# Texas Water 2007 Presentation

# CONSTRUCTION, STARTUP, AND TRAINING ISSUES FOR THE WEATHERFORD 6-MGD MEMBRANE DESIGN-BUILD WATER PURIFICATION PLANT EXPANSION

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## ABSTRACT

The city of Weatherford, Texas water purification plant (WPP) originally consisted of four 2-mgd TridentTM treatment units with a total rated treatment capacity of 8 mgd. Based on revised filtration criteria, the state regulatory agency derated the plant to 6 mgd and ordered the city to increase plant capacity by the end of 2006 so peak day demands could be met. In addition to capacity issues, the WPP struggled with meeting filtered water turbidity goals during high raw water turbidity events. Thus, the city was faced with two challenges: adding treatment capacity by the end of 2006 and to provide a new more effective treatment process. The new process selected for the WPP expansion was microfiltration/ultrafiltration membrane treatment.

Although the state mandated the capacity improvements be completed by the end of 2006, the city desired to have the plant expansion completed by the summer of 2006 in order to meet a portion of the summer peak water demand, and to ensure adequate water pressure in the distribution system. The challenge became designing and constructing a 6-mgd membrane expansion in about 1 year in a state where the design-build process is not typically used by municipalities. To solve this dilemma, use of a design/construction manager at risk (D/CMAR) contract was recommended in order to meet the aggressive schedule for completion of the project. D/CMAR is allowed by the state of Texas for municipalities for certain situations that involve public health and safety.

In June 2005, design of the 6-mgd membrane plant was initiated. In order to meet the compressed schedule, the plant design was separated into two design packages. One package contained the 6-mgd membrane plant and the second package contained the modifications to the existing plant required to support membrane treatment. By October 2005, the plant modifications package was released for construction and by January 2006, the membrane package was released for construction. Substantial completion–the production of potable water from the membrane system–was achieved on July 2006 with final completion scheduled for September 2006.

This paper will summarize the challenges and solutions faced construction, start-up and training phases of the project. Construction challenges include space constraints, schedule, and the coordination of tie-ins between the two treatment processes with minimal production downtime. In addition, the presentation will describe issues with startup and how the project team executed the multiple activities of design, procurement, construction, and startup in the short time frame allotted. Lessons learned from the project and current operating performance will also be presented.

## INTRODUCTION

In 2005, the city of Weatherford began implementing the planned 6-million-gallon-per-day (mgd) capacity expansion of its existing water purification plant (WPP). The treatment capacity of the WPP after project completion will be 14 mgd. Based on the results of pilot testing and a pre-design study, membrane filtration was selected as the treatment process that met the city's objectives for the plant capacity expansion. Project objectives include:

- Meet current and anticipated drinking water regulations
- Provide a consistent and dependable water supply
- Provide dependable, consistent operation during high, raw water turbidity events (greater than 50 NTU)
- Maintain optimum operating costs
- Maximize the ultimate treatment capacity of the existing plant site

Use of the membrane filtration process for capacity expansion will enable the city to comply with current and anticipated finished water requirements during high raw water turbidity events and provide the desired consistency in operation. Pilot test data indicated that operating costs for membrane filtration were optimal given the improvement in treated water quality and the increase in treatment capacity for the existing plant. As a result of this project, the ultimate capacity for the plant site will be increased from the original 12 mgd to 14 mgd.

An essential goal for the project was to complete the capacity expansion project in time to comply with the schedule requirements imposed by the Texas Commission on Environmental Quality (TCEQ). The TCEQ required that the expanded plant be constructed and in service by the end of 2006. In addition, the city desired to have the additional treatment capacity available for at least a portion of the 2006 peak demand period. In order to meet these challenging schedule requirements, the city elected to utilize a non-conventional design/build project delivery method.

This presentation describes the challenges faced and solutions found during the construction, startup, and training phases of the project. In addition, the presentation includes lessons learned and current operating performance for the Weatherford WPP.

## EXISTING TREATMENT PLANT FACILITIES

The Weatherford WPP was constructed in 1995. Although the original plant was designed with a treatment capacity of 8 mgd, it was derated to a treatment capacity of 6 mgd. During construction however, it was uprated back to a treatment capacity of 8 mgd. Source water for the plant is Lake Weatherford, a shallow lake constructed as the city's raw water supply in 1955.

Raw water is pumped from the 12-mgd raw water pump station through a 24-inch concrete cylinder pipe to the treatment plant, a distance of approximately one-half mile. Chlorine dioxide is injected into the raw water line as the primary disinfectant. Alum is applied to the raw water as a coagulant and cationic polymer is applied as a coagulant aid.

The coagulated water flows by gravity through four Microfloc Trident™ units, each with a capacity of 1,400 gallons per minute (gpm), or 2 mgd. An influent flow meter is located on each Trident™ unit. Disinfection and chemical addition are flow paced based on the sum of these influent meters. Each Trident™ unit consists of an upflow adsorption chamber and a multi-media filter installed in a painted steel tank. Floc formed in the coagulated water is adsorbed on to suspended plastic media (beads) in the adsorption chamber. Effluent from the adsorption chamber flows on to the multi-media filter. Filter media is 36-inches deep and includes anthracite coal, sand and garnet.

The filtered water flows through a 30-inch line to a 1-million-gallon clearwell. Sodium hydroxide is added to the filtered water in the 30-inch line to adjust pH. Chlorine and ammonia are injected into the water immediately upstream of the clearwell to form chloramines, the secondary disinfectant. Finished water is pumped into the distribution system by four high service pumps. Each high service pump has a capacity of 4 mgd.

A flow schematic of the existing Weatherford water treatment process is shown in Figure 1. The plant treatment building and the location of the membrane filtration system in the treatment building are shown in Figures 2 and 3.

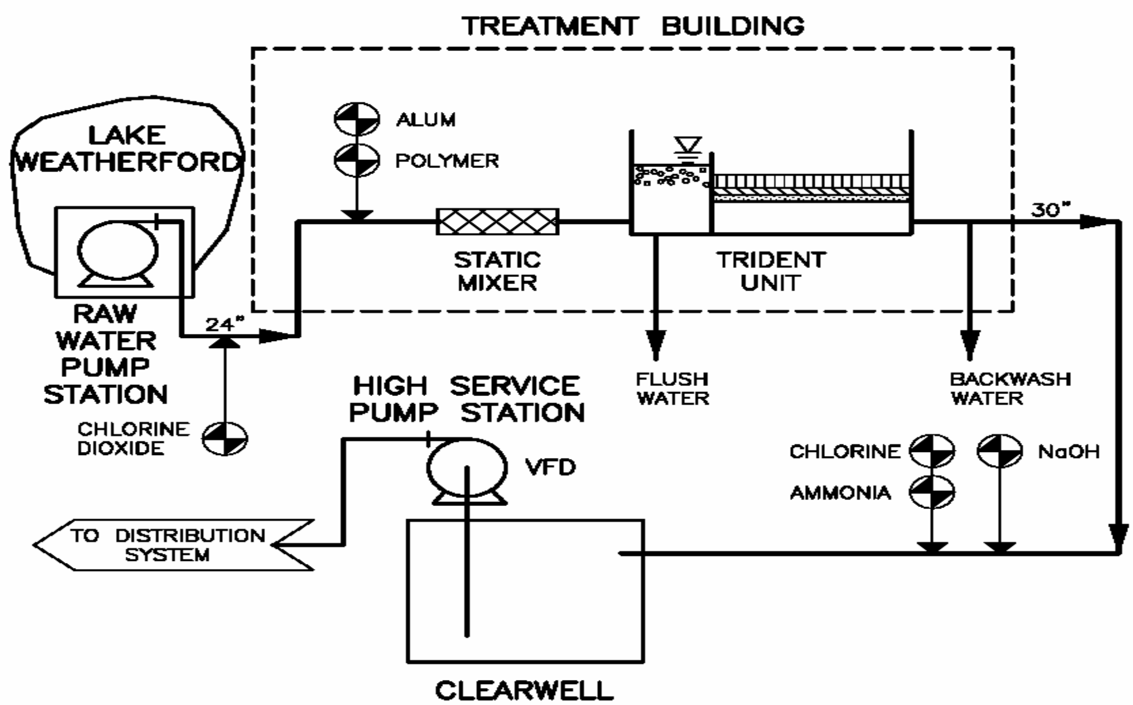


**Figure 1 – Weatherford Water Treatment System Schematic**

**Figure 2 – Weatherford Water Purification Plant Treatment Building**

**Figure 3 – Location for membrane filtration System in Existing Treatment Building.**

## SUMMARY OF MEMBRANE PILOT TESTING

Pilot testing of membrane filtration was conducted at the Weatherford WPP from September 23, 2004, through February 12, 2005. Three manufacturers participated in the pilot testing: Memcor (US Filter), Pall, and Zenon. The equipment proposed by the three pilot test participants was a good representation of current low pressure membrane technology. The pilot tested membrane characteristics are summarized in Table 1.

**Table 1 - Characteristics of Pilot Test Membranes**

| Characteristic | Memcor | Pall | Zenon |
|---|---|---|---|
| Classification | Microfiltration | Microfiltration | Ultrafiltration |
| Pore size, µm | 0.10 | 1.10 | 0.02 |
| Driving Force | Vacuum | Pressure | Vacuum |
| Membrane Location | Submerged in Tank | Enclosed in Module | Submerged in Tank |
| Membrane Material | PVDF – Polyvinylidene Fluoride | PVDF | PVDF |

The goal of the pilot testing was to obtain accurate membrane performance data and, subsequently, to determine the effectiveness and cost of membrane treatment of drinking water for Weatherford.

Pilot test data was monitored and recorded for water quality data (both raw water and filtrate) and equipment operation. The TCEQ PDW Program Staff Guidance “Review of Pilot Study Reports for Membrane Filtration” was used as the basis for the test data collection requirements. The results from Stage 5 (TCEQ Stage 2) of the Weatherford membrane pilot test are summarized in Table 3.

**Table 3 - Results from Stage 5 – Challenge Test**

| Data Parameter | Memcor | Pall | Zenon |
|---|---|---|---|
| Flux Rate at 20˚ C, GFD | 37-41 | 60-67 | 36-40 |
| Actual Flux Rate, GFD | 30.9 | 50 | 30 |
| Recovery % | 91.3 | 95 | 95 |
| Feed Water Turbidity, NTU | 60-100/72 | 60-100/72 | 60-100/72 |
| Filtrate Turbidity, NTU | 0.0112 (avg.) | 0.015 (avg.) | 0.013-.055 |
| TMP Range/Max., PSI | 3.4-11.9 | 6-16 | 8-10.5 |

**SELECTING THE MEMBRANE FILTRATION SYSTEM SUPPLIER**

The selection process used for the capacity expansion project consisted of an evaluated bid. The intent of the scope of the evaluated bid was to capture all of the costs for purchasing the equipment from a vendor and installing it in the available building space. The evaluation process was set up to “level the playing field” between the three potential membrane filtration equipment vendors. In addition to the capital cost associated with supplying the membrane equipment, the manufacturer’s operations and maintenance costs were considered as well as construction costs for modifications needed specifically for each manufacturer.

The life-cycle costs were determined based on the base bid plus the present worth value of the operations and maintenance costs for 10 years using a 6-percent discount rate. The construction costs were estimated based on information provided by each manufacturer as part of their bid.

In addition to capital cost and life-cycle costs, the membrane manufacturers were also evaluated based on a number of non-cost factors membrane characteristics, system operating characteristics, system maintenance characteristics, pilot performance, facility layout/constructability and the membrane manufacturer's ability to meet and or exceed the project schedule and provide water by the summer of 2006.

Therefore, based on the lowest total cost (capital cost plus and life-cycle cost) and the highest score for the evaluated bid criteria, Pall Corporation was selected as the membrane filtration system vendor for the project.

## DELIVERING THE PROJECT THROUGH THE DEISGN-BUILD METHOD

**Alternate project delivery method.** The pre-design report for the Weatherford WPP capacity expansion was completed in April 2005. The report concluded that the design and construction of the capacity expansion could not be completed by the end of 2006, as required by the TCEQ, through the conventional design-bid-build process. In order to comply with the completion schedule required by the state, and to provide a 12-mgd treatment capacity for at least a portion of the 2006 peak water demand period, it was recommended that a design-build project delivery method be used. The design-construction manager at risk (D-CMAR) delivery method was recommended on the basis that alternate project delivery methods are permitted in Chapter 252 of the Local Governmental Code (LGC). Section 022 of the LGC states that alternate project delivery methods can be utilized "to protect public health and safety." Provision of adequate quantities of properly treated drinking water was deemed by the city of Weatherford to be a matter of protecting the public health and safety.

In May 2005, the city contracted with CDM as the construction manager for the 6-mgd capacity expansion of the Weatherford WPP. The construction manager retained CDM and Gupta Associates, Inc. to provide design services for the project. The organization chart for the D-CMAR delivery method is illustrated in Figure 8.

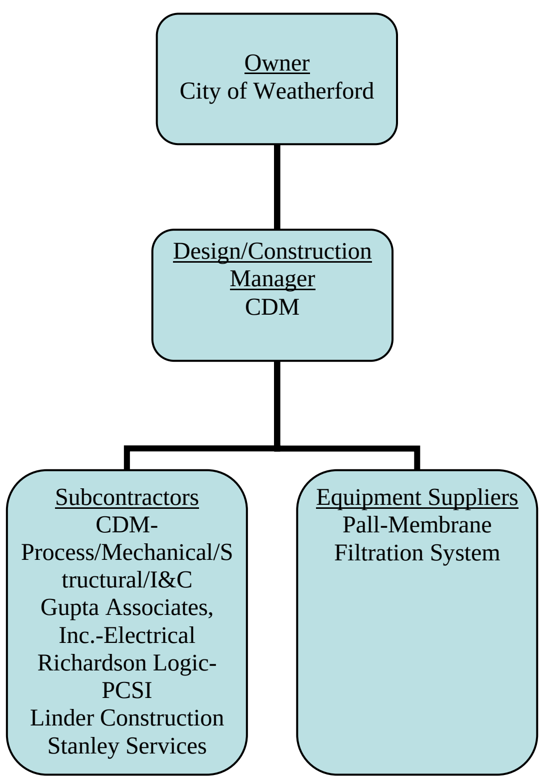

**Figure 8 – D-CMAR Organization Chart**

**Owner safeguards in the D-CMAR method.** Equipment, materials and services procurement through the D-CMAR method were competitively bid by the construction manager with review oversight by the owner. In addition, D-CMAR contract required that the construction manager provide a guaranteed maximum price (GMP) to the owner at the beginning of the project. This guaranteed maximum price provides accountability for price, time and quality for the project. Also, any cost savings from efficient scheduling, streamlined coordination, self-performance, and value engineering along with fast-tracking and good response time that bring the project in below the GMP realized at the end of the project will be shared with the owner.

**Expedited project schedule.** The principal driver for the D-CMAR delivery method is streamlining of the project schedule. The conventional design-bid-build delivery method for this project had a projected completion date of May 2007. The projected completion date for the capacity expansion through the D-CMAR delivery method is early August 2006, more than 9 months sooner than the conventional delivery method. As discussed previously, the D-CMAR delivery method enables the city to comply with the TCEQ schedule requirements for expanded treatment capacity at the WPP by fast-tracking the project by using discrete bid packages and procuring long lead equipment early in the project. These discrete pieces can also be awarded to local subcontractors.

**Simultaneous project activities.** A characteristic of the D-CMAR process is the simultaneous execution of multiple project activities. At any one time during the course of the project design, procurement, review and construction activities were being performed by the project team (owner and consultants).

## DESIGN OF THE CAPACITY EXPANSION – CHALLENGES AND SOLUTIONS

Design of the facilities required for the 6-mgd capacity expansion presented several challenges for the design team. These challenges included the small footprint of the existing plant site, limited space for the membrane filtration system and its ancillary facilities, designing parallel treatment processes with different disinfection schemes and coordinating two design packages to help reduce the construction schedule. Solutions for these challenges came about as the result of continuous communication between the owner and engineer, attention to details and close coordination with the membrane filtration system supplier.

In order to expedite timely review of the expansion design by the state regulatory agency, the project was designed in two parts, or packages. Each design package included only a portion of the total design effort allowing the TCEQ to review more modestly sized submittals. Design Package No. 1 included all of the non-membrane facilities, which would be constructed earlier in the project schedule. Design Package No. 2 included all of the membrane equipment and its support facilities.

## CONSTRUCTION OF THE CAPACITY EXPANSION – CHALLENGES AND SOLUTIONS

Construction of the facilities required for the 6-mgd capacity expansion presented several challenges for the construction team as well. Solutions for these challenges also came about as the result of continuous communication between the design-build-construction manager, the engineer, and the owner, attention to details and close coordination with the membrane filtration system supplier.

**Small site footprint.** The Weatherford WPP is constructed on a site that is approximately 3.3 acres with no additional land for extending the plant site. The treatment building has approximately 7,300 square feet (sq. ft.) for the treatment process equipment, including the existing treatment units. Approximately 2,700 sq. ft was available for the membrane filtration system and its ancillary facilities. The compact plant site and building space required careful planning for storage and construction of both the membrane filtration system and the facilities necessary to support the expansion. A site layout showing the existing and new facilities is presented in Figure 4.

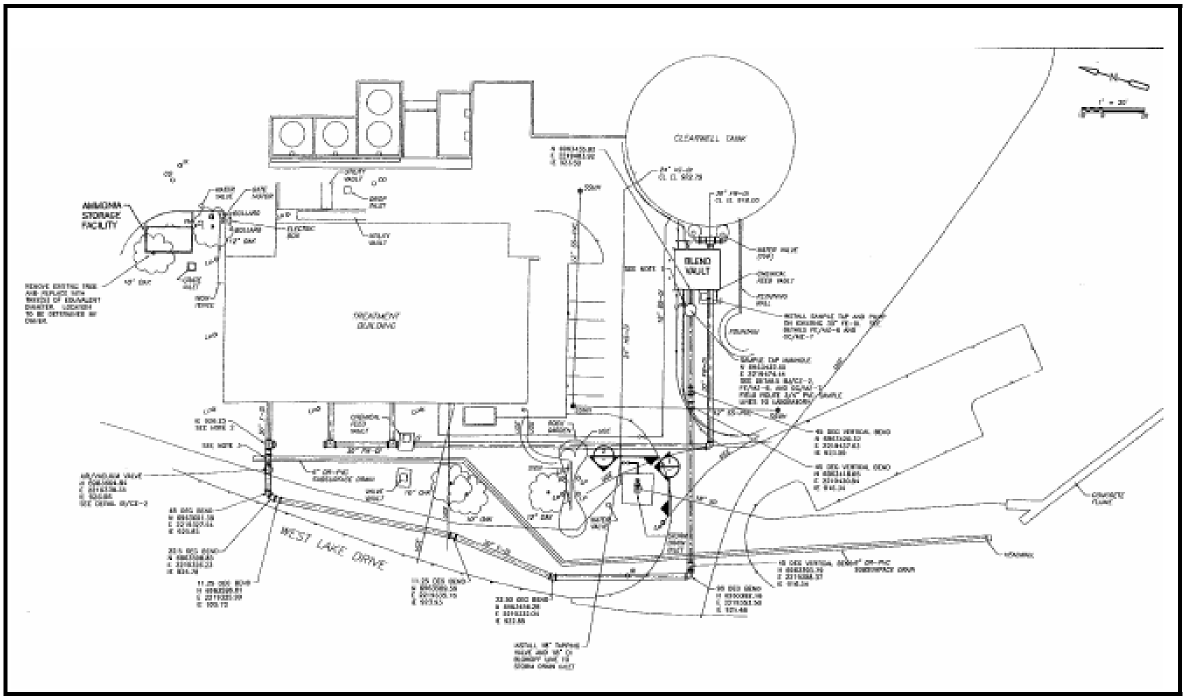


**Figure 4 – WPP Layout**

To meet these site restriction challenges, the designers effectively utilized the existing building space (i.e., planning building space utilization down to square inches). The design required the equipment to be compactly placed in the building in order to accommodate the membranes and all of the ancillary equipment. This meant that the design-build-construction Manager had little space to maneuver the equipment during installation and had to precisely place it to prevent conflicts.

A plan view of the membrane filtration system facilities is shown in Figure 5 and photos of the completed membrane facilities is shown in Figure 6.

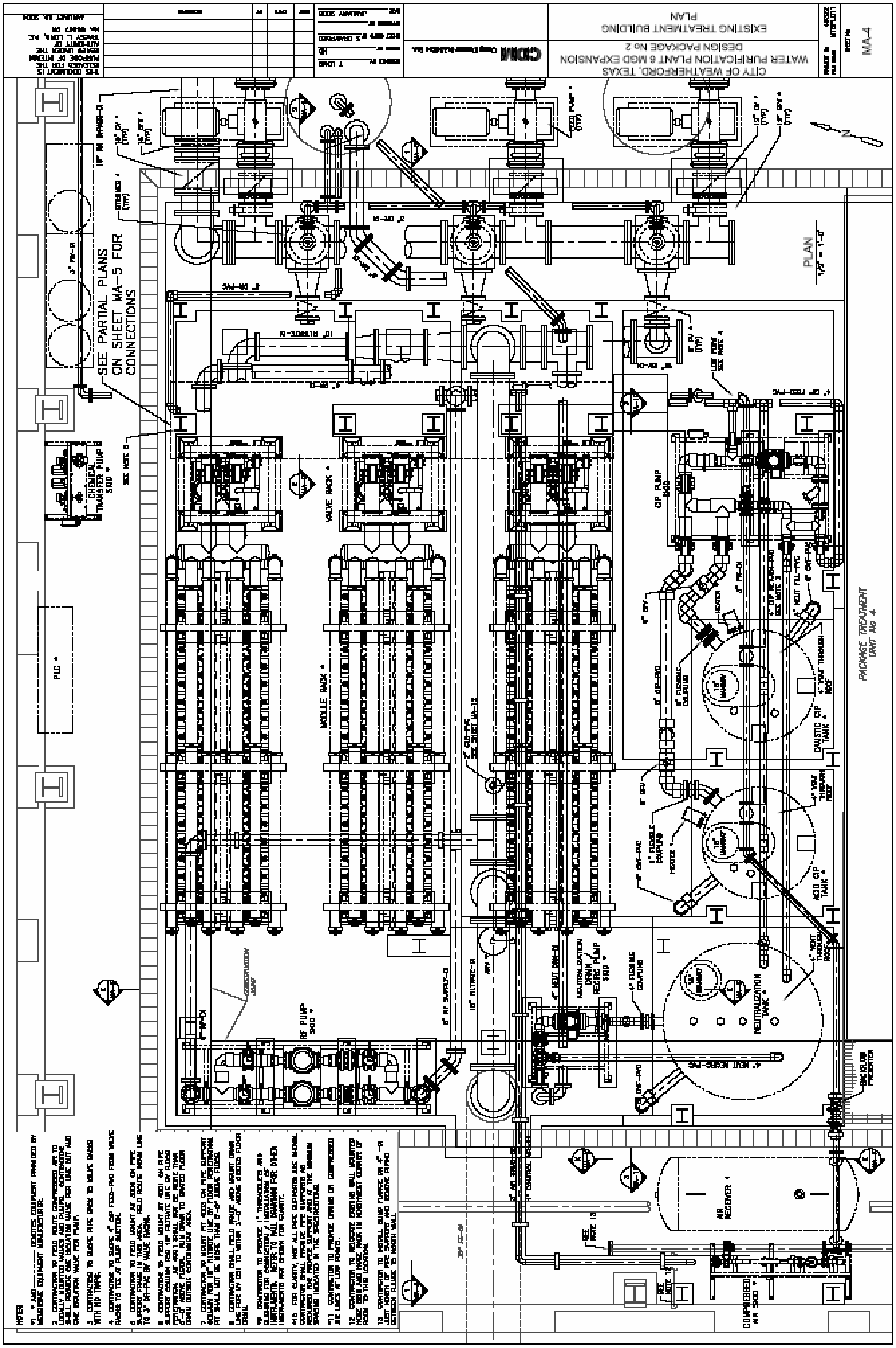


**Figure 5 – Membrane Facility Layout**

**Figure 6 – Membrane Facilities**

**Schedule.** The aggressive project schedule required more attention to the construction schedule than in a conventional design-bid-build project. Rather than activities taking place in a linear progression, the compressed construction schedule required most activities to overlap significantly and many to occur simultaneously. Therefore, additional personnel were required to complete the construction on time.

The aggressive project schedule combined with the limited storage and construction space also meant that careful consideration had to be given to equipment deliveries so the materials would be available when needed but not arrive so early that they would be in the way for other construction activities. Proper coordination of equipment deliveries were also needed to help limit construction delays caused by construction personnel waiting on supplies.

**Tie-ins for parallel treatment processes.** The expanded treatment capacity of the Weatherford WPP combined capacity of the existing Trident™ units and the membrane filtration system. A flow schematic of the expanded Weatherford water treatment process is shown in Figure 6.

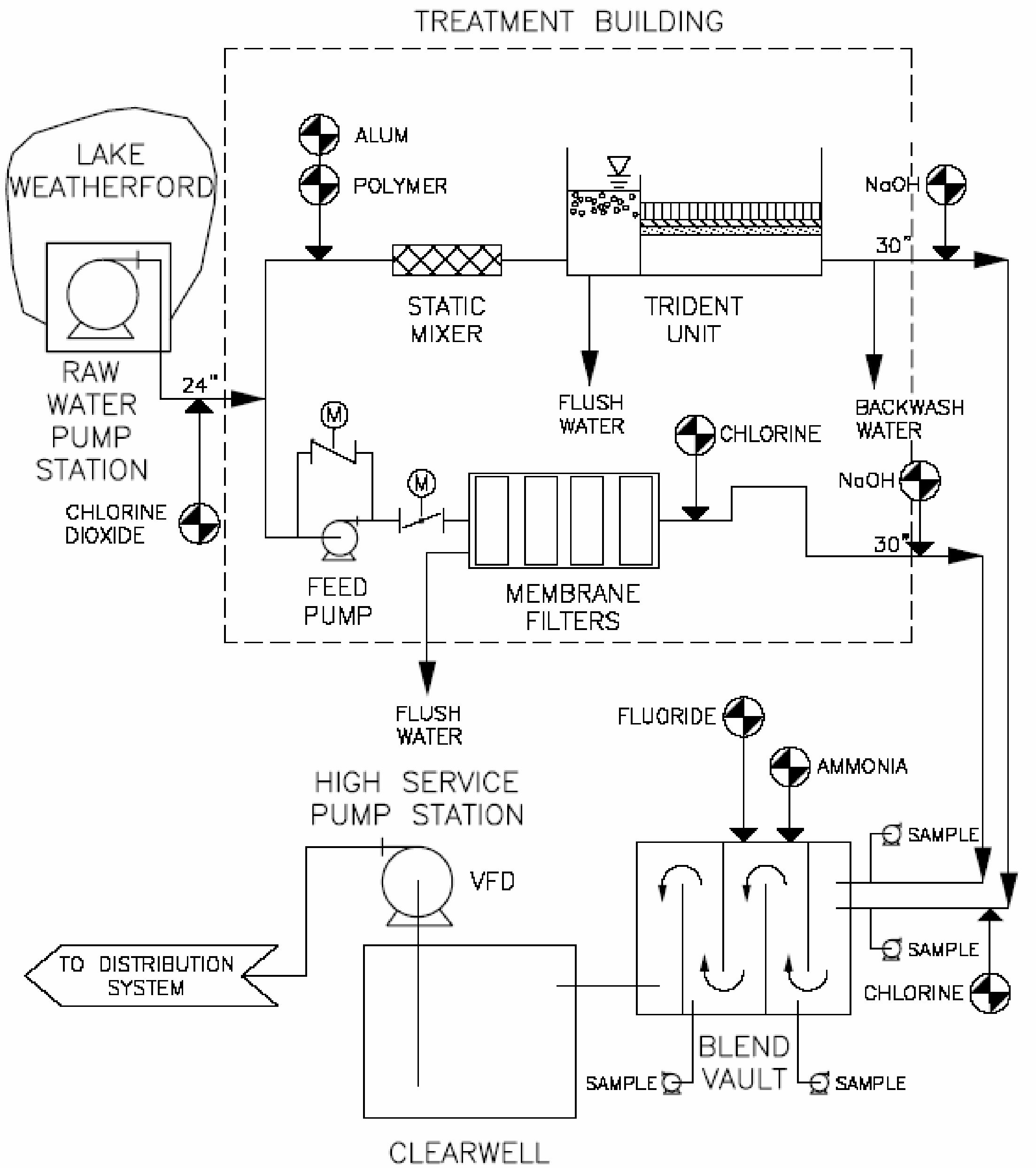


**Figure 6 – Weatherford Water Treatment Process Flow Schematic**

To enable the city to operate the two treatment processes in parallel, the capacity expansion design included the following:

- Additional yard piping for the membrane filtrate
- Separate disinfection facilities for the membrane filtrate
- Monitoring for the separate and combined treatment effluent
- Overall control for both treatment processes from the existing plant SCADA system

A new 30-inch membrane filtrate line was included in the project to provide sufficient conveyance capacity for the treated water to the plant's clearwell and a portion of the required disinfection “CT” for the membrane treated water. When operated in parallel with the existing 30-inch Trident™ filtered effluent line, the two lines will accommodate the ultimate design capacity of 18 mgd.

A blend vault was designed to combine the two treatment process effluents into a blended flow. Ammonia and hydrofluosilicic acid are injected into the blended flow for chloramine formation and fluoridation.

As shown in the process flow schematic, the existing Trident™ filters and the membranes shared a common raw water line and common blend vault. This means in order to tie-in the new membrane filtration system, the existing plant needed to be shut down during the tie-in procedures. Continuous communication between the design-build-construction manager and the owner, as well as attention to details was essential in completing the facility tie-ins while still meeting peak day water demands.

## START UP OF THE CAPACITY EXPANSION – CHALLENGES AND SOLUTIONS

Start up of the expansion facilities presented several challenges for both the construction team as well as the WPP staff. Solutions for these challenges also came about as the result of continuous communication between the design-construction Manager, the engineer, and the owner, attention to details and close coordination with the membrane filtration system supplier but most importantly the dedication of the WPP manager and staff.

**Mechanical issues.** Like any conventional design-bid-build project, start up of the Weatherford membrane design-build WPP expansion project required adjusting pumps, checking piping and supports, adjusting valves and revising membrane system programming. Programming for the membrane filtration system feed pumps had to be adjusted to coordinate with the raw water plant influent pumps. Additional pipe supports had to be added to the aerial piping system and the influent valves for both the Trident filters and membranes had to be coordinated. The main difference was that that most of the corrective actions occurred simultaneously.

**Potable water production.** In order to meet peak day water demands for the summer of 2006, the membrane filtration system was required to produce potable water before being fully optimized and completing the system performance testing. While sending potable water into the distribution system, the membrane filtration system start-up personnel continued to adjust the air scrub sequence, enhanced flux maintenance sequence and chemical concentrations and the capital improvement plan procedures and chemical concentrations in order to optimize the system.

**Treatment plant personnel training.** Due to current WPP staffing, it was necessary to perform operations and maintenance training while the membrane filtration system was already in production. The membrane filtration system manufacturer’s personnel operated the plant while the Weatherford WPP personnel operated the existing Trident plant. As time allowed in their schedules, Weatherford personnel would attend training sessions, both classroom and hands-on training, on the membrane system. The training was accomplished due to the Weatherford staff’s dedication and determination. They worked extra shifts in order to complete the training in a timely manner. Constant communication between the construction manager, the owner, and the membrane filtration system supplier was essential since peak day demands and operations requirements for the existing plant often required training sessions to be rescheduled with short notice.

## LESSONS LEARNED FROM THE PROJECT

The capacity expansion of the Weatherford WPP had several challenging and/or non-conventional elements including:

- An aggressive project schedule
- Use of the D-CMAR project delivery method to meet the project schedule
- Installation of a membrane filtration system in a limited existing building space
- Construction of the project facilities on a small footprint site
- Blending the operation of two very different treatment processes

During the course of this project, the city of Weatherford and D-CMAR team gained insights into the nature of, and learned lessons from, the unique aspects of this project. Utilities may find these lessons learned helpful when considering a similar type project.

**Understand the effects of the new treatment process on the existing treatment process.** Whenever possible, completely separate the new membrane filtration process from the existing treatment process. If this in not possible, make sure all parties fully understand both treatment processes and how one system impacts the other. For instance, in the case of the Weatherford WPP project, the common raw water line required the membrane filtration system manufacturer to use constant speed feed pumps instead of their standard pumps utilizing variable frequency drives. This resulted in changes to their standard programming and additional time to "debug" their programming in the field.

Another effect from the combined process was that the service water for the chlorine solution injection was being provided, in part, by the Trident ™ filters. Trident effluent turbidity was higher than the membrane filtrate turbidity. The chlorine solution was injected upstream of the laser turbidimenters on the individual membrane filtration racks. While the water quality exceeded state requirements, the turbidity was high enough in the service water to give the appearance that the membrane filtration system was not performing as expected.

The membrane filtration process also had hydraulic characteristics that differed from the existing treatment process. A hydraulic model of the two parallel treatment processes was prepared to determine any required modifications to existing facilities and confirm that parallel process operation was possible for the range of anticipated operating conditions. However, field modifications to the membrane systems influent valves were required in order to prevent the membrane system from pulling water from the Trident ™ filters.

**Submittal Review.** Submittal review times for conventional design-bid-build projects are typically 14 days per submittal and each submittal generally only covers one piece of equipment. Since membrane filtration submittals usually contain one large submittal containing every piece of equipment being supplied by the membrane filtration system manufacture, it is not possible to perform a thorough review of the submittal in 14 days. Therefore, it would be best to require multiple submittal packages that are submitted based on a critical path basis. In other words, long lead items should be reviewed first followed by equipment as needed for construction. In the case of the Weatherford WPP expansion, the aggressive schedule also required some equipment reviews to be completed before the design was complete. So, particular attention needs to be paid to the orientation of the equipment in the submittal compared to the orientation required for the final design to so it does not cause delays during construction.

**Stainless steel piping.** The Weatherford membrane facility included a significant amount of stainless steel piping. Caution needs to be used when specifying and installing stainless steel piping in areas where oxidizing agents such as chlorine gas may be present. Even though the piping may be pickled properly in the factory, if it comes into contact with carbon steel during shipping, installation or during maintenance procedures, it is susceptible to rusting even if it is 316L stainless steel. The carbon steel product that comes in contact with the stainless steel leaves a carbon steel residue on the stainless steel providing a source for the rust (known as “cross contamination”). Then, when an oxidizing agent such as chlorine gas is brought into contact with the carbon steel residue on the stainless steel pipe, rust occurs. Therefore, it is imperative that the stainless steel pipe be field cleaned with pickling solution after installation and maintenance personnel informed that only stainless steel tools can come into contact with the stainless steel pipe.

**Pipe supports for aerial piping.** One thing that needs to be kept in mind both during design and construction of a membrane filtration plant is that it requires a lot more aerial piping than a conventional water treatment plant. This means there is more of a possibility of pipe support problems due to surge and water hammer. Most piping specifications leave the responsibility of the pipe supports the contractor. However, since aerial piping projects are not as prevalent, the contractors are not accustomed to the number and type of pipe supports required for aerial piping systems. Slow closing valves also become more critical in minimizing the affects of water hammer and surge on the piping and pipe supports. For instance, the check valves on the reverse filtration pumps were not properly adjusted and the valves closed too quickly. Even though piping was being supported by a significant structural member, the piping shook when the valve closed. Even after the valve was adjusted, additional supports were required.

## OPERATIONAL PERFORMANCE

As of the time of this report, the membrane filtration system was still being optimized and the system’s performance was still being evaluated.

## REFERENCES

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