# IV. ENGINEERING EVALUATION OF WATER SUPPLY SYSTEM

Based upon the findings of the inspection of the existing water system infrastructure, evaluation of water quality, an assessment of District water demands and discussions with PIWD personnel, a number of system improvements are necessary to assure the long-term operability, desired level of service and performance of the public water system. Projected upgrades and improvements to the capital infrastructure include the following:

- Identification and Development of a New Water Source(s);
- Treatment of Iron and Manganese – Indian Spring Wells;
- Elimination of Low Pressure Problems in the Broadway Upland Distribution Area;
- Replacement of the Indian Spring Well Pump House;
- Monitoring and Control Instrumentation Improvements;
- Selected Improvements to the Distribution Piping System;

Additionally, District personnel have expressed concern that additional water storage capacity may be necessary to meet peak user demands and/or alleviate low pressure problems in the Broadway Upland Distribution Area.

## 4.1 Evaluation of Water Storage Tank Requirements:

The District has concerns that the existing "Big Blue" water storage tank has inadequate capacity to meeting the system demand requirements in future years. Additionally, the District is also concerned that without a second water storage tank, it is not possible to remove the existing water storage tank from service to conduct periodic inspections, cleaning and other maintenance. The "Big Blue" water storage tank is intended to serve two (2) functions in the distribution system:

- Provide sufficient reserve storage capacity to satisfy peak system demands (hydraulic equalization);
- Provide sufficient static head to maintain adequate pressure in the distribution system, at the service connections to each point of use.

The "Big Blue" water storage tank has a total effective capacity of approximately 104,700 gallons and a net effective capacity of 75,530 gallons, based upon maintaining a minimum 7 foot water depth in the tank. A comprehensive evaluation of the water storage tank function was performed using the presented and projected future system demand requirements presented in Section II of this report (Tables 2-5, 2-7, 2-9 and 2-10). The following assumptions were used for this evaluation:

- The present safe yield of the existing wells is 40,320 gpd. This yield is based upon operating Indian Spring Well #4 and the Army Camp Well for 12 hours per day, each. The system has produced a greater quantity of water on certain days during 2012 (and other years), however it is believed that results in overpumping and negative recovery of the wells, adversely impacting the aquifer.

- The safe well yield will be increased in the future to with the addition of a minimum of two (2) additional water sources, unconnected to the existing water supply wells.
  - ➢ The safe yield will be increased to 60,000 gpd within 5 years (2017);
  - ➢ The safe yield will be increased to 80,000 gpd within 20 years (2032);

- The safe well yield will be based upon pumping the source wells (existing and proposed) for 12-hours per day.

- The stored water will be effectively and efficiently transmitted to the points-of-use in the distribution system, without severe loss of pipeline pressure.

- The maximum storage/equalization requirements will occur during the peak demand season. The Peak 7-Day, 3-Day, 1-Day, 4-Hour and 1-Hour demand conditions were used for this evaluation.

Table No. 4-1 presents a summary of the water storage/equalization requirements based upon the present and projected peak day demands using the existing effective well capacities and the projected future required well capacity. The following conclusions were developed from this analysis:

1. The existing “Big Blue” water storage tank has sufficient equalization volume to meet the current Peak Demand requirements, using the existing wate supply wells with a safe yield of 40,320 gpd. However, the system is meeting demand by over pumping the existing wells and the loss of either Indian Spring Well #4 or the Army Camp Well would render the system unable to meet the Peak Season system demands.

2. Without an increase in the safe well yield to 60,000 gpd, the existing water storage tank capacity will be severely deficient by 2017, based upon the current projected increase in the user demand. However, if the safe well yield is increased to 60,000 gpd, the existing “Big Blue” water storage tank has sufficient capacity to meet the system demands for at least 15 years (2027).

3. Without an increase in the safe well yield to 80,000 gpd, the existing water storage tank capacity will be marginal by 2032 (20 years), based upon the current projection of increase in the user demand. The loss of the largest water source during the peak demand period would create maximum stress upon the supply and storage system. However, if the safe well yield is increased to 80,000 gpd, the existing “Big Blue” water storage tank has sufficient capacity to meet the system demands.

4. Increasing the total effective water storage capacity will provide no storage/equalization benefit in the short-term (5-years). Furthermore, providing additional water storage capacity will not alleviate the severe supply shortfall that is projected to occur within 5-years (unless demands remain at or near 2012 levels). **Increasing the safe well (source) yield is the most critical long-term consideration relative to maintaining high quality service to the District users.**

## Table 4-1: Water Storage/Equalization Requirements – Present and Future Operation

| **Operating Year** | **2012[1]** | **2017** | **2017** | **2022** | **2032** | **2032** | **2042** |
|---|---|---|---|---|---|---|---|
| **Effective Well Yield (Total GPD)** | **40,320 gpd** | **40,320 gpd** | **60,000 gpd** | **60,000 gpd** | **60,000 gpd** | **80,000 gpd** | **80,000 gpd** |
| | | | | | | | |
| **Peak 7-Day Demand Volume $V_{PEAK\ 7\text{-}Day}$** | 328,020 gal. | 415,446 gal. | 415,446 gal. | 432,016 gal. | 466,340 gal. | 466,340 gal. | 503,033 gal. |
| **7-Day Safe Well Yield** | 282,240 gal. | 282,240 gal. | 420,000 gal | 420,000 gal. | 420,000 gal. | 560,000 gal. | 560,000 gal. |
| **Required Effective Storage Capacity** | **45,780 gal.** | **133,206 gal.** | **0 gal.** | **12,016 gal.** | **46,340 gal.** | **0 gal.** | **0 gal.** |
| | | | | | | | |
| **Peak 3-Day Demand Volume $V_{PEAK\ 3\text{-}Day}$** | 156,100 gal | 197,721 gal | 197,721 gal. | 205,599 gal. | 221,934 gal. | 221,934 gal. | 239,396 gal. |
| **3-Day Safe Well Yield** | 120,960 gal | 120,960 gal. | 180,000 gal. | 180,000 gal | 180,000 gal. | 240,000 gal. | 240,000 gal. |
| **Required Effective Storage Capacity** | **35,140 gal.** | **76,761 gal.** | **17,721 gal.** | **25,599 gal.** | **41,934 gal.** | **0 gal.** | **0 gal.** |
| | | | | | | | |
| **Peak 1-Day Demand Volume $V_{PEAK\ 1\text{-}Day}$** | 65,920 gal. | 83,354 gal. | 83,354 gal. | 86,679 gal. | 93,565 gal. | 93,565 gal. | 100,927 gal. |
| **1-Day Safe Well Yield** | 40,320 gal. | 40,320 gal. | 60,000 gal. | 60,000 gal. | 60,000 gal. | 80,000 gal. | 80,000 gal. |
| **Required Effective Storage Volume** | **25,600 gal.** | **43,034 gal.** | **23,354 gal.** | **26,679 gal.** | **33,565 gal.** | **13,565 gal.** | **20,927 gal.** |
| | | | | | | | |
| **Peak 4-Hr Demand Volume $V_{PEAK\text{-}4Hr}$** | 20,869 gal. | 21,672 gal. | 21,672 gal. | 22,537 gal. | 24,327 gal. | 24,327 gal. | 26,241 gal. |
| **4-Hr Safe Well Yield** | 13,440 gal. | 13,440 gal. | 20,000 gal | 20,000 gal. | 20,000 gal. | 26,667 gal. | 26,667 gal. |
| **Req'd Effective Storage Volume** | **7,429 gal.** | **8,232 gal.** | **1,672 gal.** | **2,537 gal.** | **4,327 gal.** | **0 gal.** | **0 gal.** |
| | | | | | | | |
| **Peak 1-Hr Demand Volume $V_{PEAK\ –\ 1Hr}$** | 7,304 gal. | 7,585 gal. | 7,585 gal. | 7,888 gal. | 8,514 gal. | 8,514 gal. | 9,184 gal. |
| **1-Hour Safe Well Yield** | 3,360 gal. | 3,360 gal. | 5,000 gal. | 5,000 gal. | 5,000 gal. | 6,667 gal. | 6,667 gal. |
| **Req'd Storage Volume** | **3,944 gal.** | **4,225 gal.** | **2,585 gal.** | **2,888 gal.** | **3,514 gal.** | **1,847 gal.** | **2,517 gal.** |

**Note 1: 2012 demands based upon 2012 water meter data.**

## 4.2 Development of Freshwater Source(s):

The District must increase the effective (safe) source capacity from the approximate 40,000 gpd presently available, to 60,000 gpd within the next 5 years (2017) and to 80,000 gpd within 20 years (2032). The District has sufficient land area potentially accessible that will conform to the protective setback criteria for public water supply wells established by RIDOH. It is important to note however that new source wells should be located to eliminate or minimize hydraulic connectivity with the existing wells. It is also important to note that the effective yield of the existing wells has not been adequately established and the capacity of a given well may have changed over time due to a variety of operational impacts.

Initial review of geologic and hydrogeologic data suggests that additional groundwater supplies are very likely available on Prudence Island. While limited scope hydrogeologic evaluations of island recharge and groundwater potential have been conducted, these assessments admit that additional work must be undertaken to more fully understand the complex nature of fracturing and fracture recharge. Furthermore, the small number of production and monitoring wells and limited amount of pumping and observation well water level data available for analysis does not meet the scientific and engineering requirements for a reliable long term groundwater availability determination.

Our preliminary analysis of likely groundwater features indicates that groundwater targets should be found preferentially along fracture-enhanced bedding/foliation planes and within N-NNE striking fold-axis-aligned fractures. Additional photolineament, fracture fabric, geologic, structural, geophysical and well inspection investigation should be performed as necessary to identify the precise location(s), strike trends, dip angles and degree of interconnection of these and other water bearing features affecting the storage and distribution of groundwater.

While a previous fracture trace investigation suggested a few locations for water supply well targeting, the identification of additional favorable areas for groundwater development is likely. A comprehensive groundwater exploration program has yet to be undertaken, incorporating the impact of the islands stratigraphy and folded geologic structure upon groundwater occurrence. Such a study would allow the possibility of locating shallow dipping water-bearing features which are not usually detected by fracture-trace studies. A study of this sort would open up a vastly larger portion of the Island for potential groundwater development including western, west-central, and possibly some southern areas of the Island, pending a more complete contaminant threats assessment.

4.2.1 Evaluation of Source Wells: Substantial information regarding the Region IV watershed and the existing wells can be developed from a downhole inspection of the existing wells and conducting a formal pump test program. This program would include the following elements:

- Conduct a downhole video/televiewer inspection of the Indian Spring Wells (#1, #3 & #4), Army Camp Well, Bristol Colony Well and other potentially available wells (Goulet, Pier) etc.) .including; logging of geologic lithology; identification of joints and fracture location and orientation and determine the character of water-bearing fractures. By inspecting multiple wells a more detailed understanding of the subsurface geology, fraturing and water capacity can be developed. In the case of the active wells this inspection should also include an assessment of the casing seal, evaluation of sediment accumulation in the borehole, evaluation of possible oxidation product accumulation (particularly the Indian Spring Wells), etc.

- Evaluate data and develop recommendations for hydro-fracking, well re-development (cleaning borehole walls and flushing sediment out of existing fractures) and/or other methods based on the results of the inspection.
- Install stilling tubes and transducers with data logger capability into the active and inactive wells to facilitate long-term water level and conductivity monitoring.
- Following completion of the well inspections and re-development (where applicable) conduct formal well pumping tests to establish the present effective capacity of the water supply wells. This test program should include pre-test ambient monitoring, a step-pumping test and a constant rate pumping test, including full-term recovery monitoring.
- As the protection of all potentially viable ground water supply sources is paramount to maintain long-term sustainability of drinking water sources, water quality and quantity testing of Naval Station area water supply wells should also be undertaken.

Table 4-2 presents the budget cost range to complete the recommended scope of work.

**Table 4-2: Recommended Budget - Investigation of Existing Wells**

| Work Task | Minimum | Maximum |
|---|---|---|
| Video Inspection of Wells[1] | $ 17,500 | $ 32,000 |
| Re-Development of Wells[2] | $ 16,000 | $ 48,000 |
| Installation of Stilling Tubes, Monitoring Transducers[3] | $ 6,000 | $ 10,000 |
| Well Pump Test Program – Indian Springs[4] | $ 12,000 | $ 18,000 |
| Well Pump Test – Army Camp Well[4] | $ 6,000 | $ 8,000 |
| Water Quality Monitoring Program | $ 5,000 | $ 8,000 |
| Summary Engineering Report & Recommendations | $ 4,500 | $ 8,500 |
| **TOTAL WELL INSTALLATION COST** | **$ 67,000** | **$132,500** |

**Note 1: Video inspection of 3 to 5 wells. Includes well pump extraction, borehole camera inspection, preparation of detailed borehole video log, data evaluation and recommendations.**
**Note 2: If determined to be necessary, includes double-packer zone hydrofracturing, surge & pump redevelopment of bedrock wells. Redevelop 1 to 3 wells.**
**Note 3: Stilling tubes and transducers to be installed into active and inactive wells following completion of borehole video inspections.**
**Note 4: Pump Tests conducted in accordance with RIDEM requirements for groundwater withdrawals >10,000 gpd.**

4.2.2 Development of New Freshwater Water Source Wells: Development of one or more new source wells includes the following scope of recommended tasks. Table 4-3 presents the budget cost range to complete this scope of work.:

- Acquire and assess most recent geologic, hydrogeologic and water well data and reports to formulate ground water development plan for the exploration of new water sources.
- Conduct geologic and structural mapping investigation, preliminary contaminant threats assessment and a multi-platform photolineament (fracture trace) evaluation to identify potential favorable target areas for a new well(s).
- Install geophysical traverse lines and implement ground geophysical surveys at identified favorable target areas to assess geologic and structural features, identified photolineaments and determine strike and dip angle of fracturing for production well targeting.
- Prepare a site plan identifying recommended target well locations (preferably 2 sites, or more), potential sources of contamination, buildings, pavement, drainage and other site conditions. Based upon the findings of the evaluation, select the final location for an exploratory well(s).
- Construction of a 6"Ø, exploratory drilled bedrock well. During the well installation a detailed inspection and logging of bedrock unit types and thicknesses, fracture locations, field water quality interval water yield discharged from the borehole would be performed. New well construction includes installation of an appropriate well casing with a grout seal and provision of a submersible well pump and riser, power cable, pitless adapter, stilling tube, and vented sanitary cap. The recommended minimum drilled depth of the well is 400 ft, unless substantial, <u>sustainable</u>, fresh water is encountered at a lesser depth.
- Pump Test Program – Phase 1 – Step Test: The initial phase of the pump test program to assess the effective well capacity using incremental flowrates (for example: 4, 8, 12, 16 gpm, etc.). Each step phase of the test is conducted for 1- hour or until log stabilization of the water level in the well is attained. During this phase of the test, a transducer installed in the well provides continuous monitoring and logging the water column pressure, temperature and level readings.
- Pump Test Program – Phase 2 – Constant Rate Test: This test would be conducted over a 120-hour period, conforming to the RIDEM groundwater withdrawal program requirements and dependent upon achievement of minimum 24-hour stabilization, at the flowrate determined from the Step Pumping Test. A well level transducer would provide continuous monitoring of the water level, temperature and conductivity during the test phase, as well as during the recovery phase following shut down of the well pump. During the pumping phase, field monitoring of certain water quality parameters would be conducted (pH, TDS, conductivity, temperature, odor, color, iron, hardness).
- Safe Yield Assessment: The data generated by the well pumping test would be used to develop a safe yield projection for the well. This would include a projection of the well water drawdown using a 180-day, no recharge extrapolation scenario, to assess whether the well would be able to continue to produce water at a specific rate under conditions of long-term aquifer stress.
- Water Quality Monitoring: During the constant rate pump test water samples would be obtained to execute a comprehensive water quality evaluation including; inorganic contaminants, VOC's, SOC's, and radionuclides.

- Preparation and submittal of a RIDOH Application for Source Approval for the new water supply well(s).
- Based upon the community demand being greater than 10,000 gpd, and the expectation that the new well(s) would have a capacity >10,000 gpd, it is assumed that the pump test program and final report would be submitted to RIDEM for review, under the requirements of the Groundwater Withdrawal Program (>10,000 gpd).

It should be noted that there are a significant number of variables that will impact well development cost. Most significant are; (1) the need to employ differing geophysical methods and technologies depending upon site conditions and the nature and composition of underlying soils and bedrock, (2) the variables in drilling efficiency depending upon the bedrock materials and structure, (3) the need (or not) for well development following drilling. The costs presented in Table 4-3 do not include land acquisition costs and also assume that reasonable access for wheeled well drilling vehicles and equipment and a stable drilling pad around the target well site(s) is available.

**Table 4-3: Well Site Investigation & Well Installation Cost (2 New Wells)**

| Work Task | Minimum | Maximum |
|---|---|---|
| Site Technical Data Acquisition, Review | $ 3,800 | $ 9,000 |
| Multi-Area Geologic, Structural & P-L Mapping | $ 9,000 | $ 17,500 |
| On-Site Inspection & Contaminant Threats Evaluation | $ 5,400 | $ 7,400 |
| Site Ranking/Exploration Recommendations | $ 2,400 | $ 3,400 |
| Geophysical Survey Line Logistics & Installation | $ 9,000 | $ 13,000 |
| Geophysical Survey, Data Interpretation & Analysis | $ 12,600 | $ 20,600 |
| Geophysical Survey Summary & Site Staking | $ 3,000 | $ 4,000 |
| RIDOH Application for Well Site Approval | $ 3,500 | $ 7,500 |
| Well Installation (6" Bedrock Well) | $ 11,000 | $ 21,000 |
| Well Logging & Documentation | $ 5,000 | $ 9,500 |
| Well Hydro-Fracturing & Development | $ 7,500 | $ 16,000 |
| Pump Test Program & Safe Yield Assessment & Report | $ 14,000 | $ 22,000 |
| Water Quality Monitoring | $ 4,400 | $ 5,200 |
| **TOTAL WELL INSTALLATION COST** | **$ 91,600** | **$155,700** |

## 4.3 <u>Development of Brackish Water or Seawater Source Wells & Desalination Treatment System</u>:

As an alternative to new freshwater sources it may be desirable to consider the development of a brackish water or seawater source, provided with reverse osmosis desalination capability. The advantage of using a brackish or seawater source is the essentially unlimited source capacity. The principle disadvantage is the need for desalination, with the attendant process equipment and capital infrastructure, and significantly increased operating cost for treatment.

4.3.1 <u>Seaside Sand & Gravel Wells</u>: The potential exists for the development of a seaside sand and gravel well(s). The well would pump a blend of saltwater with some brackish and fresh water derived from the transition zone. Principle benefits of this type of well, compared to direct intake of seawater include; (1) the water will have a lower salinity

(TDS) content and be easier to desalinate and (2) the water will be effectively pre-filters, reducing pre-treatment prior to desalination. The projected conceptual implementation cost for development of two (2) sand & gravel wells, including state level permitting and approvals (RIDOH, RIDEM, CRMC) is approximately $175,000 to $200,000 (see Table 4-4A, below), plus the additional cost for desalination water treatment (see 4.3.2).

It may also be  possible to tap into relatively permeable seabed sand and gravel deposits using a horizontally drilled well installed at a location to pump filtered seawater from points beneath the bay on the east side of Prudence Island. Drawing water through seabed sand and gravel, this source water would also have the benefit of being pre-filterd, compared to a direct intake of seawater. The projected conceptual implementation cost for development of the well, including state level permitting and approvals (CRMC, RIDOH, RIDEM) is on the order of $250,000 to $280,000 depending upon the depth and extent of drilling (see Table 4-4A, below), plus the additional cost for desalination water treatment (see 4.3.2).

**Table 4-4A: Capital Implementation Cost for Brackish/Seawater Wells**

| **Work Task** | **Sand/Gravel[1]** | **Horiz. Drilled** |
|---|---|---|
| Site Technical Data Acquisition, Review | $ 3,800 | $ 6,000 |
| Geologic Mapping | $ 3,000 | $ 6,500 |
| On-Site Inspection & Contaminant Threats Evaluation | $ 2,700 | $ 3,700 |
| Well & Pump System Design | $ 8,500 | $ 18,000 |
| RIDOH Application for Well Site Approval | $ 3,500 | $ 3,500 |
| CRMC Application for State Assent | $ 5.500 | $ 7,500 |
| Well Installation | $ 80,000[1] | $150,000 |
| Well Logging & Documentation | $ 7,500 | $ 15,000 |
| Well Development | $ 20,000 | $ 22,000 |
| Pump Test Program & Safe Yield Assessment & Report | $ 36,000 | $ 24,000 |
| Water Characterization & Quality Monitoring | $ 8,000 | $ 4,000 |
| Submersible Pump, Piping, Wiring, Controls | $ 14,000 | $ 20,000 |
| **Total Well Installation Cost** | **$192,500** | **$280,200** |

**Note 1: Assumes 2 Seaside Sand & Gravel Wells, 30 to 40 ft. Depth**

4.3.2 Reverse Osmosis Desalination: The reverse osmosis (RO) process has been used for approximately 50 years to provide potable drinking water from brackish water and seawater sources. “Osmosis” is defined as the natural passage (due to osmotic pressure) of a liquid (in this case, water) from a dilue to a more concentrated solution, through a semi-permeable membrane. Therefore, the “reverse osmosis” process occurs when a pressure greater than the osmotic pressure is applied to the concentrated solution (brackish water or sea water) to force the water to flow from the concentrated solution to the more dilute solution.

The nominal operating pressure of the reverse osmosis system is determined by the average osmotic pressure of the concentrated (brackish water or seawater) solution, plus the net driving pressure required for optimum separation membrane performance. For example, the osmotic pressure of seawater containing 35,000 mg/l TDS is 374 psi.

Recognizing that the osmotic pressure will increase as water is transferred out of the concentrated feedwater solution, the average osmotic pressure can increase to as much as 500 psi. The membranes developed for seawater desalination require a net driving pressure up to 300 psi to achieve their rated flow and rejection, therefore the normal operating pressure for a seawater desalination membrane will be on the order of 800 psi. Brackwish water (typically 1,000 to 5,000 mg/l TDS) has a far lower osmotic pressure and therefore brackish desalination systems will operate at lower pressures that seawater desalination systems. Typical operating pressures used for design of brackish water and seawater desalination systems are the following:

| | |
|---|---|
| Brackish Water Desalination: | 250 to 400 psig |
| Seawater Desalination: | 800 to 1,000 psig |

The typical semi-permeable RO membrane has a pore size on the order of 20 angstrom, therefore virtually all molecules with a molecular weight (MW) ≥200 are rejected (cannot pass through the membrane) and a substantial percentage of molecules of 100 to 200 MW are also rejected. Thus, while water will pass through the semi-permeable RO membrane as “permeate” to the dilute side, the substantial majority of salts and other inorganic materials and compounds found in brackish water and sea water will be “rejected” by the RO membrane and remain on the “concentrate” side of the membrane. Commercially available membranes presently used for desalination applications will achieve 95% to 97% rejection of salts and other inorganics. Additionally, RO membranes will typically reject up to 95% of all pyrogens, viruses and bacteria that could be found in water supplies.

The two (2) principle types of RO membranes used for desalination are either the flat sheet membrane used in a “spiral wound” configuration or the hollow fiber membrane. In this application, the most common commercially available membranes are spiral wound, thin film composite membranes. System configurations typically utilize multiple RO membranes housed in pressure vessels, with the pressure vessels arranged in 2 to 3 stages, to maximize recovery (**Figure 4-3**). The RO membranes are the critical system operating component therefore minimizing fouling and maximizing membrane life are critical to both optimizing system performance and controlling operating cost. The typical brackish water or seawater RO system consists of the following components:

- Multi-Media Filters
- Cartridge Filters
- Chemical Feed System (bio-control/anti-foulant)
- RO Trains
- Permeate pH Adjustment System
- Permeate Storage and Pumping System

The Multi-Media Filter system assures the capture and removal of suspended solids remaining in the feedwater. The Cartridge Filters (typically 5u) serve as a media trap (for the Multi-Media Filters) and also remove smaller solids that may have passed through the

Multi-Media Filters. Normally a chemical feed system is provided to condition the feedwater for control of bacteria and bio-foulants and possibly for scale control. However, because the RO Reject will likely be discharged to Narragansett Bay, it can be expected that RIDEM will not allow any addition of pre-treatment chemicals that coule be contained in the reject discharge. The RO system operation (% recovery, operating pressures) would be adjusted to accommodate the lack of chemical pretreatment.

The RO Trains can be expected to consist of two (2) to three (3) stages of RO membrane modules, with partial recycle of RO reject to the inlet side of the system, to maximize recovery and operating efficiency. Depending upon the characterization of the feedwater (brackish or seawater) the RO system would be expected to operate from approximately 30% to 45% efficiency with the permeate discharged to a storage tank and the RO reject to a seawater outfall discharge. It can be expected that the RO product water (permeate) would have a pH on the order of 6.0 to 6.8, therefore a pH adjustment system is provided for corrosion control and to assure conformance with the RIDEM and USEPA Secondary Drinking Water Limit for pH (6.5 to 8.5 su). Upon discharge from the RO membranes the permeate is essentially at atmospheric pressure, therefore it will be necessary to provide a storage tank and booster pump system to transfer the water into the distribution system. There are several options regarding the RO desalinization system capacity.

- The RO system would be designed to supply 20,000 gpd (3 RO Trains @ 10,000 gpd, each) allowing the system to meet 100% of the the non-peak season demands with a minimum of 1 RO Train in standby status. During the peak demand season, the desalination system would be one of several water sources, with the water nominally blended in the water storage tank prior to distribution.
- The RO system would be designed to supply up to 80,000 gpd (3 RO Trains @ 40,000 gpd, each) allowing the system to meet 100% of the peak season demands as they increased over time, with 1 RO Train in standby status. The existing freshwater wells would serve to augment the desalinization system and provide reserve capacity in the event of the loss of one or more RO trains.

The principle drawback of any RO desalination system implemented to serve the District is the generation of RO reject (wastewater). In this application the RO recovery would be on the order of 30% to 45%, therefore the system will need to dispose of the substantial majority of the feedwater, as demonstrated in the table below, using a unit size of 20,000 gpd and 80,000 gpd product (freshwater) water capacity.

| | **Brackish Water** | | **Seawater** | |
|---|---|---|---|---|
| Product Water Vol. | 20,000 gpd | 80,000 gpd | 20,000 gpd | 80,000 gpd |
| RO Recovery Ratio | 45% | 45% | 35% | 35% |
| RO Makeup Water Vol. | 44,444 gpd | 177,778 gpd | 57,143 gpd | 228,571 gpd |
| Net RO Reject Vol. | 24,444 gpd | 97,778 gpd | 37,143 gpd | 148,571 gpd |

The conceptual implementation cost estimate for execution of the necessary engineering, permitting and implementation of an RO desalination system (building structure, pre- and post-treatment, storage and distribution pump, mechanical/electrical installation, etc.) is on the order of $750,000 to $1,775,000 plus the cost of the necessary brackish/seawater water supply well(s) and the RO reject discharge outfall. Table 4-4B presents a summary of this budget implementation cost for each of four (4) alternatives covering the range of potential implementation. Considerations related to the implementation of a reverse osmosis desalination system include the following:

- This process system will require an operator with a minimum Class II Treatment license, and potentially a Class III Treatment license;
- The use of a modular RO train design will provide redundant capacity and will allow the system to operate with a minimum of one (1) RO train off-line for maintenance;

**Table 4-4B Capital Implementation Cost for RO Desalination System**

| | **Brackish Water Desalination** | | **Seawater Desalination** | |
|---|---|---|---|---|
| **System Capacity** | 20,000 gpd | 80,000 gpd | 20,000 gpd | 80,000 gpd |
| **Water TDS** | ≤10,000 mg/l | ≤10,000 mg/l | ≤38,000 mg/l | ≤38,000 mg/l |
| **Estimated RO Recovery** | 40-45% | 40-45% | 30-35% | 30-35% |
| **Desalination System:** | | | | |
| Pre-Treatment Filtration | $ 38,000 | $ 86,000 | $ 38,000 | $105,000 |
| RO Desalination System | $112,500 | $281,250 | $412,000 | $675,000 |
| RO Permeate Pump Sta. | $ 9,000 | $ 11,000 | $ 9,000 | $ 11,000 |
| Chemical Feed System | $ 5,700 | $ 8,700 | $ 5,700 | $ 8,700 |
| Storage Tank & Pump System | $ 32,000 | $ 44,000 | $ 32,000 | $ 44,000 |
| Instrumentation & Controls: | $ 23,000 | $ 28,000 | $ 23,000 | $ 28,000 |
| **Installation:** | | | | |
| Building Structure & Utilities | $144,000 | $216,000 | $144,000 | $216,000 |
| Equipment Rigging | $ 6,000 | $ 9,000 | $ 6,000 | $ 10,000 |
| Mechanical Installation (L&M) | $ 24,000 | $ 36,000 | $ 24,000 | $ 36,000 |
| Electrical Installation (L&M) | $ 32,000 | $ 38,000 | $ 32,000 | $ 38,000 |
| Inst. & Controls Install.(L&M) | $ 12,000 | $ 14,000 | $ 12,000 | $ 14,000 |
| Settling Tank, Drywell & Piping | $ 18,000 | $ 22,000 | $ 18,000 | $ 22,000 |
| Connection to Distribution Sys. | $ 8,000 | $ 8,000 | $ 8,000 | $ 8,000 |
| Emergency Generator System. | $ 25,000 | $ 35,000 | $ 28,000 | $ 38,000 |
| Construction Permits | $ 2,700 | $ 3,800 | $ 2,700 | $ 3,800 |
| Contractor O&P (15%) | $ 41,350 | $ 56,700 | $ 40,800 | $ 57,300 |
| **Eng'g/ CM & Startup:** | | | | |
| Site Survey | $ 6,000 | $ 6,000 | $ 6,000 | $ 6,000 |
| Design Engineering | $ 42,700 | $ 71,600 | $ 66,800 | $104,700 |
| RIDOH Permits & Approvals | $ 3,500 | $ 3,500 | $ 3,500 | $ 3,500 |
| Construction Management | $ 53,325 | $ 82,900 | $ 83,500 | $131,000 |
| System Start-Up & Validation | $ 8,000 | $ 12,000 | $ 8,000 | $ 12,000 |
| O&M Manual | $ 7,000 | $ 7,000 | $ 7,000 | $ 7,000 |
| Operator Training | $ 5,000 | $ 5,000 | $ 5,000 | $ 5,000 |
| **Freight** | $ 20,000 | $ 30,000 | $ 20,000 | $ 30,000 |
| **Sub-Total** | **$678,775** | **$1,115,450** | **$1,035,000** | **$1,614,000** |
| **Contingency (10%)** | **$ 67,900** | **$ 111,550** | **$ 103,500** | **$ 161,400** |
| **Total Implementation Cost** | **$746,675** | **$1,227,000** | **$1,138,500** | **$1,775,400** |

- RO desalination systems can be provided as a standard commercial design provided with an integral PLC-based control system, monitoring the flowrates, operating pressures, membrane flux, temperature, etc., automatically controlling the operation of the units. The controller is provided an operator interface and manual override is provided for all controls and functions;

- Pre-filtration media filters are recommended, provided with integral PLC-based controls systems to monitor the flowrate to each filter vessel and volume filtered, automatically controlling the filter backwash and sequencing of the filters on/off line. The controller is provided an operator interface and manual override is provided for all controls and functions;
- The system will include one (1) flow-proportional chemical makeup and feed system (final pH adjustment) including chemical makeup and day tank, spill containment pallet, chemical metering pump(s), in-line static mixer and control instrumentation;.
- In addition to the RO process pumps, the system will have a dedicated RO permeate pump station and a distribution booster pump system;
- The system operator will likely spend a <u>minimum</u> of 1-hour per day involved with the operation of this system:
  - Inspecting equipment and verifying correct process operation;
  - Chemical makeup (ph Adjustment) and routine maintenance;
  - Periodic instrument calibrations, field water quality monitoring, data logging, etc;
  - Periodic (quarterly) flushing and cleaning of membranes and related maintenance;
- The necessary building footprint (800 to 1,200 $ft^2$) is necessary to house the equipmemt, provide storage capacity and an operator office. The building include capital costs for heating, lighting, ventilation/dehumidification, security, communications, etc;
- The system would be provided water storage utilizing NSF 61, polyethylene tanks, of the horizontal, cylindrical configuration installed inside the building. Recommended capacity is 5,000 for the 20,000 gpd system scope and 10,000 gallons (2, 5,000-gallon tanks) for the 80,000 gpd alternative;
- The system infrastructure should include an emergency generator sized to handle 100% of the maximum operating load;
- The RO membranes should be assumed to have an effective life of 3-years, although it may be possible to extend the life to 5-years. Periodic/annual operating and maintenance costs will include membrane flushing and cleaning, periodic membrane replacement, inspections of pressure vessels and system components, chemical metering pump maintenance (typically replace the head annually), in addition to routine preventative maintenance;
- The RO reject would be disposed via an outfall discharge into Narragansett Bay. The outfall would be on the order of 6” to 12”Ø and would be designed and installed to maximize dispersion into the bay waters and minimize the dilution zones. Features of the outfall design include the following:
  - The outfall pipeline would be of HDPE materials of construction, designed with no mechanical joints or bends, to facilitate installation, maintenance and inspections and and minimize the risk of mechanical failure;
  - The landborne portion of the outfall would be contained within a carrier pipe that would extend through the seawall entry into the bay, extending to the seafloor, to protect the outfall pipe from impact damage and wave action. The inclined

portion of the carrier pipe would be provided support from timber pilings or similar structures;

- The outfall would be assumed to extend for a minimum of 250 feet into the Bay, to achieve sufficient water depth and dispersion into the water column. The outfall would be provided with a final duffuser segment utilizing "duckbill" type diffusers (normally closed) to maximize exit velocity and minimize intrusion of sediments and debris. The diffusers would be installed in the vertical position at the crown of the pipe to maximize vertical dispersion into the water column;
- Reinforced concrete ballast blocks would be utilized to anchor the outfall pipe in position on the sea floor. Following installation, each of the ballast blocks would be nested within a protective riprap apron to provide scour protection and prevent undermining of the blocks;
- To facilitate inspection and maintenance of the outfall a "wye" connection with a blind flange would be installed at the upstream end of the outfall, at the sea wall, above the Mean High Water Level. This access port would allow the insertion of a camera to conduct internal video inspection of the outfall pipeline. Cleaning equipment would also be inserted into the outfall through this access port;

The outfall permitting will require a RIPDES permit, CRMC Assent and a RIDEM Water Quality Certification, at minimum. The permitting process will require extensive modeling (CORMIX – near field, WQMAP – far field) of the proposed outfall discharge to assess impact upon water quality. Additional studies would likely include surveying and mapping of the seabed habitat and materials, including CMECS Biotic Group Classification; sediment sampling, grain-size analysis and maping; a contaminant fate assessment and a biological impact assessment. The budget cost for implementation of an outfall to dispose of the desalination RO reject water is summarized in Table 4-4C.

**Table 4-4C: Capital Implementation Cost for RO Reject Discharge Outfall**

| **Work Task** | |
|---|---|
| Bathymetric Survey | $ 10.000 |
| Water Quality Modeling (Cormix, WQMAP) & Report | $ 25,000 |
| Seabed Habitat Survey, Analysis & Report | $ 15,000 |
| Seabed Sediment Survey, Analysis & Report | $ 15,000 |
| Design Engineering | $ 25,000 |
| RIDEM RIPDES Permit & Water Qual. Cert. Application | $ 11,000 |
| CRMC Application for State Assent | $ 4,000 |
| Legal/Hearings | $ 10,000 |
| Discharge Pipelline – Landborne | $ 30,000 |
| Outfall Installation | $212,500 |
| Construction Management | $ 24,000 |
| As-Built Survey | $ 5,000 |
| Final As-Built Documentation & RIPDES Inspection | $ 4,000 |
| **TOTAL OUTFALL INSTALLATION COST** | **$390,000** |

The overall operating cost for a desalination facility will be on the order of $3.50 to $7.00 per 1,000 gallons of produced water (permeate), depending upon key operating variables including membrane fouling, permeate recovery ratio, electic power cost and membrane life. The typical allocation of operating and maintenance costs for a desalination system is the following:

| | |
|---|---|
| Mechanical Equipment & Instrument Maintenance: | 6% to 10% |
| Operating Labor: | 6% to 10% |
| RO Membrane & Cartridge Filter Replacement: | 11% to 15% |
| Operating Power: | 50% to 60% |
| Chemicals (treatment, cleaning): | 3% to 5% |
| Waste Residuals Disposal: | 2% |
| Compliance & Operational Monitoring: | 2% to 4% |
| Misc/Other: | 5% |

## 4.4 Iron and Manganese Treatment – Indian Spring Wells:

The Indian Spring Wells demonstrate substantial iron and manganese in their produced water, resulting in chronic customer complaints including accumulation in fixtures, staining of clothing (during washing) and fixtures, fouling of water heaters and boilers and occasional taste problems. The District desires to implement a treatment system to remove iron and manganese from the water supply to conform to the RIDOH and USEPA Secondary Drinking Water Limits for iron (0.3 mg/l) and manganese (0.05 mg/l) and eliminate the problems experienced by the District customers. It should be noted that the Army Camp and the Bristol Colony Wells both consistently demonstrate non-detectable iron and manganese, therefore there is no need to treat the water produced by either of these wells. Additionally, there does not appear to be any significant corrosion problem associated with the distribution piping system that could contribute to the iron and manganese content in the water, at the points of use.

Table 4-5 presents a complete summary of the available iron and manganese monitoring data for the Indian Spring Wells. The data demonstrate that although the total iron concentration can fluctuate significantly, the average iron concentration produced by the two Indian Spring Wells is similar. Regarding manganese both wells demonstrating very consistent and similar results. This is expected given the close proximity and hydraulic connectivity of the wells. The iron and manganese concentrations both substantially and consistently exceed their respective RIDOH and USEPA limits. The recommended iron and manganese concentrations to be used for design of a treatment system are 2.0 mg/l and 0.3 mg/l, respectively.

**Table 4-5: Indian Spring Well Iron & Manganese Water Quality Monitoring Summary**

| | Total Iron | | Total Manganese | |
|---|---|---|---|---|
| **Sample Date** | **Indian Spring #1** | **Indian Spring #4** | **Indian Spring #1** | **Indian Spring #4** |
| 10/31/94 | ----- | 0.40 mg/l | 0.15 mg/l | 0.19 mg/l |
| 05/24/95 | 0.28 mg/l | 0.48 mg/l | 0.23 mg/l | 0.17 mg/l |
| 11/14/95 | 0.79 mg/l | 0.19 mg/l | 0.20 mg/l | 0.16 mg/l |
| 06/20 & 21/96 | 1.09 mg/l | 0.39 mg/l | 0.19 mg/l | 0.12 mg/l |
| 10/08/96 | 0.50 mg/l | 0.17 mg/l | ----- | ----- |
| 12/17/96 | 0.68 mg/l | 0.69 mg/l | 0.21 mg/l | 0.21 mg/l |
| 01/27/97 | 1.49 mg/l | 0.60 mg/l | 0.15 mg/l | 0.19 mg/l |
| 06/04/97 | 0.94 mg/l | 2.74 mg/l | 0.19 mg/l | 1.44 mg/l[1] |

| | | | | |
|---|---|---|---|---|
| 07/02/97 | ----- | 0.65 mg/l | ----- | 0.19 mg/l |
| 08/06/97 | 1.19 mg/l | 0.56 mg/l | 0.18 mg/l | 0.21 mg/l |
| 08/27/97 | ----- | 0.64 mg/l | ----- | 0.21 mg/l |
| 09/09/97 | 2.27 mg/l | 1.38 mg/l | 0.05 mg/l | 0.22 mg/l |
| 10/06/97 | 1.48 mg/l | 0.32 mg/l | 0.15 mg/l | 0.03 mg/l |
| 07/14/98 | ----- | 1.44 mg/l | ----- | 0.24 mg/l |
| 08/11/98 | 0.89 mg/l | 0.87 mg/l | 0.19 mg/l | 0.27 mg/l |
| 09/15/98 | 0.65 mg/l | ----- | 0.17 mg/l | ----- |
| 10/20/98 | 2.39 mg/l | ----- | 0.02 mg/l | ----- |
| 11/18/98 | 0.05 mg/l | ----- | 0.19 mg/l | ----- |
| 12/29/98 | 1.93 mg/l | ----- | 0.21 mg/l | ----- |
| 01/27/99 | 2.52 mg/l | 0.89 mg/l | 0.28 mg/l | 0.25 mg/l |
| 05/13/03 | ----- | 1.80 mg/l | ----- | 0.29 mg/l |
| 06/03/03 | 0.95 mg/l | 1.30 mg/l | 0.11 mg/l | 0.31 mg/l |
| 04/13/12 | 0.78 mg/l | 2.69 mg/l | 0.20 mg/l | 0.30 mg/l |
| 08/06/12 | 0.67 mg/l | 4.05 mg/l | 0.01 mg/l | 0.32 mg/l |
| | | | | |
| **Max Conc.** | **2.52 mg/l** | **4.05 mg/l** | **0.28 mg/l** | **0.32 mg/l** |
| **Min Conc.** | **0.05 mg/l** | **0.17 mg/l** | **0.02 mg/l** | **0.03 mg/l** |
| **Average Conc.** | **1.13 mg/l** | **1.11 mg/l** | **0.16 mg/l** | **0.21 mg/l** |
| **Qty > MCL-2$^{nd}$** | **17 of 19** | **18 of 20** | **17 of 19** | **17 of 18** |
| **Design Value** | **2.0 mg/l** | | **0.3 mg/l** | |

**Note 1: Sample result believed to be lab calculation error – not included in evaluation.**

There are a number of alternative processes used for removal of iron and manganese including softeners, media filtration, chemical precipitation, greensand filtration, and more recently membrane filtration processes. A brief summary of the applicability of each of these processes is presented below.

4.4.1 Ion Exchange Softening: Although low concentrations of iron and manganese may be removed as a collateral benefit of conventional ion exchange softening, this process is not recommended for this application, for the following reasons:

- The comparatively high total hardness content of in the water supply (average 72 mg/l as $CaCO_3$) will result in the softeners exhausting on the basis of hardness loading, rather than iron and manganese. This will result in rapid exhaustion of softening resin, excessive salt usage and cost relative to iron and manganese removal;
- Particulate and colloidal iron will foul the softening resin, degrading the operational performance and substantially increasing maintenance requirements and resin replacement cost;
- The total wastewater (backwash, resin regeneration and rinsing) generation will be significantly greater than for alternative treatment methods. Additionally, the resin is regenerated with salt brine (sodium chloride or potassium chloride), consequently the wastewater will contain a very high salt content which would re-enter the groundwater, potentially impairing the aquifer water quality;
- Softening increases the corrosivity of the water due to the reduction in the calcium content, increasing the potential for lead and copper in the distribution system. A

review of the corrosion evaluation indicates that the softened water LSI would be on the order of -3.5 to -4.0, indicating a very strong corrosion potential.

4.4.2 Media Depth Filtration: Media filtration is very effective for removal of particulate (oxidized) forms of iron and manganese. However, the majority of the manganese is unquestionably dissolved, and iron is likely present in dissolved, colloidal and particulate forms in the water. Therefore, conventional media depth filtration will be ineffective to achieve comprehensive removal of iron and manganese. Additionally, bag and cartridge type filters are not recommended for this application, as they will rapidly foul, resulting in significantly increased operator maintenance and consumables cost. Due to their process limitations regarding product water quality, these various non-chemical filtration processes are not recommended for this application.

4.4.3 Chemical Precipitation and Solids Separation: Chemical precipitation in combination with gravity separation may be effective, however the residual sludge generation can be significant, creating a solids/sludge handling and disposal issue. The cost for treatment chemicals, labor, sludge dewatering and disposal would likely render such a system excessively expensive. Similarly, chemical coagulation/precipitation in conjunction with a media filtration system will result in shorter filter operating cycles and also create a residual solids/sludge disposal issue. Conventional dry wells will require more frequent cleaning to maintain consistent leaching of the backwash water and would add dissolved solids to the groundwater. This process is unquestionably labor intensive, can be susceptible to process upset and is not believed operationally or cost effective for this application.

4.4.4 Membrane Filtration: Membrane filtration processes have received consideration and application for potable water iron and manganese treatment for approximately 15 to 20 years, using several different membrane configurations. This process was presented and in fact, recommended to the District in the Preliminary Engineering Report (C&E Partners, Inc, June, 2006) submitted to the USDA to support a funding application for a filtration pilot plant study, in 2006. This report presented a brief description of the submerged membrane filtration process, including the following excerpted statements:

*"The immersed membrane technology has had good success of iron and manganese removal but involves a higher capital cost as well as a higher operations and maintenance cost, though on small system applications these costs are not so significant as with larger system applications."*

*"Both technologies utilize pH adjustment and the addition of an oxidizing agent such as chlorine or potassium permanganate to convert soluble iron and manganese to an insoluble form."*

*"…the immersed membrane system would be a package system based upon membrane technology. The raw water would be pumped into the membrane tank to which potassium permanganate would be added to oxidize the iron and manganese to its*

*insoluble form. A vacuum pump applies a negative pressure to the inside of the tubular membrane to allow clean water to be withdrawn from the membrane tank and the contaminates are left behind. These contaminates continue to cycle up in the membrane and additional raw water is added to take the place of the clean treated water withdrawn. To keep the contaminates at a steady concentration in the membrane tank a small underflow wastestream is withdrawn and pumped to a waste holding tank in which the iron and manganese oxidized are settled and removed as a sludge and the supernatant is returned to the raw water holding/contact tank for treatment into finish water. The membrane tank has an aeration system that keeps solids in suspension, aides in the oxidation of the iron and manganese and also serves to reduce radon gas. The package also has an integral "air bump" system that automatically cleans the membranes while the system is operating. For system redundancy, two separate treatment trains will be provided so that finish water can be produced when one unit is down for service. Only one unit will be operated at one time."*

The Preliminary Engineering Report went on to advise that it would be necessary to conduct a pilot plant study of the immersed membrane filtration process to assess the viability and performance, and refine the estimates for capital and operating cost. This report also presented a capital implementation cost estimate totaling $946,675 for an immersed membrane filtration system with a rated capacity of 35 gpm. This estimate did not include the cost for the pilot plant, estimated to be an additional $15,000.

In addition to the massive capital cost, there are a number of other substantial concerns regarding the implementation of an immersed membrane (or for that matter tubular, dry-mount membrane filtration) system, including the following:

- This process system is operationally complex, far more so than other potential process technologies, and will require an operator with a minimum Class II Treatment license, and potentially a Class III Treatment license;
- The system will include a minimum of two (2) chemical makeup and feed systems to maintain, as well as a <u>minimum</u> of 2 dedicated pumping systems (vacuum pumps & sludge transfer) and a compressor for normal process operation. At minimum, this will increase the system cost for operating power by at least 200% to 300% compared to other process technologies that can provide effective treatment of iron and manganese;
- The immersed membrane system operates under a vacuum therefore a re-pressurization pump system is required (clearwell and high lift pump system) to transfer the water into the distribution piping system. This further increases the system complexity, operating cost and maintenance requirements;
- The system operator will likely spend a <u>minimum</u> of 2-hours per day involved with the operation of this system, to perform the following functions:
    - Inspecting equipment and verifying correct process operation;
    - Chemical makeup, metering pump calibration and routine maintenance;
    - Checking and balancing sludge underflow recycle to the raw water tank;

   - Checking waste sludge residuals tank level and transfer of waste residuals to the disposal system;
   - Routine pump, compressor and chemical feed pump maintenance;
   - Routine, periodic instrument calibrations, field water quality monitoring, etc.
   - Periodic chemical cleaning of membranes and related maintenance (hence the need for 2 parallel filter systems);
- The necessary building footprint (900 $ft^2$) will be a minimum of 300% greater than that required for other process technologies to provide effective treatment of iron and manganese. This will substantially increase the system operating costs for heating, lighting, ventilation/dehumidification, etc;
- The operator will have a substantially greater exposure to chemicals and the waste residuals, compared to other process technologies that can provide effective treatment of iron and manganese;
- The iron and manganese will be precipitated as solids in both the oxide (due to oxidation chemistry) and hydroxide forms (due to pH adjustment), producing a sludge that is far more gelatinous than the oxide solids generated by other process technologies that can provide effective treatment of iron and manganese. This will increase the sludge residuals mass and retained water and will render subsurface disposal systems less effective and more prone to fouling and maintenance;
- This system will require significant annual maintenance including pump and compressor maintenance, chemical metering pump maintenance (typically replace the heads annually), membrane inspection and periodic replacement, chemical cleaning of membranes, in addition to routine preventative maintenance;

The Preliminary Engineering Report presented an estimated operating and maintenance cost of $375 per month ($4,500/year), including administrative ($25), chemicals ($75), utilities ($75), operational manpower ($150) and waste disposal. Based upon experience with more than 100 membrane filtration systems, at this conceptual level of design, it is recommended that the operating and maintenance cost (including preventative and annual maintenance) be increased by at least an order of magnitude, equivalent to an annual cost of $45,000 per year.

Although it is certainly possible, if not probable, that a membrane filtration system would provide effective treatment and removal of iron and manganese in this application, the capital and operating costs are massive and prohibitive. Additionally, this process is comparatively complex compared to other effective treatment processes and would require a substantially greater level of operator technical/process proficiency than presently available on the Island.

4.4.5 Vacuum Diatomaceous Earth Filtration Treatment: This process was presented and in fact, recommended to the District in the Preliminary Engineering Report (C&E Partners, Inc, June, 2006) submitted to the USDA to support a funding application for a filtration pilot plant study, in 2006. This report presented a brief description of the vacuum DE filtration process, including the following excerpted statements:

*"The DE filtration process consists of a open fiberglass tank that contains hollow fiberglass slotted plates over which a nylon fabric is tightly stretched. The tank is flooded with clean water and DE is added while a vacuum is drawn for the interior of these plates. The DE is collected on fabric which is called a septum. This is termed "pre-coating the filter". This thin coating of DE acts as the filter for the oxidized iron and manganese. As the vacuum draws clean water from the interior of the plates additional raw water is added to the treatment tank….The raw water with oxidized iron and manganese has DE added to it just prior to entering the treatment tank. This DE acts as a bridging agent allowing the metal oxides to be filtered out without binding the filter. Eventually the septum gets so full of DE (and metal oxides) that the space between the plates can no longer pass the required flows. At this point the unit must be removed from service and drained to a dewatering tank. Most of the DE is removed by tank dewatering. The remaining is washed with a high pressure wand. Filter runs will typically be in the range of 3 to 5 days and several hundred gallons of wastewater is generated from the dewatering of the used DE. This is typically disposed of as wastewater in a dry well system. The used DE is disposed of as solid waste."*

*"Both technologies utilize pH adjustment and the addition of an oxidizing agent such as chlorine or potassium permanganate to convert soluble iron and manganese to an insoluble form."*

The Preliminary Engineering Report went on to advise that it would be necessary to conduct a pilot plant study of the vacuum DE filtration process to assess the viability and performance, and refine the estimates for capital and operating cost. This report also presented a capital implementation cost estimate totaling $625,425 for a vacuum DE filtration system with a rated capacity of 35 gpm. This estimate did not include the cost for the pilot plant, estimated to be an additional $15,000. The report also stated the following:

*"The DE vacuum filtration system has less of a chance of meeting the iron and manganese removal goals of the District but it is believed that the testing of this technology is worth the chance in that if it can be proved to be effective, this system has much lower capital and operating costs (i.e. approximately half of that of the immersed membrane technology). The disadvantage of this technology is that it works over a limited range of water quality and there are levels of iron and manganese that can exist that can render this technology ineffective. Also, other naturally occurring compounds (i.e. carbon dioxide) found in the source water can interfere with this technology. Based upon the limited testing conducted it appears that the levels of iron and manganese that can be expected from the Indian Spring Wells should fall within the capabilities of this technology but it is unknown as to whether other naturally occurring compounds exist that may make this technology non-viable…."*

In addition to the massive capital cost, there are a number of other substantial concerns regarding the implementation of a vacuum DE filtration system, including the following:

- This process system is operationally complex, far more so than other potential process technologies, and will require an operator with a minimum Class II Treatment license, and potentially a Class III Treatment license;
- The system will include a minimum of two (2) chemical makeup and feed systems to maintain, as well as a minimum of 2 dedicated pumping systems (vacuum pumps & sludge transfer) for normal process operation. At minimum, this will increase the system cost for operating power by at least 200% compared to other process technologies that can provide effective treatment of iron and manganese;
- The DE filters system operates under a vacuum therefore a re-pressurization pump system is required (clearwell and high lift pump system) to transfer the water into the distribution piping system. This further increases the system complexity, operating cost and maintenance requirements.
- The system operator will likely spend 2 to 4 hours per day involved with the operation of this system, to perform the following functions, at minimum:
  - Inspecting equipment and verifying correct process operation;
  - Chemical makeup, metering pump calibration and routine maintenance;
  - Cleaning of DE septums and tank, and makeup of fresh DE pre-coat;
  - Checking waste sludge residuals tank level and transfer of waste residuals to the disposal system and sludge dewatering;
  - Routine pump and chemical feed pump maintenance;
  - Routine, periodic instrument calibrations, field water quality monitoring, etc.
  - Periodic chemical cleaning of membranes and related maintenance (hence the need for 2 parallel filter systems);
- The necessary building footprint (900 $ft^2$) will be a minimum of 300% greater than that required for other process technologies to provide effective treatment of iron and manganese. This will substantially increase the system operating costs for heating, lighting, ventilation/dehumidification, etc;
- The operator will have a substantially greater exposure to chemicals and the waste residuals, compared to other process technologies that can provide effective treatment of iron and manganese;
- The iron and manganese will be precipitated as solids in both the oxide (due to oxidation chemistry) and hydroxide forms (due to pH adjustment), producing a sludge that is far more gelatinous than the oxide solids generated by other process technologies that can provide effective treatment of iron and manganese. This will increase the sludge residuals mass and retained water and will render subsurface disposal systems less effective and much more prone to fouling and maintenance;
- This system will require significant annual maintenance including pump and compressor maintenance, chemical metering pump maintenance (typically replace the heads annually), membrane inspection and periodic replacement, chemical cleaning of membranes, in addition to routine preventative maintenance;

With part-time operator attention, this process is prone to process upset due to the variable raw water iron content and more importantly, to the intermittent use of the treatment system and fragility of the DE media layer on the setums. Additionally, the operator may spend substantially more time than anticipated for makeup of DE, pre-coating septums, cleaning septums and handling DE sludge residuals.

The Preliminary Engineering Report presented an estimated operating and maintenance cost of $375 per month ($4,500/year), including administrative ($25), chemicals ($75), utilities ($75), operational manpower ($150) and waste disposal. Based upon experience with numerous DE filter systems, at this conceptual level of design, it is recommended that the operating and maintenance cost (including preventative and annual maintenance) be increased by at least an order of magnitude, equivalent to an annual cost of $45,000 per year and could potentially be significantly greater.

Although it is possible that a vacuum DE filtration system could provide effective treatment and removal of iron and manganese in this application, the capital and operating costs are massive and prohibitive. The proposed 4-week pilot plant program is likely insufficient to provide the necessary operating data to assess viability over the full range of operating conditions for this system. Additionally, this process is comparatively complex compared to other effective treatment processes and would require a substantially greater level of operator technical/process proficiency than presently available on the Island. This process is unquestionably labor intensive, can be susceptible to process upset and is not believed operationally or cost effective for this application.

4.4.6 Greensand Media Filtration: The most widely used and effective means to remove iron and manganese is chemical oxidation followed by media filtration. This is typically accomplished by either of two (2) methods; (a) chemical oxidation followed by conventional multi-media filtration, or (b) chemical oxidation followed by manganese greensand filtration. Iron, and to a lesser extent manganese, is readily oxidized by chlorine (sodium hypochlorite, etc.), after which it can be effectively removed by multi-media filtration. However, in this application with manganese present in a comparatively significant concentration in relation to iron in the raw water, the manganese greensand filtration process, with continuous regeneration, is recommended as the optimum means to achieve the desired reduction of both contaminants.

Manganese greensand is a granular filter media produced from a natural zeolite (glauconite). This natural zeolite has ion exchange properties, which are enhanced with a manganese dioxide coating that acts as a catalyst in the oxidation-reduction reaction of iron and manganese. Soluble iron and manganese in the raw water are oxidized and precipitated, and then filtered from the water as it passes through the media bed. Small residual amounts of soluble iron and manganese remaining in the water following oxidation can be removed by the ion exchange properties of the greensand. In addition to natural mineral (zeolite) media, there are coated silica sand and dolomite media products now commercially available.

Greensand filtration operates optimally when the water pH is in the range of 6.2 to 8.5 su. Because this application includes removal of iron and manganese, the "Continuous Regeneration" mode of operation is recommended, incorporating the addition of sodium hypochlorite (NaOCl) and/or potassium permanganate ($KMnO_4$) upstream of the greensand filtration system. The residual chemicals remaining after oxidation of the soluble iron and manganese will maintain the filtration media in a continuously regenerated condition.

The filter utilizes a dual media configuration including anthracite and greensand, and requires periodic backwash to flush accumulated particulate iron and manganese from the filter bed, thereby restoring the filter to full service. An automatic backwash control system is recommended and the full backwash duration, including time for valve positioning, is approximately 20 minutes. The backwash frequency is anticipated to be 1 to 2 times per week. Because this system operates with distinctly different hydraulic conditions during the peak and non-peak seasons design analyses were executed for both operating conditions. Tables No 4-6 and 4-7 present conceptual design alternatives for greensand filter systems considered for this application. Evaluating the findings resulted in a determination that a triplex (3-vessel) greensand filtration system utilizing 36"Ø filter vessels operating sequentially, in parallel provides the optimum system design, treating the raw well water prior to discharge to the distribution system and atmospheric water storage tank.

The design assumes that regardless of the total District water demand, the Indian Spring Wells will be operated in accordance with their design criteria, which limit the wells to 12-hour per day operation, with Indian Spring Well #1 producing a maximum of 11,520 gpd at a flowrate of 16 gpm and Indian Spring Well #4 a maximum of 25,200 gpd at a flowrate of 35 gpm. It should be noted that should these wells be operated for greater duration each day, the only impact will be to shorten the length of the operating cycle between backwash events, for each filter vessel. Benefits of this system design, configuration and operation include the following:

- The use of 36"Ø vessels allows three (3) vessels to be installed in parallel with sequencing operation. In normal peak season operation (35 gpm, 25,200 gpd) a maximum of 2 vessels would be on-line with the 3rd vessel in standby. During non-peak season operation (16 gpm, 11,520 gpd) one (1) vessel would be on-line with two (2) vessels in standby. This rotating sequence assures that 100% of the necessary capacity is on-line at any time, with sufficient reserve capacity to handle the loss of at least one vessel, for any reason;
- The filter vessels would operate on the basis of gallons treated, based upon the projected iron and manganese design loading. The operating cycles could be adjusted based upon periodic field water quality monitoring. The vessels would operate in a staggered sequence such that only one vessel would be exhausted and require backwash at any given time. Each vessel would have a nominal volumetric capacity of 46,480 gallons, based upon very conservative design criteria. The expected operating cycle for each vessel is 3.7 days during peak season operation and 4.1 days during non-peak season operation;
- The design utilizes Greensand Plus media, having a hydraulic loading operating range of 2 to 12 gpm per square foot of media bed (2-12 gpm/$ft^2$). This design results in a

hydraulic loading for each vessel that is very conservative, a maximum 2.5 gpm/$ft^2$ during the peak demand season (2 vessels on-line, in parallel). This indicates that if necessary, a single filter vessel could handle 100% of the peak season design loading during peak season, a further factor of safety to minimize operating risk;

- Greensand filtration operates optimally when the water pH is in the range of 6.2 to 8.5 su and therefore no pH adjustment is necessary upstream of the filtration process;
- This system utilizes “Continuous Regeneration” with sodium hypochlorite. The chemical is metered neat from a storage container, with flow proportional feed control to maintain the correct feed dosage. Using 12% sodium hypochlorite (12% by weight, as Chlorine) will require less than 2 gallons per day during the peak demand season and less than 1 gallon per day during the non-peak demand season. That greatly simplifies chemical handling and minimizes operator exposure to chemicals;
- Contrary to the representations in the 2006 Preliminary Engineering Report, the only wastewater normally generated by the Greensand Filter system will be the periodic backwash to flush accumulated solids from the media bed. Assuming a conservative 15 minute backwash duration (plus valve positioning time) the backwash water volume is 1,275 gallons per backwash event. Based upon a nominal treated water capacity of 46,480 gallons per operating cycle, this equates to a “parasitic” equivalent of 2.7%, which is extremely efficient. Furthermore, this water can be discharged to a drywell system which will filter out the insoluble ferric and manganic oxides, returning the spent backwash water into the Region IV watershed;
- The triplex filter system is a standard commercial design that can be provided with an integral PLC-based control system, monitoring the flowrate and water volume to each filter vessel, and automatically controlling the filter backwash and sequencing of the filters on/off line. The controller is provided an operator interface and manual override is provided for all controls and functions;
- The greensand filters operate under pressure and therefore can directly accept the discharge from the two (2) Indian Spring Wells, and then discharge directly into the distribution force main. At worst, this may require increasing the submersible pump motors by 1 HP to accommodate the additional pressure drop across the filter system and pump house piping;
- The periodic filter backwash occurs automatically, using a dedicated backwash water storage tank and pump system;
- The system will require a maximum operator requirement of 1-hour per day to perform a daily operational inspection, check chemical inventory, perform field tests of influent and effluent iron and manganese, oversee backwash events, etc. Annual maintenance includes inspection of the filter beds and replenishing media (typically 5% per year) and maintenance of the chemical feed metering pump;
- The footprint area for the Greensand Filtration system, inclusive of the filters, chemical feed system, backwash tank and pump system is approximately 225 to 250 sq. ft. It is recommended that the greensand filter system be incorporated into a new Well Pump House structure at the site of the existing Indian Spring Well Pump House. It is recommended that this new building also include a storage room/area for materials and an operator office, as well as an emergency generator;

- The backwash water generated by the greensand filter system will directly discharge to a settling tank and drywell system. Design of this system will require a soil evaluation and determination of loading rates. The settling tank shall be a minimum 1,500 gallon pre-cast concrete structure. The final sizing of the drywell system will be determined by the soil evaluation. Based upon an opinion recently provided by RIDEM personnel, a RIDEM Underground Injection Control (UIC) approval will not be required;
- The system will likely require a treatment operator with a Class 1T certification;
- There is no need for a pilot plant study to evaluate this treatment process because the Greensand Filtration process is the most widely applied process technology for treatment of iron and manganese, having a very substantial application data base including numerous successful systems in Rhode Island;

**Table No. 4-6: Greensand Filtration System – Peak Season Design Analysis**

| | **Peak Season Operating Conditions** | | |
|---|---|---|---|
| Vessel Diameter | **30" Ø** | **36" Ø** | **42"Ø** |
| Volume Treated per Day | 25,200 gpd | 25,200 gpd | 25,200 gpd |
| Average Iron Concentration | 2.0 mg/l | 2.0 mg/l | 2.0 mg/l |
| Average Manganse Concentration | 0.3 mg/l | 0.3 mg/l | 0.3 mg/l |
| Operating Flowrate – Total | 35 gpm | 35 gpm | 35 gpm |
| Number of Vessels | 4 | 3 | 2 |
| No. of Vessels On-Line | 3 | 2 | 1 |
| Installation Configuration | Parallel | Parallel | Parallel |
| Operating Configuration | Sequencing | Sequencing | Alternating |
| Operating Flowrate Per Vessel | 11.7 gpm | 17.5 gpm | 35 gpm |
| Hydraulic Loading Rate - Operation | 2.4 gpm/ft$^3$ | 2.5 gpm/ft$^3$ | 3.6 gpm/ft$^3$ |
| Chlorine Dosage | 8.6 mg/l | 8.6 mg/l | 8.6 mg/l |
| Regeneration | Continuous | Continuous | Continuous |
| Residual Chlorine Concentration | 0.2 mg/l | 0.2 mg/l | 0.2 mg/l |
| Media Configuration | Dual Bed | Dual Bed | Dual Bed |
| Anthracite Bed Depth | 18" | 18" | 18" |
| Greensand Bed Depth | 24" | 24" | 24" |
| Greensand Bed Volume/Vessel | 9.8 ft$^3$ | 14.1 ft$^3$ | 19.2 ft$^3$ |
| Nominal Bed Unit Capacity | 1,000 gr/ft$^2$ | 1,000 gr/ft$^2$ | 1,000 gr/ft$^2$ |
| Vessel Capacity/Cycle | 32,304 gallons | 46,480 gallons | 63,224 gallons |
| Vessel Operating Cycle | 3.8 days | 3.7 days | 2.5 days |
| Backwash Loading Rate (55$^o$F) | 12 gpm/ft$^2$ | 12 gpm/ft$^2$ | 12 gpm/ft$^2$ |
| Backwash Bed Expansion | 40% | 40% | 40% |
| Backwash Flowrate | 60 gpm | 85 gpm | 115 gpm |
| Backwash Duration | 15 minutes | 15 minutes | 15 minutes |
| Backwash Volume | 900 gallons | 1,275 gallons | 1,730 gallons |
| % Parasitic Water | 2.7% | 2.7% | 2.7% |

Figure 4-1 presents the recommended Process & Instrumentation Diagram for the proposed Greensand Filtration System. Figure 4-2 presents a conceptual layout for a new Indian Springs Well Pump House, including the treatment system. A cost estimate has been prepared for implementation of a Greensand Filtration System to treat the water generated by the Indian Spring Wells, summarized in Table 4-8. The total implementation cost, including project contingency is $264,720, inclusive of the pro-rated portion of the proposed Well Pump House necessary to house the treatment system. This estimate does not include legal, accounting, or administrative costs associated with obtaining project financing, nor land acquisition or lease fees.

**Table No. 4-7: Greensand Filtration System – Non-Peak Season Design Analysis**

| | **Non-Peak Season Operating Conditions** | | | |
|---|---|---|---|---|
| Vessel Diameter | **30" Ø** | **30" Ø** | **36" Ø** | **42"Ø** |
| Volume Treated per Day | 11,520 gpd | 11,520 gpd | 11,520 gpd | 11,520 g[d |
| Average Iron Concentration | 2.0 mg/l | 2.0 mg/l | 2.0 mg/l | 2.0 mg/l |
| Average Manganse Conc. | 0.3 mg/l | 0.3 mg/l | 0.3 mg/l | 0.3 mg/l |
| Operating Flowrate – Total | 16 gpm | 16 gpm | 16 gpm | 16 gpm |
| Number of Vessels | 4 | 4 | 3 | 2 |
| No. of Vessels On-Line | 2 | 1 | 1 | 1 |
| Installation Configuration | Parallel | Parallel | Parallel | Parallel |
| Operating Configuration | Sequencing | Sequencing | Sequencing | Alternating |
| Operating Flowrate Per Vessel | 8.0 gpm | 16.0 gpm | 16.0 gpm | 16.0 gpm |
| Hydraulic Loading - Operation | 1.6 gpm/ft$^3$ | 3.3 gpm/ft$^3$ | 2.3 gpm/ft$^3$ | 1.7 gpm/ft$^3$ |
| Chlorine Dosage | 8.6 mg/l | 8.6 mg/l | 8.6 mg/l | 8.6 mg/l |
| Regeneration | Continuous | Continuous | Continuous | Continuous |
| Residual Chlorine Conc. | 0.2 mg/l | 0.2 mg/l | 0.2 mg/l | 0.2 mg/l |
| Media Configuration | Dual Bed | Dual Bed | Dual Bed | Dual Bed |
| Anthracite Bed Depth | 18" | 18" | 18" | 18" |
| Greensand Bed Depth | 24" | 24" | 24" | 24" |
| Greensand Bed Volume/Vessel | 9.8 ft$^3$ | 9.8 ft$^3$ | 14.1 ft$^3$ | 19.2 ft$^3$ |
| Nominal Bed Unit Capacity | 1,000 gr/ft$^2$ | 1,000 gr/ft$^2$ | 1,000 gr/ft$^2$ | 1,000 gr/ft$^2$ |
| Vessel Capacity/Cycle | 32,304 gallons | 32,304 gallons | 46,480 gallons | 63,224 gallons |
| Vessel Operating Cycle | 5.6 days | 2.8 days | 4.1 days | 5.5 days |
| Backwash Loading Rate (55$^o$F) | 12 gpm/ft$^2$ | 12 gpm/ft$^2$ | 12 gpm/ft$^2$ | 12 gpm/ft$^2$ |
| Backwash Bed Expansion | 40% | 40% | 40% | 40% |
| Backwash Flowrate | 60 gpm | 60 gpm | 85 gpm | 115 gpm |
| Backwash Duration | 15 minutes | 15 minutes | 15 minutes | 15 minutes |
| Backwash Volume | 900 gallons | 900 gallons | 1,275 gallons | 1,730 gallons |
| % Parasitic Water | 2.7% | 2.7% | 2.7% | 2.7% |

## Table 4-8: Capital Implementation Cost Estimate
## Indian Springs Well Greensand Filtration System

| | | | |
|---|---|---|---|
| Capital Equipment: | | | |
| 1. | Triplex Greensand Filtration System[2,3]: | $ 41,540 | |
| 2. | Backwash Tank; | $ 2,700 | |
| 3. | Basckwash Pump & Controls: | $ 3,670 | |
| 4. | Chemical Feed System (NaOCl)[1]: | $ 5,650 | |
| 5. | Chlorine Residual Analyzer: | $ 5,375 | |
| 6. | Tank Level Monitoring Instrumentation: | $ 1,850 | |
| 7. | Central Alarm & Communication Panel: | $ 1,500 | |
| 8. | Misc. Mechanical Components, Gages, Etc.: | $ 750 | |
| | **Equipment Sub-Total:** | | **$ 63,035** |
| | **Freight:** | | **$ 4,000** |
| Civil/Mechanical/Electrical Installation[4]: | | | |
| 1. | Well Pump House Building Structure[4]: | See Below | |
| 2. | Equipment Rigging & Mounting: | $ 2,720 | |
| 3. | Interior Mechanical Piping – Labor & Mat'ls: | $ 13,800 | |
| 4. | Interior Electrical – Labor & Mat'ls: | $ 7,100 | |
| 5. | Instrumentation Installation, Testing: | $ 4,400 | |
| 6. | Backwash Piping, Settling Tank & Drywell: | $ 18,000 | |
| 7. | Pipe & Valve Labels & ID: | $ 350 | |
| | **Construction Sub-Total:** | | **$ 46,370** |
| | **Construction Permits:** | | **$ 1,000** |
| | **Contractor O&P (15%):** | | **$ 6,955** |
| Engineering/Construction Phase Services: | | | |
| 1. | Design Engineering: | $ 13,800 | |
| 2. | Regulatory Permits & Approvals: | $ 2,800 | |
| 3. | Construction Management: | $ 15,520 | |
| 4. | System Start-Up & Validation: | $ 4,200 | |
| 5. | O&M Manual & Operator Training: | $ 4,500 | |
| | **Engineering/CM/Start-Up Total:** | | **$ 40,820** |
| **Project Sub-Total:** | | | **$162,180** |
| **Project Contingency (10%):** | | | **$ 16,220** |
| **Pro-Rated Portion of Well Pump House Building:** | | | **$ 86,320** |
| **Total Project Cost:** | | | **$264,720** |

**Note 1: Chemical Feed System includes; In-Line Static Mixer w/2 Injection Quills, Electronic Chemical Metering Pumps (2), Day Tank, Day Tank Agitator, Spill Containment Pallet, Electronic Flowmeter w/Pulsed Output.**

**Note 2: Greensand Filtration System includes vessels, filter media, face piping, automatic and manual valves, interior distributors and collectors, control panel, integral wiring, etc. Media to be installed in field following installation of filters.**

**Note 3: Greensand Filtration System is provided with PLC control panel for monitoring of gallons treated and flowrate, sequencing of filter vessels, backwash control (cycle time and valve positioning), etc. Includes data logging capability with download to flash drive or similar device.**

**Note 4: Installation cost assumes the Greensand Filtration Treatment System will be installed into the new Indian Spring Well Pump House. This cost estimate includes the pro-rated portion of the Pump House (250 sq. ft.) required for the treatment system.**

## 4.5 Elimination of Low Pressure Problems in the Broadway Upland Distribution Area:

Due to the significant disparity in elevation in the system the PIWD system essentially functions with two (2) pressure zones. The substantial majority of the District users are located in the lowland areas along the eastern coatline of Prudence Island, at elevations ranging from 1 ft. MSL to 50 ft. MSL, comprising the "high pressure" zone of the system. The upland areas to the west of Governor Paine Road, between Hillside Road and Sunset Hill Avenue, between Daniel Avenue and Homestead Avenue and the Broadway area at the southern end of the system are the "low pressure" zone, typically experiencing distribution pressures between 2 and 30 psig. The installation of the "Big Blue" water storage tank alleviated some of the low pressure problems in the upland areas in the central portion of the distribution system, however the area generally described as the Broadway Upland Distribution Area has experienced chronic low pressure problems despite the installation in 1991 of the Broadway Booster Pump Station.

The area presently defined as the service area for the Broadway Booster Pump Station includes 17 residences, with the potential to develop a maximum of 16 additional residences (per 2006 Study by Town of Portsmounth). Based upon the number of active connections, this represents approximately 5.0% of the service connections. In the absence of specific demand data for this portion of the District, the water demands were estimated based upon the number of connections, as a % of the total. This resulted in a determination that during non-peak periods the demand flowrates were minimal (1 to 2 gpm). However during the peak demand periods the sustained peak hour flowrates could be as high as 6.5 gpm and the peak instantaneous flowrate could be as high as 8.5 gpm.

The combined Broadway and Bristol Colony portions of the PIWD distribution system have a total of 67 residences served via a 1.5"/1.25"Ø HDPE pipeline installed in John Oldham Road, along the coastal lowland, and a 2"Ø HDPE pipeline installed in Narragansett Avenue, extending from the 6"Ø main just north of the former Goulet Well, to Broadway Road. This combined service area represents approximately 20% of the total service connections. Therefore, assuming a proportional ratio of the water demand the peak hour demand flowrates can be as high as 26 gpm and the peak instantaneous flowrates up to 33 gpm.. Recognizing that the 2"Ø pipeline in Narragansett Avenue will likely handle up to 60% of the peak hour demand flowrate (up to 20 gpm), the anticipated pipeline (friction) losses for this approximately 1,600 ft. length of 2"Ø force main are on the order of 4 to 7 psig.

The Army Camp Well has a 2" discharge service the feeds directly to the southern end of the distribution system and when this well is operating the pressure at the Broadway Booster Pump Station is 25 to 28 psig. However this well has limited capacity, operates part-time and cannot be expected to provide consistent service to the upland area. Therefore the hydraulic grade for the majority of the system (including Broadway) is defined by the operating elevations of the "Big Blue" tank, which operates at a maximum (overflow) elevation of 148.60 ft. MSL and a minimum elevation of 127.50 ft. MSL. The upland areas at the southern end of the system range in elevation from 90 to 130 ft. MSL. Based simply upon the elevation differential, the available static head ranges from a maximum of approximately 58 ft. (25.1 psi) when the "Big Blue" tank is completely full to zero (0) ft. (0 psi) when the "Big Blue" tank is at the minimum established working elevation. Factoring in the pipeline losses occurring in the distribution system, the distribution pressure is reported (by PIWD personnel) to be a maximum of 11 psig at the Broadway Booster Pump Station when the "Big Blue" tank is full and <5 psig when it is ≤1/3 full. It should be noted that if there is an increase in the number of service connections in the Broadway/Bristol Colony service area, the pressure problems will be aggravated as the peak demand flowrates increase. Four (4) alternatives have been identified for consideration, to alleviate the chronic low pressure problems occurring in the Broadway Upland Distribution Area.

4.5.1 New Water Storage Tank to Serve Broadway Area: Installing a water storage tank to provide improved pressure to the Broadway Upland Distribution Area would require the tank to be installed at an elevation sufficient to provide the necessary static head to maintain minimum pressures. Recognizing that the most serious pressure problems are in an area between 110 ft. to 130 ft. MSL, the tank would have to be located in the vicinity of the Army Camp Well (approx. grade El. 165 ft. MSL). The minimum tank working elevation would have to be a minimum elevation of 180 ft. MSL, with an overflow elevation of 200 ft. MSL to assure available static pressures between 20 and 39 psig.

At low demand flowrates (<10 gpm) the existing 2"Ø force main from Army Camp Well to Broadway Road (approx 2,850 lf) has minimal pipeline pressure losses (<4 psig. However during peak demand perioids (20 to 30 gpm) the pipeline losses would range from 13 to 28 psig, negating much of the static head available from the storage tank and lowering the service pressure in the Broadway Upland Distribuiton Area. The existing 2"Ø HDPE force main from the Army Camp Well to Broadway Road would be replaced with a minimum 3"Ø gravity main, to minimize pressure losses and assure adequate long-term capacity for future growth of the user demands.

Because this tank would be at an elevation substantially higher than the "Big Blue" tank (overflow EL. 148.60 ft. MSL) the system operational controls could become substantially more complex. The Army Camp Well would discharge to the new storage tank, which would principally serve the southern portion of the distribution system. It should also be noted that due to the substantial increase in static head the Bristol Colony area of the distribution system would experience a substantial increase in distribution system pressure, likely operating in the range of 55 to 75 psig. The system would likely require a pressure regulating valve in the distribution service to the Bristol Colony and Narragansett Avenue areas to assure that these lower areas would not be over-pressurized. Also, the Broadway Booster Pump Station would be eliminated from service.

The ability of the new tank to provide service to the south-central portion of the distribution system (Sandy Point area) would be constrained by the hydraulic limitations of the 1.5"/1.25"Ø HDPE pipeline installed in John Oldham Road and the 2"Ø HDPE pipeline installed in Narragansett Avenue. These small diameter pipelines create significant pressure losses that would severely limit the utilization of this new tank, to provide service to the District during periods when the "Big Blue" tank was off-line for inspection and maintenance. Furthermore, as noted in Table 4-1, the proposed smaller capacity (12,000 gallons to 20,000 gallons) capacity of the proposed new tank would be inadequate to meet the equalization requirements of the entire District. Should the District desire to further consider this option, a more detailed hydraulic evaluation would is necessary to assess the system hydraulics, and impacts upon the "Big Blue" tank, than is possible in this Plan.

Locating a new water storage tank in the vicinity of the Broadway Booster Pump Station (approx. El. 130.00 MSL) would provide limited local benefit however, as noted above, there wouild be minimal (or no) benefit to the other portions of the distribution system and the booster pump station would also continue in operation. The system would continue to suffer problems because there is a continuing need to improve the distribution hydraulics in the southern portion of the distribution system, to allow sufficient water to reach the upland area, including the storage tank.

Summarized in Table 4-9A, the recommended budget to implement a new storage tank in the area of the Army Camp Well is $271,000, not including the cost to replace the 2"Ø HDPE force main with a 3"Ø pipeline. This budget assumes a vertical, cylindrical standpipe type tank of nominal 30,000 gallon gross tank volume (20,000 gallon effective volume) installed upon a reinforced concrete ring foundation. The scope of work includes site preparation and erosion control, sitework, cast-in-place ring foundation and tank bearing pad, rigging and erection of tank, construction of a valve vault (pre-cast concrete enclosure), mechanical piping, valves and controls, monitoring instrumentation (level, temperature, etc.,), panel and alarming, site restoration and security fence, system flushing, sanitization and validation, design engineering and construction phase engineering services and a project contingency.

**Table 4-9A: Capital Implementation Cost Estimate - New Water Storage Tank**

| | |
|---|---|
| Site Preparation & Erosion Control: | $ 3,500 |
| Excavation, Materials, Compaction: | $ 12,000 |
| Tank Foundation & Valve Vault: | $ 24,000 |
| Water Storage Tank : | $ 105,000 |
| Tank Rigging w/Crew: | $ 6,500 |
| Mechanical Piping: | $ 14,400 |
| Electrical Power, Wiring, Security Lighting: | $ 9,000 |
| Instrumentation & Monitoring Panel: | $ 7,000 |
| Final Site Restoration & Security Fence: | $ 17,000 |
| Permits: | $ 2,000 |
| Site Survey: | $ 5,000 |
| Eng'g.– Final Design: | $ 18,000 |
| Construction Management: | $ 13,600 |
| Field Hydrostatic Testing & Flushing: | $ 4,000 |
| Sanitization & Analytical Validation: | $ 5,000 |
| **Project Sub-Total:** | **$246,000** |
| **Project Contingency (10%):** | **$ 25,000** |
| **Total Project Cost:** | **$271,000** |

The budget for construction of a new 3"Ø pipeline along Old Army Road from the storage tank to Broadway Road is $213,750, based upon a unit cost of $75 per lf for overland construction, to be performed by PIWD personnel and other island-based resources. Therefore the total budget for implementation of a new water storage tank near the Army Camp Well is $484,750.

Another option considered was the re-location of the "Big Blue" water storage tank from its present location to a new location adjacent to the Army Camp Well. The storage tank would located to provide a minimum working elevation of 180 ft MSL with the overflow elevation set at 208 ft/ MSL. These elevations would assure a working pressure range between 20 and 39 psig in the Broadway Upland Distribution Area and 35 psig to 80 psig in the central and northern areas of the distribution system and along Narragansett Avenue. The water storage tank would be connected to the distribution system via a 6"Ø pipeline extending north to a connection to the 4"Ø pipeline in Prospect Terrace, and via a 4"Ø pipeline extending south to Broadway Road. The Army Camp Well would discharge directly into the storage tank while the Indian Spring Wells would continue to discharge into the distribution system. Submersible well pumps with larger motors would be required for the Indian Spring Wells.

Summarized in Table 4-9B, the recommended budget to relocate the existing storage tank to the area of the Army Camp Well is $310,900, not including the cost for the new connecting pipelines. The scope of work includes site preparation and sitework; cast-in-place ring foundation and tank bearing pad; dismantling, rigging and erection of tank; valve vault; mechanical piping, valves and controls; instrumentation, panel and alarming; site restoration and security fence, system flushing, sanitization and validation, design engineering and construction phase engineering services and a project contingency.

**Table 4-9B: Capital Implementation Cost Estimate – Relocate Water Storage Tank**

| | |
|---|---|
| Site Preparation & Erosion Control: | $ 3,500 |
| Excavation, Materials, Compaction: | $ 12,000 |
| Tank Foundation & Valve Vault: | $ 40,000 |
| Water Storage Tank Dismantled & Rebuilt: | $ 125,000 |
| Tank Rigging w/Crew: | $ 8,000 |
| Mechanical Piping: | $ 14,400 |
| Electrical Power, Wiring, Security Lighting: | $ 9,000 |
| Instrumentation & Monitoring Panel: | $ 7,000 |
| Final Site Restoration & Security Fence: | $ 17,000 |
| Permits: | $ 2,000 |
| Site Survey: | $ 5,000 |
| Eng'g.– Final Design: | $ 18,000 |
| Construction Management: | $ 13,600 |
| Field Hydrostatic Testing & Flushing: | $ 4,000 |
| Sanitization & Analytical Validation: | $ 5,000 |
| **Project Sub-Total:** | **$282,900** |
| **Project Contingency (10%):** | **$ 28,000** |
| **Total Project Cost:** | **$310,900** |

The cost for the connecting pipelines is approximately $210,000 to construct a 6" pipeline to Prospect Terrace and $213,750, based upon a unit cost of $75 per lf for overland construction, to be performed by PIWD personnel and other island-based resources. Therefore the total budget for relocation of the existing water storage tank to a new location near the Army Camp Well is $734, 650.

4.5.2 Improvements to Distribution Pipeline System: The distribution service to the Broadway/Bristol Colony area is limited by the constraints of the two (2) principle service mains (1.25"/1.5"Ø and 2"Ø) extending from the 6"Ø main in Naragansett Avenue. A possible means to improve service (capacity and pressure) is to increase the size of the pipeline in the southern end of Narragansett Avenue from 2"Ø to 4"Ø. Operating under present conditions this would increase the service pressure at the connection at Broadway Avenue by 2 to 6 psig, with greater benefit during peak demand periods and in the future as service demands increase. The most significant benefit of upsizing this pipeline would be to improve the ability of the distribution system to transmit water to the Broadway/Bristol Colony area and more specifically, the upland areas that can be severely de-pressurized during peak demand periods.

The cost to implement approximately 1,600 feet of new 4"Ø distribution main in Narragansett Avenue to replace the existing 2"Ø main is on the order of $160,000, based upon a unit cost of $100.00 per linear foot of pipeline. This cost assumes open trench pipeline construction to a depth of 4 to 5 feet below grade, during the non-peak season (Fall or Spring). It is believed there are a minimum of utility conflicts in this area, traffic control will be modest and the pavement restoration consistent with that appropriate for secondary roads. This unit cost fee includes design engineering, construction management and field engineering, erosion control, materials (pipe, bedding materials, service connections, valves, etc.). traffic control, pavement restoration, adjacent surface restoration, testing, sanitation and validation.

4.5.3 Upgrade Existing Booster Pump Station: The existing Broadway Booster Pump Station accepts feedwater from the 2"Ø distribution main in Broadway Road, discharging via a 4"Ø connection into the distribution system. The lead booster pump is controlled on/off between pressure control setpoints of 42 psig and 52 psig. The lag pump activates when the pressure falls to 36 psig. The present pump controls result in the distribution system experiences relatively significant variability in pressure, which can be aggravated during peak demand periods.

The performance of this pump station could be improved by replacing the existing single speed pump drives with variable frequency drives. The pumps would discharge into the distribution force main, controlled by the discharge pipeline pressure. Two (2) pressure tanks would handle small, short-term demands with the distribution pumps activated on the basis of pressure control. The distribution pumps would be designed for single pump operation, with the second pump providing 100% standby capacity, and would be designed to maintain the system operating pressure at 50 psig at the Pump House. The distribution system would be provided with a pressure transducer to monitor the line pressure and provide high/low pressure alert and alarm notification.

Although it is possible that the existing pumps could be modified to accept variable frequency drives, this would require upgrading the motors to inverter duty, as well as providing new controls therefore, only the pump wet ends would be salvaged. It would likely be simpler to install an entirely new package pump system in the existing Pump House. The budget to implement this upgrade is estimated to be $42,000 including a new duplex booster pump system with variable frequency drive controls, control panel with motor staters, HOA starter switches, status indiction and alarming, associated instrumentation, and mechanical/electrical installation. Also included is the engineering necessary for final pump sizing and selection and submittal of a RIDOH Application for Approval.

It should be noted that a potentially significant concern regarding upgrade of the existing booster pump station is the ability of the existing distribution system to provide the necessary water supply into the pumps. It is possible that during peak demand periods the pumps could be “starved” due to the competing demands elsewhere in the system lowering distribution pressure and the excessive pressure losses in the existing piping system feeding the pump station. This may require a more detailed hydraulic evaluation and possible increase in the size of the 2”Ø pipeline in Narragansett Avenue.

4.5.4 Implement New Booster Pump Station: As noted above, in its present location the Broadway Booster Pump Station may occasionally experience inadequate feedwater service during peak demand periods, due to the inability of the existing 2”Ø force main to deliver sufficient water to the inlet side of the pumps. A possible solution would be to implement a new pump house in the area of the former Goulet Well, drawing feedwater from a connection to the 6”Ø main in Narragansett Avenue. This pump system could utilize the existing 2”Ø forcemain in the southern portion of Narragansett Avenue to deliver water to the Broadway service area.

The pump system would utilize duplex distribution pumps provided with variable frequency drives, controlled to maintain a consistent pipline pressure in upland area. Reviewing the available mapping, it appears there are a maximum of three (3) service connections between the proposed pump station location and the point of connection at Broadway Avenue. The design evaluation for this pump station should include an assessment of the impact of distribution pressures in the low lying Bristol Colony area.

Summarized in Table 4-10 the budget to implement a new booster pump station is $135,100, including sitework, foundation, pump house (14’ x 16’) building, duplex pump system and related equipment, instrumentation & controls, new power supply, interior electrical installation, interior mechanical piping, exterior pipe connections, site restoration, erosion control, design engineering, permitting and construction phase engineering services, and a project contingency. Not included are any costs for land acquisition, legal, financing, etc.

**Table 4-10: Capital Implementation Cost Estimate**
**New Broadway Booster Pump Station**

| | |
|---|---|
| Site Preparation & Erosion Control: | $ 1,800 |
| Foundation & Floor: | $ 12,000 |
| Building Superstructure: | $ 11,200 |
| Ventilation: | $ 4,300 |
| Duplex Pump System & VFD Controls: | $ 22,000 |
| Misc. Mechanical Equipment & Rigging: | $ 5,000 |
| Process (Water) Piping (Interior): | $ 11,000 |
| Exterior Piping/Connections: | $ 7,000 |
| Electrical Power, Wiring, Lighting: | $ 12,000 |
| Instrumentation & Monitoring Panel: | $ 8,000 |
| Final Site Restoration: | $ 5,000 |
| Permits: | $ 500 |
| Eng'g.– Final Design: | $ 11,000 |
| Construction Management: | $ 9,000 |
| Building Start-Up Commission: | $ 3,000 |
| **Project Sub-Total:** | **$122,800** |
| **Project Contingency (10%):** | **$ 12,300** |
| **Total Project Cost:** | **$135,100** |

## 4.6 Replacement of the Indian Spring Well Pump House:

The existing Well Pump House is deteriorating and must be replaced. It is recommended that the new pump house have the spatial size and configuration to accommodate the following functions:

- Well Pump Controls, Instrumentation, Meters, Sample Taps, Piping;
- Iron & Manganese Treatment System;
- Materials and Supplies Storage;
- Operator Office;
- Emergency Generator;

Figure 4-2 presents the conceptual layout of the Indian Spring Well Pump House. This building is nominally 24 ft. x 36 ft., with a minimum clear height of 9'-0". The building can be of wood-frame or concrete masonry unit construction with a truss-supported roof, or a pre-engineered metal building. The building is provided a perimeter, cast-in-place, concrete foundation wall and a 6" thick interior concrete floor with reinforcing mesh, overlying a compacted gravel base. The building is also provided with 2-leaf doors for equipment and materials access as well as personnel doors. The power supply is provided in interior main disconnect switch, primary power distribution panel, step-down transformer, 120 vac power distribution panel, etc. Additionally, a gas-fired generator, with auto-switchover capability is recommended, for exterior installation adjacent to the building.

The mechanical/treatment room includes dedicated services from Indian Spring Wells #1 and #4, each provided with isolation valves, pressure gage, source sample tap, and a mechanical master meter with electronic output to a data logger. The well discharge piping is combined into a common manifold provided with a reduced pressure backflow preventor. The iron and manganese treatment system (chemical feed system, triplex greensand filters, duplex media trap system, and backwash tank and pump) is installed around the room perimeter providing generous room for access and maintenance. The local instrumentation, monitoring and control panel would be wall-mounted adjacent to the electrical panels.

The operator office is provided a desk, work table and storage and it would be possible to provide a PC workstation in this office for downloading monitoring data and maintaining electronic records. Optimally a telephone/internet communications service connection would be provided for purposes of safety, alarm notification and remote data transmission. The operator office has direct access to the Mechanical/Treatment room. The Materials Storage area is provided a 2-leaf access door and would be used to store portable equipment (generators, pumps, etc.), tools, spare parts, valves, meters and other materials that are used for maintenance, repairs, etc. The Pump House has a total plan area of 864 sq. ft. with the Mechanical/Treatment room allocated 480 sq. ft. with approximately 225 sq. ft. dedicated to the greensand filter system with the balance used for the water well supply piping, power supply and controls. The Operators Office is approximately 128 sq. ft. and the Materials Storage room approximately 256 sq. ft. The new pump house would be constructed adjacent to the existing pump house, and when complete, the final service cut-ins to the existing well discharge mains and the distribution force main would occur. This would allow the work to be completed without disruption of service. The budget estimate for the new pump house construction is presented in Table 4-11, below:

**Table 4-11: Capital Implementation Cost Estimate**
**Indian Springs Well Pump House**

| | |
|---|---|
| Site Preparation & Erosion Control: | $ 2,200 |
| Foundation & Floor: | $ 18,000 |
| Building Superstructure: | $ 86,400 |
| HVAC/Electrical (Interior): | $ 43,200 |
| Process (Water) Piping (Interior): | $ 7,000 |
| Exterior Piping/Connections: | $ 6,000 |
| External Power & Communications: | $ 12,000 |
| Exterior Power/Lighting: | $ 5,000 |
| Emergency Generator: | $ 16,000 |
| Instrumentation & Monitoring Panel: | $ 14,000 |
| Final Site Restoration: | $ 4,500 |
| Permits: | $ 3,000 |
| Site Survey: | $ 6,000 |
| Eng'g/Arch.– Final Design: | $ 27,700 |
| Construction Management: | $ 17,200 |
| Building Start-Up Commission: | $ 3,000 |
| **Project Sub-Total:** | **$271,200** |
| **Project Contingency (10%):** | **$ 27,120** |
| **Total Project Cost:** | **$298,324** |

## 4.7 Monitoring and Control Instrumentation Improvements:

The existing system has minimal monitoring instrumentation resulting in extremely limited information with which to operate the system. To facilitate system operations, data management and reporting, and optimize utilization of personnel resources, it is recommended that the District implement a comprehensive operational monitoring program, inclusive of data accumulation from multiple remote locations, to a central data management system. Properly designed and implemented, the monitoring system will provide continuous monitoring, data logging and reporting of the critical system functions and operation. This information allows effective analysis of system operations, provides the basis for system trouble shooting and engineering assessments, and can provide immediate notification of pipeline breaks, pump failures and other problems. Additionally, the data can be used to assess unaccounted for water, the effectiveness of repairs and maintenance and can provide key data for hydraulic modeling of the system. Furthermore, critical operating data can be automatically logged and presented in the appropriate reporting formats, reducing administrative labor requirements. The recommended scope of system monitoring includes the following:

4.7.1 Water Supply Wells: In addition to monitoring water level in the wells, multi-function transducers are available that will also monitor conductivity, salinity, total dissolved solids and temperature. Due to concerns regarding potential sea water intrusion the District may want to consider monitoring conductivity and/or salinity in observation wells.

4.7.2 Water Supply Wells Discharge Flowmeters: Electronic flowmeters have been included in the upgrade of the Indian Spring Well Pump House, for each well discharge, including monitoring and data logging of flow rate and water volume totalizing.

4.7.3 Water Supply Wells Motor Status Indication: Motor starter status indication and operating hour monitoring has been included in the upgrade of the Indian Spring Well Pump House.

4.7.4 Atmospheric Water Storage Tank Monitoring: The existing storage tank should be provided continuous level and temperature monitoring. This data is critical to system operation and the level control signal should be used to activate/deactivate the well pumps.

4.7.5 Distribution Pressure Monitoring: Pressure monitoring should be conducted at critical locations within the system including the Broadway Pump Station

4.7.6 Pump House Temperature Monitoring: temperature monitoring has been included into the scope of work for the Indian Spring Well Pump House upgrade, and also the improvements to the Army Camp Well.

4.7.7 Water Treatment System Monitoring: Effluent chlorine residual and pH monitoring has been included in the capital cost estimate for the iron and manganese treatment system.

At the present time the system would have four (4) principle monitoring locations; (1) “Big Blue” Water Storage Tank, (2) Indian Spring Well Pump House, (3) Army Camp Well, and (4) Broadway Booster Pump Station. Additional monitoring locations could be incorporated in the future, depending upon the addition of new water sources, service pressure monitoring locations, etc. An initial system engineering survey and evaluation will require a budget of $6,000 to $8,000. Assuming the viability and use of wireless communications technology to link the various remote locations to a central monitoring station, the implementation cost is approximately $6,000 to $15,000 per monitoring site for instrumentation, wireless transmitter and antenna installation and startup. The budget for the central system management and monitoring station, including operator interface hardware, software, programming and custom logging and reporting is $15,000 to $25,000.

### 4.8 Army Camp Well Improvements:

As noted in Section 1.2.1 the Army Camp Well Housing is installed within a below grade rectangular vault, with a grade-mounted enclosure that is in poor condition. It is recommended that the District implement the following improvements to eliminate potential hazards and enhance the operability of this well. The recommended budget to complete this work is $10,000.

- Extend the wellhead to a minimum elevation of 18” above the finished grade around the wellhead. Provide the wellhead with a sanitary cover with vent.
- Salvage mechanical and electrical components from the vault, based upon physical and operating condition (meter, valves, motor starter, etc.)
- Construct a new wood frame shed building with a slab-on-grade concrete floor, adjacent to the wellhead. This shed will house the well pump power supply, controls, isolation valves, flowmeter and sample tap. Extend the well discharge piping into the new pump house and then reconnect the discharge to the existing discharge force main, outside of the pump house structure. Installing these components within an above ground shed structure will simplify access for routine inspections, sampling, data acquisition and maintenance.
- Following completion of the new shed and commissioning of the new well controls, dispose of the former vault cover and fill the vault structure with gravel and a compacted backfill cover, to close the vault and direct runoff away from the wellhead.

### 4.9 Water Distribution Piping System Improvements:

Based upon a limited inspection of the piping and recent improvements, that with the selected additional improvements noted herein and diligence to routine maintenance and repairs, the principle (6”Ø/4”Ø) distribution piping infrastructure has a minimum effective remaining life of thirty (30) years, to as much as 70 years (new 6”Ø in Narragansett Avenue). The 1998 Water System Master Plan prepared by Pare Engineering Corporation evaluated the water distribution system and presented specific recommendations (page 22) for water system improvements to alleviate system deficiencies and improve system pressure and reliability. Excepting the recommended improvements to Brown Lane (upsizing from 2”Ø to 4”Ø) and a one segment of

Fairview Avenue (Segment #82 – upsize from 1-1/4"Ø to 2"Ø), all other recommended improvements have been implemented, in addition to other improvements to the distribution system. The recommended scope of additional distribution system improvements, including those presented in the Pare Report and in Section 2.5.3 herein, are summarized in Table 4-12.

**Table 4-12: Summary of Water Distribution System Improvments**

| Street Location | Proposed Material | Pipeline Diameter | | Length | Budget |
|---|---|---|---|---|---|
| | | Existing | Proposed | | |
| Brown Lane | PVC/HDPE | 2"Ø | 4"Ø | 1,094 lf | $ 54,700 |
| Fairview Avenue | HDPE | NA | 2"Ø | 419 lf | $ 20,950 |
| Governor Paine (paper Rd) | HDPE | 2"Ø | 2"Ø | 1,400 lf | $ 70,000 |
| 3rd Street | HDPE | NA | 2"Ø | 400 lf | $ 20,000 |
| Harriet Avenue | HDPE | 1-1/4"Ø | 2"Ø | 825 lf | $ 41,250 |
| Narragansett Avenue | HDPE | 2"Ø | 4"Ø | 1,600 lf | $ 80,000 |
| Landing Lane | Flush Hydrant[1] | NA | NA | NA | $ 1,300 |
| Ross Avenue | Flush Hydrant[1] | NA | NA | NA | $ 1,300 |
| Second Avenue | Flush Hydrant[1] | NA | NA | NA | $ 1,300 |
| Harriet Avenue | Flush Hydrant[1] | NA | NA | NA | $ 1,300 |
| Governor Paine | Flush Hydrant[1] | NA | NA | NA | $ 1,300 |
| Narragansett Avenue | Fire Fill Hydrant | NA | NA | NA | $ 2,200 |
| **Total Cost** | | | | | **$295,600** |
| **Implementation Duration** | | | | | **10 years** |
| **Average Cost/Year** | | | | | **$ 29,560/yr** |

**Note 1: Flush Hydrants assume 2" Slim Line Hydrant w/valve box, flush mount at grade.**

As noted in Section 1.2.5 a significant portion of the smaller diameter HDPE distribution piping is 35 to 40 years old. In many cases this pipe is reportedly thinner wall material and it can be expected to begin reaching the end of its effective life during the next 10 to 20 years. The District should develop a formal replacement plan to occur over a 10-year period, beginning in approximately 2022. This plan should include a detailed inventory of the pipe, fittings and valves (developed in accordance with recommendations in Sections 2.5.6 and 4.10), and a planned schedule of replacement with new, AWWA compliant HDPE piping.

Deleting the pipeline segments that have been upgraded/replaced since 1998, and also those identified in Table 4-12 for near-term future replacement/upgrade, the remaining distribution piping is approximately 22,000 to 24,000 lf of pipeline 1" Ø to 2.5"Ø that will need replacement. For the purpose of this evaluation it will be assumed that this piping will be replaced over a 10-year period, equivalent to an average of approximately 2,400 LF per year. At an estimated average cost of $50 per LF, this equates to an average present day annual cost of $120,000 per year. This cost assumes implementation by PIWD personnel and Island-based labor, and is determined as presented in Table 4-13.

**Table 4-13: Summary of Water Distribution Piping Upgrade Cost per Foot**

| | | |
|---|---|---|
| Average Pipeline LF/Year | 2,400 LF/Year | |
| Average Construction Speed | 7.5 LF/Hour | |
| No. Construction Hours/Year | 320 Hrs/Year | |
| **Construction Cost:** | **Unit Cost** | **Cost/Year** |
| Excavator & Operator Unit Cost | $75/Hr | $ 24,000 |
| Pipeline Labor (2 = 640 MH's) | $30/Hr | $ 19,200 |
| Materials | $15/LF | $ 36,000 |
| Site Restoration | $10/LF | $ 24,000 |
| Administration | $2/LF | $ 4,800 |
| Sub-Total Cost | | $108,000 |
| Contingency (10%) | | $ 10,800 |
| **Total Cost/Year (2012)** | | **$118,800** |
| **Average Unit Cost 2012)** | **2,400 LF/year** | **$49.50/LF** |

## 4.10 Modification of Big Blue Water Storage Tank:

It is recommended that the "Big Blue" water storage tank be upgraded with the capability to recirculate water, to facilitate periodic sanitization and maintenance cleaning. This requires implementation of: (1) a branch service with isolation valve and quick-disconnect fitting in the valve vault, (2) a chemical injector quill installed into the branch service, provided with an isolation valve and connection fitting to accept a pumped feed of liquid chemical, (3) a new external service connection in one of the upper tier sidewater panels of the storage tank, and (4) a new fill pipe extending down the sidewater of the storage tank from the new connection to a point of connection approximately 3 feet above grade, provided with a sampling port., isolation valve and quick-disconnect fitting. A free-standing support structure would be provided for the fill pipe extending down the exterior of the storage tank.

When it is necessary to sanitize or perform chemical cleaning of the tank, a portable pump would be utilized with hose connections to the supply side fitting in the vault and the new inlet connection to the storage tank. The isolation valve downstream of the branch service connection would be closed to isolate that storage tank from the distribution system. Optimally, the pump would recirculate water at a minimum flowrate of 300 gpm, to assure a minimum of 4 tank turnovers within a 24-hour period (more turnovers are preferable, if possible). The pump would also blend the sanitant/cleaning chemical with the recirculating water to assure a consistent dosage into the recirculating water and effective contact with the interior wetted surfaces of the tank. The sampling port on the vertical tank fill pipe provides the capability to obtain samples to monitor the sanitant dosage and for water quality monitoring of the recirculating solution. The capital implementation cost for this improvement is summarized in Table 4-14.

**Table 4-14: Capital Implementation Cost Estimate**
**Modification of Big Blue Water Storage Tank**

| | |
|---|---|
| Field Modification of Tank Panel: | $ 2,850 |
| Process (Water) Piping (Exterior): | $ 1,300 |
| Valve Vault Piping Modifications: | $ 2,350 |
| Exterior Piping Support Structure: | $ 3,200 |

| | |
|---|---|
| Recirculation Pump (Portable,Gas-Fired): | S 750 |
| Start-Up & Testing: | $ 300 |
| **Project Sub-Total:** | **$ 10,750** |
| **Project Contingency (10%):** | **$ 1,075** |
| **Total Project Cost:** | **$ 11,825** |

## 4.11 Management & Maintenance Systems:

It is recommended that the District implement a comprehensive, PC-based management software system incorporating system inventory, operating records, preventative maintenance programs and emergency service programs. Aspects of this system would include the following:

4.11.1 Cross Connection Inspections & Backflow Device Testing: Because 99% of the service connections are residential and there are no industrial or heavy commercial connections, a Cross Connection Ordinance should suffice for this system, augmented with periodic inspections of residential services. The recommended ordinanceis would include the following, at a minimum:

| | |
|---|---|
| Policy; | Existing Backflow Prevention Devices; |
| Purpose; | New Backflow Prevention Devices; |
| Authority; | Periodic Testing Requirements; |
| Responsibility; | Records and Reporting; |
| Definitions; | Fees; |
| Administration; | Enforcement; |
| Requirements; | Information, Forms and Data Sheets; |
| Degree of Hazard; | |

4.11.2 Valve Inventory & Maintenance Program: Isolation valves used in the system include service connections (318) and valve boxes, plus distribution system isolation valves, hydrant valves and other system components. Working in conjunction with the Town of Portsmouth GIS personnel, this program includes developing a comprehensive GIS-based valve and component location plan and inventory program. District personnel would inventory the critical data (i.e. valves, water stops, meter pits, hydrants, etc.). These components would be physically located in the field and surveyed as necessary, based upon survey grade GPS. The data would then be entered into the GIS data-base with the appropriate attributes attached. Once the GIS data base system is established it will need to be maintained and periodically updated. This work would be coordinated with a protocol for provision of As-Builts (system modifications, new connection, etc.) using a digital format, and for GPS data to be obtained during inspections of system modifications and improvements, to support and simplify ma intenance of the GIS.

District personnel would establish and conduct a formal distribution system valve and hydrant inspection and maintenance program established as part of the Preventative Maintenance Program (see below). Valve inspections shall include annual inspections of valve boxes, operators, etc., as well as exercising of the valves. Valves and hydrants that are determined to be defective or damaged shall be repaired as possible, or replaced.

4.11.3 Comprehensive Preventative Maintenance Program: It is recommended that the District establish a comprehensive, formal Preventative Maintenance Program to assure the long-term viability of the system, and protect asset value. This program shall utilize a PC-based management system and shall include, but not be limited to, the following:

- Comprehensive inventory of all system components and infrastructure;
- Comprehensive inventory of all equipment, instruments, tools, etc.;
- Calendar and/or meter based PM for each asset (pumps, pipelines, tanks, generators, meters, valves, buildings, control systems, etc.);
- PM work order generation, list and schedule;
- Inventory maintenance;
- Cost tracking

A preventative maintenance task list and schedule shall be developed for each system asset. For example, the water storage tank schedule should include annual inspections; periodic (5 year) internal inspections; cathodic protection system monitoring and maintenance; corrosion evaluations; scheduled cleaning, sanitizations & flushing; instrument calibrations; etc. Pump maintenance would include motor inspections; vibration testing and balancing; seal inspections and periodic replacement; lubrication; impeller and wear ring maintenance and adjustments; hydraulic testing; etc. In addition to water storage, transfer and distribution system components, the scope of the program would also include buildings and grounds, security systems, generators, test equipment, control & motor starter panels, etc.

4.11.4 System O&M Manual: In accordance with the requirements of RIDOH and good engineering practice, it is recommended that the District prepare a comprehensive Operation and Maintenance (O&M) Manual for the Water Supply, Storage and Distribution System. The O&M Manual should be prepared in electronic and hard-copy format, should be coordinated with the Preventative Maintenance Program and should include the following, at a minimum:

- Basis of system design and operation;
- Description of the overall system and each sub-system;
- Operating procedures (daily, monthly, annual);
- Maintenance schedules (daily, monthly, annual);
- Instrumentation and control systems;
- Operating specifications and control parameters;
- Water sampling and monitoring protocols;
- Recordkeeping and reporting;
- Maintenance procedures;
- Safety;

- Manufacturers literature and equipment data;
- Spare parts list.

## 4.12 System Upgrade Prioritization

The recommended improvements to the Prudence Island Water District system must be implemented using a comprehensive methodology. The scope and cost of the improvements mandate that they be implemented over a long-term, exceeding the typical 5-year planning period, more likely involving up to 20-years.The prioritization of the upgrades is based upon the combination of need and risk minimization regarding operating security and protection of public health. Recognizing that the system upgrade will likely be a multi-phase project implemented over a number of years, the recommended priority sequence of installation is the following:

4.12.1 New Water Source Development: Development of a new water source(s) is deemed critical to the long-term ability of the District to maintain service and system performance its customers and minimize operating risk. To accomplish this objective, it is necessary to initiate the various engineering investigations and redevelopment of the existing source wells, conduct the requisite studies to identify alternative source target areas, install and evaluate exploratory wells and increase the safe source yield to achieve a firm safe yield of 60,000 gpd within 5 yeaars and 80,000 gpd within 20 years.

- Investigate, Evaluate and Re-Develop the Existing Water Source Wells (2013/2014);
- Engineering Studies for Development of a New Water Source (2014/2015);
- Development of New Water Source(s) to Achieve 60,000 gpd Safe Yield (2016/2017);

Should it be possible to improve the yield of the Army Camp Well, it may beneficially impact distribution pressures in the Broadway Upland Distribution Area.

4.12.2 Near-Term Implementation: These tasks include critical system documentation, system monitoring to enhance operations and security, implement formal preventative maintenance, and upgrades to enhance system operating efficiency, safety and improvements to critical building infrastructure. The recommended scope of implementation includes the following:

- Inspection of “Big Blue” Water Storage Tank (2013);
- Modification to “Big Blue” Storage Tank – Recirculation System (2013);
- Comprehensive System Documentation, O&M Manuals, Preventative Maintenance Program, etc. (2013);
- Army Camp Well House (2013);
- Monitoring Instrumentation, Control and Data Management System (2013/2014);
- Upsize Distribution Pipeline in Narragansett Avenue (4”Ø) (2013/2014)
- Implementation of New Indian Springs Well Pump House (2014);
- Implementation of Iron & Manganese Treatment System (2014/2015);

4.12.3 Water Distribution System Improvements: In addition to the upsizing of the existing 2"Ø force main to 4"Ø in the southern end of Narragansett Avenue, it is recommended that the District continue with the distribution system improvements identified in Table 4-12, prioritized for implementation over a 5 to 10 year period. This work should be coordinated with improvements and upgrades to the water supply wells and the implementation of recommended monitoring instrumentation that will enhance the District's understanding of the system operation, demands, pressures, etc. It is anticipated that as pipeline improvements, particularly increasing pipeline sizes, are implemented, there will be a continued improvement in the system operation related to distribution pressures and flowrates at points of use. The District must also conduct the long-term planning for the scheduled replacement of the majority of the smaller diameter sub-distribution laterals, tentatively recommended to occur from 2022 to 2032.

- Near Term (Table 4-12) Distribution System Improvements (2012 to 2017-22);
- Final Planning & Design of Low Pressure Zone Improvments (2013/2014)
- Implementation of Low Pressure Zone Improvements (2014/2015)
- Long Term (Table 4-13) Distribution System Improvements (2022 to 2032);

It should be noted that it has been assumed that the distribution system improvements shall be implemented by PIWD personnel and other island-based resources.