Winton Water and Sanitary District: Treatment Technologies and Costs to Treat 1,2,3-Trichloropropane

Final Report

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Prepared by Corona Environmental Consulting, LLC

CORONA ENVIRONMENTAL CONSULTING

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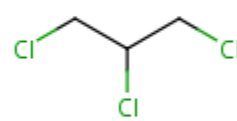
Introduction

Winton Water and Sanitary District (Winton) has engaged Corona Environmental Consulting, LLC (Corona) to assess treatment technologies and costs to treat 1,2,3-trichloropropane (1,2,3-TCP). Both the U.S. Environmental Protection Agency (USEPA) and the State of California have determined that 1,2,3-TCP is a probable human carcinogen at low levels. The State of California has yet to release a draft rule regulating 1,2,3-TCP in drinking water. Winton has three of their four groundwater wells contaminated with detectable levels of 1,2,3-TCP. The purpose of this report is to evaluate the performance of 1,2,3-TCP treatment technology alternatives and develop costs for these technologies to be able to plan for future capital improvements and rate setting. This report incorporates a technology evaluation including GAC adsorption, aeration, and oxidative processes for applicability to Winton's system water quality for costs and performance. Based on the technology evaluation, well specific cost estimates are presented for 1,2,3-TCP treatment.

TCP Properties, Regulation, and Treatment Objectives

TCP is an anthropogenic contaminant occurring in agricultural areas from land application of certain nematicides that contained 1,2,3-TCP as an impurity. The physical properties of 1,2,3-TCP are presented in Table 1.

Table 1 Physical properties of TCP at 25°C

Contaminant	Units	1,2,3-trichloropropane ($C_3H_5Cl_3$)
Structure		
Molecular weight	g/mol	147.43
Solubility	mg/L	1,750
Specific gravity		1.39
log octanol-water (Kow)		2.27
Henry's law constant	dimensionless	0.0139

Both the USEPA and the State of California are in the process of developing regulations for 1,2,3-TCP in drinking water. The USEPA has identified 1,2,3-TCP as a likely candidate to be regulated under the group carcinogenic volatile organic compound (cVOC) rule. 1,2,3-TCP is included in the third unregulated contaminants monitoring rule (UCMR3) at a reporting level of 0.03 µg/L (equivalent to parts-per-billion, or 30 ng/L), which indicates the lowest concentration to be considered on a national level. However, in 1999, California Department of Public Health established a notification level of 0.005 µg/L (5 ng/L). Additionally, in 2009 the California Office of Environmental Health and Hazard Assessment set a public health goal of 0.0007 µg/L (0.7 ng/L). It is Winton's intent to treat 1,2,3-TCP to below detectable levels to avoid potential health hazards. California's current 1,2,3-TCP detection limit for purposes of reporting (DLR) is 0.005 µg/L (5 ng/L). More recently, 1,2,3-TCP detection methods have been developed to measure as low as 0.0007 µg/L (0.7 ng/L). The treatment objective for Winton's water system is to remove 1,2,3-TCP to non-detect levels, <0.005 µg/L (<5 ng/L).

California's Extremely Impaired Drinking Water Sources

If the raw water concentration of a contaminant with non-acute health effects is greater than 10 times the maximum contaminant level (MCL), then the water source is classified as "extremely impaired" by the State of California. Additionally, waters with low raw water concentrations of regulated contaminants, but experience co-occurring contaminants, may also be classified as extremely impaired. Classification as an extremely impaired water could have system wide impacts on Winton depending on a future 1,2,3-TCP MCL.

Extremely impaired waters are subject to additional permitting, monitoring, and public notification requirements. Extremely impaired waters must use the defined best available technology (BAT) and under certain circumstances may be required to employ multi-barrier treatment. Though not explicitly stated, the State of California has interpreted the extremely impaired waters rules to mean that the contaminant should be treated to non-detect at all times. Therefore, classification as an extremely impaired water may dictate the required treatment technology and associated costs on a site specific basis after an MCL is promulgated.

Water System Overview

The Winton drinking water system (PWSID CA2410010) is comprised of four groundwater wells, three of which are active. Figure 1 displays the locations of the four groundwater wells with the active wells in dark-blue and the standby well in yellow. The Winton drinking water system serves a population of approximately 8,500 people in Merced County.

[redacted]

Data Collection

The results of this report are based on information collected during site visits, operator interviews, water quality monitoring data, and other operational data provided by Winton.

Site Visits

Corona visited all four of Winton’s wells. On each site visit, representatives of Winton were available to answer questions about each source. Site visits were designed to obtain information about the existing treatment system, the available footprint at each site, and collect operational data that may not be otherwise available in a recorded format. Site visits were also used to verify the validity of the other data collected. A site visit log for each impacted source is presented in Appendix A – Site Visit Logs.

Water Quality Data

Corona obtained water quality data for all four wells from the California State Water Resources Control Board Division of Drinking Water (DDW) database and directly from BSK Labs, Winton's contract water quality analytical laboratory, for data not available in the DDW database. Data included 1,2,3-TCP sample results; background water quality data such as pH, alkalinity, total dissolved solids; and co-occurring contaminant data. We also reviewed data for the following potentially co-occurring organic contaminants: trichloroethylene (TCE), tetrachloroethylene (PCE), 1,2-dibromo-3-chloropropane (DBCP), and ethylene dibromide (EDB); and the following potentially co-occurring inorganic contaminants: iron, manganese, arsenic, chromium, and nitrate. Water quality data are summarized for each well by reporting the number of samples (count), the average, minimum, and maximum concentrations. A table of the water quality summary is presented in Appendix B – Historical Water Quality Summary. Figures presenting concentration versus time for 1,2,3-TCP for individual wells are presented on the site visit log sheets in Appendix A – Site Visit Log.

Operational Data

Operational data were collected from Winton and supplemented by site visits. Operational data consisted of the pump type, treatment system, flow rate, well utilization, and well performance (sanding, air, etc.). Well flow rates were obtained from Winton's operation staff records during site visits and well pumping data were obtained dating back to 2012. Utilization rates were calculated based on historical pumping records.

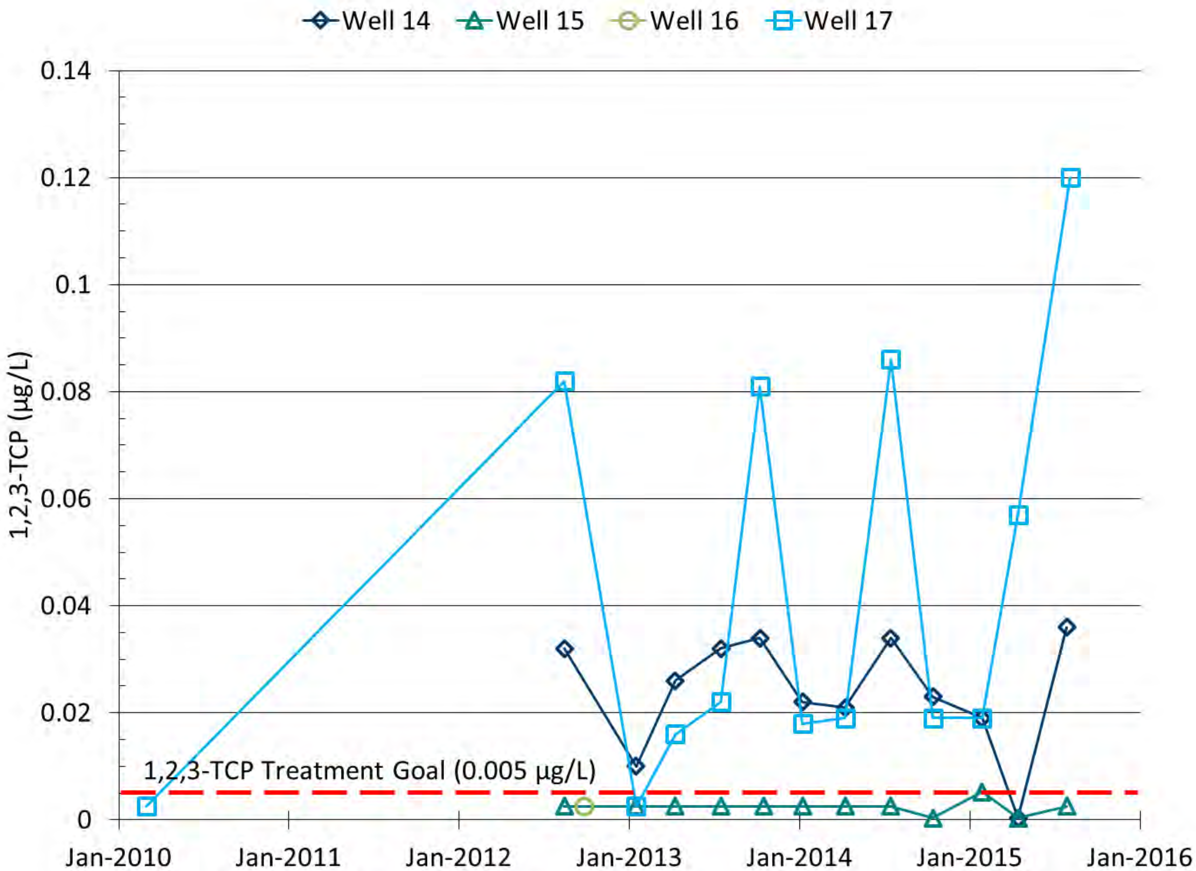
Water Quality

The treatment effectiveness and cost impacts of each of the treatment alternatives will be dictated by the 1,2,3-TCP concentration, the background water quality, and the presence of co-occurring contaminants in the source water. 1,2,3-TCP results for the past five years (2010-2015) and general water quality for the past ten years (2005-2015) are summarized below.

All 1,2,3-TCP results from 2003 to 2010 were analyzed using a high detection limit of 0.5 µg/L (500 ng/L) and were reported as non-detect; therefore, these results were not included in this analysis. Figure 2 shows the historical 1,2,3-TCP concentrations from 2010 to May 2015. The maximum 1,2,3-TCP concentration in Well 14 is 0.034 µg/L and the minimum is non-detect. The maximum 1,2,3-TCP concentration in Well 15 is 0.0052 µg/L and the majority of the results have been reported as non-detect. Well 16 has one 1,2,3-TCP sample analyzed in the last five years, in 2012, and resulted in non-detect. Well 17 has a maximum observed concentration of 0.120 µg/L and a single non-detect result in 2012. 1,2,3-TCP concentrations reported as non-detect are displayed in Figure 2 as half of the 0.005 µg/L detection limit (0.0025 µg/L), or 0.00035 µg/L for results reported in the last quarter of 2014 and 2015 which were analyzed to the lower detection limit of 0.0007 µg/L.

Wells requiring 1,2,3-TCP treatment have historical results above the 0.005 µg/L treatment objective. Based on this objective, Well 14 and Well 17 require 1,2,3-TCP treatment. Due to the recent detection of 1,2,3-TCP just above the DLR in Well 15, we have included Well 15 in this analysis as a well requiring treatment out of an abundance of caution. Additional 1,2,3-TCP sampling and analysis for Well 15 is recommended in order to determine whether treatment will indeed be needed at Well 15.

Figure 2 Historical 1,2,3-TCP concentrations in Winton's four groundwater wells (2010 through May, 2015)



[redacted] the Central Valley Regional Water Quality Control Board's direction, the responsible parties engaged Trihydro Corporation to evaluate the nature and extent of 1,2,3-TCP and nitrate in groundwater emanating from the facility (Tryhydro Corporation, 2015). Figure 3 shows the [redacted]

[redacted]

µg/L in February, 2015. Additional monitoring wells on the contaminated site have had concentrations reported as high as 7 µg/L in April, 2015. The investigation results also show that the contamination has migrated not only laterally but vertically to the deep drinking water aquifer pumped by Well 17. As noted in Figure 2, Well 17 has demonstrated somewhat variable 1,2,3-TCP concentrations. The high 1,2,3-TCP concentrations dispersing from the facility, along with Well 17 pumping cycles, could explain this variability. Due to the point source influence of 1,2,3-TCP on the deep drinking water aquifer pumped by Well 17, we expect 1,2,3-TCP concentrations in Well 17 to increase in the future. Nitrate as NO3 is also a contaminant of concern at the contaminated site. Recent nitrate sampling of Well 17 in July 2015 yielded a result of 39 mg/L as NO3.

[redacted]

None of the wells requiring treatment (Well 14, Well 15, and Well 17) have iron or manganese above the secondary MCLs; however, other co-occurring contaminants exist in these wells. Table 2 shows the past five years (2010-2015) of 1,2,3-TCP results and the last ten years (2005-2015) of Nitrate as NO_3 and DBCP for the four groundwater wells serving Winton. Nitrate in Wells 14 and 17 is of concern as it has been above half (22.5 mg/L) of the 45 mg/L nitrate as NO_3 MCL with a maximum concentration observed of 39 mg/L in both wells. Nitrate at or above half of the 45 mg/L MCL can cause issues during GAC treatment in the form of nitrate peaking. Well 14 and Well 17 have average DBCP concentrations of 0.011 µg/L and 0.028 µg/L, respectively. Well 15 has non-detect DBCP in the last five years. The MCL for DBCP is 0.2 µg/L. DBCP concentrations have been observed up to 0.022 µg/L in Well 14 (May, 2015), and 0.084 µg/L in Well 17 (July, 2015), both below the MCL. DBCP can be removed by any of the 1,2,3-TCP treatment options considered in this study. DBCP is not anticipated to impact the efficiency of GAC for 1,2,3-TCP removal. Complete historical summary tables for TCP, general, mineral and physical parameters, co-occurring organic, and inorganic contaminants are in

Appendix B – Historical Water Quality Summary.

Table 2 1,2,3-TCP concentrations over the past five years (2010-2015); Nitrate as NO_3 and DBCP concentrations over the past five years (2010-2015)

		Well 14	Well 15	Well 17
1,2,3-TCP (µg/L)	Average	0.024	0.002	0.042
	Maximum	0.036	0.005	0.120
	Minimum	<0.0007	<0.0007	<0.005
	Count	12	12	13
Nitrate as NO_3 (mg/L)	Average	22	11	19
	Maximum	39	12	39
	Minimum	12	11	14
	Count	7	9	7
DBCP (µg/L)	Average	0.011	<0.01	0.028
	Maximum	0.022	<0.01	0.084
	Minimum	<0.01	<0.01	<0.01
	Count	8	7	7

Water Production

The Winton drinking water system features four groundwater sources that can feed the distribution system. Well 14, Well 15, and Well 17 are primary production wells, with Well 16 serving as a standby well. Figure 4 displays monthly well production results in millions of gallons (MG) dating back to 2012. Water production has decreased in 2014 and 2015 as compared to the historical maximum annual and monthly (July 2013) production experienced in 2013, likely due to drought conditions experienced across California over that period. The 2013 production values have been used as the basis for the subsequent cost analysis as a conservative estimate. Table 3 shows the well design capacities, average annual and maximum month well utilization values from 2013, and community settings for Winton's groundwater wells.

Figure 4 Monthly production for the active wells serving Winton

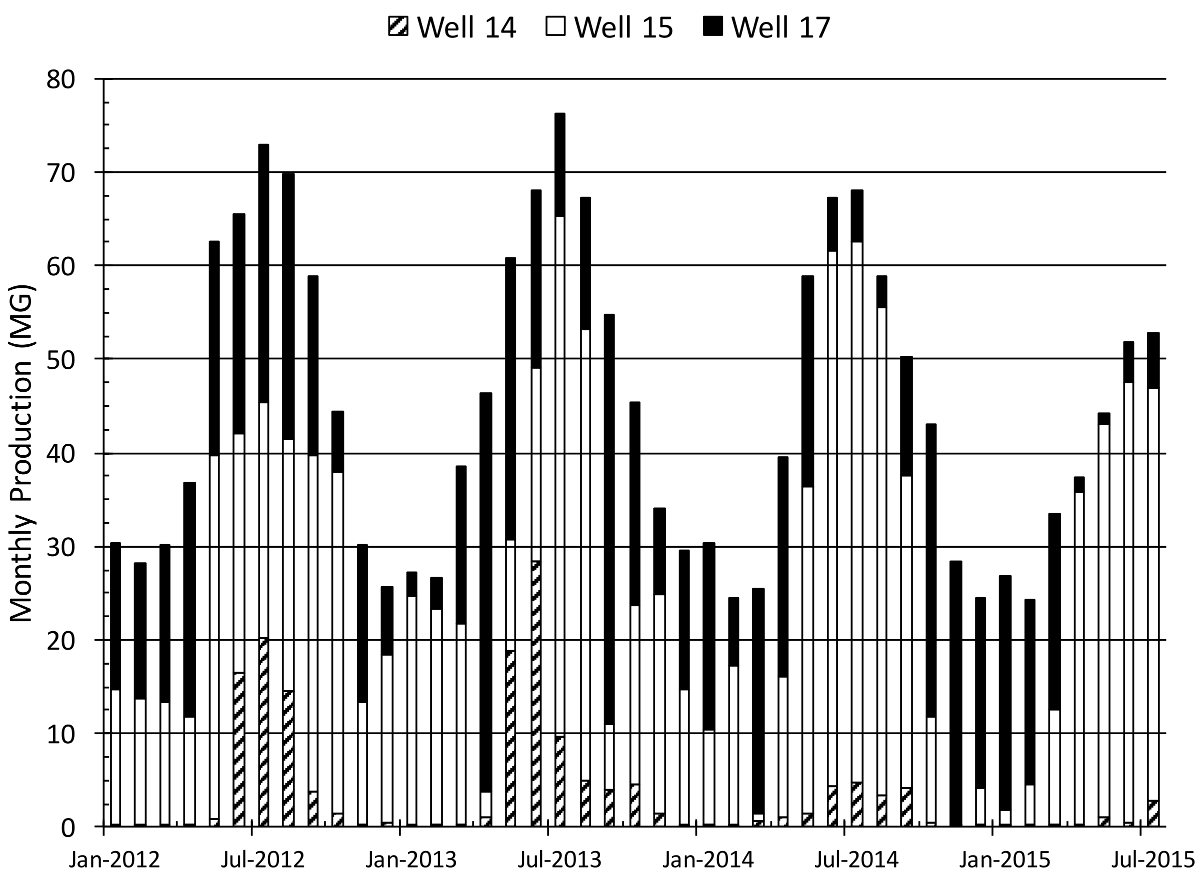


Table 3 Well specific design capacity, average and maximum utilization in 2013, and setting for Winton's Wells

Well ID	Design Capacity (gpm)	2013 Average Annual Utilization	2013 Maximum Month Utilization	Setting
Well 14	1,200	12%	55%	Residential
Well 15	2,400	22%	52%	Nonresidential
Well 16	2,400	0%	0%	Nonresidential
Well 17	2,400	18%	42%	Residential

The average annual utilization values presented in Table 3 have been used to calculate expected operations and maintenance costs. To account for an increase in future water demands, 1.9 % average annual population increase projections for Merced County (Merced County, 2012) have been applied.

Treatment Technology Evaluation

The following section summarizes the technologies that have been considered for 1,2,3-TCP treatment at the contaminated well sites. The technologies considered are:

- Granular activated carbon (GAC) adsorption
- UV oxidation with and without hydrogen peroxide
- Ozone with hydrogen peroxide oxidation
- Aeration (air stripping)

None of the above processes present appreciable residuals disposal concerns. Also, these processes do not significantly change the finished water chemical composition that would lead to stability concerns within the distribution system. However, these process aspects should be evaluated on a site-specific basis before applying any technology at a given site.

Blending is not considered an applicable treatment method for 1,2,3-TCP for the Winton system. For example, the treatment objective of 5 ng/L would require Well 17 (2,400 gpm well), with a maximum 1,2,3-TCP concentration of 120 ng/L, to be blended with at least seventeen other wells of equal size and no 1,2,3-TCP. Winton does not have enough groundwater wells or low enough 1,2,3-TCP concentrations in the wells to blend to achieve adequate 1,2,3-TCP control. Additionally, blending is prohibited if a source is categorized as “extremely impaired.”

GAC Adsorption

GAC adsorption is a proven technology for the removal of 1,2,3-TCP, and will likely be the BAT once regulated. GAC can reliably remove 1,2,3-TCP to below the detection limit of 5 ng/L and is relatively insensitive to fluctuations in the influent 1,2,3-TCP concentration. GAC is listed by the DDW as a BAT for the control of 55 of the 60 regulated organic contaminants. GAC is also operationally simple and is insensitive to on/off cycles. However, adsorption is a non-steady state process which requires periodic replacement of the GAC media. GAC replacement or reactivation typically accounts for the bulk of the operational costs.

Wells with co-occurring nitrate may be subject to nitrate peaking after the installation of GAC and following well cycling. The GAC will adsorb nitrate for a short time while the media is fresh. As GAC adsorption capacity is consumed, the weakly adsorbing nitrate starts being displaced by more strongly adsorbing organics and can appear in the effluent at concentrations higher than in the raw water. Nitrate peaking can also be observed in wells that are cycled on and off. Nitrate peaking is of concern and should be considered any time the raw water nitrate is greater than half of the 45 mg/L as NO_3 MCL. Wells treated by GAC with nitrate over half of the MCL require an online nitrate analyzer.

When treating to non-detect (e.g. <5 ng/L), the GAC bedlife is insensitive to influent concentration of 1,2,3-TCP, meaning that wells with very high concentrations of TCP will be able to treat about 30,000 bed volumes before break through (Corwin and Summers, 2012). The high level of removal needed to treat to non-detect also means that longer EBCTs are likely to be favorable, although the effect is typically small (Corwin and Summers, 2012). GAC is ideal for 1,2,3-TCP treatment at Winton's wells and considered in the subsequent cost analysis.

UV Based Processes

To our knowledge, direct UV photolysis of 1,2,3-TCP has not been demonstrated at a full-scale water treatment facility. While photolysis of 1,2,3-TCP is known to occur in air, it is generally accepted that the oxidation is due to indirect photolysis by hydroxyl radicals, which is commonly referred to as an advance oxidation process (AOP) in water treatment. Advanced oxidation of 1,2,3-TCP in water has been reported with the ozone-hydrogen peroxide process (Dombeck and Borg, 2005). Previous studies have evaluated the efficiency of the UV-hydrogen peroxide process for 1,2,3-TCP removal.

In 2013, Corona conducted a bench-scale study evaluating the efficiency of UV based AOP to remove 1,2,3-TCP. Results indicate that UV-AOP is relatively ineffective at removing 1,2,3-TCP. Even at the very high UV dose of 1,000 mJ/cm^2 and AOP conditions, a maximum of 32% of the 1,2,3-TCP was oxidized. Results at the same UV dose without the addition of hydrogen peroxide indicate that about half of the 1,2,3-TCP destruction is due to direct photolysis. These results are consistent with findings of a recent study of AOP for the chlorinated alkane 1,1-dichloroethane (Roccaro et al, 2012), and indicate that full-scale UV-AOP systems designed for destruction of 1,2,3-TCP would need to be very large. Experience from Trojan UV indicate that removals of greater than 95% of 1,2,3-TCP will not be achievable. Based on the current 1,2,3-TCP reporting level of 5 ng/L and assuming up to 95% removal is achievable, the maximum influent concentration that can be treated with a UV-AOP process is about 100 ng/L. Given this, UV-AOP is not ideal for 1,2,3-TCP treatment at Winton's wells and not considered in the subsequent cost analysis.

Ozone Advanced Oxidation

Ozone based AOP has been demonstrated for 1,2,3-TCP destruction by Dombeck and Borg (2005). Ozone based AOP is generally more energy intensive than UV-AOP, but has the benefits of ozonation of reduced TOC and color. Ozone-AOP generally results in the production of high levels of AOC and bDOC that requires biofiltration after the process to produce a biologically stable water for distribution. The use of the biofilter will quench any residual hydrogen peroxide providing a secondary benefit. Like UV-AOP, ozone-AOP provides a multiple barrier disinfection benefit. Waters high in bromide may be limited by the production of the regulated inorganic DBP, bromate. The bromate MCL is 10 µg/L and experience indicates that raw water bromide levels above 80 µg/L may be problematic. Bromide concentrations in Winton's wells are not known at this time. Because of the higher energy and additional biofilter footprint requirements for ozone-AOP and corresponding operational complexities, it is not ideal for 1,2,3-TCP treatment at Winton's wells and not considered in the subsequent cost analysis.

Aeration

Aeration strategies such as packed tower aeration (PTA) and similar tray tower configurations were evaluated for 1,2,3-TCP control. The Henry's constant for 1,2,3-TCP is more than an order of magnitude lower than trichloroethylene (TCE), making it only sparingly volatile. For example, an existing packed tower that removes 90% of TCE will remove only about 15% of the 1,2,3-TCP. Countercurrent packed towers have the lowest air-to-water ratios of applicable aeration technologies. The minimum air-to-water ratio in a packed tower to prevent equilibrium from being reached before gas leaves the tower to reduce 1,2,3-TCP from 0.1 µg/L to 0.005 µg/L (95% removal) is about 100:1 at 15°C. A packed tower design will provide an air-to-water ratio up to 3.5 times higher for an efficient reactor, resulting in an air-to-water ratio of around 350:1. These values are far above the normal design range of 50:1 and up to 100:1. At these high air-to-water ratios, the blowers become large and require large amounts of electrical energy.

Other process disadvantages of packed tower aeration include:

1. Hydraulic head must be broken, which requires finished water pumping
2. Potential for hardness to precipitate on packing material
3. Changes in pH that require acid or caustic addition
4. Potential increased downstream disinfection requirements due to the open process

Aeration transfers 1,2,3-TCP from the water phase to the air phase and does not sequester or destroy 1,2,3-TCP (like GAC or oxidative process); therefore, all air pollution regulations must also be met. A site-specific evaluation of the cancer risk at the property line for airborne contaminants would be needed. If the cancer risk is determined to be greater than 1 in 1,000,000, then air treatment will be required. Due to these process limitations, aeration is not recommended for 1,2,3-TCP treatment; consequently, no cost information was developed for aeration.

Site Specific Evaluation of GAC Treatment Feasibility

Impacted wells were evaluated for the feasibility of GAC treatment based on footprint availability, water quality conditions, and hydraulic considerations. GAC treatment will be conducted using dual 10' diameter vessels, operating in a lead-lag configuration. A lead-lag configuration involves vessels to be operated in series, with one vessel acting as the "polishing" vessel. When the lead vessel reaches a desired threshold, the lead and the lag switch and the media is replaced in the lead vessel.

Footprint Evaluation

GAC treatment feasibility based upon available footprint was determined by assessing the size of the required GAC treatment unit, and then comparing that to the available space on the impacted wellhead site. The size of the treatment unit was based on the flow rate and whether redundancy was needed. For this evaluation, a ten foot diameter dual-vessel pressure GAC adsorber operated in series was considered as the basic treatment unit. Dual-vessel pressure GAC adsorbers operated in series are needed to ensure 1,2,3-TCP treatment objectives are met given TCP toxicity and treatment objective (<5 ng/L). A maximum flow of 950 gpm was assumed for a single dual-vessel system based on a loading rate of 12 gpm/ft^2. Larger adsorbers do exist, but they typically come with drawbacks that favor the use of multiple ten foot dual-vessel systems (Chowdhury et al., 2012). These drawbacks include 1) increased complexity of GAC replacements, 2) increase backwash supply rate and volume, 3) higher head loss, 4) increased height, and 5) complex fabrication and shipping.

Impacted wells need GAC treatment redundancy to ensure consistent supply of treated water. Treatment redundancy may be required for wells that are located in areas of high demand that cannot be easily fed from other sources. These wells are often referred to as base load wells and typically have high utilization rates. Well 14 has low utilization rates, but, according to Winton, must always be able to deliver water to the distribution system. Wells with standby power also require treatment redundancy so they can be relied upon to produce water to meet system demand during an extended power outage. Impacted wells requiring redundancy will need additional vessels in order to be operable at all times, most notably while exhausted GAC media is being replaced. Well 14, Well 15, and Well 17 will require treatment redundancy.

A single dual-vessel unit requires an area of approximately 10 feet by 30 feet. Two units can be placed adjacent to each other in a space of approximately 20 feet by 30 feet. Additional units require an access aisle between them of about 8 feet, for instance three dual vessel units would require an area of 38 feet by 30 feet. For oddly shaped lots, each 10 foot by 30 foot single unit can be located separately. During GAC changeout, space is needed for GAC replacement trucks to access the site and be able to turn around. Table 4 shows the design capacity, redundancy required, number of dual 10' GAC units, and an indication of if the site is footprint limited. Well 14 is the most limited site; there is no available room surrounding the well site and there is not enough space to make any site improvements. In order to accommodate GAC treatment at Well 14, acquisition of an adjacent lot or land in the vicinity would be required. Well 15 is footprint limited, but with additional site modifications and improvements to remove the existing surge tank, GAC treatment is estimated to fit. Well 17 has more than enough room to accommodate GAC treatment and would not require additional land or site improvements.

Table 4 Footprint evaluation for the TCP impacted wells in Winton

Well	Flow rate (gpm)	Redundancy Needed	# dual 10' units	Footprint Limited
Well 14	1,200	Yes	3	Yes
Well 15	2,400	Yes	4	Partially
Well 17	2,400	Yes	4	No

Cost Estimate

Capital Cost Estimate

In order to assess GAC treatment costs, Corona utilized full-scale GAC system cost data. One dual 10' diameter vessel unit costs $350,000 ($970,000 installed) and can treat a system flow up to 950 gpm. Higher treatment flows will require additional dual vessel units. Two dual vessel units can treat up to 1,900 gpm, and three dual vessel units can treat 2,850 gpm. Equipment costs for GAC systems consist of two-dual-vessel 10' diameter units (three with redundancy) for Well 14 (1,200 gpm), and three-dual-vessel 10' diameter units (four with redundancy) for Well 15 and Well 17 (2,400 gpm). Multipliers were applied to the equipment costs to develop estimates for total installed capital costs. The construction cost multipliers that were used in this analysis are shown in Table 5. The capital cost multipliers used in Table 5 closely approximated the total installed cost reported by other utilities in the Central Valley for a dual vessel GAC system before the contingency was applied. The individual multipliers presented in Table 5 comprise an overall installed capital cost multiplier of 2.8.

Table 5 Installed capital cost multipliers

Category	Denotation	Percentage	Formula
Equipment Costs	A		
Installation	B	30%	A x 0.30
Electrical and I&C	C	20%	A x 0.20
General Site Civil	D	15%	A x 0.15
Subtotal	**E**		**A + B + C + D**
Overhead and Profit	F	15%	E x 0.15
Contingency	G	25%	E x 0.25
Total Construction Capital Costs	**H**		**E + F +G**
Planning, Engineering, Legal and Admin	I	11%	H x 0.11
Construction Admin	J	9%	H x 0.09
Total			**H + I +J**

These cost estimates correspond to a Class 4 Estimate as defined by the Association for the Advancement of Cost Engineering (AACE) International. This level of engineering cost estimating is appropriate for feasibility study evaluations. Cost estimates prepared at this level of engineering are generally considered to have an expected accuracy range of +50/-30 percent.

Wells 14 and 17 have nitrate concentrations greater than 22.5 mg/L, half of the 45 mg/L nitrate as NO_3 MCL as observed by the maximum concentration of 39 mg/L in both wells. An additional $20,000 has been included for each of these wells to account for on-line nitrate monitoring.

In addition to monitoring, these treatment systems will be equipped with an option to filter to waste upon well startup to mitigate nitrate peaking. The city engineer for Winton, Lee Fremming of Quad Knopf, Inc., has generated a cost estimate for the associated costs to facilitate filter to waste operations upon well startup at Wells 14, 15, and 17; only costs associated with Wells 14 and 17 have been included since only those wells have demonstrated nitrate concentrations greater than 22.5 mg/L. The complete estimate along with a description of how the system will be operated can be viewed in Appendix D –Design and Cost Estimate for Well Startup Water Disposal. The necessary improvements and additional land costs have been included as a single line item in Table 7.

Well 14 is footprint limited and will require additional land for GAC treatment. Approximately 5,000 square feet will be required for offsite treatment. Table 6 shows the two alternative methods that have been used to generate the expected additional costs for offsite treatment. Alternative 1 involves acquisition of an adjacent lot and incorporates a 2x multiplier to account for markup pricing, structure demolishing, and land development. This alternative does not require additional piping. Alternative 2 involves pumping water from Well 14 to a parcel of land approximately 520 feet north, on the corner of Olive Avenue and California Street, and back (1,040 feet total distance) to Well 14 for distribution using a 10 inch diameter pipe to maintain linear velocity less than 5 feet per second. The pipeline cost was estimated at $25/inch diameter/linear foot and is representative of current installed pipeline costs. This parcel of land would have to be purchased from the land owner by Winton. Alternative 1 resulted in a cost of $410,000 and Alternative 2 resulted in a cost of $460,000. As such, $460,000 was added to the capital cost for Well 14.

Table 6 Alternate treatment locations and associated costs for Well 14 GAC treatment

Alternative	Location	Eminent Domain	Land Cost	Multiplier/ Overhead	Pipeline Distance (ft.)	Pipeline	Total
Alternative 1	7542 California St.	$150,000	$130,000	2	NA	0	$410,000
Alternative 2	Olive Ave & California St.	$150,000	$50,000	1	1,040	$260,000	$460,000

Well 15 is footprint limited, but will not require additional land for GAC treatment. For this analysis, a 25% installed capital cost increase was assumed for Well 15 to account for the site improvements needed to accommodate GAC treatment. Well 17 will have enough room to accommodate the required treatment system. Table 7 shows a summary of the items that comprise the capital costs for 1,2,3-TCP treatment at Well 14, Well 15, and Well 17.

Table 7 Summary of capital cost items for 1,2,3-TCP treatment at Well 14, Well 15, and Well 17

	Well 14	Well 15	Well 17
Equipment Costs			
GAC Vessels	$1,050,000	$1,400,000	$1,400,000
Nitrate Analyzer	$20,000	$0	$20,000
Total Capital	$1,070,000	$1,400,000	$1,400,000
Installed Capital	$2,966,040	$3,880,800	$3,880,800
Improvements/ Land	$460,000	$970,200	$0
Nitrate Peaking Mitigation	$132,000	$0	$200,000
Total Capital	$3,560,000	$4,850,000	$4,140,000

Operations and Maintenance Costs

GAC operation and maintenance (O&M) costs are primarily driven by the flow production (flow rate and utilization rate). Thus, the O&M estimates were prepared based on the number of dual-vessel treatment units. Redundant treatment units had to be accounted for separately because they impact the capital cost but not the O&M cost.

In this study, additional pumping costs are accounted for by calculating the additional electrical cost to overcome the additional head loss caused by the GAC. In actuality, the increased head loss due to the addition of the GAC treatment system will result in lower flow rates from each well pump and a longer run time (higher utilization). This approach has been taken so that only the additional electrical energy to overcome the treatment system is accounted for and not all the electrical to run the well.

Labor Costs

The labor effort required for operation and media change outs of GAC systems was obtained from Winton. Winton reports a licensed operator bills at a rate of $24.45 an hour. During normal operation, an operator will spend an average of 45 minutes at each GAC system on each normal work day. During a GAC media changeout of a 20,000 lb. vessel, an operator will spend an average of 8 regular time hours and 6 overtime hours ($36.68/hr). Additionally, 10 total hours of office staff time is required at $26.02/hr for a total labor value of $680 needed for changeout of each 20,000 lb. vessel, or $0.03/lb.

Wells 14 and 17 require an online nitrate analyzer. The operator time has been increased by 10% to account for maintenance of the nitrate analyzer and additional time in controlling the operation of the well to avoid nitrate problems.

Basin Maintenance Costs

Well 14 and Well 17 require additional land for discharge of water during filter to waste upon well startup to mitigate nitrate peaking. The additional land needed will result in associated annual maintenance costs. These costs include weed control, disking, ripping, and fence maintenance to be performed by Winton staff. Table 8 shows the associated basin maintenance costs.

Table 8 Annual basin maintenance costs for Well 14, Well 15, and Well 17

	Well 14	Well 15	Well 17
Discharge Basin Cost ($/yr)	$3,000	$0	$5,000

Consumables Costs

Consumables consist of the following cost components:

- Energy
- Media replacement

Table 9 displays the unit cost assumptions used for consumables. Power inputs were converted to total energy requirements and to annual cost. The unit energy cost was provided by Winton as their current average electrical cost.

Media costs include the GAC media. The GAC media cost was based on a bedlife of 30,000 bed volumes treating to non-detect. GAC systems have to be backwashed if the media is not replaced. In this analysis, media replacement has been assumed over backwashing due to the relatively low concentration of co-occurring organic contaminants. GAC disposal has been assumed to be 50% hazardous for the cost of media disposal.

Table 9 Unit costs of consumables

Consumable	Units	Unit cost
Electricity	$/kWh	0.13
GAC Media	$/lb	2.20

The operations and maintenance costs are presented in Table 10 on an annual basis and over the present worth periods of 20, 30, and 40 years.

Table 10 Summary of O&M items on a $/year cost basis and 20-year, 30-year, and 40-year amortized O&M costs

	Well 14	Well 15	Well 17
Annual GAC Cost ($/yr)	$20,104	$74,911	$62,923
Annual Electric Cost ($/yr)	$1,052	$3,919	$3,291
Annual GAC Disposal ($/yr)	$3,427	$12,769	$10,726
Annual Operator Cost ($/yr)	$5,555	$5,925	$6,217
Annual Basin Maintenance Cost ($/yr)[1]	$3,000	$0	$5,000
Annual O&M	$33,138	$97,524	$88,158
20-year Present Worth O&M	$600,000	$1,770,000	$1,600,000
30-year Present Worth O&M	$900,000	$2,640,000	$2,380,000
40-year Present Worth O&M	$1,210,000	$3,550,000	$3,210,000

[1]Taken from Appendix D –Design and Cost Estimate for Well Startup Water Disposal

Aggregated Net Present Worth Cost Estimate

Net present worth (NPW) cost estimates are a compilation of the installed capital cost and the 20, 30, and 40 year NPW costs assuming a 5% interest rate and an annual increase of 1.9% in population growth and corresponding water demand (Merced County, 2012). The following section summarizes the NPW estimates for 1,2,3-TCP treatment using GAC at Well 14, Well 15, and Well 17.

Each impacted well has an associated capital cost estimate. The total present value was summed from the estimates. The total estimated 20-year NPW is $16,520,000 and is shown in Table 11. Of this total, $12,900,000 results from capital costs, and the remaining $3,970,000 results from the NPW of 20 years of O&M costs.

This NPW estimate is based on a feasibility level evaluation of site conditions. No property surveys or underground utility surveys were performed. No site specific consideration was given to individual site improvements that may be required. These were considered to be covered by the equipment cost multipliers. Assumptions and outcomes of the cost models used to generate the NPW estimates are presented in Appendix C – Cost Estimates.

Table 11 Aggregated NPW for 1,2,3-TCP treatment in millions of dollars

Well ID	Capital (M$)	20-year O&M (M$)	30-year O&M ($M)	40-year O&M ($M)	20-year NPW	30-year NPW	40-year NPW
Well 14	$3.46	$0.60	$0.90	$1.21	$4.16	$4.46	$4.77
Well 15	$5.20	$1.77	$2.64	$3.55	$6.62	$7.49	$8.40
Well 17	$4.14	$1.60	$2.38	$3.21	$5.74	$6.52	$7.35
Total	$12.90	$3.97	$5.92	$7.97	$16.52	$18.47	$20.52

Recommendations and Next Steps

This report is representative of a feasibility level study. We recommend continuing to the preliminary design phase, representative of 30% design. This level of study would include a site survey to reveal any constraints not identified at this level of analysis. This evaluation will be particularly important for Well 14 and Well 15 where the available footprint is limited. Well 14 will require additional land for GAC treatment. Well 15 is footprint limited and will require site improvements to accommodate GAC treatment. During the preliminary design phase, an evaluation of the system pressure in Winton should be conducted to determine if the headloss through GAC can be overcome with the current pumps or if pump upgrades will be needed. The study of distribution system pressure requirements was not undertaken in this study and should be included in the preliminary design.

The NPW estimates herein are based on a GAC bed life of 30,000 bed volumes. While this was based on full-scale data from two currently operating systems, variability of GAC bed life is expected due to water quality variations at the impacted wells. Also, none of the well sites have TOC concentration analyzed recently. All well sites should be tested to discern the degree to which TOC would adversely impact GAC bed life. Different GAC products should be tested to determine the most cost effective media for 1,2,3-TCP treatment. Last, Winton may wish to consider investigation of 1,2,3-TCP occurrence in Well 16 more fully as there is only one result (collected in 2012) in the last five years.

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Appendix B – Historical Water Quality Summary

TCP and general water quality parameters

Well Name	1,2,3-TCP (ng/L)				pH				Alkalinity (mg/L as $CaCO_3$)				TDS (mg/L)			
	Count	Avg	Min	Max	Count	Avg	Min	Max	Count	Avg	Min	Max	Count	Avg	Min	Max
Well 14	12	24	<0.7	36	3	8.1	8.1	8.2	3	86	76	100	3	217	200	240
Well 15	12	<5	<0.7	5	2	8.2	8.2	8.2	2	76	73	79	2	200	200	200
Well 16	1	<5	<5	<5	0	No data			0	No data			0	No data		
Well 17	13	41	<5	120	3	8.1	8.1	8.1	3	79	68	89	3	200	170	220

Co-occurring organic contaminants

Well Name	TCE (µg/L)				PCE (µg/L)				DBCP (µg/L)				EDB (µg/L)			
	Count	Avg	Min	Max	Count	Avg	Min	Max	Count	Avg	Min	Max	Count	Avg	Min	Max
Well 14	2	<0.5	<0.5	<0.5	2	<0.5	<0.5	<0.5	8	0.011	<0.01	0.022	5	<0.02	<0.02	<0.02
Well 15	2	<0.5	<0.5	<0.5	2	<0.5	<0.5	<0.5	7	<0.01	<0.01	<0.01	5	<0.02	<0.02	<0.02
Well 16	0	No data			0	No data			0	No data						
Well 17	4	<0.5	<0.5	<0.5	4	<0.5	<0.5	<0.5	7	0.028	<0.01	0.084	5	<0.02	<0.02	<0.02

Co-occurring inorganic contaminants

Well Name	Fe (µg/L)				Mn (µg/L)				As (µg/L)				NO_3 (mg/L as NO_3)			
	Count	Avg	Min	Max	Count	Avg	Min	Max	Count	Avg	Min	Max	Count	Avg	Min	Max
Well 14	3	<20	<20	<20	3	<10	<10	<10	3	1	ND	3	7	22	13	39
Well 15	2	<20	<20	<20	2	<10	<10	<10	2	3	2.7	3.2	9	11	11	12
Well 16	0	No data			0	No data			0	No data			1	<1	<1	<1
Well 17	3	20	<20	59	3	<10	<10	<10	3	3.9	3.5	4.3	7	19	14	39

Appendix C – Cost Estimates

Baseline	units	Average flow rate (gpm) Well 14	Well 15	Well 17
		1,200	2,400	2,400
Capital				
Dual vessel units to meet flow	ea	2	3	3
Redundant dual vessel units	ea	1	1	1
M_{GAC}/vessel	lb	20,000	20,000	20,000
Apparent density	g/cm^3	0.45	0.45	0.45
Equipment cost dual vessel unit	$/vessel	350,000	350,000	350,000
Total Equipment Cost	$	1,050,000	1,400,000	1,400,000
Installation	$	315,000	420,000	420,000
I&C	$	210,000	280,000	280,000
Civil site work	$	157,500	210,000	210,000
Subtotal	$	1,732,500	2,310,000	2,310,000
Overhead and Profit	$	259,875	346,500	346,500
Contingency	$	433,125	577,500	577,500
Construction Total	$	2,425,500	3,234,000	3,234,000
Design and permitting	$	266,805	355,740	355,740
Construction Admin	$	218,295	291,060	291,060
Total Capital	$	2,910,600	3,880,800	3,880,800
O&M				
Media:				
Bedlife	BV	30,000	30,000	30,000
EBCT	min	17.8	13.3	13.3
Average Utilization	%	12%	22%	18%
Average Bedlife	days	3195	1286	1531
GAC Consumption	lb/yr	9,138	34,050	28,602
Unit GAC media cost	$/lb	2.20	2.20	2.20
Annual GAC media cost	$/yr	20,104	74,911	62,923
Energy:				
Headloss through GAC	ft	27	27	27
unit electrical cost	$/kWh	0.13	0.13	0.13
Pumping costs	$/hr	1.04	2.07	2.07
Annual electrical cost	$/yr	1,052	3,919	3,291
Residuals:				
non-haz. GAC disposal	$/yr	685	2,554	2,145
hazardous GAC disposal	$/yr	2,741	10,215	8,580
Annual GAC disposal	$/yr	3,427	12,769	10,726
Labor:				
Operator during run	$/yr	4,768	4,768	4,768
Labor for media repl.	$/yr	311	1,158	972
Annual Operator Cost	$/yr	5,078	5,925	5,740
Total O&M	$/yr	29,661	97,524	82,681
Combined Costs				
Amortized Capital Costs	$	233,554	311,405	311,405
Total Annual Cost	$	263,215	408,929	394,086
Present Value O&M	$	369,644	1,215,358	1,030,385
Total Present Value	$	3,280,244	5,096,158	4,911,185
Production Costs:				
Total	$/1,000 gal	3.61	1.50	1.72
Capital	$/1,000 gal	3.20	1.14	1.36
O&M	$/1,000 gal	0.41	0.36	0.36
Total	$/acre·ft	1,175	490	562
Capital	$/acre·ft	1,043	373	444
O&M	$/acre·ft	132	117	118

Nitrate Peaking	units	Average flow rate (gpm) Well 14	Well 15	Well 17
		1,200	2,400	2,400
Capital				
Dual vessel units to meet flow	ea	2	3	3
Redundant dual vessel units	ea	1	1	1
M_{GAC}/vessel	lb	20,000	20,000	20,000
Apparent density	g/cm^3	0.45	0.45	0.45
Equipment cost dual vessel unit	$/vessel	350,000	350,000	350,000
Total Equipment Cost	$	1,070,000	1,420,000	1,420,000
Installation	$	321,000	426,000	426,000
I&C	$	214,000	284,000	284,000
Civil site work	$	160,500	213,000	213,000
Subtotal	$	1,765,500	2,343,000	2,343,000
Overhead and Profit	$	264,825	351,450	351,450
Contingency	$	441,375	585,750	585,750
Construction Total	$	2,471,700	3,280,200	3,280,200
Design and permitting	$	271,887	360,822	360,822
Construction Admin	$	222,453	295,218	295,218
Total Capital	$	2,966,040	3,936,240	3,936,240
O&M				
Media:				
Bedlife	BV	30,000	30,000	30,000
EBCT	min	17.8	13.3	13.3
Average Utilization	%	12%	22%	18%
Average Bedlife	days	3195	1286	1531
GAC Consumption	lb/yr	9,138	34,050	28,602
Unit GAC media cost	$/lb	2.20	2.20	2.20
Annual GAC media cost	$/yr	20,104	74,911	62,923
Energy:				
Headloss through GAC	ft	27	27	27
unit electrical cost	$/kWh	0.13	0.13	0.13
Pumping costs	$/hr	1.04	2.07	2.07
Annual electrical cost	$/yr	1,052	3,919	3,291
Residuals:				
non-haz. GAC disposal	$/yr	685	2,554	2,145
hazardous GAC disposal	$/yr	2,741	10,215	8,580
Annual GAC disposal	$/yr	3,427	12,769	10,726
Labor:				
Operator during run	$/yr	5,245	5,245	5,245
Labor for media repl.	$/yr	311	1,158	972
Annual Operator Cost	$/yr	5,555	6,402	6,217
Total O&M	$/yr	30,138	98,000	83,158
Combined Costs				
Amortized Capital Costs	$	238,003	315,854	315,854
Total Annual Cost	$	268,141	413,854	399,012
Present Value O&M	$	375,586	1,221,300	1,036,327
Total Present Value	$	3,341,626	5,157,540	4,972,567
Production Costs:				
Total	$/1,000 gal	3.67	1.52	1.75
Capital	$/1,000 gal	3.26	1.16	1.38
O&M	$/1,000 gal	0.41	0.36	0.36
Total	$/acre·ft	1,197	496	569
Capital	$/acre·ft	1,062	378	450
O&M	$/acre·ft	135	117	119

Appendix D –Design and Cost Estimate for Well Startup Water Disposal

X130411
10/3/2015
Prepared by Lee Fremming, RCE (Quad Knopf, Inc.)

ROUGH DESIGN & COST ESTIMATE (INCLUDING MAINTENANCE) FOR WELL STARTUP WATER DISPOSAL

General Operation

Due to nitrate spiking, 1 hour of pump-to-waste will occur each time the wells are offline and then started. A pump control valve (PCV) will be installed on a discharge-to-waste line just upstream of the main line check valve. A check valve will also be installed on the discharge line downstream of the PCV to protect the discharge line when the PCV is open. When a pump is off, the PCV is wide open. When the pump starts the water is allowed to be discharged to waste for 1 hour and then a solenoid valve on the PCV is energized and the valve begins to slowly close. As the PCV closes the water is gradually diverted to the main line. When the pump is shut-off the solenoid is de-energized and the PCV fully opens. The water will be discharged to a percolation basin at each well site.

Water Volumes

As indicated above, 1 hour of pump-to-waste will occur each time the wells are offline and then started.

		1-Hour Volumes	
Well No.	Capacity (gpm)	Gallons	Acre-Feet (AF)
14	1,200	72,000	0.22
15	2,400	144,000	0.44
17	2,400	144,000	0.44

Land Requirements for Percolation Basins

Well 14-

Assume that discharge-to-waste will occur a maximum of once per day, the discharged water must percolate within a day to mitigate the possibility of mosquito breeding and the long term sustainable percolation rate is 0.25 ft/day (typical for all well sites).

Bottom Area Required = (0.22 AF)/(0.25 ft/day) = 0.88 Acres

Assume basin length to width ration is 2:1, provide 4:1 side slopes for ease of maintenance, 1 foot of freeboard and 10' clearance from top of slope to fence line (typical for all well sites).

See attached plan view and cross section of the basin.

Wells 15 & 17-

Bottom Area Required = (0.44 AF)/(0.25 ft/day) = 1.76 Acres

See attached plan view and cross section of the basin.

Project Cost Estimate

See attached cost estimate

Estimated Basin Maintenance Cost

Required maintenance will include weed control, disking, ripping and fence maintenance.

Yearly Maintenance for Well 14 Basin = $3,000 per year

Yearly Maintenance for Well 15 & 17 Basins = $5,000 per year

JOB

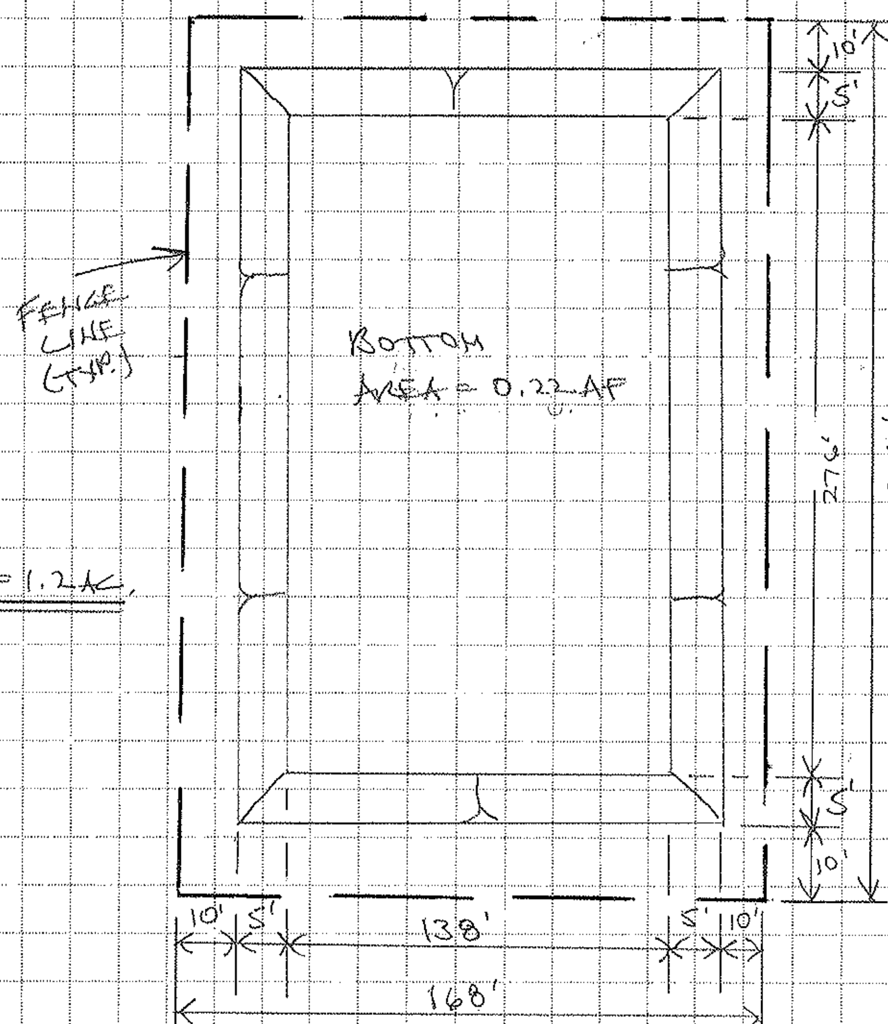
SHEET NO. 3 OF 4

CALCULATED BY DATE

CHECKED BY DATE

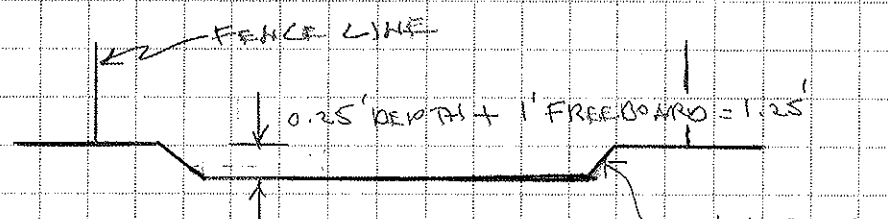
SCALE

WELL 14 BASIN



TOTAL AREA = 1.2 AC.

PLAN VIEW
NTS



CROSS SECTION
NTS

JOB

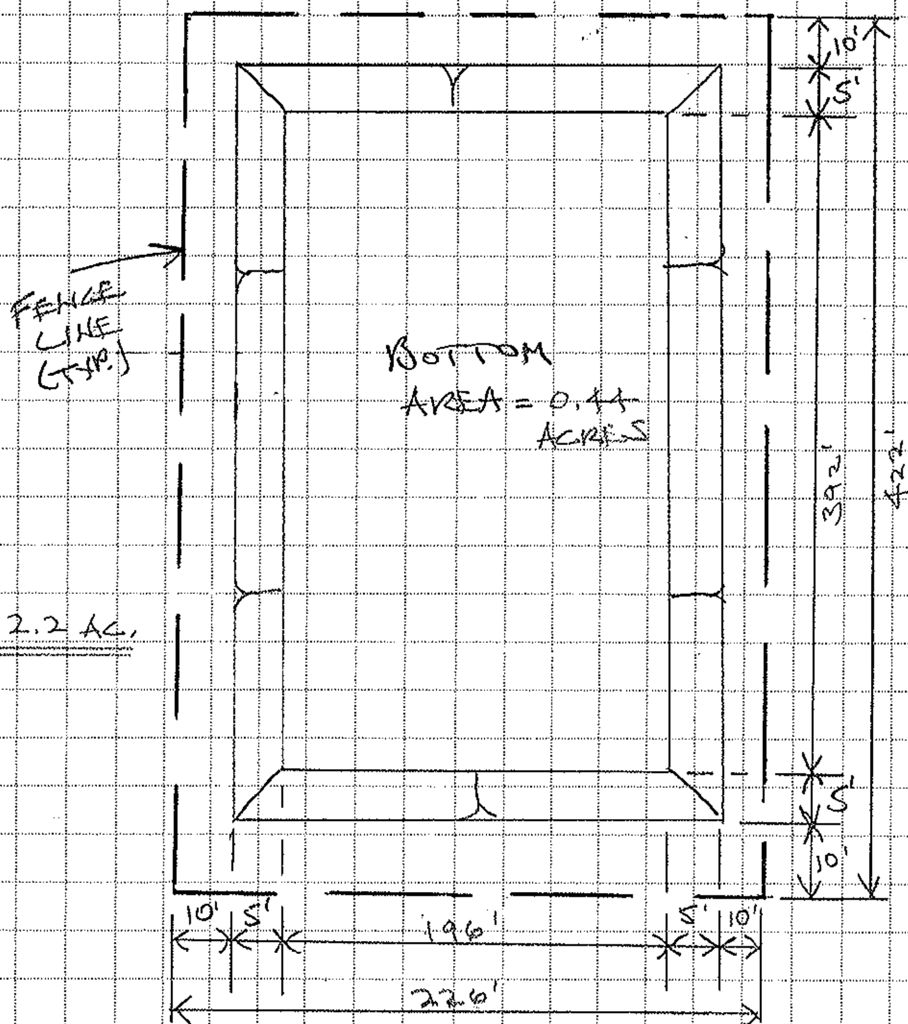
SHEET NO. 4 OF 4

CALCULATED BY DATE

CHECKED BY DATE

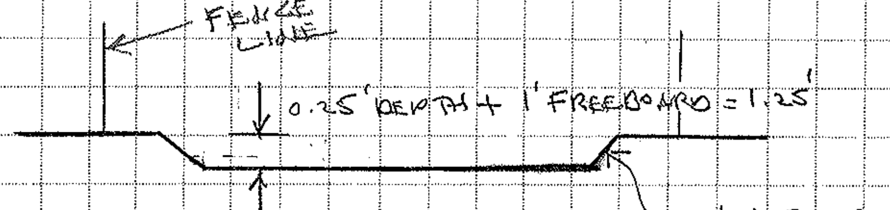
SCALE

WELL 15 & 17 BASINS



TOTAL AREA = 2.2 AC.

PLAN VIEW
NTS



CROSS SECTION
NTS

PROJECT COST ESTIMATE				
DESCRIPTION	QUANTITY	UNIT	UNIT COST	TOTAL
Construction & Design Cost				
Well 14-				
6" Pump Control Valve (PCV)	1	LS	$10,000.00	$10,000.00
6" Discharge Check Valve	1	LS	$3,000.00	$3,000.00
6" Pump Discharge Piping & Fittings	1	LS	$5,000.00	$5,000.00
Pump Discharge Structure	1	LS	$5,000.00	$5,000.00
Piping to Basin & Outlet Structure	1	LS	$5,000.00	$5,000.00
Chain Link Fence, Gates (948 LF)	1	LS	$15,000.00	$15,000.00
Electrical Controls for PCV	1	LS	$5,000.00	$5,000.00
			Subtotal	$48,000.00
Well 15-				
10" Pump Control Valve (PCV)	1	LS	$15,000.00	$15,000.00
10" Discharge Check Valve	1	LS	$5,000.00	$5,000.00
10" Pump Discharge Piping & Fittings	1	LS	$8,000.00	$8,000.00
Pump Discharge Structure	1	LS	$5,000.00	$5,000.00
Piping to Basin & Outlet Structure	1	LS	$2,000.00	$2,000.00
Chain Link Fence, Gates (1,296 LF)	1	LS	$20,000.00	$20,000.00
Electrical Controls for PCV	1	LS	$5,000.00	$5,000.00
			Subtotal	$60,000.00
Well 17-				
10" Pump Control Valve (PCV)	1	LS	$15,000.00	$15,000.00
10" Discharge Check Valve	1	LS	$5,000.00	$5,000.00
10" Pump Discharge Piping & Fittings	1	LS	$8,000.00	$8,000.00
Pump Discharge Structure	1	LS	$5,000.00	$5,000.00
Piping to Basin & Outlet Structure	1	LS	$2,000.00	$2,000.00
Chain Link Fence, Gates (1,296 LF)	1	LS	$20,000.00	$20,000.00
Electrical Controls for PCV	1	LS	$5,000.00	$5,000.00
			Subtotal	$60,000.00
	Total Well Related Construction Cost			$168,000.00
Engineering Design & Construction Services (20%)				$33,600.00
			Subtotal	$201,600.00
			Contingency (25%)	$50,400.00
	Total Estimated Design & Construction Cost			$252,000.00
Land Related Costs				
Land for Well 14 Basin (1.2 Acres)				$60,000.00
Land for Well 15 Basin (2.2 Acres)				$110,000.00
Land for Well 17 Basin (2.2 Acres)				$110,000.00
Eminent Domain Cost for Well 15 Basin*				$150,000.00
	Total Estimated Land Related Costs			$430,000.00
		Total Estimated Project Cost		**$682,000.00**
*Assumes Well 14 eminent domain cost included in treatment cost. Area around				
Well 17 owned by District				