combination of wells or individually from each well.

TABLE 2-1
HISTORICAL RAW WATER QUALITY

		Iron			Manganese				
Well No.	Flow (gpm)	2005 Fe (mg/L)	Historical Average (mg/L)*	Historical Maximum (mg/L)*	2005 Mn (mg/L)	Historical Average (mg/L)*	Historical Maximum (mg/L)*	pH**	Alkalinity (mg/L as $CaCO_3$)**
North Side									
4	300	0.8	0.67	1.7	0.02	0.05	0.1	5.6	4.38
9	600	0.2	0.13	0.3	0.03	0.05	0.07	5.4	1.50
11	500	1.2	0.75	1.8	0.07	0.10	0.17	5.56	5.13
19	700	0.4	0.22	0.6	0.04	0.04	0.07	7.08	29.1
20	700	0.47	0.60	1.3	0.04	0.04	0.11	6.01	8.88
South Side									
7	450	0.1	0.09	0.1	0.08	0.09	0.14	5.81	3.25
8	300	0.5	0.35	0.7	0.26	0.25	0.40	5.59	2.88
15	700	0.33	0.21	0.4	0.05	0.06	0.19	7.06	32.9
16	450	0.1	0.12	0.3	0.15	0.22	0.30	6.99	60.1
21	700	0.36	0.25	0.4	0.10	0.10	0.10	5.27	6.33

*Wells No. 4 through No. 19: average and maximum data over 14 years. Well No. 20: average and maximum data over 8 years. Well No. 21: average and maximum data over 2 years.
**Wells No. 4 through No. 20: average data over 8 years. Well No. 21: average data over 2 years.

B. IRON AND MANGANESE

Iron (Fe) and Manganese (Mn) are minerals in drinking water which when present at elevated levels cause aesthetic and nuisance issues as follows:

- Stain laundry and water use fixtures
- Cause metallic or vinyl type taste in the water
- Clog household water filters
- Cause objectionable water color
- Prompt customer complaints
- Support growth of Fe/Mn bacteria, non-health related bacteria that clog strainers/pumps/valves
- May increase the number of coliform "hits" in the distribution system

The Environmental Protection Agency (EPA) and MA DEP regulate iron and manganese in drinking water as Secondary Maximum Contaminant Levels (SMCLs) to protect public welfare and promote increased customer satisfaction. The SMCL for Fe is 0.3 mg/L and Mn is 0.05 mg/L. Levels above SMCLs lead to loss of customer confidence in water quality/health, resulting in customers seeking alternate supplies. Compliance with SMCLs is strongly encouraged by the MA DEP.

The District noticed an increasing problem with Fe and Mn after implementation of their corrosion control program. Using potassium hydroxide (KOH), the District raises the pH of the groundwater to approximately 7.2 pH units. Fe and Mn precipitate more readily at this pH. However, the increase in pH is required to be in compliance with the Lead and Copper Rule, as the District has attempted to reduce the pH recently in order to minimize the Fe and Mn problems, but could not maintain this lower pH and maintain compliance with the Lead and Copper Rule.

In past years, the District has attempted to control the precipitation of Fe and Mn from the water in the distribution system through dosing of sequestering chemicals such as sodium hexametaphosphate. However, the levels of Fe and Mn have become unmanageable using the existing mitigation methods. Additionally, historical data show that a trend of increasing Fe and Mn levels in some wells.

Fe and Mn removal is the final method of mitigation and this is achieved using a water treatment facility. After review of the data, the District determined that the preferred treatment alternative for Fe and Mn removal would be two water treatment facilities, one for each zone, and both facilities would utilize pressure filtration.

SECTION 3

Pilot Testing Program

3. PILOT TESTING PROGRAM

A. PILOT TESTING EQUIPMENT AND OPERATION

Two iron and manganese removal processes were tested for this study. The first is a pressure filtration system utilizing GreensandPlus media by Hungerford and Terry and the second is a pressure filtration system utilizing granular oxidative media called LayneOx by Layne Christensen Company. These removal processes were selected because each has a proven success at full scale for the removal of iron and manganese from groundwater supply sources. Figure 3-1 (see next page) shows a process schematic for the two pilots. Each pilot process is described in detail below.

FIGURE 3-2
CORROSION CONTROL FACILITY

At Well No. 20 water was taken from the discharge of the well pump for the first phase of testing and from the 100 foot sample line located downstream of the corrosion control facility for the second phase of testing. At Well No. 8 water was taken from the 100 foot sample line located downstream of the corrosion control facility for all tests. The pH of the water was adjusted prior to entering the filter. During test phase 1 at Well No. 20, the pH of the water was using potassium hydroxide (KOH) dosed and controlled by the individual pilot operators. During phase 2 testing at Well No. 20 and testing at Well No. 8, water was pH adjusted at the corrosion control facilities by the District and then taken from the 100 foot sample water line, which provided water of the same pH to each pilot unit.

The intent, for full-scale treatment, is to inject KOH and sodium hypochlorite (NaOCl) at the existing corrosion control facilities. The chemically adjusted water would flow through transmission mains to the water treatment facilities. This design allows the District to utilize the existing chemical feed systems and to customize chemical dosing to each well. The transmission main design was simulated during the pilot study through the use of 1,200 feet of 1-inch service pipe installed downstream of the chemical injection ports but upstream of the filter vessels.

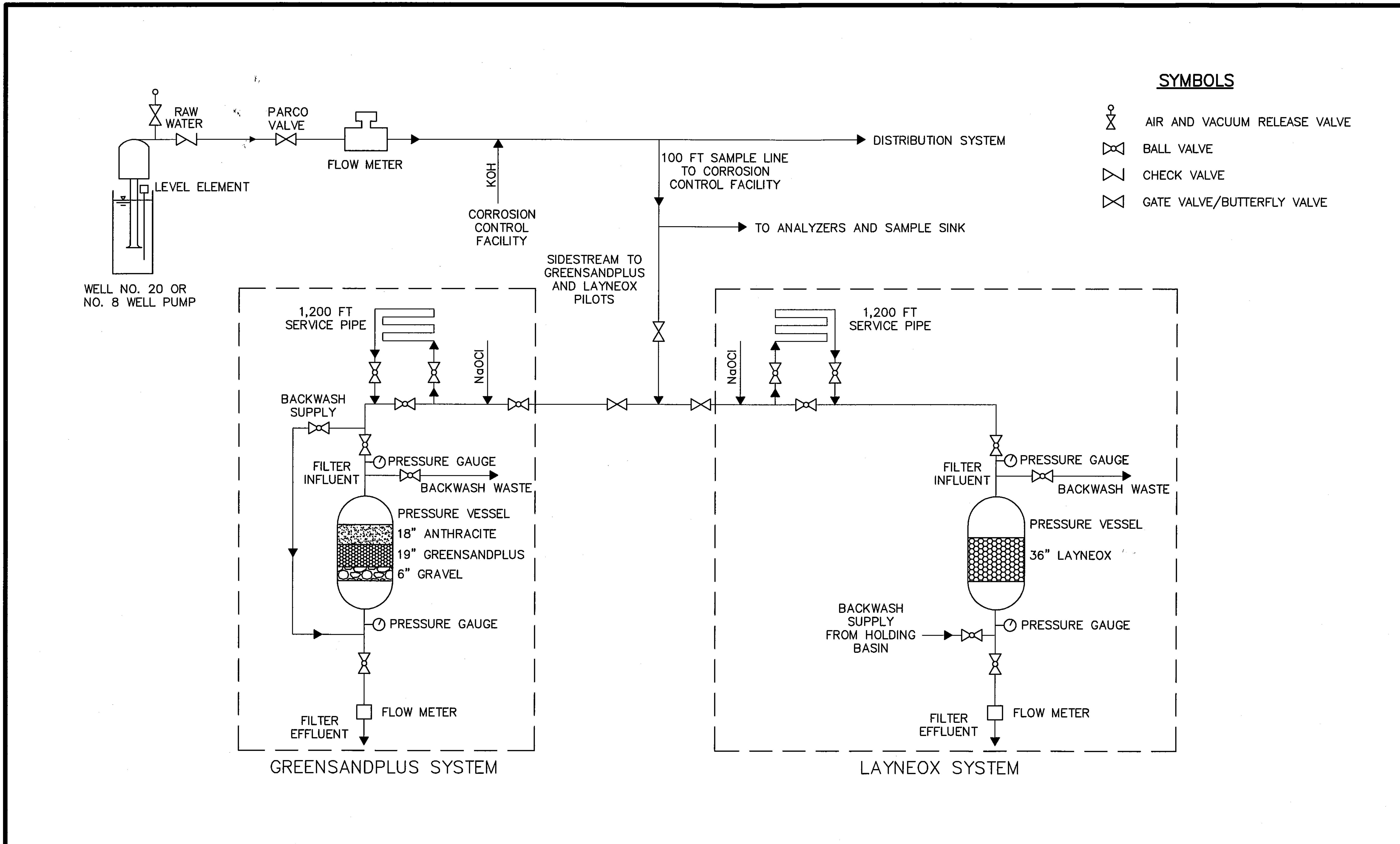

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FIGURE NO. 3–1
PILOT PROCESS SCHEMATIC
DENNIS WATER DISTRICT

1. GreensandPlus System

The pilot study evaluated the effectiveness of Hungerford and Terry's GreensandPlus media on the removal of iron (Fe) and manganese (Mn) from groundwater supply sources located at Wells No. 8 and No. 20. GreensandPlus is a silica sand core media coated with manganese dioxide (MnO_2). The GreensandPlus media was contained within a closed, pressure type vessel with a surface area of approximately 0.5 square feet (sf). The filter vessel contained 18-inches of anthracite over 19-inches of GreensandPlus media supported by 6-inches of gravel. The 18x60 mesh GreensandPlus media has an effective size of 0.3 to 0.35 millimeters (mm). Sodium hypochlorite was used for oxidation prior to filtration through the GreensandPlus pressure filter vessel. A picture of the pilot unit is shown in Figure 3-3. A data sheet describing the GreensandPlus media is provided in Appendix A.

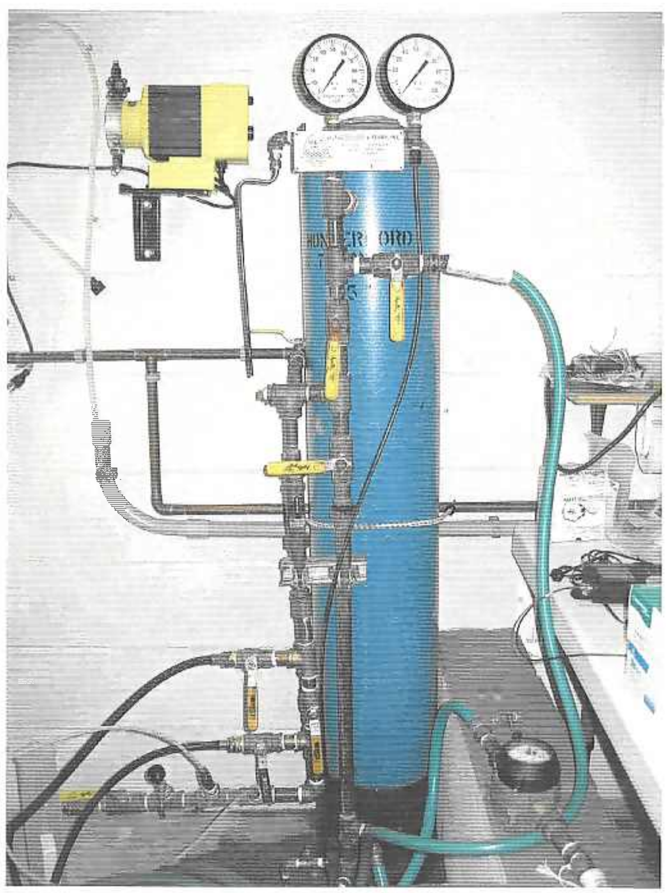

FIGURE 3-3
GREENSANDPLUS PILOT VESSEL

The GreensandPlus filtration pilot was operated in continuous regeneration (CR) mode during which most of the soluble iron and manganese were oxidized before entering the greensand filter. This was accomplished by the continual pre-feed of sodium hypochlorite. The oxidized precipitates were then filtered by the media with subsequent removal during backwashing. The filter bed was capped with anthracite coal to remove the majority of the precipitates so as not to blind the GreensandPlus media.

The GreensandPlus filter pilot unit loading rates tested were from 4 gallons per minute per square foot (gpm/sf) and 6 gpm/sf. The unit was backwashed at the end of each run which was determined based on time or water quality breakthrough. Pressure differential did not dictate backwash during this study. The maximum recommended pressure differential for this media is 8 to 10 pounds per square foot (psi). The filter media was typically backwashed at 10 gpm/sf for 10 minutes.

2. LayneOx System

The LayneOx process utilizes granular oxidative media to remove iron and manganese from water supplies. Sodium hypochlorite was used for oxidation prior to filtration through the LayneOx pressure filter vessel. The LayneOx process has manganese dioxide (MnO_2) present on the media, which provides additional iron and manganese oxidation from the water and adsorption to the media. As the process continues the differential pressure across the media bed increases and requires backwashing. The LanyeOx media was contained within a closed, pressure type vessel with a surface area of approximately 0.785 sf. Most of the pilot was operated with the 20x40 mesh media with an effective size of 0.3 to 0.5 mm. One run was completed with the 8x20 mesh media with an effective size of 1 to 1.3 mm. A data sheet describing the LayneOx media is provided in Appendix A.

The LayneOx filter pilot unit loading rates were 6, 8 and 10 gpm/sf. The media was backwashed based on time, breakthrough of water quality or differential pressure. The manufacturer recommended maximum pressure differential of 10 psi, was reached during some of the pilot runs. The 20x40 mesh media was typically backwashed at 25 gpm/sf for 5 minutes and the 8x20 mesh media was backwashed at 30 gpm/sf for 5 minutes.