

ENGINEERING REPORT



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TO:	Russell Schreiber, P.E.
FROM:	David W. Sloan, P.E., BCEE
SUBJECT:	Conceptual Plan for Integrated Desalination Treatment of Lake Kemp Water and River Road WRRF Effluent
PROJECT:	WCH14515
DATE:	March 3, 2015
CC:	Daniel Nix, Shawn Garcia, Mark Southard



FREESE AND NICHOLS, INC.
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ENGINEERING FIRM
F-2144

1.00 BACKGROUND

1.01 PURPOSE

The City of Wichita Falls continues to face a historic, catastrophic drought which has diminished available municipal water supplies and challenged the City to maintain essential water service through this period. Although the intensity of heat and evaporation has abated, rainfall has continued below normal for the region, and lake levels continue to decline. The City has responded with a series of measures, most notably extreme conservation measures which have reduced water consumption, and implementation of an emergency program to blend purified effluent from the River Road Water Resource Recovery Facility (WRRF) with water from Lake Arrowhead and Lake Kickapoo prior to final treatment at the Cypress Water Treatment Plant. This program is generally referenced as the Emergency Direct Potable Reuse (DPR) program.

By letter dated June 27, 2014, The Texas Commission on Environmental Quality (TCEQ) provided conditional authorization for the City to blend effluent from the River Road WRRF, following treatment through the City's 2008 microfiltration/reverse osmosis (MF/RO) treatment facility, with other raw surface water supplies prior to final treatment. The City proceeded with blending in accordance with these provisions on July 9, 2014. The authorization was limited to an initial period of six months, but the City recently started up UV disinfection equipment to comply with the TCEQ's

principal condition for extended operation, and the authorization has now been extended through March 31, 2015 to allow final documentation and approval of the UV system. Extended authorization is anticipated with final approval of the UV system. However, concerns regarding continued loss of water supply remain, threatening even the DPR program, which is dependent on blending with equal parts of fresh water from Lakes Arrowhead and/or Kickapoo.

The City's third reservoir, Lake Kemp is a brackish source which requires desalination prior to use for drinking water. The facilities constructed for this purpose are the same facilities currently used for the DPR program, which was presumed to be of limited duration and therefore not in long-term conflict with the use of the Lake Kemp supply. The City now proposes to blend and concurrently treat reclaimed water and Lake Kemp water through the City's existing desalination facility, and credit the Lake Kemp blending as a substitute for all or a portion of the current Arrowhead/Kickapoo blending. Total finished water from the Cypress WTP derived from reclaimed water would remain at or below 50%. The City proposes to implement this source as soon as possible to conserve the Arrowhead and Kickapoo supplies for continued, but reduced, use to delay or prevent their exhaustion.

This report is to present the recommended approach and facilities to concurrently treat reclaimed water and Lake Kemp water through the City's existing desalination facility.

2.00 DATA

The Cypress Water Treatment Plant has demonstrated ability to produce high quality drinking water from raw water with significant variation in chemical parameters and suspended solids characteristics. This section focuses on the salinity parameters of different sources and the plant's ability to meet the secondary salinity standards through desalination and blending.

2.01 HISTORICAL SOURCE WATER QUALITY

Recent (2011-2014) historical water quality data for three sources of supply are summarized in this section. The sources represented are the Secondary Reservoir, blended from Lakes Arrowhead and Kickapoo, Lake Kemp, and treated effluent from the River Road WRRF. Figure 1 shows total dissolved solids, and Figure 2 shows chloride, consistently higher than sulfate and likely to be the limiting secondary parameter. This period may not be representative of long-term water quality but represents the recent years affected by the area's extreme drought, and is therefore useful in evaluating likely near-term future conditions relevant to the City's proposed contingency plans.

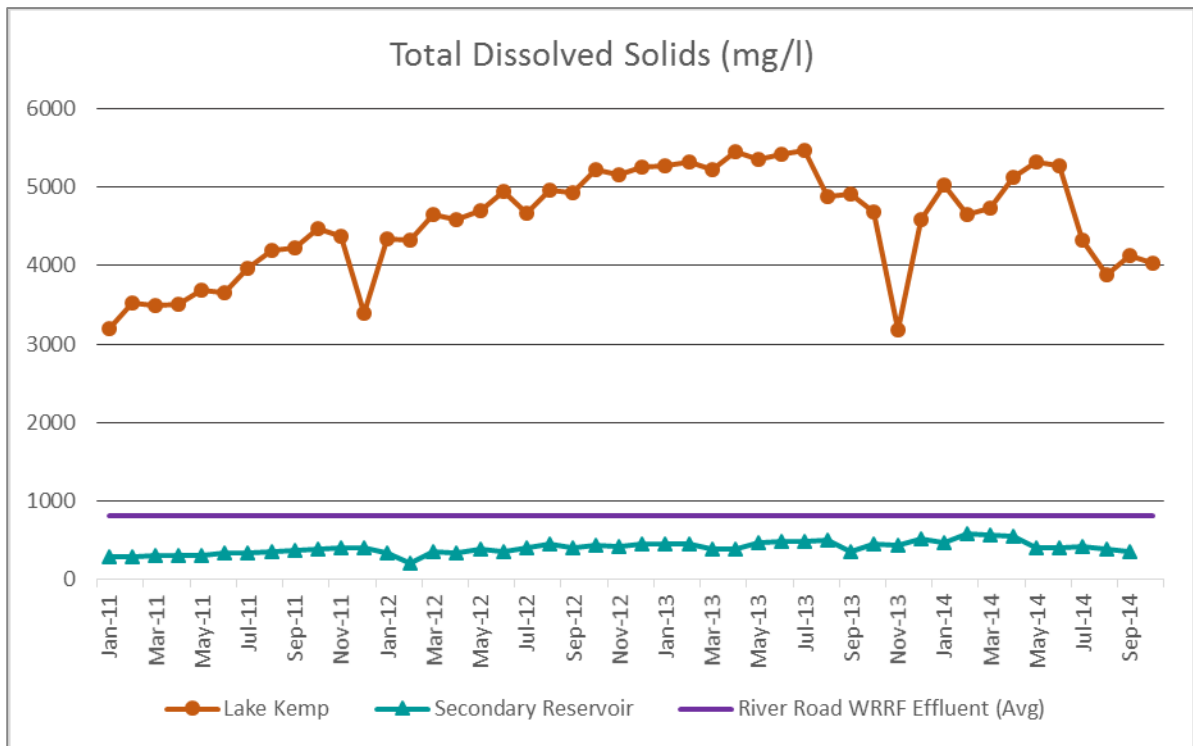


Figure 1 - Recent Historical TDS

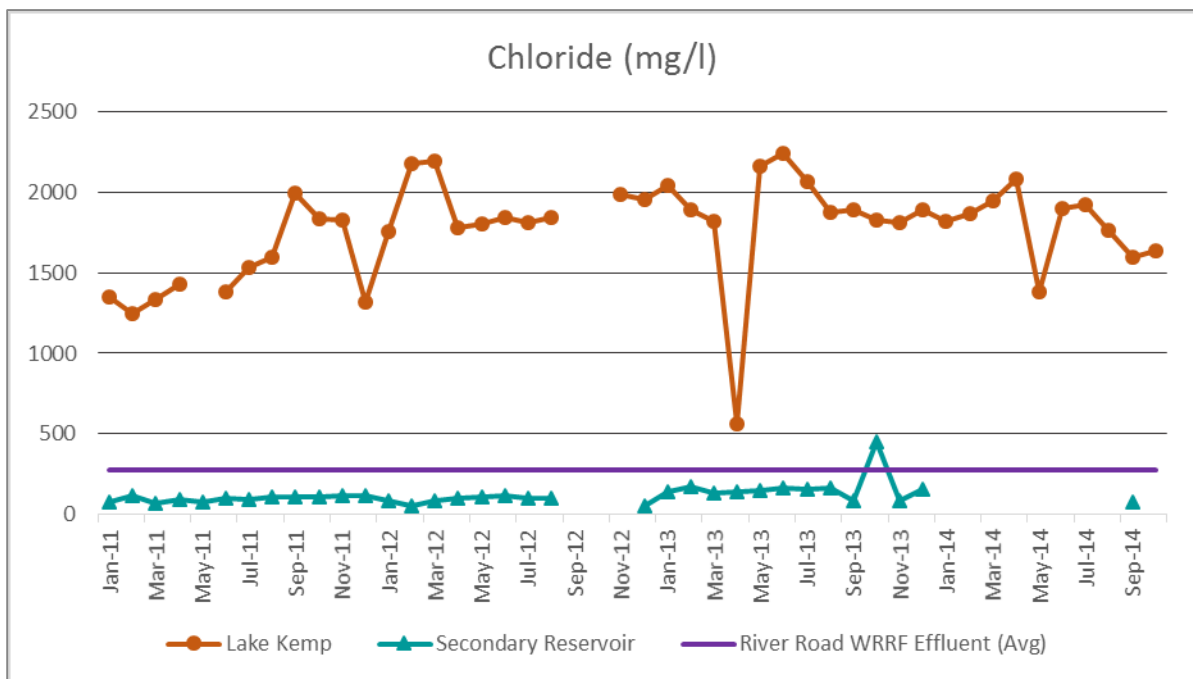


Figure 2 - Recent Historical Chloride

2.02 PROJECTED LAKE KEMP AND BLENDED RAW WATER QUALITY

Based on the recent historical data summarized in the previous section, Lake Kemp raw water is expected to have a TDS of about 4500 mg/l at the time of implementation for integrated desalination operations. If the drought intensifies with a return to high evaporation conditions, water quality could again worsen, and an extreme condition of 6000 mg/l is proposed for contingency planning. This is not considered a worst-case boundary, but does represent an extreme condition worse than measured values from the summer of 2013. Corresponding values proposed for chloride are 1800 mg/l initial and 2400 mg/l extreme. The maximum monthly value for sulfate during the period reviewed was 1394 mg/l, and is therefore not a controlling parameter.

Blended raw water quality is projected in Table 1 for two conditions, assuming an equal blend of treated effluent from the River Road WRRF and raw water from Lake Kemp. The first condition is for initial anticipated raw water quality and the second condition is for extreme water quality conditions as described above.

Table 1 - Projected Blended Raw Water Quality

Sources	Initial Concentrations (mg/l)		% Share
	TDS	Chloride	
River Road WRRF	1000	350	50%
Lake Kemp	4500	1800	50%
Blended Raw	2750	1075	

Sources	Extreme Concentrations (mg/l)		% Share
	TDS	Chloride	
River Road WRRF	1816	654	50%
Lake Kemp	6000	2400	50%
Blended Raw	3908	1527	

3.00 TREATMENT EVALUATION

3.01 PROJECTED MF/RO TREATED WATER QUALITY

RO membranes for Train 4 were replaced in December 2013, and the remainder were replaced in October 2014. Based on the current upgraded performance and allowing for some modest reduction

over time, projected water quality for this report assumes 95% rejection of TDS and chloride, as indicated in Table 2.

Table 2 - Projected Treated Water Quality

Sources	Initial Concentrations (mg/l)		Flow (mgd)
	TDS	Chloride	
Blended Raw	2750	1075	15.0
RO Removal	95%	95%	33%
Permeate	137.5	53.75	10.0

Sources	Extreme Concentrations (mg/l)		Flow (mgd)
	TDS	Chloride	
Blended Raw	3908	1527	15.0
RO Removal	95%	95%	33%
Permeate	195.4	76	10.0

3.02 PROJECTED BLENDED FINISHED WATER QUALITY

This report assumes the blending of River Road effluent with an equal or greater quantity of Lake Kemp raw water will replace the need for blending water from the secondary reservoir to meet regulatory conditions. As the MF/RO permeate continues through the conventional treatment processes, final quality for salts will be similar to that projected for the permeate, as described in the previous section. If additional Lake Kemp water is needed to meet total demands, it would exceed the capacity of the existing membrane facility. This condition could occur if all water supply was lost from Lakes Arrowhead and Kickapoo, but is not anticipated under current drought modeling scenarios. Therefore, this condition will not be addressed by this report.

4.00 CONCEPTUAL TREATMENT CONFIGURATIONS

The proposed incorporation of Lake Kemp water into the Cypress Water Treatment Plant is through the 2008 membrane facility constructed specifically to treat Lake Kemp source water. This section examines the limitations of the existing membrane treatment facility to determine the production available when treating a blend of source water from River Road WRRF and Lake Kemp. Additional

demands will require continued treatment of water from the Secondary Reservoir (Arrowhead and/or Kickapoo source water) at either the Cypress WTP or Jasper WTP.

4.01 MAXIMIZING EXISTING CONFIGURATION

The existing membrane treatment plant at Cypress WTP has a nominal treatment capacity of 10 MGD as treated permeate, requiring approximately 15 MGD of raw water as source water. The DPR operation was intended to use half the production capacity, producing up to 5 MGD of permeate to blend with an equal amount of raw water from the secondary reservoir for treatment through the 2010 conventional treatment facility, which also has a rated treatment capacity of 10 MGD.

The proposed integrated desalination concept is to blend equal portions of Kemp raw water with River Road WRRF effluent prior to treatment through the membrane plant, followed by additional treatment through the 2010 plant. Alternatively, blending could be accomplished through a combination of Lake Kemp raw water prior to membrane treatment, followed by additional blending with raw water from the secondary reservoir prior to conventional treatment.

Additional system demands would be met by water from the secondary reservoir treated at the Jasper WTP.

4.02 BLEND RATIO ACCOUNTING

As noted above, the original DPR concept assumed blending raw surface water at least equal to the amount of permeate derived from the DPR source water. If Lake Kemp is used as the sole source of blend water, an equivalent blend would result from blending raw Kemp supply at least equal to the amount of DPR source water prior to membrane treatment. However, it is also appropriate to consider a combination of raw water supplies to meet the overall blending requirement. This will allow the City maximum flexibility to utilize sources in response to their current and projected availability while maintaining compliance with TCEQ authorization.

The proposed combination blend calculation considers the share of RO permeate originating from the DPR source as a percentage of the total water produced. This approach considers the blending from brackish surface water prior to desalination, and blending from fresh surface water prior to conventional treatment.

$$\text{DPR \% of permeate} = \text{DPR source flow (MGD)} / (\text{DPR source flow} + \text{Kemp raw flow}) \times 100\%$$

$$\text{DPR share of permeate} = \text{DPR \%} \times \text{Total permeate flow}$$

$$\text{DPR \% of total} = \text{DPR share of perm. (MGD)} / (\text{permeate flow} + \text{Arrowhead/Kickapoo raw flow}) \times 100\%$$

The following **example** illustrates this approach:

7.2 MGD of DPR source water is mixed with 5 MGD of raw water from Lake Kemp. At an overall MF/RO recovery of 67%, 8.17 MGD of permeate is produced. An additional 1.8 MGD of raw water from Lake Arrowhead is blended with the permeate before treatment through the 2010 conventional plant. The resulting DPR source percentage is calculated as follows and illustrated in Figure 3:

$$\text{DPR \% of permeate} = 7.2 / (7.2 + 5) \times 100\% = 59.0\%$$

$$\text{DPR share of permeate} = 59\% \times 8.17 \text{ MGD} = 4.82 \text{ MGD}$$

$$\text{DPR \% of total} = 4.82 / (8.17 + 1.8) \times 100\% = 48.4 \%$$

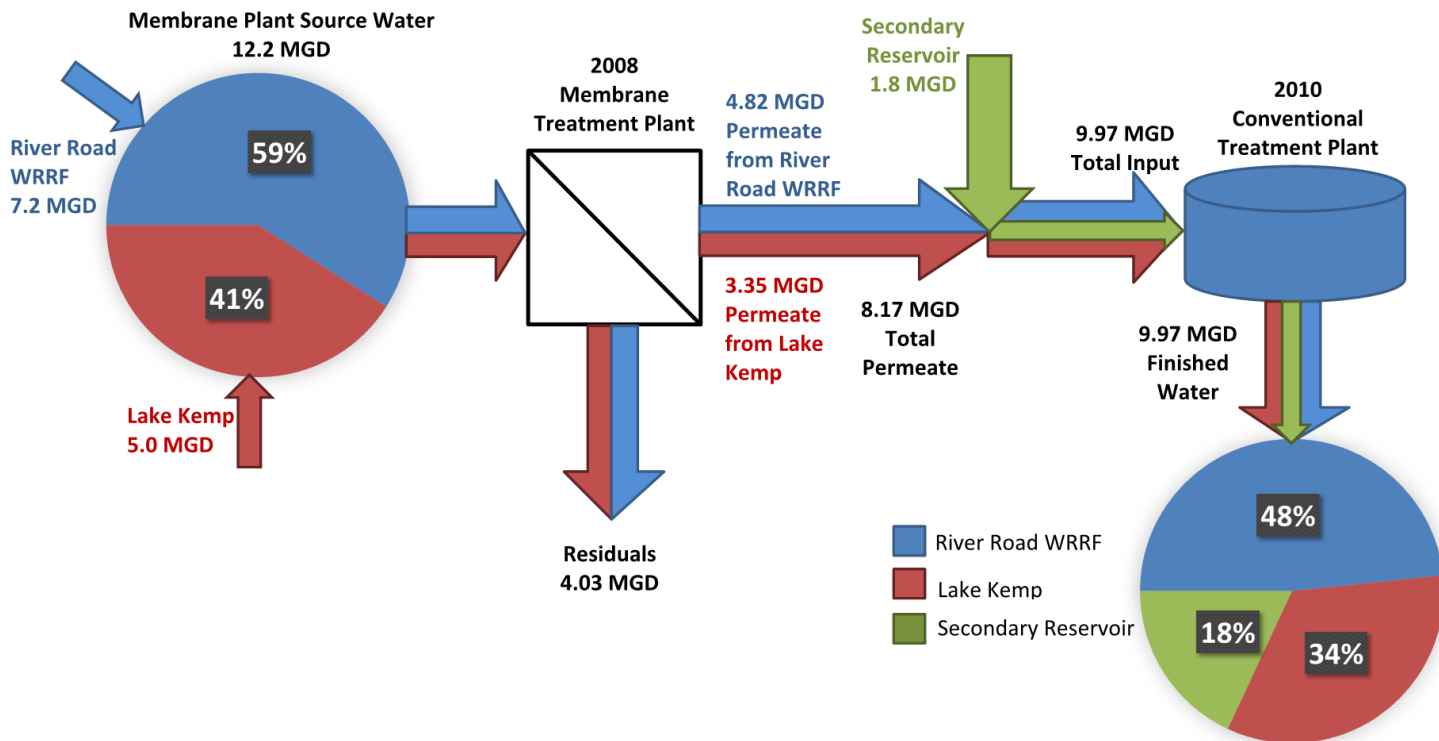


Figure 3 – Illustration of Blend Ratio Calculation Example

4.03 DISINFECTION EVALUATION

Disinfection goals will be similar to the existing DPR disinfection goals, except that Lake Kemp raw water will be disinfected with chlorine dioxide applied at the Headquarters Road pump station while DPR water will continue to be treated with chloramines applied at the River Road WRRF. As a conventional surface water source, the Lake Kemp raw water would not normally be subject to supplemental disinfection requirements, but after blending with the DPR source water, it will be subject to all subsequent disinfection zones, thus far exceeding conventional disinfection requirements. For simplicity, this section will focus on disinfection achieved through the path of the DPR source water.

The following tables summarize the projected disinfection/inactivation provided through the proposed DPR treatment processes and disinfection zones. A new free chlorine zone is proposed for the permeate discharge line between the permeate storage tanks and the permeate storage lagoon to provide standby virus inactivation during lower temperature conditions. Figure 4 is taken from the current CT Study for the DPR facility, modified to illustrate the relationship of the additional disinfection zones and facilities. An updated CT Study reflecting the additional zone for each source (River Road WRRF and Lake Kemp/Headquarters Road) is attached to this report.

Table 2 - Virus Inactivation Evaluation (9-log total inactivation required)

Process	Credit Basis	CT Zone	Flow (MGD)	30°C		7°C	
				Conc. (mg/l)	log inactivation	Conc. (mg/l)	log inactivation
RR WRRF Source Pipeline	Monochloramine	D1	7.5	1	3.87	2.5	1.97
MF/RO Pretreatment	Coagulation		15		0.5		0.5
MF/RO Clarifier	Monochloramine	D2	15	1	1.21	2.5	0.61
Microfiltration	Physical Removal		15		2		2
Microfiltration	Monochloramine	D3	15	1	0.01	2.5	0.03
Reverse Osmosis	Physical Removal		10		0		0
UV Disinfection	UV Radiation		10		0		0
Permeate Pipeline	Free Chlorine	D4 (new)	10	0	0	1	1.43
2010 Coagulation/Clarification	Physical Removal		10		0.5		0.5
2010 Filtration	Physical Removal		10		2		2
2010 Process Units	Chloramine	D5 [ex. D4]	10	3.5	2.55	4	0.59
10 MG GST	Chloramine	D6 [ex. D5]	10	3.8	9.21	4	1.97
Chemical Disinfection Sub-Total					16.85		6.6
UV Disinfection Sub-Total					0		0
Physical Removal Sub-Total					5		5
TOTAL					21.85		11.6

Table 3 - Giardia Inactivation Evaluation (8-log total inactivation required)

Process	Credit Basis	CT Zone	Flow (MGD)	30°C		7°C	
				Conc. (mg/l)	log inactivation	Conc. (mg/l)	log inactivation
RR WRRF Source Pipeline	Monochloramine	D1	7.5	1	1.4	2.5	1.33
MF/RO Pretreatment	Coagulation		15		0.5		0.5
MF/RO Clarifier	Monochloramine	D2	15	1	0.44	2.5	0.42
Microfiltration	Physical Removal		15		2.8		2
Microfiltration	Monochloramine	D3	15	1	0	2.5	0.02
Reverse Osmosis	Physical Removal		10		0		0
UV Disinfection	UV Radiation		10		3		3
Permeate Pipeline	Free Chlorine	D4 (new)	10	0	0	1	0.06
2010 Coagulation/Clarification	Physical Removal		10		0.5		0.5
2010 Filtration	Physical Removal		10		2		2
2010 Process Units	Chloramine	D5 [ex. D4]	10	3.5	0.92	4	0.4
10 MG GST	Chloramine	D6 [ex. D5]	10	3.8	3.33	4	1.34
	Chemical Disinfection Sub-Total				6.09		3.51
	UV Disinfection Sub-Total				3		3
	Physical Removal Sub-Total				5.8		5
			TOTAL		14.89		11.51

Table 4 - Cryptosporidium Inactivation Evaluation (5.5-log total inactivation required)

Process	Credit Basis	CT Zone	Flow (MGD)	Conc. (mg/l)	log inactivation
RR WRRF Source Pipeline	Monochloramine	D1	7.5	1	0
MF/RO Pretreatment	Coagulation		15		0.5
MF/RO Clarifier	Monochloramine	D2	15	1	0
Microfiltration	Physical Removal		15		2.8
Microfiltration	Monochloramine	D3	15	1	0
Reverse Osmosis	Physical Removal		10		0
UV Disinfection	UV Radiation		10		3
Permeate Pipeline	Free Chlorine	D4 (new)	10	0	0
2010 Coagulation/Clarification	Physical Removal		10		0.5
2010 Filtration	Physical Removal		10		2
2010 Ind. Filter Effluent Credit	Physical Removal		10		1
2010 Process Units	Chloramine	D5 [ex. D4]	10	3.5	0
10 MG GST	Chloramine	D6 [ex. D5]	10	3.8	0
	Chemical Disinfection Sub-Total				0
	UV Disinfection Sub-Total				3
	Physical Removal Sub-Total				6.8
			TOTAL		9.8

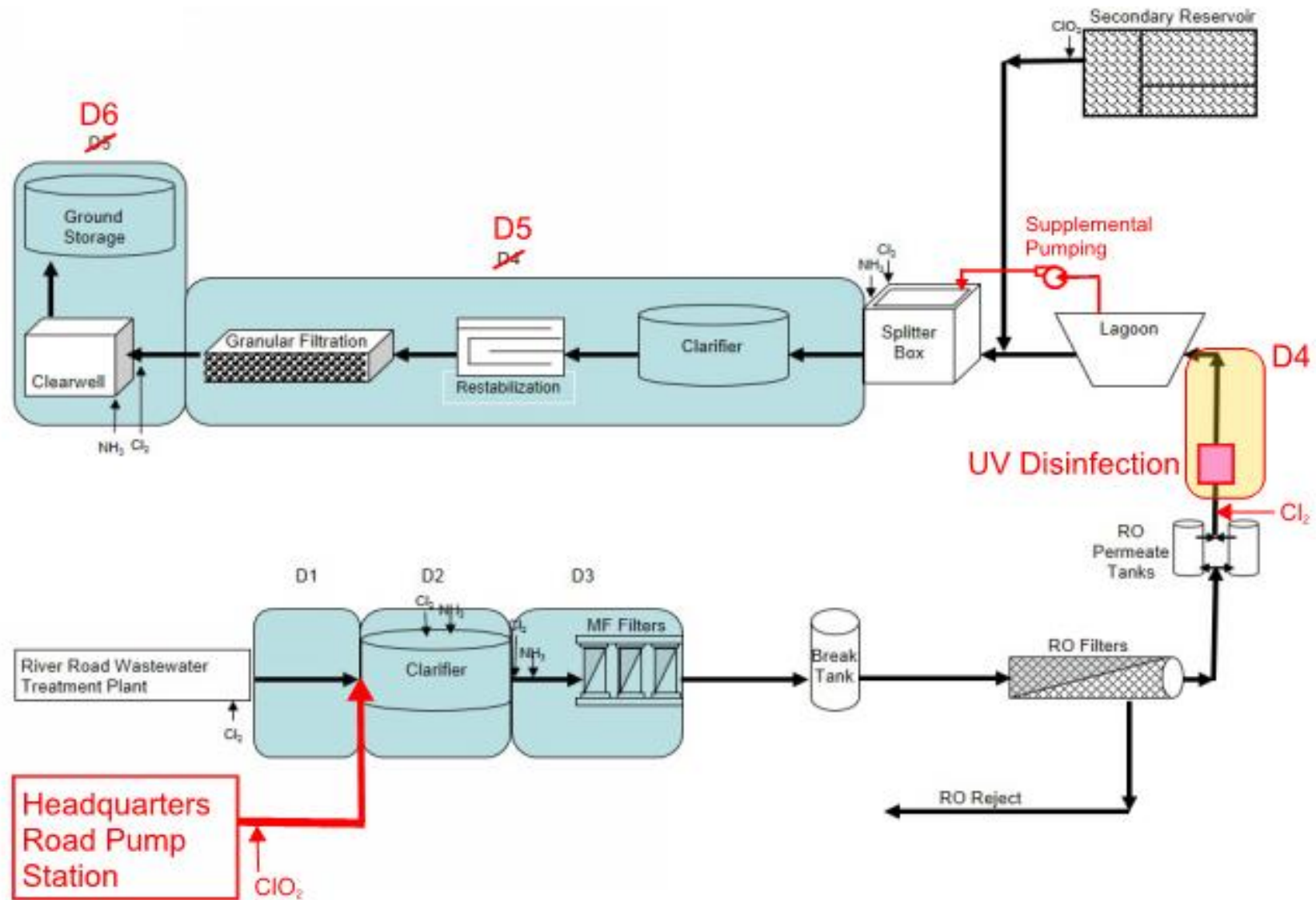


Figure 4 - Flow Schematic with Disinfection Zones

5.00 CONCEPTUAL IMPLEMENTATION PLAN

5.01 STEP-WISE IMPLEMENTATION OF INITIAL INTEGRATION

No major improvements are required to begin the initial integration plan. Lake Kemp raw water is already piped to the proposed flow path and no additional infrastructure is required. The 2008 membrane facility was designed to treat water from Lake Kemp, and has been extensively proven and monitored treating effluent from the River Road WRRF. While adjustments to chemical feed and RO recovery rate are to be expected to optimize treatment of the blended water, the blended water quality is within the range for which the facility was designed. Final treatment through the 2010 conventional plant will continue, initially with continued raw water blending, and phasing out the fresh blend water over time. Supplemental pumping will eventually be required to augment the existing Washwater Reclaim Pump Station, lifting water into the raw water splitter box as illustrated in Figure 4. Approximately 4 MGD of additional capacity is proposed, based on the 6 MGD design capacity of the existing station.

A. Implementation Sequence

1. **Minimum Lake Kemp Flow.** The minimum flow available from the Headquarters Road Pump Station (HRPS) is 3 MGD, which provides a reasonable starting flow for demonstration. Flow from the River Road WRRF will be reduced to approximately 3 MGD and the raw water valve on the Lake Kemp inlet will be opened. One pump at HRPS will be started up at 3 MGD, providing a raw water blend of approximately 50% reclaimed water. This 6 MGD of blended raw water will yield approximately 4 MGD of permeate to the backwash lagoon. Consistent with current practice, this will be blended in the line approaching the splitter box with an equal amount of raw water from the secondary reservoir. This mode of operation will be operated for one week to verify continued consistent operation of both the membrane and conventional processes, with particular attention to salinity, nitrate and turbidity performance.
2. **Ramp Up to 2010 Capacity.** Following successful operation at minimum flow, flow from both the DPR source and Lake Kemp will be brought up to approximately the current flow of the MF/RO facility, about 3.75 MGD from each source. After stabilizing operation at this level, a sampling event will be scheduled to test for pathogens and other parameters of special concern as agreed between the City and TCEQ. Operation will remain in this mode for approximately an additional month to allow for receipt and review of test results.
3. **Taper Fresh Water Contribution.** Following successful operation and testing at current flow and blending, the contribution from the Secondary Reservoir will be reduced in stages, allowing the Kemp water to substitute for the Arrowhead/Kickapoo supply to continue meeting the overall 50% dilution requirement. Following testing at 50% DPR, 50% Kemp, TCEQ approval of the full range of flow combinations will be sought, subject to the overall limitation of 50% total DPR as described in Section 4.02.

B. Proposed Testing Plan

1. **Minimum Lake Kemp Flow.** Testing for the initial Lake Kemp/DPR blend will follow the existing DPR test protocol. Daily RO rejection rates will be compared to recent values to assess any variation in performance due to changed salinity conditions. A summary of RO rejection and finished water turbidity for the first 7 days of operation will be submitted to TCEQ prior to proceeding with increased production rates.
2. **Ramp Up to 2010 Capacity.** A quarterly sampling event will be conducted after reaching consistent operation of the facility at a production of 5 MGD with approximately 50% contribution from Lake Kemp. Following receipt of results, a summary of results will be prepared and submitted to TCEQ prior to proceeding with final substitution of Lake Kemp water for all blending.
3. **Taper Fresh Water Contribution.** Upon submission of Step 2 results, the membrane plant will be gradually ramped up to approach the nominal capacity of 10 MGD, limiting the DPR contribution to less than 50%. An additional quarterly sampling event will be conducted following achieving consistent operation at greater than 9 MGD permeate production. A summary of results will be prepared and submitted to TCEQ.

5.02 PROPOSED CHANGES TO EXISTING DPR AUTHORIZATION

Several requirements contained in the TCEQ authorization (final version dated August 5, 2014) will require modification to accommodate the proposed integrated desalination. Specific proposed language is included in Attachment A, but the modifications primarily concern the following items:

- A. Adjusted blend ratio calculation to account for blending credit from Lake Kemp flow
- B. Modification to isolation provisions at Lake Kemp pipeline connection and splitter box

5.03 SUPPLEMENTAL PUMPING FROM PERMEATE LAGOON

The Washwater Reclaim Pump Station (WRPS) is currently used to lift stored permeate from the membrane treatment facility into the raw water splitter box for subsequent conventional treatment. This pump station has not been tested to its full capacity, but is estimated to have a capacity of 6 MGD, and has consistently pumped 5 MGD since the DPR operation began. Additional capacity is needed to allow full usage of the 10 MGD desalination capacity through the existing membrane plant. Two temporary pumps are proposed to provide the additional capacity. Each pump should have a nominal capacity of 1500 gpm to provide a total supplemental capacity of 3000 gpm. These pumps will be placed on a concrete slab on the south side of the lagoon and pump into the forebay of the splitter box to mix with discharge from the WRPS and any flow arriving from the Secondary Reservoir. Each pump will be a horizontal self-priming type, provided with a dedicated 12" HDPE suction line placed to access the pond contents to a depth of approximately five feet. Both pumps will discharge to a common 18" HDPE discharge line to convey water to the west end of the splitter box. An

ultrasonic transit time flow meter will be included to continuously monitor flow from the supplemental pumping. Plans and specifications for the proposed pump station are provided with this report.

6.00 CONCLUSIONS

Current water supply conditions in Wichita Falls warrant modification of the emergency direct potable reuse operation to allow blending of River Road WRRF effluent and Lake Kemp raw water to allow integrated desalination treatment of both sources to extend the City's available fresh water supplies for the benefit of Wichita Falls as well as other users of Lakes Arrowhead and Kickapoo during the continuing drought conditions. Modest physical improvements will be required to fully utilize the existing desalination facilities at the Cypress Water Treatment Plant, as well as simple changes to the City's current TCEQ authorization to operate the DPR facility. The overall blend ratio, conservative disinfection practices and other protections will continue in place to maintain the production of safe and excellent quality water from the Cypress Water Treatment Plant. Prioritized evaluation is sought to allow the City increased flexibility to manage limited water supplies through the remainder of the drought.