City of Lindsay
Well 11 Feasibility Study

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1 Background

1.1 Purpose of Report

The City of Lindsay operates a community water system located in Tulare County, California that is regulated by the California State Water Resources Control Board Division of Drinking Water (DDW). The system's sources of supply are Central Valley Project (CVP) Friant Kern Canal water treated at a single surface water treatment plant and two active groundwater wells (Wells 14 and 15). A third well (Well 11) is currently inactive due to nitrate and perchlorate contamination at levels exceeding their respective maximum contaminant levels (MCLs). The distribution system is operated as a single pressure zone and includes one 4-million-gallon at-grade water storage reservoir located on a hill near the north end of the City.

During normal years, the City's contracted CVP water allocation is 2,500 acre-feet, which is sufficient for the City to supply most of its water needs using its surface water treatment plant. However, during years of severe or extreme drought, including 2022, the City's Friant Kern Canal water allocation can be severely reduced. Unless a special Health & Safety CVP water allocation is granted to the City, it will be necessary to reactivate Well 11 to meet system demands, even if water conservation measures are implemented. Without mitigation of the nitrate and perchlorate contamination at Well 11, any use of the well would result in a violation of two primary drinking water standards, both of which have the potential to result in acute health effects.

The purpose of this report is to evaluate non-treatment and treatment alternatives to mitigate the perchlorate and nitrate contamination at Well 11 so that this source can be returned to active service or a replacement source developed; to recommend a preferred solution; and to estimate capital and operations & maintenance (O&M) costs associated with that solution.

1.2 Well 11 Description

Well 11 is located at the north end of a City storm water detention basin south of W. Mariposa Street approximately 900 feet east of Highway 65. The well was drilled in 1980 to a total depth of 668 feet, includes a 150-foot sanitary seal, and is perforated from 300 to 550 feet. The well is equipped with a 125-horsepower submersible pump capable of producing a flow rate of approximately 1,400 gpm into an on-site hydropneumatic pressure tank.

1.3 Water Quality

1.3.1 Water Quality

Water quality characteristics for Wells 11, 14, and 15 are summarized in Tables 1-1, 1-2, and 1-3 respectively. Tables 1-4 and 1-5 contain individual nitrate and perchlorate results for Well 11.

Notable geochemical characteristics of the Well 11 water include intermittently elevated iron levels and moderate sulfate and chloride levels. Iron levels exceeding the 0.3 mg/L secondary drinking water standard are interspersed with non-detect results. It is likely that these elevated iron levels are a result of the well not being pumped long enough to purge stagnant water prior to sampling events. Sulfate levels, and to a lesser extent chloride levels, have a significant impact on the anion exchange process typically used to remove nitrate and perchlorate from water. The highest recorded sulfate level was 90 mg/L in 1984. All twenty-four subsequent sulfate results were 57 mg/L or less. Chloride levels average 233 mg/L.

Well 11 is contaminated with perchlorate and nitrate at levels exceeding their respective MCLs. The synthetic organic chemical (SOC) 1,2-dibromo-3-chloropropane (DBCP) has also been detected, but is present at levels below one-half of the MCL. Perchlorate results from 2001 through 2020 range from 8 to 13 μg/L and are relatively stable. The levels are consistently greater than the 6 μg/L MCL. The single non-detect perchlorate result from the sample collected on January 22, 2008, is suspect. Nitrate levels have typically been within 20% of the 10 mg/L MCL value since 2007 with four out of the 67 results measuring at, or greater than, the 10 mg/L MCL.

The SOC 1,2,3-trichloropropane (TCP), which has been regulated in drinking water since 2017, has been detected extensively throughout the Central Valley, including in the nearby communities of Tulare and Woodville. A single detection of TCP at a concentration of 34 ng/L was reported at Well 11 in 2001. Eight TCP results reported between the 2001 detection and 2017 were non-detect, but are suspect as reporting limits significantly greater than the MCL value were commonly used until 2017. At the beginning of this study, only one sample had been analyzed for TCP since 2017 and that result was non-detect. The City recently re-tested the well for TCP with another non-detect result.

The water quality characteristics at Wells 14 and 15, which are located approximately 2.5 miles to the northwest of Well 11 were considered when evaluating potential blending and well replacement mitigation alternatives. Nitrate levels at Wells 14 and 15 have recently been in the range of 6.5 – 7.3 mg/L. Perchlorate has not been detected at either Well 14 or Well 15. Well 14 is also contaminated with DBCP and levels have only been consistently below the 0.2 μg/L MCL since 2017. Well 15 has notably higher hardness than the other two wells.

Table 1-1: Well 11 General Water Quality

ANALYTE	UNITS	DATA POINTS AVAILABLE	MIN	AVERAGE	MAX
GENERAL					
AGGRESSIVE INDEX		1	12	12	12
ALKALINITY, BICARBONATE AS CACO3	MG/L	9	110	250.84	1230
ALKALINITY, CARBONATE AS CACO3	MG/L	9	0	0	0
ALKALINITY, HYDROXIDE AS CACO3	MG/L	8	0	0	0
ALKALINITY, TOTAL AS CACO3	MG/L	9	110	257.89	1300
ALUMINUM	UG/L	7	0	8.57	60
ANTIMONY	UG/L	5	0	0	0
ANTIMONY, TOTAL	UG/L	1	0	0	0
ARSENIC	UG/L	11	0	1.38	7
BARIUM	UG/L	9	0	210	260
BENZENE	UG/L	8	0	0	0
BERYLLIUM, TOTAL	UG/L	1	0	0	0
BORON	UG/L	2	0	140	280
CADMIUM	UG/L	9	0	0	0
CALCIUM	MG/L	9	60	68.56	73
CHLORIDE	MG/L	12	150	233.17	305
CHROMIUM (TOTAL CR-CRVI SCREEN)	UG/L	1	5	5	5
CHROMIUM, HEX	UG/L	2	0.9	2.6	4.3
CHROMIUM, TOTAL	UG/L	10	0	5.50	30
COLOR		9	0	1.56	8
COPPER	UG/L	9	0	0	0
CYANIDE	UG/L	6	0	0	0
FLUORIDE	UG/L	9	0	120	310
HARDNESS, TOTAL AS CACO3	MG/L	9	280	314.67	340
IRON	UG/L	11	0	196.36	1000
LANGELIER INDEX		1	0.27	0.27	0.27
LANGELIER INDEX @ 60 C		4	0.23	0.72	0.97
LEAD	UG/L	9	0	0	0
MAGNESIUM	MG/L	9	28	34.44	39
MANGANESE	UG/L	9	0	0	0
MERCURY	UG/L	9	0	0.02	0.2
NICKEL	UG/L	6	0	0	0
NITRATE (AS N)	MG/L	67	0.2	7.86	11.75
NITRATE + NITRITE (AS N)	MG/L	5	1.7	7.08	10
NITRITE (AS N)	MG/L	7	0	0	0
ODOR THRESHOLD		1	0	0	0
ODOR THRESHOLD @ 60 C		7	0	0.29	1
PERCHLORATE	UG/L	14	0	10.11	13
PH @23C		1	8	8	8
PH, LAB		8	7.4	7.85	8.1
POTASSIUM	MG/L	8	3.8	19.18	120
SELENIUM	UG/L	9	0	0	0
SILVER	UG/L	9	0	0.22	2
SODIUM	MG/L	9	4	73.44	140
SPECIFIC CONDUCTANCE	UMHOS/CM	19	840	1030.89	1800
SULFATE	MG/L	9	25	42.22	90
TDS	MG/L	9	500	657.67	764
THALLIUM, TOTAL	UG/L	6	0	0	0
TURBIDITY, LAB		8	0	0.47	1.8
ZINC	UG/L	9	0	0	0
RADIOACTIVE					
GROSS ALPHA PARTICLE ACTIVITY	PCI/L	16	0	2.41	13.1
RADIUM-226	PCI/L	1	0.126	0.13	0.126
RADIUM-228	PCI/L	4	0	0.28	1.1
URANIUM	PCI/L	3	0	1.14	2.07
VANADIUM	UG/L	2	20	22	24
ORGANIC					
1,1-DICHLOROETHANE (1,1-DCA)	UG/L	8	0	0	0
1,2,3-TRICHLOROPROPANE	UG/L	14	0	0.0024	0.034
BROMOFORM (THM)	UG/L	8	0	0	0
CHLOROMETHANE	UG/L	8	0	0	0
DIBROMOCHLOROPROPANE	UG/L	55	0	0.09	0.19
DICHLOROMETHANE (METHYLENE CHLORIDE)	MG/L	9	0	0.00013	0.0012
TETRACHLOROETHYLENE (PCE)	UG/L	8	0	0	0

Table 1-2: Well 14 General Water Quality

ANALYTE	UNITS	DATA POINTS AVAILABLE	MIN	AVERAGE	MAX
GENERAL					
AGGRESSIVE INDEX		5	12	12.60	13
ALKALINITY, BICARBONATE AS CACO3	MG/L	5	190	224	260
ALKALINITY, CARBONATE	MG/L	5	0	0	0
ALKALINITY, TOTAL AS CACO3	MG/L	5	180	190	210
ALUMINUM	UG/L	4	0	0	0
ANTIMONY, TOTAL	UG/L	4	0	0	0
ARSENIC	UG/L	4	0	2.03	3.1
BARIUM	UG/L	4	160	172.50	190
BENZENE	UG/L	4	0	0	0
BERYLLIUM, TOTAL	UG/L	4	0	0	0
BORON	UG/L	1	220	220	220
CADMIUM	UG/L	4	0	0	0
CALCIUM	MG/L	5	48	51.60	57
CHLORIDE	MG/L	5	180	206	220
CHROMIUM, HEX	UG/L	2	4.2	4.45	4.7
CHROMIUM, TOTAL	UG/L	4	0	0	0
COLOR		4	0	1.25	5
COPPER, FREE	UG/L	5	0	0	0
CYANIDE	UG/L	4	0	0	0
FLUORIDE	UG/L	4	150	170	190
FOAMING AGENTS (SURFACTANTS)	UG/L	5	0	0	0
HARDNESS, TOTAL AS CACO3	MG/L	6	250	261.67	290
HYDROXIDE AS CALCIUM CARBONATE	UG/L	5	0	0	0
IRON	UG/L	5	0	280	1200
LANGELIER INDEX (PH(S))		5	0.49	0.55	0.67
LANGELIER INDEX @ SOURCE TEMP		1	1.1	1.10	1.1
LEAD	UG/L	4	0	0	0
MAGNESIUM	MG/L	5	30	32.40	36
MANGANESE	UG/L	5	0	6.80	34
MERCURY	UG/L	4	0	0	0
NICKEL	UG/L	4	0	0	0
NITRATE (AS N)	MG/L	45	5.6	6.57	8.36
NITRATE + NITRITE (AS N)	MG/L	2	6.6	6.95	7.3
NITRITE (AS N)	MG/L	4	0	0	0
ODOR THRESHOLD		4	0	0	0
PERCHLORATE	UG/L	5	0	0	0
PH, LAB		5	8	8.14	8.3
POTASSIUM	MG/L	5	3.6	3.66	3.8
SELENIUM	UG/L	4	0	0	0
SILVER	UG/L	5	0	0	0
SODIUM	MG/L	5	110	124	130
SPECIFIC CONDUCTANCE	UMHOS/CM	8	1000	1125	1200
SULFATE	MG/L	5	36	40.80	43
TDS	MG/L	5	590	614	660
THALLIUM, TOTAL	UG/L	4	0	0	0
TURBIDITY, LAB		4	0	0.42	0.88
ZINC	UG/L	5	0	0	0
RADIOACTIVE					
GROSS ALPHA PARTICLE ACTIVITY	PCI/L	7	0.95	3.12	6.29
RADIUM-228	PCI/L	2	0	0	0
ORGANIC					
1,1-DICHLOROETHANE (1,1-DCA)	UG/L	4	0	0	0
1,2,3-TRICHLOROPROPANE	UG/L	6	0	0	0
BROMOFORM (THM)	UG/L	4	0	0	0
CHLOROMETHANE	UG/L	4	0	0.25	1
DIBROMOCHLOROPROPANE	UG/L	69	0.053	0.23	0.53
DICHLOROMETHANE (METHYLENE CHLORIDE)	MG/L	4	0	0	0
TETRACHLOROETHYLENE (PCE)	UG/L	4	0	0	0
TTHM	UG/L	4	0	0	0

Table 1-3: Well 15 General Water Quality

ANALYTE	UNITS	DATA POINTS AVAILABLE	MIN	AVERAGE	MAX
GENERAL					
AGGRESSIVE INDEX		5	13	13	13
ALKALINITY, BICARBONATE AS CACO3	MG/L	5	170	178	190
ALKALINITY, CARBONATE	MG/L	5	0	0	0
ALKALINITY, TOTAL AS CACO3	MG/L	5	140	146	150
ALUMINUM	UG/L	4	0	0	0
ANTIMONY, TOTAL	UG/L	4	0	0	0
ARSENIC	UG/L	4	0	0.58	2.3
BARIUM	UG/L	4	430	497.50	570
BENZENE	UG/L	11	0	0	0
BERYLLIUM, TOTAL	UG/L	4	0	0	0
BORON	UG/L	2	150	195	240
CADMIUM	UG/L	4	0	0	0
CALCIUM	MG/L	5	120	144	170
CHLORIDE	MG/L	21	600	875.71	1100
CHROMIUM, HEX	UG/L	1	4.2	4.20	4.2
CHROMIUM, TOTAL	UG/L	4	0	0	0
COLOR		4	0	0	0
COPPER, FREE	UG/L	5	0	0	0
CYANIDE	UG/L	4	0	0	0
FLUORIDE	UG/L	4	0	102.50	150
FOAMING AGENTS (SURFACTANTS)	UG/L	5	0	0	0
HARDNESS, TOTAL AS CACO3	MG/L	5	650	778	910
HYDROXIDE AS CALCIUM CARBONATE	UG/L	5	0	0	0
IRON	UG/L	5	0	134	670
LANGELIER INDEX (PH(S))		5	0.58	0.68	0.74
LANGELIER INDEX @ SOURCE TEMP		1	0.32	0.32	0.32
LEAD	UG/L	4	0	0	0
MAGNESIUM	MG/L	5	86	103.80	120
MANGANESE	UG/L	5	0	0	0
MERCURY	UG/L	4	0	0	0
NICKEL	UG/L	4	0	0	0
NITRATE (AS N)	MG/L	33	3.16	5.48	7.2
NITRATE + NITRITE (AS N)	MG/L	2	5	5.80	6.6
NITRITE (AS N)	MG/L	4	0	0	0
ODOR THRESHOLD		4	0	0	0
PERCHLORATE	UG/L	4	0	0	0
PH, LAB		5	7.9	7.98	8.1
POTASSIUM	MG/L	5	4.9	5.62	6.3
SELENIUM	UG/L	4	0	0	0
SILVER	UG/L	5	0	0	0
SODIUM	MG/L	5	220	244	270
SPECIFIC CONDUCTANCE	UMHOS/CM	22	2400	2840.91	3200
SULFATE	MG/L	5	30	35.40	38
TDS	MG/L	39	1500	1805.13	2300
THALLIUM, TOTAL	UG/L	4	0	0	0
TURBIDITY, LAB		4	0	0.09	0.25
ZINC	UG/L	5	0	12	60
RADIOACTIVE					
GROSS ALPHA PARTICLE ACTIVITY	PCI/L	9	0.18	4.34	9.99
RADIUM-226	PCI/L	1	0.024	0.02	0.024
RADIUM-228	PCI/L	5	-0.077	0.32	1.7
COMBINED URANIUM	PCI/L	1	3.3	3.30	3.3
ORGANIC					
1,1-DICHLOROETHANE (1,1-DCA)	UG/L	11	0	0.10	0.61
1,2,3-TRICHLOROPROPANE	UG/L	6	0	0	0
BROMOFORM (THM)	UG/L	7	0	0.21	1.5
CHLOROMETHANE	UG/L	7	0	0	0
DIBROMOCHLOROPROPANE	UG/L	5	0	0	0
DICHLOROMETHANE (METHYLENE CHLORIDE)	MG/L	11	0	0	0
TETRACHLOROETHYLENE (PCE)	UG/L	11	0	0.10	0.56
TTHM	UG/L	7	0	0.21	1.5

Table 1-4: Well 11 Nitrate Levels

DATE	RESULT (µg/L)
6/7/1984	7
1/18/1989	4.38
9/25/1989	2.71
10/16/1990	6.33
4/28/1992	6.62
2/11/1993	0.2
7/1/1994	6.44
12/22/1994	1.69
3/8/1995	6.55
7/26/1995	7.45
11/28/1995	7.68
6/26/1996	7.68
9/19/1996	7.45
12/12/1996	7.45
3/28/1997	6.1
6/30/1997	8.13
4/7/1998	7.45
7/1/1998	6.78
12/10/1998	7.91
2/5/1999	7.45
6/30/1999	7.68
12/28/1999	7.45
3/9/2000	7.68
6/21/2000	7
9/13/2000	8.13
12/19/2000	7.23
3/14/2001	7.91
5/30/2001	7
9/25/2001	8.36
12/13/2001	9.04
3/12/2002	8.58
6/11/2002	8.36
9/4/2002	8.36
12/11/2002	7.91
2/12/2003	7.45
5/19/2003	8.81
8/4/2003	8.81
10/27/2003	8.58
2/2/2004	9.04
5/3/2004	8.58
8/2/2004	8.58
11/15/2004	8.36
2/14/2005	8.58
5/9/2005	8.81
8/9/2005	8.58
11/28/2005	8.81
2/13/2006	8.13
5/15/2006	9.04
7/24/2006	8.81
10/16/2006	8.58
2/12/2007	3.61
6/4/2007	11.75
7/16/2007	7.45
8/6/2007	9.71
8/13/2007	9.49
8/20/2007	9.26
9/4/2007	9.71
9/17/2007	9.04
10/1/2007	9.71
10/15/2007	9.04
10/29/2007	9.04
11/19/2007	9.04
1/7/2008	7.91
4/21/2014	10.62
5/21/2014	11.07
9/24/2020	10

Table 1-5: Well 11 Perchlorate Levels

DATE	RESULT (µg/L)
5/30/2001	8
12/13/2001	9.2
12/21/2007	10
1/4/2008	11
1/22/2008	ND
1/28/2008	11
2/4/2008	13
2/11/2008	11
2/19/2008	11
2/25/2008	11
2/18/2010	9.3
4/21/2014	11
5/21/2014	13
9/24/2020	13

1.3.2 2022 Water Quality Cycle Testing

The water quality data considered in Section 1.3.1 represents data available at the start of this study. Provost & Pritchard subsequently recommended that the City conduct additional testing to confirm the 2017 non-detect result for TCP and to characterize how nitrate levels vary with the duration of pumping.

It has been the experience of some Central Valley utilities that nitrate levels in certain wells drop as the well is pumped for longer periods of time. In these cases, blending the water produced by the well in a storage tank can be considered as a potential means of mitigating short-duration nitrate spikes. In order to determine if this is the case at Well 11, a cycle test was performed. On November 29, 2022, the well was pumped to waste for 10 minutes to purge the well casing after more than two years of non-operation. On November 30th, the well pump was again flushed to waste while samples were collected for nitrate analysis immediately following start-up and 5 minutes, 20 minutes, 1 hour, and 1 day following start-up. The nitrate concentrations measured during all five intervals of this cycle test were the same, 11 mg/L (as N). This indicates that nitrate levels are unlikely to change significantly with well run time and buffering of the water in a storage tank would be of no benefit to water quality.

Additional samples were collected on December 1st, at the conclusion of the 24-hour cycle test. Those samples were analyzed for TCP, DBCP, and EDB. TCP and EDB were not detected. DBCP was detected at a concentration of 0.075 µg/L, less than one-half of the 0.2 µg/L MCL

1.4 Applicable Regulations

Nitrate is regulated at the federal and state level with a MCL of 10 mg/L (reported as nitrogen). The Detection Limit for Purposes of Reporting (DLR) is 0.4 mg/L.

Perchlorate in drinking water is not regulated at the federal level but is regulated in California with a MCL of 6 μg/L. The DLR was recently reduced from 4 μg/L to 1 μg/L and the State Water Resources Control Board has stated that they will use new occurrence data resulting from the lower DLR to make a determination whether the MCL value should be lowered.

Both nitrate and perchlorate are regulated as acutely toxic substances and, as a result, any confirmed exceedance of their respective MCL values results in a violation of drinking water standards and the need for public notification. Compliance is not determined based on running annual average values as is the case for most regulated inorganic and organic contaminants.

1.5 Production and System Demand

Prior to Well 11 being taken out of service due to perchlorate contamination in 2008, the well was a significant source of supply for the system. Table 1-1 summarizes annual water production in million gallons per year for the City's water sources over the period of 2001 through August 31, 2020.

Table 1-6: Historical Water Production by Source

									2,500 AF Contract
	Well 11		Well 14		Well 15		Water Treatment Plant		USBR Allocation %
	MG	AF	MG	AF	MG	AF	MG	AF	
2001	173.01	530.95	0.08	0.26	236.62	726.17	305.39	937.21	
2002	50.44	154.8	0.05	0.16	37.24	114.28	689.42	2115.75	
2003	66.61	204.41	0.00	0.00	118.91	364.91	694.78	2132.2	
2004	9.11	27.95	0.00	0.00	129.27	396.72	672.85	2064.90	
2005	27.09	83.15	0.00	0.00	236.60	726.10	631.16	1936.96	
2006	233.15	715.51	0.00	0.00	0.00	0.00	537.00	1647.99	
2007	231.53	710.54	0.00	0.00	135.58	416.09	452.55	1388.82	
2008	0.00	0.00	0.00	0.00	297.71	913.64	671.96	2062.17	
2009	0.00	0.00	137.83	422.98	110.05	337.73	662.14	2032.03	
2010	0.00	0.00	219.46	673.51	75.98	233.18	591.17	1814.23	
2011	0.00	0.00	235.40	722.42	181.35	556.54	437.72	1343.31	
2012	0.00	0.00	193.75	594.59	298.43	915.85	382.71	1174.49	
2013	0.00	0.00	262.38	805.21	259.21	795.48	420.12	1289.30	55%
2014	0.00	0.00					198.77	610	0%
2015	0.00	0.00	170.94	524.59	313.2	961.17	246.35	756.02	0%
2016	0.00	0.00	110.22	338.25	251.6	772.13	431.41	1323.95	100%
2017	0.00	0.00	139.63	428.51	269.51	827.09	396.62	1217.18	100%
2018	0.00	0.00	64.7	198.56	175.09	537.33	548.25	1682.51	88%
2019	0.00	0.00	82.95	254.56	135.5	415.83	572.7	1757.55	100%
2020*	0.00	0.00	67.34	206.66	136.86	420.01	340.99	1046.46	65%

2 Non-Treatment Alternatives

2.1 Consolidation

The closest water system serving a population larger than Lindsay's is the City of Tulare, which is more than 10 miles away. Consolidation is therefore not a viable alternative.

2.2 Well Modification or Replacement

Well completion reports for the City's three wells are not available. However; the construction details in Table 2-1 were reported in DDW's 2013 Sanitary Survey Engineering Report for the City's system.

Table 2-1: Well Construction Characteristics

	Well 11	**Well 14**	**Well 15**
Capacity	1,400 gpm	750 gpm	1,100 gpm
Sanitary Seal Depth	150 ft	255 ft	200 ft
Well Depth	668 ft	415 ft	530 ft
Perforations	300-550	285-405	210-510

The source of both the nitrate and perchlorate contamination was likely the land application of fertilizers in the region surrounding Well 11. The origin of the contamination, the fact that a 150-foot sanitary seal has not prevented the contamination from migrating down to the aquifer supplying the well; and the single interval of continuous perforations indicate that modifying the existing well by filling in the bottom portion of the well or blinding off a portion of perforated casing is unlikely to be successful at mitigating the contamination.

The City investigated replacing Well 11 in 2019 by drilling a test well at the City park located northwest of the intersection of Avenue 232 and N Elmwood Avenue. Water quality analyses were performed on water collected at five discrete depth intervals (i.e. zone testing). Key water quality results are summarized in Table 2-2.

Table 2-2: 2019 Test Well Results

Depth Interval (feet bgs)	Units	MCL	213-225	276-283	330-335	357-368	462-468
Nitrate	mg/L (as N)	*10*	12	14	8.8	8.5	7.9
Perchlorate	µg/L	*6*	14	9.0	11	7.8	5.9
Aluminum	mg/L	*0.2/1**	0.053	ND	0.28	ND	1.8
Arsenic	µg/L	*10*	ND	ND	2.7	2.2	7.6
Chromium***	µg/L	*50/10**	25	ND	ND	ND	11
DBCP**	µg/L	*0.2*	ND	0.5	0.027	0.022	ND
Hardness	mg/L (as $CaCO_3$)	*NA*	420	220	260	240	150
Iron	mg/L	*0.3*	0.23	0.17	0.54	0.15	3.2
Manganese	mg/L	*0.05*	ND	ND	0.012	ND	0.046

* Primary/Secondary MCL
** All zones were also analyzed for TCP with a reporting limit of 0.7 ng/L and non-detect results.
*** The water was not specifically tested for hexavalent chromium, which has a proposed MCL of 10 µg/L. It is unknown whether the chromium is predominantly trivalent or hexavalent.

The test well results indicate that nitrate levels may drop below the MCL deeper than 330 feet bgs, however, levels are not expected to be lower than approximately 80% of the MCL. The lowest measured nitrate concentration of 7.9 mg/L occurred in the deepest zone. Perchlorate was present above the MCL at all depths except for the deepest zone, where the measured level was only 0.1 µg/L below the MCL value. The water quality observed at the deepest zone (462-468 bgs) also indicates that metals, including aluminum, arsenic, iron, manganese, and potentially chromium are all likely to be problematic at depths greater than the 468-foot test well. The results of the test well indicate that construction of a replacement well in the central part of the City is not a feasible solution.

Wells 14 and 15 currently produce water meeting all drinking water standards. However, Well 14 is contaminated with DBCP and was out of compliance with the DBCP standard from 2012 through 2016. Tetrachloroethylene (PCE) was detected at Well 15 as recently as 2019. Well 15 has also historically produced water with non-fecal coliform bacteria and, as a result, DDW requires that disinfection of the water produced by the well be achieved through chlorination and contact time within the transmission pipeline between the well and the City's water distribution system. Despite the water quality challenges at Wells 14 and 15, the area surrounding these wells would be the most likely location for construction of a new well to replace Well 11. However, even if the City could be certain that acceptable water quality would be produced by a new well located near Wells 14 and 15, there are several logistical challenges associated with construction of another well in that area. Wells 14 and 15 are located approximately 2.5 miles outside of the City limits. The City would need to acquire property for construction of the well, and this property would need to be situated such that the new well would not interfere with operation of the two existing City wells or the numerous private agricultural and domestic wells in the area. The existing 12-inch water transmission pipeline from Wells 14 and 15 into the City is not large enough to accommodate the additional flow from a third well. Therefore, additional right-of-way would need to be acquired and a new approximately 2.5-mile-long parallel transmission pipeline constructed to bring the water into the City. Modifications to the western portion of the City's water distribution system would also likely be required to efficiently distribute the concentrated flow coming from three wells.

2.3 Blending

Blending of the water from different sources is often considered for mitigation of nitrate contamination in order to avoid the high costs associated with treatment of that contaminant. Blending is also, on occasion, considered for anthropogenic contaminants, such as perchlorate, when no other feasible alternatives exist. For blending to be feasible, there must be a source of water with low enough concentrations of the targeted contaminants so that combining that water with the contaminated water will result in blended concentrations that are comfortably below the MCL values. The only potential source of blending water in this instance is the water being produced by Wells 14 and 15. The City's surface water treatment plant is located too far away from Well 11 for blending with surface water to be practical. Furthermore, as noted in Section 1, the City needs the water from Well 11 most when the surface water supply is unavailable. Wells 14 and 15 are located west of Well 11 outside of the City limits. Water from the two wells is conveyed to the city through a 12-inch transmission main along Highway 65 (W Tulare Road). The first service connection off of that transmission main is located approximately 1/8 of a mile east of Cedar Avenue. Approximately 3,200 feet of pipe would need to be constructed between Well 11 and the first service connection if blending was to be implemented.

Prior to the Well 11 being taken off-line due to perchlorate contamination in 2008, nitrate levels had trended gradually upward from approximately 6.8 mg/L (as N) in 1994 to 9 mg/L in 2008. The well has been tested for nitrate three times since 2008: twice in 2014 and once in 2020. Those three results ranged from 10 to 11 mg/L (as N). The recent cycle testing confirmed a current concentration of 11 mg/L. Nitrate concentrations at Wells 14 and 15 have ranged between 4.5 and 7.5 mg/L over the past five years. If the concentration of nitrate at Wells 14 and 15 is assumed to be 7.5 mg/L and Wells 14 and 15 are assumed to produce 750 and 1,200 gpm respectively, the nitrate concentration that would result if the water from all three wells was blended together would be 9 mg/L. The 1 mg/L difference between the potential blended nitrate concentration and the MCL provides inadequate margin of safety. A small rise in nitrate levels at any of the three wells would result in blending not being effective.

Over the period of 2001 through 2020, the perchlorate levels at Well 11 have varied between 8 and 13 µg/L with the two most recent samples measuring 13 µg/L. Perchlorate has not been detected at Wells 14 and 15 with reporting limits ranging from 2 to 4 µg/L. Even if the concentration of perchlorate in the water produced by Wells 14 and 15 is truly 0 µg/L, which is not certain, the perchlorate concentration that would result from all three wells being blended together would be 5.4 µg/L, or 90% of the current MCL. The 10% difference between the potential blended perchlorate concentration and the current MCL provides inadequate margin of safety. Furthermore, DDW is actively evaluating lowering the perchlorate MCL. Any decrease in the perchlorate MCL would result in blending being infeasible.

Irrespective of the fact that blending provides unacceptably low margins between blended nitrate and perchlorate levels and their respective MCLs, there are several additional issues associated with blending as a potential solution:

1. Blending would not work if either Well 14 or Well 15 were out of service. In essence the loss of either one of those two wells would also result in the loss of Well 11 or the need to violate the nitrate and perchlorate standards.

2. Tying operation of Well 11 to operation of the City's other two wells results in significantly less operational flexibility than if Well 11 were treated and remained an independently operated source.
3. Even if the surface water treatment plant were located closer to Well 11 so that blending could be considered, the surface water supply is not available when Well 11 would be needed most.

Blending is not a viable solution to either the nitrate or perchlorate contamination issues.

2.4 Surface Water

The City's existing CVP surface water supply is not reliable during drought years so replacing water from Well 11 with additional surface water is not feasible. During drought years, such as this year (2022), the City's allocation of CVP water is significantly curtailed and can be reduced to 0%. This is the primary reason for the city conducting this study and exploring alternatives to recover or replace the lost production from Well 11.

3 Treatment Alternatives

3.1 Treatment Process Alternatives

Three treatment processes have been demonstrated to be effective at removing perchlorate from drinking water: ion exchange, biological treatment, and reverse osmosis. The same three technologies are also those that have been demonstrated to be effective at removing nitrate from drinking water. Each of the three processes is discussed in more detail in the following sections.

3.1.1 Reverse Osmosis

Reverse osmosis (RO) treatment has been demonstrated to be effective at removing both perchlorate and nitrate from water. However, this process is impractical to implement at the municipal level in the Central Valley due to issues associated with waste disposal. RO membrane treatment produces a continuous "concentrate" waste stream. The percentage of the source water that becomes concentrate is a function of the water chemistry and the number of RO stages that are operated in series. Multiple RO stages involve the concentrate from one stage becoming the feed water for a subsequent stage. Even when three RO stages are used to minimize the generation of waste concentrate, the concentrate will comprise approximately 15% of the source water flow rate. Therefore, for Well 11, which produces approximately 1,400 gpm, a continuous concentrate waste stream of 210 gpm would be generated. The concentrate would contain levels of perchlorate, nitrate, and other raw water constituents at more than 8 times the raw water levels. It is unlikely that the Central Valley Regional Water Quality Control Board would permit this water to be discharged to land and the volumes involved are too great for evaporation to be economical. For these reasons, RO is not considered a viable solution.

3.1.2 Biological Treatment

Biological treatment under anaerobic conditions has been demonstrated to be effective for the treatment of both perchlorate and nitrate. Biological treatment has been used for remediation of perchlorate contamination of groundwater at several facilities in California. However, in most cases, perchlorate levels are significantly higher than at Well 11 and the treated water has not been used as a source of drinking water. One exception to that is a treatment plant at the West Valley Water District in Rialto, CA. West Valley operates a fluidized bed reactor biological treatment plant for drinking water contaminated with both nitrate and perchlorate. The only other California biological drinking water treatment plant Provost & Pritchard is aware of is a nitrate removal treatment plant operated by the City of Delano.

Biological treatment has the advantage of destroying the perchlorate and nitrate by converting them to carbon dioxide, nitrogen, chloride, and oxygen, meaning that no contaminated waste needs to be disposed of. However, biological treatment results in several permitting and operability issues. Some of the more significant obstacles to implementation of biological treatment of drinking water include:

- Biological treatment systems function most reliably when operated continuously or near-continuously. If biological treatment were added to Well 11, the City would need to modify its water supply approach such that Well 11 would become a primary source of supply, which would limit operational flexibility.
- Biological treatment processes are operationally complex and typically involve the addition of several chemicals and extensive instrumentation. For example, 6 chemicals are used at the Delano nitrate treatment plant. Figure 3-1 illustrates a typical fixed bed bioreactor process flow diagram.
- The City of Delano reports that significant operator attention is required to keep their treatment plant operational. Delano assigns a near full-time operator to the nitrate treatment plant when it is in operation.
- There is the potential for the bacteria to convert sulfate to sulfide, which would then need to be removed through post-treatment.
- In permitting a biological treatment plant, DDW will impose post-treatment requirements similar to those imposed on a surface water treatment plant. This will include filtration, disinfection log-inactivation through CT, and monitoring requirements.
- Given the limited operational experience with biological treatment in California, it is recommended, and anticipated that DDW will require, that a pilot study be performed before proceeding with a full-scale biological treatment process.

While it is technologically feasible to treat Well 11 for both nitrate and perchlorate using biological treatment, this process is not recommended due to the significant operability and permitting concerns.

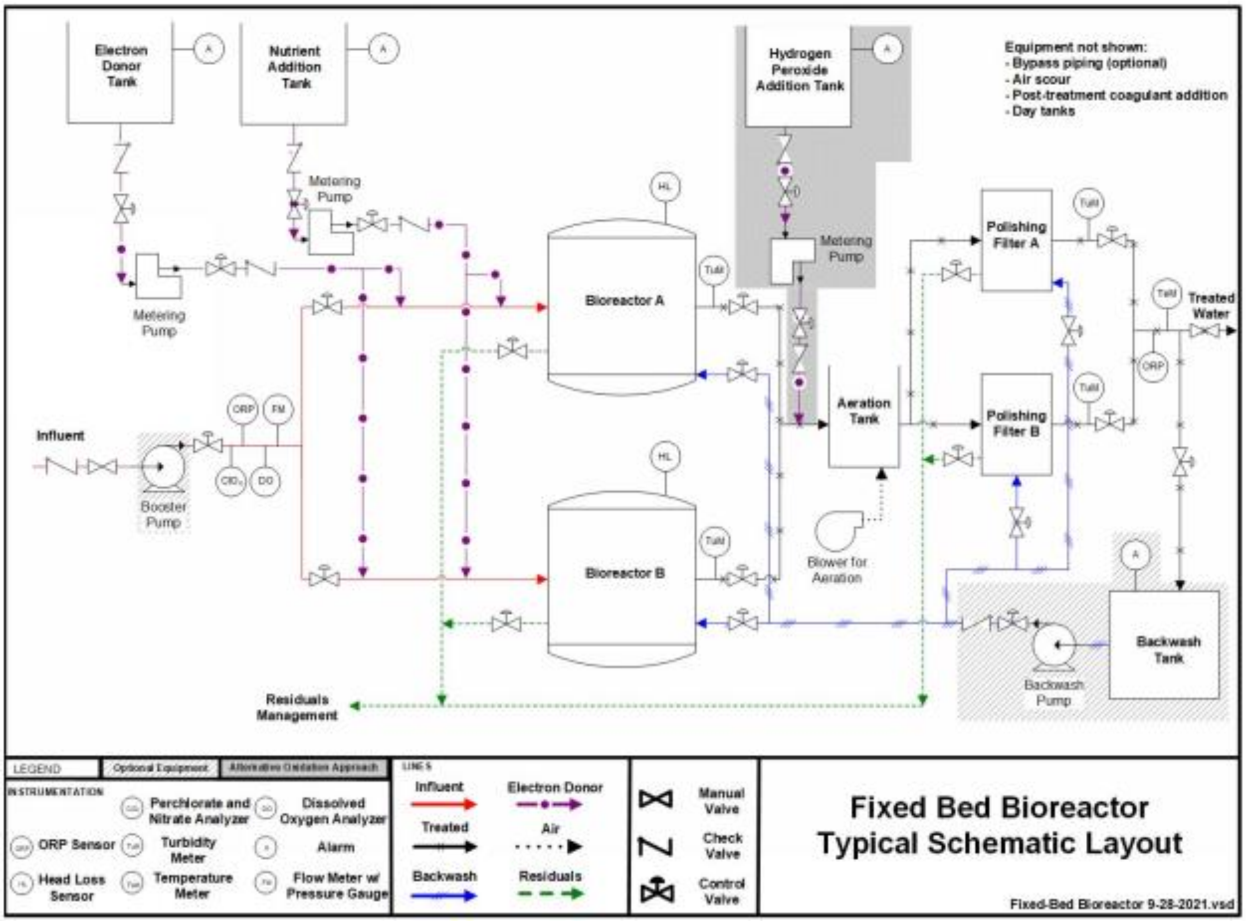

Figure 3-1: Fixed Bed Bioreactor Typical Layout (Source: EPA WBS Cost Model)

3.1.3 Ion Exchange

Ion exchange is the most commonly used treatment process for removal of perchlorate and/or nitrate from drinking water. Ion exchange - more specifically anion exchange, utilizes a synthetic resin to exchange negatively charged nitrate and/or perchlorate ions in the water for negatively charged chloride ions pre-loaded on the resin. Typical anion exchange resins preferentially remove anions other than nitrate and perchlorate from the water (e.g. sulfate and bicarbonate), which results in a reduction in the resin capacity available to remove the nitrate and/or perchlorate being targeted. To help improve the resin performance in the presence of high concentrations of these competing ions, resin manufacturers have developed special "nitrate-selective" and "perchlorate-selective" resins. As described below, the approach to implementing ion exchange for nitrate and perchlorate is different.

For nitrate treatment, irrespective of whether a nitrate-selective resin is used, the resin will become exhausted and no longer efficiently remove nitrate from the water in a relatively short period of time - on the order of hours or a few days. When this occurs, the resin will need to be regenerated by soaking it in a concentrated salt brine solution. A solution of approximately 10% sodium chloride is often used. The brine solution left over from regeneration of the resin, which will contain high concentrations of nitrate and other anions removed from the water, must then be disposed of.

Waste brine generation can be partially minimized using techniques such as recycling of regeneration rinse water. The brine generated by a nitrate treatment plant incorporating brine-minimization techniques typically comprises between 0.25 and 0.5% of the volume of water treated. Because the nitrate levels at Well 11 are only slightly greater than the MCL value, another approach to minimizing brine waste would be to only treat a portion of the flow produced by the well (i.e. side stream treatment). If a raw water nitrate level of 13 mg/L is assumed and a treated water nitrate level of 8 mg/L (as N), is targeted, only approximately 45% of the water produced by the well would need to be treated through the ion exchange system. The remaining 55% of the flow could be bypassed around the nitrate treatment process. This bypass ratio could be adjusted to compensate for higher or lower raw water nitrate levels. Implementing both rinse water reclaim and side-stream treatment at Well 11 would result in the generation of approximately 4,770 gallons of waste brine per 24 hours of operation. In inland areas such as the Central Valley, the two most feasible means of disposing of this brine are to discharge it into evaporation ponds or to haul it off to an approved disposal facility, which will typically be a coastal wastewater treatment plant.

Because raw water perchlorate levels are so much lower than nitrate levels (µg/L compared to mg/L), it is economical to use perchlorate-selective resin in a single-use mode that involves disposing of the resin when it becomes exhausted instead of regenerating it. Once the perchlorate resin is exhausted and perchlorate is detected in the lead vessel effluent, the resin must be changed out and the spent resin incinerated. Placing a separate perchlorate treatment system upstream of nitrate treatment also offers the significant benefit of avoiding contamination of the nitrate treatment waste brine with perchlorate. The approach of placing non-regenerable perchlorate-selective ion exchange treatment upstream of regenerable nitrate ion exchange treatment is one that has been successfully implemented by other California water utilities and is the approach recommended at Well 11 if treatment is the solution ultimately selected.

3.2 Treatment Plant Design Parameters

As noted in Section 3.1, it is recommended that treatment of the water be accomplished in two stages. The first stage would consist of a single-use perchlorate-selective ion exchange system for removal of perchlorate from the water. The second stage would consist of a regenerable ion exchange system for removal of nitrate from the water. The full 1,400-gpm flow from the well would be treated by the perchlorate removal system whereas only approximately 630 gpm would be treated through the downstream nitrate removal system. Following are preliminary design parameters for both treatment systems.

3.2.1 Perchlorate Treatment

Ion exchange resins are susceptible to being blinded off by even low levels of sediment of other suspended solids that may be present in the raw water. In single-use resin applications, the vessels cannot be backwashed after being placed into service to remove solids accumulated on top of the resin. Doing so would disrupt the mass transfer zone and likely result in premature breakthrough of perchlorate in the treated water. For this reason, manufacturers recommend that five-micron bag or cartridge filters be placed upstream of the perchlorate treatment ion exchange system.

Purolite, a manufacturer of specialized ion exchange resins, was contacted to assist in establishing preliminary system operational parameters and to estimate resin life. Based on Purolite's recommendations, a single pair of 12-foot diameter vessels operated in series has been assumed. This results in the following operating conditions:

Table 3-1: Perchlorate Treatment Process Design Parameters

Parameter	Recommended Range	Proposed Value
Design raw water perchlorate		13 ppb
Treatment objective		Non-detect (< 1 ppb)
Flow Rate		1,400 gpm
Resin		Purolite A532E (Perchlorate Selective)
Vessel configuration	Lead-lag	Lead-lag
Number of vessels		2
Vessel diameter		12 ft
Vessel area		113 ft^2
Resin load per vessel		420 ft^3
Bed depth	3.7 ft min.	3.7 ft
Loading rate	6 - 18 gpm/ft^2	12.4 gpm/ft^2
Specific flowrate	1 – 5 gpm/ft^3	3.3 gpm/ft^3
Empty bed contact time	1.5 -2.5 minutes (lead vessel)	2.2 minutes

Based on the water quality characteristics at Well 11, Purolite estimates that the resin in the lead vessel will last for 60,000 bed volumes (BV), which is equivalent to 188 million gallons (MG) treated before needing to be replaced.

3.2.2 Nitrate Treatment

Preliminary sizing of a regenerable ion exchange nitrate treatment system was established using Purolite's Resin System Modeling (PRSM) software. The results of the PRSM analysis were also confirmed with a Purolite technical expert. The PRSM analysis resulted in the preliminary treatment system configuration described in Table 3-2. It is noted that, for the relatively low sulfate levels at Well 11, use of a higher capacity Type 1 resin (such as Purolite A600E/9149) is predicted to result in lower waste volumes than if a nitrate selective resin was used.

Table 3-2: Nitrate Treatment Process Design Parameters

Parameter	Proposed Value
Design raw water nitrate	13 mg/L as N
Treatment objective	8 mg/L as N
Design plant flow rate	1,400 gpm
Resin	Purolite A600E/9149 (High cap. Type 1)
Flow treated through IX	630 gpm
Flow bypassed around IX	770 gpm
Number of vessels	3 (2 in service)
Flow rate per vessel	315 gpm
Vessel diameter	7 ft
Vessel area	38.5 ft^2
Resin load per vessel	155 ft^3
Bed depth	4 ft
Loading rate	8.2 gpm/ft^2
Specific flowrate	2.03 gpm/ft^3
Regeneration water reclaim	50% of slow rinse and 100% of fast rinse water reclaimed

This vessel configuration – three 7-foot diameter vessels with 2 in service at any given time, represents one of several possible system arrangements. Configurations with two larger vessels with only one vessel in service or configurations incorporating more than three vessels could also be used. Generally, systems utilizing a greater number of vessels should result in some increase in process efficiency and waste reduction. However, this would come at the expense of greater capital costs, a larger footprint, and increased operational complexity. Because disposal of waste brine is anticipated to be the largest operating cost item, it is recommended that the system include brine minimization features including a system that permits all of the high-rate rinse and approximately half of the slow-rate rinse water used during regeneration to be reclaimed. Only the brine and a portion of the slow-rate rinse water would be sent to the waste tank for disposal.

The process performance parameters resulting from the configuration described above are summarized in Table 3-3.

Table 3-3: Nitrate Treatment Process Performance

Parameter	Predicted Value (In terms of water treated through IX vessels)	Predicted Value (In terms of water produced by well)
Vessel cycle duration	29 hours	-
Net water per vessel/cycle[1]	548.1 kgal	1,234 kgal
Salt dosage	10 lbs/ft^3	-
Salt load per vessel/cycle[2]	1,550 lbs	-
Salt usage	2.83 lbs/kgal	1.4 lbs/kgal
Percent of water through IX that becomes waste brine	0.53%	0.23%
Waste generated per vessel/cycle[2]	2,890 gal	-
Waste generated per full day of operation	4,770 gal	

[1] This value represents the volume of water that will be produced by one of the three vessels before regeneration of that vessel is required.

[2] This value is for regeneration of one vessel only. Regeneration of the three vessels will be staggered with two vessels in service at any one time.

3.2.3 Nitrate Treatment Waste Management

The perchlorate treatment system will generate only a small volume of waste during backwashing, which only occurs when resin is changed out. This backwash waste will be nonhazardous, will not include brine, and should be of a quality that can be discharged into the adjacent storm water basin. Conversely, the nitrate treatment process will generate waste brine daily. Provided the perchlorate is removed upstream of the nitrate treatment plant, the nitrate treatment brine should be classified as nonhazardous. However, the brine will be very high in total dissolved solids (i.e. salt) and will also contain elevated levels of nitrate and other anions the treatment system removes from the water. The two most feasible brine disposal alternatives for inland water systems are lined evaporation ponds and hauling the brine off to be disposed of at a coastal wastewater treatment plant.

On-Site Evaporation Ponds:

For the on-site evaporation alternative, a total of approximately 1.5 acres of ponds would be required. This assumes the monthly production volumes, evaporation rates, and rainfall amounts listed in Table 3-4. The monthly production values represent approximately 100% duty cycle during the summer months and 33% duty cycle during winter months, with spring and fall months falling in between.

Table 3-4: Evaporation Pond Sizing Assumptions

Month	Assumed Well 11 Production (MG)	Monthly Evaporation (inches)[1]	Monthly Precipitation (inches)[2]
January	20	1.0	2.25
February	20	1.5	2.18
March	30	2.6	2.00
April	40	3.9	1.25
May	50	5.3	0.49
June	60	6.0	0.10
July	60	6.2	0.08
August	60	5.5	0.01
September	50	4.2	0.07
October	40	2.9	0.65
November	30	1.4	1.11
December	20	0.4	1.92
TOTAL	**480**	**41.1**	**12.11**

[1] From California Irrigation Management Information System (CIMIS) reference evapotranspiration zones (2012). A factor of 1.1 was applied to the evapotranspiration values to account for an open water body based on UC Publication 21427. A factor of 0.7 was applied to the evapotranspiration values to account for the reduced evaporation rates as brine concentration increases.

[2] From NOAA climate data for Lindsay, CA

The following evaporation pond design features have been preliminarily assumed. These assumptions would need to be confirmed through coordination with the Central Valley Regional Water Quality Control Board during pre-design:

- The pond depth required for operational storage (balancing inflows and evaporation throughout the year) would be minimal (less than 1 foot). However, several feet of additional depth would be required for solids accumulation and freeboard. A 6-foot total depth has been assumed.
- The ponds would need to be lined to prevent percolation of salts into the underlying groundwater. The most practical lining material for this pond configuration would be polyethylene. It has been assumed that the ponds will need to be double-lined
- A pond leakage detection system, including lysimeters, will likely be required.
- Netting over the ponds and potentially other wildlife deterrents may be required.

Operation and maintenance associated with the evaporation pond alternative would consist of monitoring the ponds for leakage, occasional removal of crystalized salt from the bottom of the ponds and repair of the liner as necessary. The rate that solids will build up in the ponds can be approximated by the salt load used for regeneration of the ion exchange resin: 1.4 lbs per 1,000 gallons of water produced by the well.

The well is located adjacent to an approximately 8-acre storm water basin. The City also owns an additional approximately 3-acre parcel adjacent to the southwestern portion of the storm water basin (refer to Figure 3-2). This additional parcel should be large enough to accommodate the proposed evaporation ponds.

Off-Site Disposal of Brine

The other alternative for managing the brine waste is to haul it to a coastal wastewater treatment plant where it would ultimately be discharged into the ocean. East Bay Municipal Utility District (EBMUD) in Oakland accepts brine. There may also be facilities in Southern California that accept brine. Infrastructure required for off-site disposal of the brine would consist of waste holding tanks with air-gap inlets and truck hook-ups. Waste brine would need to be hauled off approximately daily during periods when the well was in service at a 100% duty cycle.

Between these two alternatives, disposal into evaporation ponds will result in significantly lower operating costs compared to hauling the brine to a coastal wastewater treatment plant. Capital and O&M cost differences for the two disposal alternatives are presented in Section 4.

Figure 3-2: Well 11 Vicinity Map and City Property

3.3 Incidental Water Quality Impacts

The addition of any treatment process that results in a change to the raw water chemistry has the potential to result in unintended impacts to distribution system water quality. The ion exchange process proposed for Well 11 will result in the exchange of anions such as nitrate, sulfate, and bicarbonate, with chloride ions pre-loaded onto the resin. Nitrate and sulfate levels will be lower in the treated water than in the raw water. Bicarbonate levels will also be lower during the early phase of a vessel operational cycle. Chloride levels will be correspondingly higher in the treated water than in the raw water.

California drinking water standards include secondary consumer acceptance contaminant level ranges for chloride. The recommended, upper, and short-term limits are 250, 500, and 600 mg/L respectively. If ion exchange treatment is implemented at Well 11, the resulting chloride level will exceed the recommended value of 250 mg/L. This exceedance, by itself, is unlikely to result in the treatment plant not being permitted by DDW.

Elevated ratios of chloride to sulfate (Cl/SO_4), known as the chloride-to-sulfate mass ratio (CSMR), have been associated with galvanic corrosion and leaching of lead from lead-tin solders and consumer plumbing. The current CSMR at Well 11 averages 5.5, which is considered high. Implementing ion exchange treatment will result in an increase in the CSMR. Raw and treated water alkalinity, chloride, sulfate, and CSMR values are summarized in Table 3-5. The values of these parameters at Well 15 have also been included for the purpose of comparison.

Table 3-5: Chloride and Sulfate Levels

	Well 11 Raw Water	Well 11 Ion Exchange Effluent	Well 11 Treatment Plant Effluent	Well 15 Raw Water
Alkalinity (mg/L as $CaCO_3$)	128	128	128	146
Chloride (mg/L)	233	317	270	876
Sulfate (mg/L)	42	0	23	35
CSMR	5.5	-	11.7	25

The actual impact of the increase in CSMR at Well 11 on lead levels is difficult to predict, particularly given the water's moderate alkalinity level, which may act to mitigate the effects of elevated CSMR. Well 15, which has been in active use for many years, produces water with chloride and CSMR values that are significantly higher than those predicted for the Well 11 treatment plant. However, it is noted that the City experienced a lead action level exceedance during the 2019-2021 monitoring period.

At a minimum, if ion exchange treatment is added to Well 11, the City should provide increased lead monitoring at consumer taps following treatment plant startup to quickly identify any potential rise in lead levels. It is also recommended that the treatment plant design include provisions for the addition of a corrosion control chemical such as an orthophosphate or silica-based corrosion inhibitor if lead levels do rise.

4 Cost Estimates

4.1 Capital Costs

The estimated capital project costs for the perchlorate and nitrate treatment plant described in Section 3.2 are summarized in Table 5-1.

Table 4-1: Capital Cost Opinion (Evaporation Ponds)

Bid Item	**Cost**
Site demolition, clearing and grubbing	$20,000
Perchlorate treatment vessels w/ initial load of resin	$750,000
Perchlorate vessel installation and testing	$45,000
Perchlorate IX vessel foundation	$45,000
Pre- and post-treatment cartridge filters	$100,000
Nitrate IX system with tanks, resin, controls, and softener	$1,000,000
Nitrate IX system foundations	$75,000
Installation of IX system	$100,000
Yard piping	$250,000
Pipe to evaporation pond (500 ft)	$50,000
Electrical and controls	$400,000
Well pump upgrades (to overcome head loss)	$100,000
Miscellaneous site work, paving, vaults, fences	$200,000
Evaporation ponds (1.5 acres, double lined)	$650,000
Mobilization (5%)	$157,000
Subtotal Estimated Bid Cost	$3,942,000
Estimate contingency (25%)	$985,500
Subtotal Estimated Construction Cost	$4,927,500
Engineering Design (8%)	$394,200
Construction Management and Inspection (7%)	$344,900
Environmental, Legal, Administration (5%)	$246,400
Operations Plan and permitting	$30,000
Total Capital Cost	$**5,943,000**

If the City was to haul brine off-site to a coastal wastewater treatment plant for disposal, the capital cost would be reduced as shown in Table 5-2.

Table 4-2: Capital Cost Opinion (Off-Site Brine Disposal)

Bid Item	**Cost**
Site demolition, clearing and grubbing	$20,000
Perchlorate treatment vessels w/ initial load of resin	$750,000
Perchlorate vessel installation and testing	$45,000
Perchlorate IX vessel foundation	$45,000
Pre- and post-treatment cartridge filters	$100,000
Nitrate IX system with tanks, resin, controls, and softener	$1,000,000
Nitrate IX system foundations	$75,000
Installation of IX system	$100,000
Yard piping	$250,000
Pipe to evaporation pond (500 ft)	$50,000
Electrical and controls	$400,000
Well pump upgrades (to overcome head loss)	$100,000
Miscellaneous site work, paving, vaults, fences	$200,000
Waste tanks	$50,000
Mobilization (5%)	$157,000
Subtotal Estimated Bid Cost	$3,342,000
Estimate contingency (25%)	$835,500
Subtotal Estimated Construction Cost	$4,177,500
Engineering Design (8%)	$334,200
Construction Management and Inspection (7%)	$292,400
Environmental, Legal, Administration (5%)	$208,900
Operations Plan and permitting	$30,000
Total Capital Cost	**$5,043,000**

4.2 O&M Costs

O&M costs associated with the proposed treatment plant include replacement of perchlorate system resin, purchasing salt for nitrate system resin regeneration, an increase in pumping power, labor, laboratory fees, replacement cartridge filters, brine disposal, and maintenance. Of these costs, labor, laboratory fees, and maintenance have been considered fixed costs and resin, salt, power, cartridge filters, and brine disposal have been considered variable – a function of the volume of water treated.

The estimated O&M costs assuming on-site brine disposal in evaporation ponds is summarized in Table 4-3. It should be noted that there is significant uncertainty in the cost to dispose of the dried salt that will accumulate in the bottom of the evaporation ponds. O&M costs for two assumed annual production volumes: 100 MG and 250 MG have been presented to illustrate the economies of scale associated with higher annual production volumes. These economies of scale result from spreading the fixed costs (labor, laboratory, and maintenance over a larger volume of water produced.

Table 4-3: O&M Cost Opinion (Evaporation Ponds)

Item	**Annual Cost**
Labor[1]	$39,000
Laboratory[2]	$1,690
Maintenance[3]	$79,000
Subtotal fixed O&M costs	**$119,690/Year**
Item	**Cost/kgal**
Power[4]	$0.03
Perchlorate Resin[5]	$0.74
Salt[6]	$0.25
Solids Disposal[7]	$0.04
Subtotal variable O&M costs	**$1.06/kgal**
Total O&M Cost (100 MG/year)	**$225,690/year ($2.26/kgal)**
Total O&M Cost (250 MG/year)	**$384,690/year ($1.53/kgal)**

[1] Labor cost is based on 10 hours per week plus 15 minutes per perchlorate sample at $70/hour.

[2] Laboratory perchlorate testing. Assumes raw, lead vessel, and finished water are sampled monthly at a cost of $47/sample.

[3] 2% of estimated construction cost.

[4] Assumes 15 psi total head loss across treatment plant

[5] Assumes 60,000 BV life and $330/f^3 resin replacement cost.

[6] Based on Purolite PRSM output (2.83 lbs NaCl per kgal through IX vessels / 1.4 lbs NaCl per kgal produced by well with 55% bypass. Assumes $400/ton for salt.

[7] Assumes 1.4 lbs solids consisting primarily of NaCl per kgal produced by well and $50/ton disposal cost.

Resin replacement will be the largest O&M cost item. Based on the historical geochemical water quality at Well 11, Purolite predicts that breakthrough of perchlorate into the effluent of the lead vessel will occur after 60,000 bed volumes have been treated. This is equivalent to 188 million gallons treated. The cost of changing out the resin in the lead vessel, including service and disposal of the spent resin, is estimated to be $140,000.

Table 4-4: O&M Cost Opinion (Off-Site Brine Disposal)

Item	**Annual Cost**
Labor[1]	$39,000
Laboratory[2]	$1,690
Maintenance[3]	$67,000
Subtotal fixed O&M costs	**$107,690/Year**
Item	**Cost/kgal**
Power[4]	$0.03
Perchlorate Resin[5]	$0.74
Salt[6]	$0.25
Brine Disposal[7]	$1.07
Subtotal variable O&M costs	**$2.09/kgal**
Total O&M Cost (100 MG/year)	**$316,690/year ($3.17/kgal)**
Total O&M Cost (250 MG/year)	**$630,190/year ($2.52/kgal)**

[1] Labor cost is based on 10 hours per week plus 15 minutes per perchlorate sample at $70/hour.

[2] Laboratory perchlorate testing. Assumes raw, lead vessel, and finished water are sampled monthly at a cost of $47/sample.

[3] 2% of estimated construction cost.

[4] Assumes 15 psi total head loss across treatment plant

[5] Assumes 60,000 BV life and $330/f^3 resin replacement cost.

[6] Based on Purolite PRSM output (2.83 lbs NaCl per kgal through IX vessels / 1.4 lbs NaCl per kgal produced by well with 55% bypass. Assumes $400/ton for salt.

[7] Assumes $450 per 1,000 gallons of brine including transportation and disposal.

The payback for the additional capital costs associated with construction of on-site evaporation ponds is anticipated to be less than 10 years.

5 Recommendation

Non-treatment alternatives including consolidation, well replacement, blending, and increased reliance on surface water were considered and determined to be not feasible. There are no nearby large water systems with which consolidation can be considered. An analysis of blending Well 11 water with water produced by Wells 14 and 15 was conducted, and under the best-case blending conditions, with both Wells 14 and 15 assumed to be in service and operating at their design capacity, blending results in nitrate and perchlorate concentrations within 10% of their respective MCL values. The City's existing surface water allocation is not reliable and hence increasing reliance on surface water is not a solution to the City's problem. Among the non-treatment alternatives, constructing a new well 2.5 miles west of the City appears to be the only potentially feasible alternative. However, other water quality issues have been encountered in that area and there are numerous logistical challenges with constructing a third well outside of the city limits.

Treating Well 11 appears to be the best alternative available to the City and is the project that could be implemented in the shortest period of time. Treatment for both perchlorate and nitrate would be accomplished utilizing ion exchange treatment processes. Perchlorate would first be removed utilizing a single-use perchlorate-selective ion exchange resin. Nitrate would then be removed using a regenerable ion exchange treatment system. The most economical means of managing the waste brine from the nitrate treatment process is to discharge it to new evaporation ponds located southwest of the well on property already owned by the City.