Signed: July 5, 2007

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City of Vernon

DHS ENGINEERING REPORT ON IRON AND MANGANESE TREATMENT

TREATMENT ALTERNATIVES AND COST ESTIMATES

DRAFT
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City of Vernon

DHS ENGINEERING REPORT ON IRON AND MANGANESE TREATMENT

TREATMENT ALTERNATIVES AND COST ESTIMATES

TECHNICAL MEMORANDUM
NO. 1

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TREATMENT ALTERNATIVES AND COST ESTIMATES

1.0 BACKGROUND

The City of Vernon (City) is located near the geographic center of metropolitan Los Angeles County, situated within 2 miles of four major freeways and near the site of Hobart Yard, which is a major rail terminal for Los Angeles. Elevated levels of iron (Fe) and manganese (Mn), both classified by the Environmental Protection Agency (EPA) as non-hazardous contaminants, have been found in four of the City wells. Levels in the wells exceeded the California Safe Drinking Water Act of 1986 (SDWA) secondary maximum contaminant level (MCLs). Although these are secondary MCLs, the City is required either to comply with the MCLs or to obtain a waiver in accordance with Title 22, Section 64449 of the California Code of Regulations (CCR).

In order for the City to obtain a waiver on treatment and to comply with the CCR requirement, the City needs to conduct a study to evaluate treatment alternatives and develop costs for Fe and Mn treatment.

This report constitutes the requirements for the study. The cost information will be used as a basis for developing rate increases to be included in the mailer survey to the residents to vote whether or not the treatment option should be implemented.

2.0 EXISTING WATER SYSTEM

The City Water Department serves water to the majority of the City. A small portion of the northeast corner of the City is served by California Water Service and a small area in the southeast area of the City is served by Maywood Mutual No. 3. Figure 1.1 shows the City's service area.

The City has approximately 45,000 daytime residents and 93 permanent residents. Based on the City's 2006 Annual Report to the Drinking Water program, only 21 of the 1,760 active connections were residential, and the remaining were mainly commercial and industrial. The approximate annual water demand was estimated to be 11,000 acre-feet or 3.9 billion gallons (2006 data). Table 1.1 summarizes the number and types of connections the City currently has.

Table 1.1 City of Vernon Water Service Connections
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

Type/Category	Metered
General and Residential	16
Commercial	1,343

Table 1.1	City of Vernon Water Service Connections DHS Engineering Report on Iron and Manganese Treatment City of Vernon
Type/Category	**Metered**
Industrial	404
Irrigation (Ag and Residential)	0
Total Active Connections	**1,763**

2.1 Water Supply

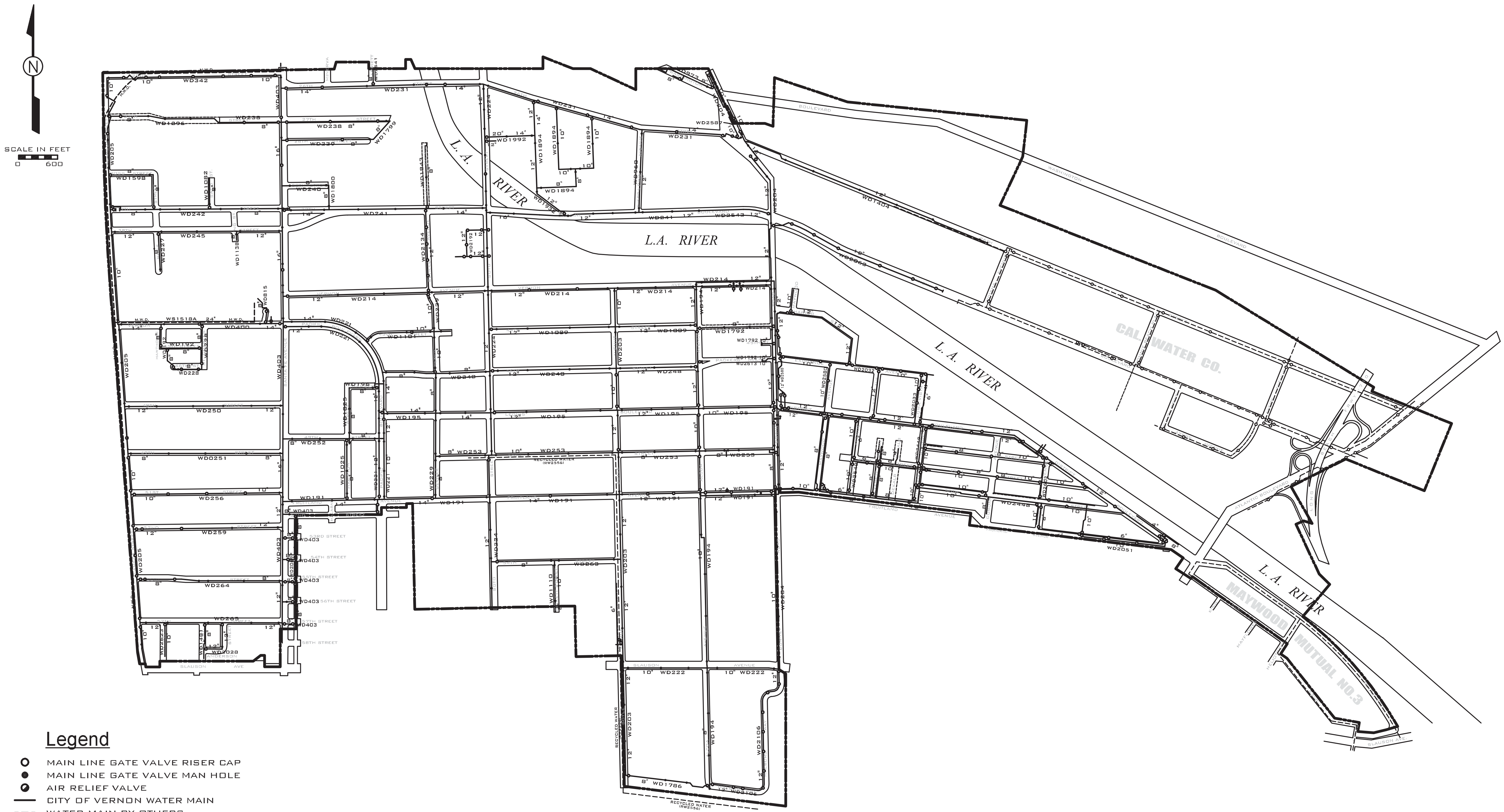
The primary water supply for the City is groundwater. In addition, the City has a direct connection to the Metropolitan Water District of Southern California (MWD). The MWD connection provides both a supplemental water source and an emergency supply in the event of a major power outage. The City's ground water system is made up of eight active wells and one inactive well. There is no treatment of the water other than chlorination. Table 1.2 provides a summary of selected information about the nine wells.

Table 1.2 Information About Existing Potable Water Wells
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

Well No.	Date Drilled	Perforated Intervals, ft	Total Depth, ft	Ground Elevation, ft	Capacity, gpm
11	5/23/1952	741-776, 816-826, 863-871, 983-997, 1,105-1,142, 1,163-1,186	1,343	197.22	1,143
12	11/20/1953	996-1,015, 1,067-1,169, 1,260-1,580	1,588	183.29	700
14	3/23/1962	360-1,251	1,302	203.75	1,351
15	10/27/1966	510-1,502	1,550	177.76	1,953
16	8/18/1970	510-1,460	1,520	197.22	1,450
17	11/1/1970	510-1,500	1,550	183.29	1,750
18 (inactive)	11/30/1958	510-1,361	1,443	184.57	1,450
19	9/19/1988	510-1,550	1,660	180.45	1,380
20	9/23/1988	510-1,550	1,620	159.47	1,460

2.2 Storage and Distribution System

The City's water distribution system consists of 250,000 linear feet of pipe, six ground level reservoirs, one elevated tank, and one belowground reservoir. The total storage capacity in these facilities is 16 million gallons (MG). The average pressure in the distribution system is about 75 psi.



Legend

- ○ MAIN LINE GATE VALVE RISER CAP
- ● MAIN LINE GATE VALVE MAN HOLE
- AIR RELIEF VALVE
- CITY OF VERNON WATER MAIN
- WATER MAIN BY OTHERS
- ABANDONED WATER MAIN
- MAINS ARE NOT CONNECTED
- TEE OR CONNECTION IN MAIN
- CROSS OR CONNECTION IN MAIN
- LH LEFT HANDED VALVE (LEFT TO CLOSE)
- BF BUTTERFLY VALVE

CITY OF VERNON SERVICE AREA

FIGURE 1.1

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Figure 1.2 shows the City's overall distribution system. It is made up of three main booster pump stations/plants. Booster Plant 1 is fed by Well Nos. 11 and 16, has a 10-MG reservoir, and has five distribution pumps. A 24-inch MWD connection is also available at this location. Booster Plant 2 is supplied by Well Nos. 12 and 17, has three 1-MG storage tanks, and has six distribution pumps. Booster Plant 3 is supplied by Well Nos. 15 and 19, has three 1-MG storage tanks, and has five distribution pumps. Well No. 19 can discharge either directly to the distribution system or to the three storage tanks. The remaining three wells, Well Nos. 14, 18, and 20, discharge directly to the distribution system without going through any storage. In addition, the City also owns a 0.6-MG elevated storage tank.

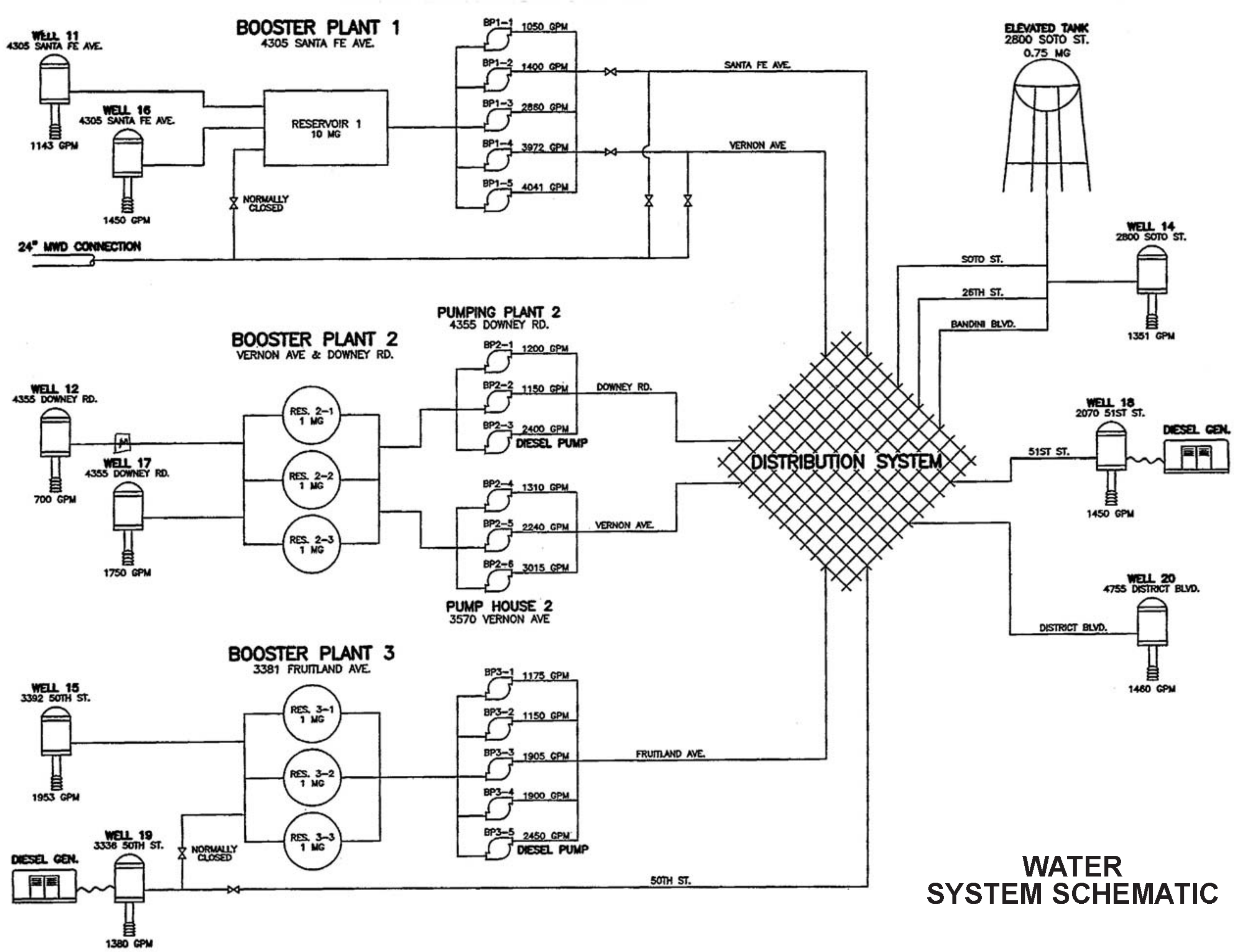
3.0 WATER QUALITY

Overall, the groundwater quality of the City's wells is good. However, the groundwater sources have a history of exceeding the secondary MCLs for Fe (300 µg/L) and Mn (50 µg/L). Both of these secondary limits are regularly exceeded in water pumped from Wells Nos. 12 and 14, while the Mn MCL is exceeded regularly in water pumped from Wells Nos. 17 and 20. These findings have been noted in the Consumer Confidence Reports that the City distributes to its customers annually.

Table 1.3 summarizes the water quality of the four wells for selected parameters.

Table 1.3 Historical Water Qualities of Well Nos. 12, 14, 17, and 20
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

Parameter	Units	Secondary MCL	Well No. 12	Well No. 14	Well No. 17	Well No. 20
Manganese	µg/L	50	54-180	40-1200	30-120	30-111
Iron	µg/L	300	ND-2,000	ND- 5,400	ND-144	ND-740
Sulfate	mg/L	250	79-82	75-110	62-67	50-79
TDS	mg/L	500	370-380	450-520	350-390	350-420
Alkalinity	mg/L	--	190-210	180-240	180-200	170-210
Hardness	mg/L	--	212-220	240-300	200-217	190-200
Bicarbonate	mg/L	--	230-250	229-284	220-250	210-250
pH		--	7.8-7.9	7.4-8.2	7.6-7.9	7.7-8.0
Flow rate	gpm	--	700	1,350	1750	1460



WATER SYSTEM SCHEMATIC

FIGURE 1.2

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CITY OF VERNON

4.0 DRINKING WATER REGULATIONS

4.1 Iron

The California Department of Health Services (DHS) has set a secondary MCL for Fe of 300 µg/L. Exceeding the suggested level usually results in discolored water, laundry, and plumbing fixtures. This, in turn, results in consumer complaints and potential dissatisfaction with the water utility.

4.2 Manganese

Based on the health effects, the California DHS has set a notification level for Mn, which is currently at 500 µg/L. However, at concentrations exceeding 100 µg/L, Mn imparts an undesirable taste and stains plumbing fixtures and laundry. These considerations lead the EPA to set a secondary MCL of 50 µg/L for Mn in drinking water (Federal Register, 1979).

5.0 IRON AND MANGANESE ALTERNATIVE TREATMENT METHODS

As mentioned earlier, the City can apply for a compliance waiver to meet the secondary standards for Fe and Mn. However, the City is still required to evaluate the treatment alternatives and report the findings to the DHS, under this option.

There are several treatment alternatives available for Fe and Mn control in a water treatment plant. The most basic methods are chemical oxidation followed by clarification and filtration. Other treatment alternatives are described in the following paragraphs and include ion exchange, sequestering processes, biological removal, GAC, and membranes.

5.1 Oxidation and Filtration

Oxidation followed by filtration is the most popular process in the United States (U.S.) for Fe and Mn removal. Under reducing conditions, Fe and Mn are stable as soluble forms (ferrous [Fe^{2+}] and manganous [Mn^{2+}] ions). When they are oxidized, they become insoluble ferric (Fe^{3+}) and manganic hydroxide (Mn^{3+}) species, and these can be physically removed with a filtration process.

Chlorine and potassium permanganate are common oxidants applied in commercial packaged systems. It has been reported that soluble Mn (II) was rapidly oxidized by potassium permanganate, chlorine dioxide, and ozone in low dissolved organic carbon (DOC) waters. When chlorine is used as an oxidant, it may react with natural organic matter in the raw water to form trihalomethanes (THMs) and haloacetic acids (HAAs), which are regulated contaminants under the Stage 2 Disinfectants/Disinfection By-products (DBPs) Rule (D/DBPR). Therefore, if halogenated DBPs are an issue, other oxidants may offer benefits compared to chlorine, such as potassium permanganate, ozone, and chlorine dioxide. In the City's case, it is not an issue since the water organic content is expected to be low.

Optimal Mn oxidation occurs in the pH range of 8.0 to 8.5. Chlorine dosages as high as five times the theoretical stoichiometric requirements may be necessary to oxidize Fe and Mn within reasonable detention times. Potassium permanganate is a stronger oxidant than chlorine and chlorine dioxide and can be effective with regard to dissolved Mn oxidation at pH values above 7.5. The rates of reactions of Fe and Mn with permanganate are very fast and could minimize the space requirement by eliminating the reaction vessel sometimes needed with chlorine oxidation. However, the chemical is more expensive than chlorine.

Once oxidized and precipitated, particulate Fe and Mn must be removed from the water. Several technologies are available and have been applied to accomplish this solids separation step. Dual-media filters with anthracite and sand are commonly used for solids separation in the water treatment and can be applied for the removal of Fe and Mn. Fe and Mn can also be removed with a catalytic filter media that uses oxygen in the water to convert metal ions from a soluble form to an insoluble form. This insoluble precipitate is then filtered out onto the surface of the media.

Most of the commercial systems use Mn greensand medium, which is a term used for naturally rich Mn dioxide minerals, which promote adsorption of dissolved Mn or other proprietary media. Greensand medium can also serve for physical removal of ferric hydroxide and ferric oxide precipitates.

5.2 Sequestration

Sequestration means preventing the formation of objectionable color and turbidity without actually removing the Fe and Mn. It is the addition of chemicals to groundwater aimed at controlling problems caused by Fe and Mn. These chemicals are usually added to groundwater at the wellhead or at the pump intake before the water has a chance to come in contact with air or chlorine. This ensures that the Fe and Mn stay in the soluble form.

Polyphosphate is one of the sequestering agents that can bond with Fe and Mn and thus prevent them from precipitating in water. Although this approach requires only minor modifications to any existing system, it does not provide a permanent solution (removal) for high Fe and Mn concentrations. Furthermore, depending on the type of polyphosphate used, the Fe-polyphosphate complex may break down when heated. The Fe and Mn released may then cause a problem such as precipitation or staining. Thus, high-temperature processes or laundries using hot water may experience potential problems when sequestering agents are used. Furthermore, sequestration of Fe and Mn may pose negative effects on some of the City's customers' internal processes. If a customer is using some type of oxidation and filtration processes to remove Fe and Mn from the tap water, this process may not operate as designed because the sequestered Fe and Mn are complexed (bound) with the polyphosphate. That is, Fe and Mn would not be removed from the water. Another process that may be affected by the sequestration process is reverse osmosis (RO) filtration. The polyphosphate agent and sequestered compounds could increase the fouling potential on the RO membranes. Additional pretreatment processes could be required for removal of these compounds to prevent membrane fouling. In addition, there may be other potential interferences from polyphosphate on different types of water treatment and manufacturing processes, but it is difficult to ascertain exact impacts without detailed information about these processes.

In terms of chemical dose, theoretically, there is no limit to the amount of soluble Fe and Mn that would make sequestration an effective mitigation method. However, various studies have reported some upper limits for chemical sequestration of Fe and Mn. The National Drinking Water Clearing House states that sequestration followed by chlorination can be effective for water containing less than 1,000 µg/L Fe and 300 µg/L Mn. According to the California Department of Health Services Policy Memo 2001-1 Secondary Standards, various levels of Fe and Mn up to 5,000 µg/L have been cited as the economical and technical limit for effective mitigation method. The policy also states that levels above 2,000 µg/L are less likely to be successfully mitigated with polyphosphates based on their experience. If sequestration is selected, bench- or pilot-scale testing is highly recommended to evaluate the feasibility and effects of using this method to address the Fe and Mn issues in the groundwater.

Sequestering agents are injected via a chemical metering pump at the wellhead before other chemical additives (chlorine, fluoride, caustic soda, etc.). If permissible, these agents are injected down the well casing to mix with groundwater at the pump intake.

5.3 Ion Exchange

The ion exchange process involves exchange of soluble ionic species. Application of softening in water treatment for Fe and Mn removal is limited since it can only be used where Fe and Mn exist completely in the soluble forms. In addition, the system should be airtight; otherwise, oxidation of Fe and Mn with oxygen could result in breakthrough from the ion exchange resin bed. The potential of fouling in ion exchange resins may increase as Fe and Mn concentrations increase. This alternative is not considered to be a practical application in this case.

5.4 GAC

Bituminous-based GACs can remove Fe. However, these systems are not capable of removing Mn unless the pH is greater than 8.5. Therefore, GAC is not considered as a suitable alternative.

5.5 Membranes

Both reverse osmosis (RO) and nanofiltration (NF) can remove the soluble forms of Fe and Mn. The true benefit of the high-pressure membrane treatment processes is their ability to also remove other dissolved contaminants at the same time. However, because of their high capital and operating costs and concentrate stream disposal issues, it is not economically feasible to apply these technologies for Fe and Mn removal alone.

Low-pressure membranes such as ultrafiltration (UF) and microfiltration (MF) can be used downstream of pre-oxidation of Fe and Mn, as a filtration step to remove the insoluble precipitates. For treating Fe and Mn removal, membrane systems will be more costly than granular media pressure filter-based systems.

5.6 Biological Filtration

Biological filtration uses indigenous microorganisms that are able to metabolize Fe and Mn to reduce their levels in source water. It offers lower operating and capital costs than comparable physical/chemical processes. It also produces less waste product that allows easier dewatering and disposal of residual. However, biological treatment requires specific raw water qualities and conditions, and not all groundwater or surface water can be treated economically using this technique. Success of this treatment process depends on several factors such as nutrient availability, oxidation/reduction conditions, temperature, and filter operation strategy. When both Fe and Mn are present in the water, a two-stage process is required. Cost and practicality of a two-stage process are considerations that make this alternative less attractive. Biological filtration also requires equalization to ambient pressure for operation and needs permitting by DHS for implementation for drinking water application. Therefore, biological filtration is not considered a practical alternative in this case.

5.7 Fe/Mn Summary and Recommendation

A summary of the advantages and disadvantages for each of the alternative for treatment of Fe and Mn is presented in Table 1.4.

6.0 RECOMMENDED TREATMENT TRAINS

6.1 Summary of Recommended Processes

Based on the water quality of the wells and the above discussion on the various unit processes, the oxidation/filtration process is the recommended approach for the Fe and Mn removal. Figure 1.3 depicts the possible treatment train at each of the well sites. Even though the sequestration approach is not a removal process (Fe and Mn still remain in the water in dissolved forms), it was evaluated for comparison purposes per City's request to apply for a waiver. Figure 1.4 shows the typical setup of a sequestration system.

Table 1.4 Advantages and Disadvantages of Fe/Mn Treatment Technologies
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

Process	Advantages	Disadvantages
Oxidation and Filtration	• Proven process. • Effective for iron and manganese removal. • Most cost-effective.	• Must maintain oxidant residual. • Over feeding $KMnO_4$ can result in pink water.
Sequestration	• Cost-effective.	• Does not remove Fe/Mn from water. • Precipitate out Fe/Mn when heated(1)
Ion Exchange	• Common treatment process.	• Limited to completely dissolved forms of Fe/Mn.
GAC	• Could help with VOC treatment.	• Can only remove Mn at pH values greater than 8.5.
Membranes	• Small footprint. • Effective for Fe/Mn removal.	• Costly when treating only Fe/Mn.
Biological	• May offer lower operating cost than comparable physical/chemical processes. • May produce fewer waste products.	• Requires specific raw water qualities and conditions. • Success depends on nutrient availability, oxidation/reduction conditions, temperature, and filter operation strategy.

Notes:
(1) Although some sequestrants are reported to be heat resistant.

Table 1.5 Summary of Available Oxidation Alternatives for Fe/Mn Removal
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

	Oxygen	Ozone	Chlorine	Potassium Permanganate
Oxidation Potential	Low-short contact time	Highest	Medium high	High
Cost	Low	High	Medium low	Medium high
Ease of Handling	High	Medium low	Medium	Medium
Potential Issues	Slow oxidation	Ozone by products	Potential formation of THMs (but not for low DOC water)	Pink water if overdosed

6.2 Oxidation/Filtration Treatment System

Oxidation with chlorine or potassium permanganate, followed by media filtration and greensand filtration with chemical feed for regeneration are the best alternatives for treating the Fe and Mn. This conclusion is based on an evaluation of available oxidation and filtration alternatives, as shown in Tables 1.5 and 1.6.

Table 1.6 Summary of Available Filter Media for Fe/Mn Removal
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

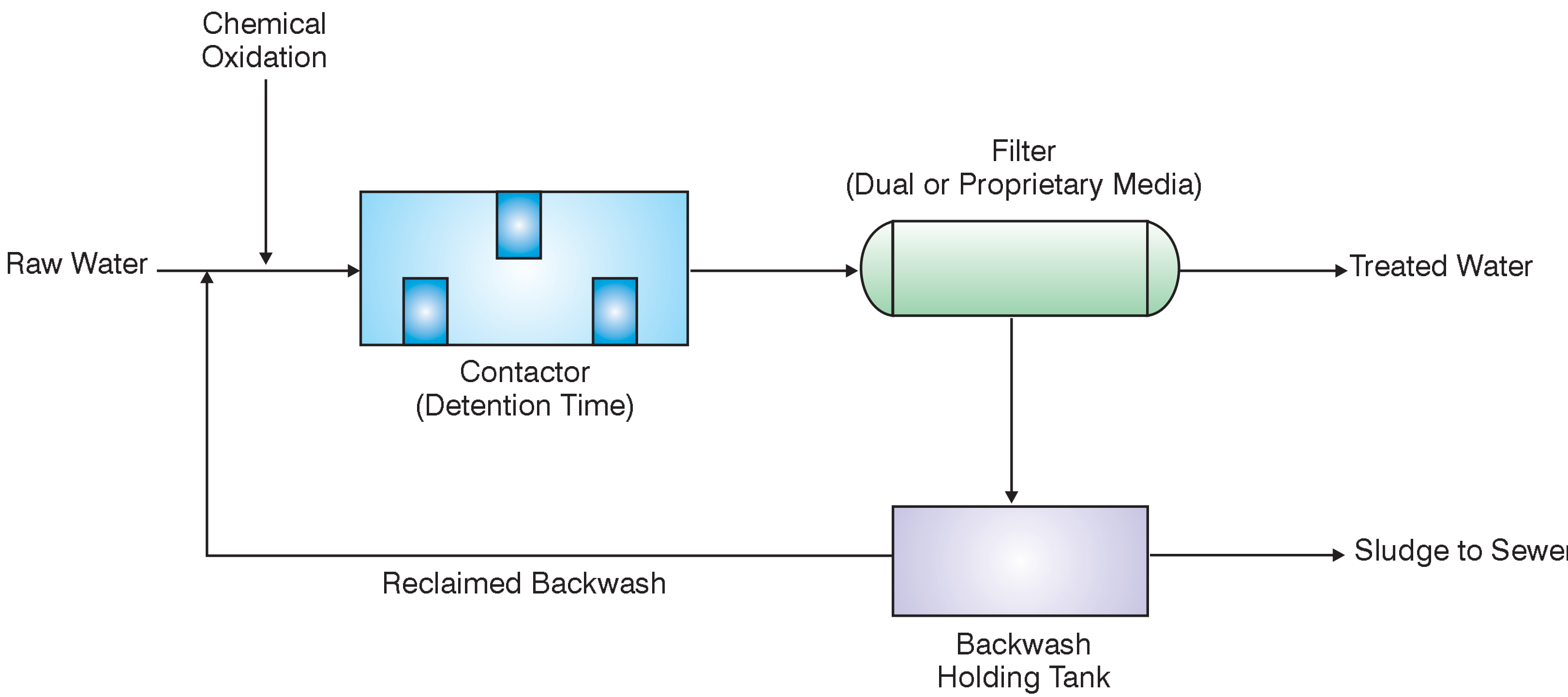
	Dual Media	Catalytic Media (Greensand without Regeneration)	Greensand with Regeneration
In-situ (in-vessel) Oxidation	No	Partial	Yes
Media Regeneration	No	No	Yes, with $KMnO_4$
Media Cost	Low	High	High
Pre Reaction Vessel Requirements	Yes	No	No
Oxidant Compatibility	No specific requirement	No specific requirement	Must use $KMnO_4$

Several Fe and Mn oxidation and filtration systems are available as supplied by the manufactures listed in Table 1.7.

Table 1.7 Oxidation and Filtration Systems for Fe and Mn
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

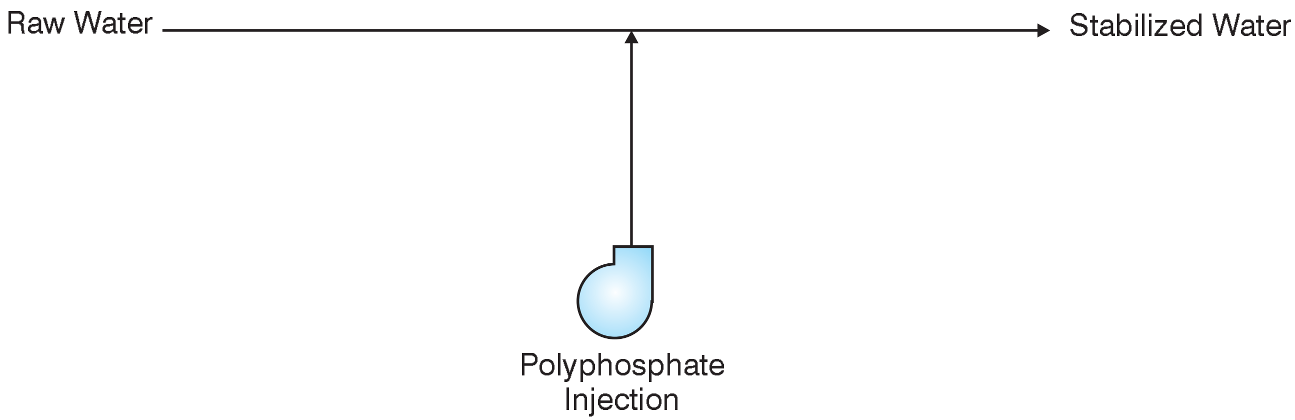
Alt 1 - Loprest Water Company	• Greensand and anthracite filter vessel.
Alt 2 - Filtronics, Inc.	• Reaction vessel with sodium hypochlorite. • Reaction vessel with sodium bisulfite. • Filter vessel with Electromedia I.
Alt 3 - Pureflow	• Proprietary treatment process.

All of the above systems have proven capability for treating water with elevated levels of Fe and Mn. These packaged systems have vertical or horizontal vessels depending on the system size. Due to the difference in the type and depth of the media, the filtration rate ranges from 2 to 10 gpm/ft^2. Some of the packaged systems (e.g., Filtronics) require additional reaction tanks to oxidize Fe and Mn to the insoluble forms upstream of the filters in order to provide enough time to ensure sufficient oxidation of Fe and Mn. Non-greensand medium is used in the filter to remove the insoluble particles produced from the reaction tanks.



SCHEMATIC OF AN OXIDATION/FILTRATION TREATMENT SYSTEM

FIGURE 1.3



SCHEMATIC OF A SEQUESTRATION SYSTEM

FIGURE 1.4

When greensand is used in other packaged systems, reaction tanks are generally not required unless the Fe and Mn concentrations are very high (greater than 5,000 µg/L). Most systems can operate on pressurized lines such that no additional backwash pumps are required. These systems typically have multiple-vessel designs and can backwash one vessel using the treated water from the other vessels. Backwash water is typically directed to a wastewater decant tank. Approximately 80 to 90 percent of the backwash wastewater can be reclaimed in most cases. The backwash water is stored in a backwash tank, where solids such as precipitated Fe and Mn settle to the bottom of the tank. Sewer disposal for the sludge would be desired, but this option depends on other contaminants in the raw water, the proximity of a sewer, and the local sewer discharge regulations. The cost of discharge to the sewer is expected to be low if a nearby sewer pipe exists already. However, if there is no existing sewer connection in close proximity, trucking may be more cost effective than building a sewer line. Local trucking companies have been contacted to gather pricing information for the off-site disposal alternative, which is listed with the other O&M costs below.

The filter run time varies from system to system. Typically, every system provides a pressure sensor to initiate a backwash cycle at a selected filter head loss. The head loss cannot exceed 10 psig since higher headloss accumulation may damage the filter media. Backwashing after a set operating time is a common practice for most of the systems. For systems treating Fe and Mn at concentrations occurring in the four wells, backwash is typically set once per day in the early morning when water demand is low. Backwash time is estimated to be 5 to 30 minutes with backwash loading rates at 12 to 14 gpm/ft^2, depending on the systems.

6.2.1 Alternative 1 - Loprest - Greensand Filtration (with Chlorine Oxidation)

For Wells 12 and 17 sites, Loprest recommends a treatment process that consists of two horizontal pressure filter tanks (8 feet in diameter and 16 feet long) based on the 1,750-gpm flow rate (Well 17) and the existing background concentrations. The filter media consists of manganese greensand (24-inch) and anthracite (12-inch). Chlorine dosage of 2.2 mg/L for Well 12 and 0.9 mg/L for Well 17 mg/L would be used for oxidation of Fe and Mn at the design concentrations for these contaminants.

For the Well 14 site, the treatment system is similar, but will only require one horizontal pressure filter tank (8 feet in diameter and 32 feet long) based on the 1,350-gpm flow rate and concentrations. The recommended chlorine dosage is 2.2 mg/L.

Finally, for the Well 20 site, a similar set up would be used, with one horizontal pressure filter tank (8 feet in diameter and 24 feet long) at a flow rate of 1,460 gpm. The recommended chlorine dose is 1.5 mg/L.

6.2.2 Alternative 2 - Filtronics - Chlorine and Sodium Bisulfite with Electromedia Filtration

The Fe and Mn removal systems designed and manufactured by Filtronics require an additional step compared to the system offered by Loprest and Pureflow. The Filtronics system consists of two in-series reactor vessels (5-foot diameter with an 11-foot straight side shell) and one filter vessel (ranging from 84-inch diameter with a 161-inch straight side shell (at Well 14 or Well 20), to 7-foot diameter with a 21-foot straight side shell (at Well Nos. 12 and 17)). In the lead reaction vessel, Mn is oxidized by addition of an oxidizing chemical (sodium hypochlorite). The second vessel is used to quench the remaining concentration of oxidizer (chlorine) by reaction with sodium bisulfite. The filter vessels contain proprietary Electromedia I, which is granulated, naturally occurring sand-like filtering media. A typical design feed loading rate is 15 gpm/ft^2.

6.2.3 Alternative 3 - Pureflow

The Pureflow treatment process is a proprietary process. Well waters containing Fe and Mn along with other dissolved contaminants, such as organic carbon, are first treated with chlorine prior to filtration. This step oxidizes these contaminants to a form that can be processed and provides free chlorine residual to the water distribution system.

The oxidation step is then followed by filtration, in which the Fe and Mn precipitates are removed by a NSF-approved proprietary media that has an adsorptive attraction for partially oxidized Fe and Mn. The contaminants are held in the filter bed allowing the total oxidizing reaction to occur in the filter. The filter media is cleaned by reversing the flow using processed water. The filter effluent is continuously monitored with a chlorine residual analyzer to ensure complete oxidation of contaminants and disinfection of the treated water.

For all three well sites, Pureflow recommends their C-3000 filter system, with a filter vessel of 7-foot diameter and 21-foot straight side shell. The filtration-loading rate averages between 9 to 11 gpm/ft^2. The backwash rate is 20 gpm/ft^2 for 4 minutes.

6.3 Sequestration Using Polyphosphate

A few vendors were contacted for the sequestration option, but only one company provided information for evaluation of this treatment option. SPER Chemical recommends their Sequest-All Potable Water System for all three (or four) wells. The system simply consists of an injection pump (LMI model AA 151-490HI) that injects the chemical into discharge pipe from the well. Sequest-All is a blend of granular or liquid polyphosphates, each having different properties that enhance the overall ability and function of the product. Sequest-All will inactivate minerals including iron, calcium, and manganese preventing scale buildup and "red water". According to SPER Chemical, it can also slowly soften and remove existing scale present within the water distribution system and it suppresses both anodic and cathodic electrochemical reactions along with depositing a protective coating effectively reducing corrosion rates. The chemical also comes in liquid form, in which case a

200-gallon tank and mixing system would be required. The system is designed to be stable under otherwise extreme conditions of temperature and time. As mentioned previously, it should be noted that polyphosphate sequestration does not remove Fe and Mn but rather stabilizes them in water to attenuate the effects of Fe and Mn.

Sequestration is only needed at the wells with high Fe and Mn levels, and a system-wide application of polyphosphate injection is not necessary, as blending of sequestered and non-sequestered water does not pose any water quality degradation issues.

However, enough time should be allowed for Fe and Mn to completely react with polyphosphate (at least 15 to 30 seconds) before chlorine is injected. If chlorine or another oxidant is injected too soon after polyphosphate injection, Fe and Mn may not be completely sequestered and may precipitate out in the distribution system. Thus, the actual time required between polyphosphate injection and chlorine injection to allow effective sequestration must be tested prior to system installation.

The recommended dosage and usages for each well are listed in Tables 1.8 and 1.9.

Table 1.8 Recommended Dosage for Sequestration Chemical from SPER Chemical
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

Well No.	Dosage (mg/L as PO_4)
12	1.5 - 2.75
14	2 - 4
17	1.5 - 1.75
20	1.75 - 2.25

Table 1.9 Chemical Usages for Sequestration Chemical from SPER Chemical
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

Well	Granular Form	Liquid Form
12 (700 gpm)	0.53 lbs - 0.96 lbs. per well hour	0.13 gal - 0.24 gal. per well hour
14 (1,350 gpm)	1.35 lbs - 2.71 lbs. per well hour	0.33 gal - 0.68 gal. per well hour
17 (1,750 gpm)	1.30 lbs - 1.55 lbs. per well hour	0.33 gal - 0.39 gal. per well hour
20 (1,460 gpm)	1.28 lbs - 1.65 lbs. per well hour	0.32 gal - 0.41 gal. per well hour

7.0 PRELIMINARY CAPITAL AND O&M COSTS FOR SELECTED TREATMENT SYSTEMS

Preliminary cost estimates are provided below for planning purposes. Cost estimates are based on information provided by the vendors and other similar projects completed recently. It should be noted that these are planning level costs with an estimated accuracy of +30 percent to -20 percent. These estimates reflect professional opinion of accurate costs at this time and are subject to change depending on the final design. Engineers have no control over variances in the cost of labor, materials, equipment, services provided by others, contractor's methods of determining prices, competitive bidding or market conditions, practices, or bidding strategies.

7.1 Assumptions Used to Develop Preliminary Cost Estimates

The following is a list of assumptions used in preparing the budget level capital and O&M costs:

1. One system will be installed for Wells 12 and 17, as only one of these wells will be in operation at any given time.

2. The wells operate 24 hours per day, 6 days per week (Monday through Saturday).

3. Water Quality: Table 1.1, presented earlier, shows the historical data of the Fe and Mn concentrations in the wells. The median concentration of Fe in the wells ranges from 88 to 94 µg/L; while the median Mn concentration ranges from 120 µg/L to 480 µg/L. However, for the purpose of establishing a cost estimate, the historical maximum data was used. The design values for the contaminants are listed in Table 1.10.

Table 1.10 Water Qualities of Wells Nos. 12, 14, 17, and 20 and Treatment Goals
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

Parameters	Well No. 12	Well No. 14	Well No. 17	Well No. 20	Finished Water Goal
Manganese, µg/L	180	430	120	110	40
Iron, µg/L	1,300	2,200(1)	140	740	240
pH	7.8-7.9	7.4-8.2	7.6-7.9	7.7-8.0	-
Hardness, mg/L as $CaCO_3$	212-220	240-300	200-217	190-200	-
Alkalinity, mg/L as $CaCO_3$	190-210	180-240	180-200	170-210	-
Flow Rate, gpm	700	1,350	1,750	1,460	-

Notes:
(1) The historical maximum iron concentration of 5,400 µg/L for Well 14 was not used, as this data may be erroneous.

4. The treatment goal is set to the 80 percent of the respective contaminant MCLs. Table 1.9 presents the finished water goal for each contaminant to be used as a basis for the treatment system.

5. The chlorine-dosing requirement is calculated based on Fe and Mn concentrations only.

6. The calculation of pounds per year of sodium hypochlorite needed was based on the typical stoichiometric (chlorine to Fe and Mn ratio) without major chlorine demand and does not take into account any organic or other constituents in the water that may affect chlorine demand.

7. Power costs are based on the unit cost of $0.09/kWhr provided by the City.

8. Mid-point of construction is January 2010. This is based on DHS' requirement of the City to construct and build the system in three years once the waiver survey is completed. Since the waiver survey has to be signed and completed by August 29, 2007, the City would need to start construction of the system by summer of 2009, assuming one-year construction time. This would put January 2010 as the mid-point of construction for cost estimate purposes.

9. Estimated project costs (2007 dollars) will be escalated with an annual rate of 8 percent to determine mid-point construction dollars (2010 dollars).

10. Amortized capital cost is based on 20 years and 6-percent interest rate.

11. O&M Costs will also be escalated to January 2010 using a standard inflation rate of 3 percent.

7.2 Equipment Capital Cost Estimates

The capital cost estimates of the treatment systems are based on various sources, including quotes from commercial system providers, recent projects, and other standard cost estimating tools available. Equipment costs from various vendors may not be comparable since the equipment supplied from each vendor is configured differently, such as chemical feed set-up, the number of vessels, etc.

Table 1.11 lists items included and excluded in the cost estimates.

Table 1.11 Treatment Cost Estimate Factors
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

1. Items Included in the Cost Estimates:
• Equipment Purchase (vessels, valves, etc). • Media. • Delivery and Setup. • Installation and Start-up Equipment. • System Hook-up. • Yard Piping. • Electrical. • Instrumentation. • Engineering, Legal, and Administration. • Contingency.

Table 1.11	Treatment Cost Estimate Factors DHS Engineering Report on Iron and Manganese Treatment City of Vernon
2. Items Not Included in the Cost Estimates:	
• Building. • New Sewer Connection. • Permitting. • Disinfection System.	

7.3 Cost Estimates for the Iron and Manganese Oxidation and Filtration Treatment System

7.3.1 Capital Cost Estimate of Iron and Manganese Treatment System

The unit equipment cost estimates for the oxidation and filtration systems offered by the three vendors for each of the three sites are summarized in Tables 1.12 to 1.14.

Table 1.12 Iron/Manganese Equipment Cost-Alternative 1 Loprest System
DHS Engineering Report on Iron and Manganese Treatment
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Water Source	Process Description and Items	Equipment Costs
Wells 12 and 17	Greensand and anthracite filter vessel (two horizontal pressure tank 8 ft by 16 ft); Chemical feed system.	$400,000
Well 14	Greensand and anthracite filter vessel (One horizontal pressure tank 8 ft by 32 ft); Chemical feed system.	$290,000
Well 20	Greensand and anthracite filter vessel (one horizontal pressure tank 8 ft by 24 ft); Chemical feed system.	$260,000
	Total	**$950,000**

Notes:
Cost Estimate Disclaimer: See Section 7.0 (+30% to -20%).

Table 1.13	Iron/Manganese Equipment Cost-Alternative 2 Filtronics System DHS Engineering Report on Iron and Manganese Treatment City of Vernon	
Supplier	**Process Description and Items**	**Equipment Costs**
Well Nos. 12 and 17	Reaction Vessel No. 1 with sodium hypochlorite and Reaction Vessel No. 2 sodium bisulfite and one filter vessel with Electromedia I (7-foot diameter with a 21-foot straight side shell, working pressure of 60 psi) with chemical feed systems, plus reclaim system (without the reclaim tank).	$420,000
Well No. 14	Reaction Vessel No. 1 with sodium hypochlorite and Reaction Vessel No. 2 sodium bisulfite and one filter vessel with Electromedia I (7-foot diameter with a 13.5-foot straight side shell, working pressure of 60 psi) with chemical feed systems, plus reclaim system (without the reclaim tank).	$345,000
Well No. 20	Reaction Vessel No. 1 with sodium hypochlorite and Reaction Vessel No. 2 sodium bisulfite and one filter vessel with Electromedia I (7-foot diameter with a 13.5-foot straight side shell, working pressure of 60 psi) with chemical feed systems, plus reclaim system (without the reclaim tank).	$345,000
	Total	**$1,110,000**

Notes:
Cost Estimate Disclaimer: See Section 7.0 (+30% to -20%).

Table 1.14	Iron/Manganese Equipment Cost-Alternative 3 Pureflow System DHS Engineering Report on Iron and Manganese Treatment City of Vernon	
Supplier	**Process Description and Items**	**Equipment Costs**
Well Nos. 12 and 17	One filter vessel (7-foot diameter with a 21-foot straight side shell), back wash valve, chemical feed system, and reclaim pump.	$500,000
Well No. 14	One filter vessel (7-foot diameter with a 21-foot straight side shell), back wash valve, chemical feed system, and reclaim pump.	$500,000
Well No. 20	One filter vessel (7-foot diameter with a 21-foot straight side shell), back wash valve, chemical feed system, and reclaim pump.	$500,000
	Total	**$1,500,000**

Notes:
Cost Estimate Disclaimer: See Section 7.0 (+30% to -20%).

The total capital cost estimate for the oxidation and filtration systems from the three vendors are presented in Table 1.15. On an annualized basis, (amortized over 20 years at 6-percent interest rate) the capital cost varies between $440,000 and $600,000 per year.

Table 1.15 Iron/Manganese System Capital Cost Estimate
DHS Engineering Report on Iron and Manganese Treatment
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Items	Alt 1 - Loprest	Alt 2 - Filtronics	Alt 3 - Pureflow
Equipment Cost:	$950,000	$1,110,000	$1,500,000
• Vessels.			
• Valves and Gauges.			
• Flow Meters.			
• Media.			
• Chlorine Analyzer.			
• Filter Control Panel.			
• Start-up and Training Services.			
• Backwash Reclaim Pump.	$30,000	Included	Included
• Sales Tax.	$76,000	$86,000	$116,000
• Freight Charge.	$20,000	$20,000	Included
• Subtotal (Oxidation/Filtration plus Backwash Reclaim Pump.	$1,080,000	$1,220,000	$1,620,000
• Backwash Reclaim Tank.	$410,000	$410,000	$410,000
SUBTOTAL (EQUIPMENT COST)	**$1,480,000**	**$1,620,000**	**$2,020,000**
Contractor Markup Cost (15%)	$223,000	$244,000	$304,000
Installation Cost:			
• Installation including Yard Piping and site work (45%).	$670,000	$730,000	$910,000
SUBTOTAL (INSTALLED COST)	**$2,370,000**	**$2,598,000**	**$3,239,000**
Construction Cost:			
• Electrical (15% of installed cost).	$360,000	$390,000	$486,000
• Instrumentation (10% of installed cost).	$237,000	$260,000	$324,000
SUBTOTAL (CONSTRUCTION COST)	**$2,970,000**	**$3,250,000**	**$4,050,000**

Table 1.15 Iron/Manganese System Capital Cost Estimate DHS Engineering Report on Iron and Manganese Treatment City of Vernon			
Items	**Alt 1 - Loprest**	**Alt 2 - Filtronics**	**Alt 3 - Pureflow**
Project Cost:			
• Engineering, Legal, and Administrative (25%).	$742,000	$812,000	$1,012,000
• Construction Management (10 %).	$297,000	$325,000	$405,000
• Contingency (35%).	$1,039,000	$1,137,000	$1,417,000
TOTAL PROJECTED CAPITAL COST	**$5,050,000**	**$5,520,000**	**$6,880,000**
AMORTIZED CAPITAL COST (20 years, 6% interest rate)	**$440,000**	**$480,000**	**$600,000**
Notes: **Cost Estimate Disclaimer:** See Section 7.0 (+30% to -20%).			

7.3.2 O&M Costs for the Fe/Mn Treatment System

O&M requirements by each treatment system are listed in Table 1.16. Orders of magnitude O&M costs for commercially available oxidation/filtration processes are presented in Table 1.17. O&M costs include the use of oxidant, media replacement, and electrical costs, sludge hauling and disposal costs, and labor. The annual O&M cost is estimated to be between $260,000 to $320,000.

Table 1.16 Oxidation and Filtration O&M Requirements DHS Engineering Report on Iron and Manganese Treatment City of Vernon			
O&M Items	**Alt 1 - Loprest**	**Alt 2 - Filtronics**	**Alt 3 - Pureflow**
Oxidant Usage - Chlorine (12.5%)			
• Well Nos. 12 and 17	Well 12 - 2.2 mg/L (20 lbs/day) Well 17 - 0.9 mg/L (20 lbs/day)	NA	1.25 mg/L (26 lbs/day)
• Well No. 14	3.6 mg/L (60 lbs/day)	NA	2.95 mg/L (48 lbs/day)
• Well No. 20	1.5 mg/L (27 lbs/day)	NA	1.61 mg/L (28 lbs/day)
Sludge Disposal Volume (gal)	71,000	NA	NA
Electricity	NA	NA	268 kWh/day
Media Replacement	$60/ft^3 1,150 ft^3 (lasts for 10 years)	NA	NA

Table 1.17 Iron/Manganese System Annual O&M Cost Estimate DHS Engineering Report on Iron and Manganese Treatment City of Vernon			
Category	**Alt 1 - Loprest**	**Alt 2 - Filtronics**	**Alt 3 - Pureflow**
Oxidant Use (e.g., chlorine)(1)	$50,000	$12,000	$49,000
Media Replacement(2)	$8,500	$1,500	NA
Electrical Costs(3)	$10,000	$4,000	$6,500
Sludge Hauling Cost(4)	$15,000	$15,000	$15,000
Sludge Disposal(5)	$5,000	$5,000	$5,000
Replacement Parts and Valves (allowance - 5% equipment cost)	$74,000	$76,000	$95,000
Labor (8 hours per day, $60/hr)(6)	$150,000	$150,000	$150,000
Total Annual O&M Cost	**$310,000**	**$264,000**	**$320,000**

Notes:

Cost Estimate Disclaimer: See Section 7.0 (+30% to -20%). Escalate at 3% to 2010.

(1) Assume $2.1/gallon for Sodium hypochlorite (12.5% assume 1.3 SG, Cost was provided by the City.

(2) Media cost for Loprest was based on $60/ft^3$, media has shelf life of 10 years, for Pureflow media, minimal media loss per year and no requirement of media change out.

(3) Assume control panel and chemical pump operating 24 hours/day, 6 days a week, reclaim pump works 6 hours/day.

(4) Assume $0.25/gallon for sludge hauling.

(5) Estimated based on past projects. The final cost will depend on feed water quality, which will affect chemical dosing and sludge volume. It will also depend on final disposal site location.

(6) Assume about 8 hours per day of labor needed for these systems.

7.3.3 Total Annualized Cost for Oxidation and Filtration

Table 1.18 shows the total annualized costs of each oxidation and filtration system, capital cost plus annual O&M cost in 2007 dollars and mid-point construction dollars (January 2010).

Table 1.18 Total Annualized Costs for Oxidation and Filtration System DHS Engineering Report on Iron and Manganese Treatment City of Vernon			
Annualized Cost	**Alt 1 - Loprest**	**Alt 2 - Filtronics**	**Alt 3 - Pureflow**
Project Costs (June 2007 Dollars)			
Annualized Project Costs ($)	$440,000	$480,000	$600,000
Annual O&M Costs ($) (Year 2007)	$310,000	$260,000	$320,000
Total Annualized Cost ($) 2007	**$750,000**	**$740,000**	**$920,000**

Table 1.18	Total Annualized Costs for Oxidation and Filtration System DHS Engineering Report on Iron and Manganese Treatment City of Vernon		
Annualized Cost	**Alt 1 - Loprest**	**Alt 2 - Filtronics**	**Alt 3 - Pureflow**
Mid-Point Construction Costs (January 2010 Dollars)			
Project Capital Costs ($)	$6,200,000	$6,700,000	$8,400,000
Annualized Project Costs ($)	$540,000	$590,000	$730,000
Annual O&M Costs ($) (Year 2010)	$330,000	$280,000	$350,000
Total Annualized Cost ($) 2010	**$870,000**	**$870,000**	**$1,100,000**

Notes:
Cost Estimate Disclaimer: See Section 7.0 (+30% to -20%).
(1) Based on 20 years and 6-percent interest, escalation annual rate of 8% for capital costs and standard inflation rate of 3% for O&M costs.

Based on the total annualized costs listed above, Alternatives 1 and 2 have the lowest cost.

7.4 Cost Estimates for the Iron and Manganese Sequestration System

The sequestration system (same for all wells) consists only of an injection pump and cost of installing an injection tap at the well site if using the liquid chemical. Additional equipment is required as mentioned earlier if the granular form of the chemical is used. Table 1.19 lists the estimated capital costs.

Table 1.19	Estimated Capital Cost for Sequestration System DHS Engineering Report on Iron and Manganese Treatment City of Vernon	
Items	**Liquid**	**Granular**
Equipment Costs:		
• Injection Pumps.	$5,800	$5,800
• Injection Tap.	$800	$800
• Tank Assembly (200-gallon tank and mixing system).	NA	$17,000
• Disinfection Control System Upgrade.	$40,000	$40,000
• Sales Tax (7.75%).	**$3,600**	**$5,000**
TOTAL EQUIPMENT COST	**$50,000**	**$69,000**
Contractor markup cost (15%).	$7,500	$10,00
Installation Costs:	$23,000	$31,000
• Installation Including Yard Piping and Site Work (45%).		
TOTAL INSTALLED COSTS	**$80,000**	**$110,000**

Table 1.19 Estimated Capital Cost for Sequestration System DHS Engineering Report on Iron and Manganese Treatment City of Vernon		
Items	**Liquid**	**Granular**
Construction Cost:		
• Electrical (15% of installed cost).	$12,000	$17,000
• Instrumentation (10% of installed cost).	$8,000	$11,000
TOTAL CONSTRUCTION COSTS	**$100,000**	**$138,000**
Project Cost:		
• Engineering, Legal, and Administrative (25%).	$25,000	$34,000
• Construction Management (10%).	$10,000	$14,000
• Contingency (35%).	$35,000	$48,000
TOTAL PROJECTED CAPITAL COST	**$170,000**	**$230,000**
AMORTIZED CAPITAL COST (20 years, 6% interest)	**$15,000**	**$20,000**
Notes: **Cost Estimate Disclaimer:** See Section 7.0 (+30% to -20%).		

The estimated O&M costs based on the recommended chemical usage rate are shown in Table 1.20.

Table 1.20 Estimated O&M Cost for Sequestration System (for High Concentration) DHS Engineering Report on Iron and Manganese Treatment City of Vernon		
	Liquid	**Granular**
Sequestering Chemical(1)	$104,000	$95,000
Freight Charges(2)	$38,000	$20,300
Replacement Parts and Valves (Allowance - 5% equipment cost)	$2,500	$3,500
Labor (4 hours per day, $60/hr)(3)	$74,900	$74,900
Total Annual O&M Costs	**$219,000**	**$194,000**
Notes: **Cost Estimate Disclaimer:** See Section 7.0 (+30% to -20%). (1) Based on vendor quotes, for liquid media $513 per 55-gal drum (625-lbs poly drum), for granular media $647 per 323 lbs (30-gal steel drum), based on 24 hr/day, 6 days per week. (2) Freight charge - Granular: $190/drum, $521 per four drums, $878 per eight drums; Liquid: $292 per drum, $836 per four drums, and $1,250 per eight drums. (3) Assumed a maximum of 4 hours per day of labor at $60/hr rate.		

The total annualized costs for sequestration treatment system in June 2007 dollars and January 2010 dollars (mid-point construction) are summarized in Table 1.21.

Table 1.21 Total Annualized Costs for Sequestration System
DHS Engineering Report on Iron and Manganese Treatment
City of Vernon

Annualized Cost	Liquid	Granular
Project Costs (June 2007 Dollars)		
Annualized Project Costs ($)	$15,000	$20,000
Annual O&M Costs ($) (Year 2007)	$219,000	$194,000
Total Annualized Cost ($) 2007	**$234,000**	**$214,000**
Mid-Point Construction Costs (January 2010 Dollars)		
Project Capital Costs	$207,000	$281,000
Annualized Project Costs ($)	$18,000	$24,000
Annual O&M Costs ($) (Year 2010)	$236,000	$209,000
Total Annualized Cost ($) 2010	**$254,000**	**$233,000**

Notes:
Cost Estimate Disclaimer: See Section 7.0 (+30% to -20%).
(1) Based on 20 years and 6-percent interest, escalation annual rate of 8% for capital costs and standard inflation rate of 3% for O&M costs.

8.0 SUMMARY AND RECOMMENDATION

Based on the findings from the feasibility study, the following key points are presented in this report:

- The iron level ranges from 140 to 2,200 µg/L and manganese level ranges from 110 to 430 µg/L. These were the historical maximum data and were used as the basis for estimating the cost of treatment.
- The total design flow rate for all four wells averages about 4,560 gpm. Based on the production data provided by the City for the last three years, the total average production from these wells is estimated to be 3,200 AFY.
- An oxidation/filtration system is recommended to treat Fe and Mn from the well water. Chlorine or potassium permanganate is recommended as the chemical to be used for oxidation. Proprietary media or greensand media can be used for filtration.
- Based on DHS's requirement of 3 years to construct from the completion of the waiver process, the mid-point of construction is estimated to be January 2010.

- Three major equipment suppliers have been contacted and three estimates have been obtained for oxidation and filtration. Filtronics, Loprest, and Pureflow have provided costs.
- The total projected capital costs (2010 dollars) for the treatment plants (oxidation/filtration system) are estimated to be in the range of $6,200,000 to $8,400,000 and the amortized capital cost is expected to be between $540,000 and $730,000. The capital costs include equipment, media, delivery and setup, installation and start-up, instrumentation, engineering, legal, and administration, with a 35-percent contingency.
- The projected annual O&M costs (2010 dollars) are estimated to be approximately $280,000 to $350,000. These O&M costs cover oxidant use, media replacement, labor costs, and electrical costs. Sludge hauling and disposal cost allowances were included, but refined costs are needed once the disposal facility is identified for this project.
- The total annualized costs in 2010 (mid-point construction) dollars range from $870,000 to $1,100,000.
- An oxidant demand test can be done at the bench scale to better estimate the chemical dose requirement and the cost for such tests can be provided once the scope of the test is defined if needed.
- Although sequestration is not a removal process and not considered as a compliance alternative, the costs are included in the evaluation for comparison purposes per City's request.
- The total projected capital costs (2010 dollars) for the sequestration system ranges from $210,000 for a liquid phosphate system to $280,000 for a granular polyphosphate system. The annual O&M costs (2010 dollars) are estimated to be about $236,000 for liquid phosphate or $210,000 for granular polyphosphate.

Table 1.22 summarizes the pros and cons of doing nothing, using an oxidation filtration treatment system, and using sequestration to treat/mitigate the Fe and Mn in the City water supply.

Table 1.22 Pros and Cons of Alternatives for Fe and Mn DHS Engineering Report on Iron and Manganese Treatment City of Vernon		
Alternative Processes	**Advantages**	**Disadvantages**
Alt 1. No Change	• Does not cost anything. • Does not change the current condition of water.	• Does not address iron and manganese issue. • Waiver needs to be reapplied every 9 years.
Alt 2. Conditioning System (Sequestration)	• Removes the impact of iron and manganese at a substantially lower cost than full treatment (Alt 3). • Proven process for iron and manganese.	• Does not remove iron and manganese from water. • May precipitate out iron and manganese at high temperature. • May have negative impacts on customers' internal processes that involve treating or heating water. • Waiver needs to be reapplied every 9 years. • Rate increase is expected.
Alt 3. Oxidation and Filtration Treatment System (using chlorine solution)	• Full removal of iron and manganese. • Proven process for iron and manganese.	• Costs more than other alternatives. • Rate increase is expected.

Table 1.23 summarizes the cost estimates of each system for the recommended oxidation and filtration treatment system and the sequestration treatment system in 2010 dollars. In order to put these numbers into perspective, the unit costs of the product water are calculated and presented in Table 1.23. The costs of the most expensive system for each treatment method are used for the comparison. This is to provide the most conservative estimates for the unit costs of the product water.

Table 1.23 Summary of Cost Estimates - in 2010 Dollars DHS Engineering Report on Iron and Manganese Treatment City of Vernon		
Cost	**Oxidation/ Filtration System (Pureflow)**	**Conditioning System (Sequestration - Liquid)**
Project Capital Cost	$8,400,000	$210,000
Amortized Capital Cost (20 years, 6% interest	$730,000	$18,000

Table 1.23 Summary of Cost Estimates - in 2010 Dollars DHS Engineering Report on Iron and Manganese Treatment City of Vernon		
Cost	**Oxidation/ Filtration System (Pureflow)**	**Conditioning System (Sequestration - Liquid)**
rate)		
Annual O&M Cost	$350,000	$236,000
Total Annualized Cost	$1,100,000	$254,000
Additional Annual Water Treatment Cost ($/AF)(1)	$343.8	$79.4
Additional Annual Water Treatment Cost ($/1,000 gal)(1)	$1.05	$0.24
Additional Annual Water Treatment Cost ($/100 ft^3)(1)	$0.79	$0.18

Notes:
Cost Estimate Disclaimer: See Section 7.0 (+30% to -20%).
(1) The Total water production is based on the last three years production data.

Based on the estimated project costs shown in Table 1.23, the City estimates that up to a 21 percent City-wide increase in the user rate would be required to undertake treatment of the well water to remove Fe and Mn. The additional annual water treatment costs shown in Table 1.23 are for the wells that require either treatment or conditioning, and the increase in these costs for the subject wells was used by the City to calculate the City-wide increase in the commodity cost of water. This will increase the current user rates from $1.16/100 ft^3 to $1.41/100 ft^3. If sequestration were used, the City estimates that up to a 5 percent increase in the user rate would be required, from the current $1.16/100 ft^3 to $1.22/100 ft^3.