Technical Memorandum - DRAFT

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Title:	TCP Planning Study	Date:	September 27, 2017

INTRODUCTION

A new MCL for 1, 2, 3-Trichloropropane (TCP) was recently introduced by the California State Water Resources Control Board. Since 2009, TCP has been detected above the Maximum Contaminant Level (MCL) concentration at four Chino Desalter Authority (CDA) wells that convey water to be treated at the Chino I Desalter (Chino I). Additionally, a recent report prepared for the County of San Bernardino Department of Airports Administration recommended the construction and operation of remediation wells (Airport Wells) to treat TCP, Trichloroethylene (TCE), cis-1, 2-dichlorethene, and 1, 2-dichlorethane present in a groundwater plume in the vicinity of the Chino Airport (Tetra Tech, 2017). The report also recommended operating CDA's Well I-18 (currently off-line). If implemented, the extraction system would send the contaminated water to Chino I for treatment.

The goal of this Memo is to evaluate TCP treatment options for MCL compliance in the Chino I Clearwell for two alternatives:

- **Alternative 1:** no flows from the Chino Airport remediation system are sent to Chino I.
- **Alternative 2:** flows from the Chino Airport plume remediation system are treated at Chino I, and Well I-18 is turned-on. For this Memo, it is assumed that all the Airport Well flows are treated at Chino I.

BACKGROUND

1, 2, 3-Trichloropropane (TCP) is a manmade chlorinated hydrocarbon. Typically found at industrial or hazardous waste sites, it was traditionally used as a cleaning and degreasing solvent, and incorporated into certain pesticides. In California, TCP has been found in numerous drinking water wells and is recognized as a potential cancer causing substance. As a result, on July 18, 2017, the State Water Resources Control Board adopted a new primary MCL of 5 part per trillion (ppt) for TCP.

Various treatment technologies have been evaluated for the removal of TCP. Granular activated carbon (GAC) removes the totality of the compound and is considered the Best Available Technology (BAT) by the EPA and California. Air stripping is another technology that provides partial removal of TCP but is dependent on the sizing of the air stripper. Reverse osmosis (RO) can achieve up to 90% removal of TCP but is more costly to operate and maintain.

Another technology considered for TCP removal is electrocoagulation. However, this technology is only applicable for very small-scale facilities. Large-scale electrocoagulation is infeasible due to high coagulant accumulation on the electrodes (electrode passivation). Also, removal of TCP by electrocoagulation has not been widely studied and the coagulant dosage and design requirements to achieve significant removal (along with chemical doses to maintain pH) is unknown.

CHINO I DESALTER

Chino I currently treats water from 16 individual wells: I-1, I-2, I-3, I-4, I-5, I-6, I-7, I-8, I-9, I-10, I-11, I-13, I-15, I-16, I- 20, and I-21. Well I-17 cannot be run at the same time as Well I-16 due to drawdown issues, and is currently off-line. Well I-18 is also currently off-line.

Chino I has two independent treatment trains:

- Volatile Organic Compounds (VOCs) treatment: This train consists of one air stripper, with a rated capacity of 1,800 gpm, for VOC removal.
- Reverse Osmosis (RO) / Ion Exchange (IX) treatment: Most of the water in this train is treated with RO (maximum 5,800 gpm at 80% recovery) for TDS removal. The remaining water that is over the capacity of the RO is treated with IX (maximum 3,600 gpm) for nitrate removal.

The current configuration of wells treated by each treatment train at Chino I is summarized in **Table 1**. Since the total pumping capacity of the RO/IX train wells exceeds the train nominal capacity, wells (preferably with high TDS concentration) must be temporarily turned off on a rotational basis. Similarly, at least one of the Air Stripping wells is temporarily shut-down at a time in order to rest the pumps.

Table 1 – Chino I Well Sources per Treatment Train

	Air Stripping	RO/IX
Wells on-line	I-1, I-2*, I-3*, I-4	I-5, I-6, I-7, I-8, I-9, I-10, I-11, I-13, I-14, I-15, I-16, I-17**, I-18**, I-20, I-21
Current Operation	At least one on-line well temporarily shut down	Raw water flow is kept below treatment train nominal capacity of 5,800/3,600 gpm for RO/IX.

*Wells with TCP concentration above the new MCL.

**Wells not currently operated.

PIPING CONFIGURATION

Currently, raw water from CDA's wells enters Chino I through three pipe systems, as depicted in **Figure 1**. The combined flow from CDA wells I-1 thru I-4 (North wells) enters the site from the Northeast through a 16-inch pipeline along Euclid Ave to Kimball Ave. The pipeline is reduced to a 12-inch pipeline and is routed directly to the air stripper.

The combined flow from CDA wells I-5 thru I-15 (East wells) also enters Chino I from the Northeast along Kimball Ave but through a separate 30-inch pipeline. The pipeline is reduced to 24-inches once entering the site and is directed to either the RO or IX systems. As the pipeline enters the RO building, it increases to 30-inches and as it enters the IX system, it is reduced again to 18-inches. The flow split between RO and IX can be designated by operators due to influent water quality and subject to the maximum treatment flow capacities.

Flows from the south wells (I-16 or I-17) travel north on Fern Ave through a 12-inch pipeline which increases to a 16-inch pipe traveling East on Kimball Ave. This pipeline connects with the 30-inch pipeline from the East wells as it enters the Chino I site to combine with the flow headed to treatment with either RO or IX. Before connecting to the 30-inch pipeline, the 16-inch pipe branches off to an 8-inch pipeline that is capped.

Well I-18 is currently off-line, and is connected to a 4" line connected to the RO/IX train.

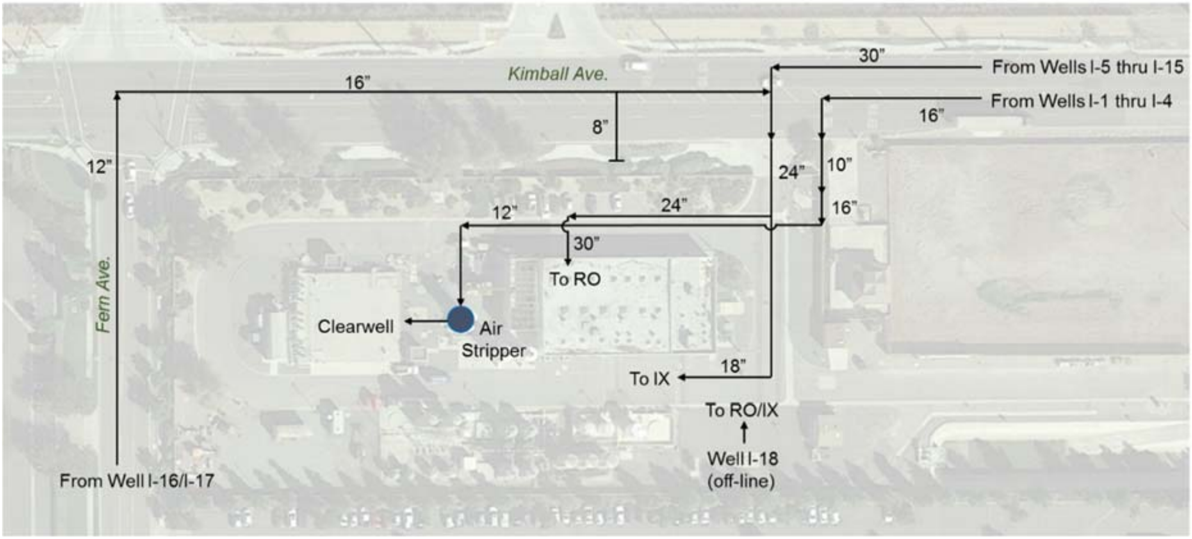

Figure 1 - Chino I Piping Configuration

Table 2 presents the current maximum flows through each pipe and the available remaining capacity. The flows assume that the on-line wells are all operating at capacity (no well temporarily off-line).

Table 2 - Pipe Capacities

Pipes	Diameter (in)	Total Capacity* (gpm)	Current Maximum Well Flow (gpm)	Remaining Capacity (gpm)
North Wells	16	3,800	1,012	2,788
East Wells	30	13,300	11,239	2,061
South Wells	16	3,800	226**	3,574

* Total capacity is an approximation based on an assumed maximum pipe velocities of 6 ft/s. This would need to be confirmed with a hydraulic analysis of the conveyance system.
** Flow only for well I-16 since I-16 and I-17 cannot be operated at the same time due to drawdown.

CURRENT TREATMENT CONFIGURATION

Since 2009, TCP has been detected above the MCL at Wells I-2, I-3, I-17, and I-18. Based on the TCP removal rates summarized in **Table 3** for each of the processes at Chino I, a system-wide mass balance was performed to determine the anticipated TCP concentration for the current system configuration in the Chino I Clearwell. Since the current TCP analysis Method Reporting Limit is currently 5 ppt, the TCP concentration in wells with non-detect TCP was assumed at 2.5 ppt. Model results and assumptions are presented in in **Appendix A**. Under current operations, the expected TCP concentration in the Clearwell is estimated to be 4.6 ppt (below the MCL of 5 ppt). This is due to partial removal through the air stripper and dilution.

Table 3 – Expected TCP Removal Rates

	RO	IX	Air Stripper	GAC
TCP removal in %	90%	0%	78%	99.99%
Reference	Agenson et. al, 2003	-	Calculated - see **Appendix A**.	Media supplier

Although the TCP estimates do not exceed the MCL in the Clearwell under the assumed current conditions, GAC treatment is recommended to ensure compliance under the following alternative operating scenarios:

- The wells are operated at flows different than modeled, which could impact the TCP concentration in the Clearwell (different dilution effect)
- If Well I-17 or I-18 is needed for treated water capacity, the MCL would be exceeded given the current configuration
- The TCP concentration increases over time at Wells I-2 and I-3
- The TCP plume travels and additional CDA wells are impacted by TCP.

Different treatment configurations are evaluated in the next Section for both Alternatives.

GAC TREATMENT CONFIGURATION

ALTERNATIVE 1

A system-wide mass balance was used to determine how different pumping and treatment configurations would affect TCP concentration in the Clearwell. The mass balance results are presented in **Table 4**. All scenarios assume that Wells I-1 thru I-4 are treated by the Air Stripper and Wells I-5 thru I-21 are treated by the RO/IX train as currently configured (see **Table 1**), unless otherwise stated in the “Notes” column. It is also assumed that Wells I-1, I-5, I-7, and I-8 are temporarily off-line to reflect current Plant operations.

Table 4 - CDA Wells Mass Balance Configurations

Scenario #	Wells treated with GAC	Wells ON (I-16 or 17, and/or 18)*	Clearwell TCP (ppt)	Notes
1	None (baseline scenario)	I-16	4.6	
2	None (baseline scenario)	I-17	>5	
3	I-1 thru I-4	I-16	1.1	
4	I-1 thru I-4	I-17	>5	
5	I-17 only	I-17	4.6	GAC treatment located at the wellhead for Well I-17
6	I-1 thru I-4, I-17	I-17	1.1	Well I-18 is OFF
7	I-1 thru I-4, I-17	I-17, I-18	>5	Well I-18 is ON and to RO/IX
8	I-1 thru I-4, I-17, I-18	I-17, I-18	1.1	Well I-17 and I-18 sent directly to GAC, not through RO/IX train

According to **Table 4**, if Wells I-17 or I-18 are on-line, they must be treated with GAC.

Installing a centralized GAC treatment at Chino I that treats Wells I-1 thru I-4, I-17, and I-18 is recommended for Alternative 1 to maximize the treated flow and minimize the risks of exceeding the TCP MCL. Assuming that Wells I-1, I-3, I-4, I-16 (higher capacity than I-17) and I-18 are all on-line simultaneously, a total combined flow of 1,186 gpm would be treated with GAC. I-2 is assumed off-line for system sizing purposes since at least one of the North wells must be turned off (on a rotational basis), and I-2 flow is the smallest.

ALTERNATIVE 2

Alternative 2 would treat both CDA wells and flows from the Chino Airport plume remediation system at Chino I. A map of the proposed Chino Airport extraction wells and conveyance system to Chino I, and maps of the contaminant plumes are provided in **Appendix B**.

The North Airport Wells (EW-1 thru EW-5) would combine with CDA wells I-1 thru I-4 into the 16" pipeline and be treated with the GAC system. The South Airport Wells (EW-6 thru EW-10) would combine into the 12" pipeline from CDA wells I-16 and I-17. **Table 5** presents the expected flows and water quality from the Airport Wells. By referring back to **Table 2**, it is clear there is sufficient capacity in the existing pipelines to accommodate the additional flows.

Table 5 - Airport Wells Water Flow and Quality

Parameter	Unit	EW-1	EW-2	EW-3	EW-4	EW-5	EW-6	EW-7	EW-8	EW-9	EW-10
Flow Rate	gpm	100	100	150	50	100	150	50	50	100	50
cis-1,2-Dichloroethene	µg/L	3	3	3	3	3	3	--	3	3	--
1,2-Dichloroethane	µg/L	0.3	0.7	0.3	0.3	0.3	0.3	--	0.7	0.3	
1,2,3-Trichloropropane (TCP)	µg/L	30	30	0.5	0.3	0.3	10	0.5	30	10	0.5
Trichloroethylene	µg/L	100	100	100	3	3	3	--	100	20	3

Table 6 presents various treatment combinations analyzed for Alternative 2, and demonstrates that in order to comply with the MCL, all Airport Wells must be treated with GAC in addition to the Alternative 1 wells. All scenarios assume that Wells I-1 thru I-4 are treated by the Air Stripper, and Wells I-5 thru I-21 are treated by RO/IX as is currently configured (see **Table 1**) unless otherwise stated in the "Notes" column. It is also assumed that Wells I-1, I-5, I-7, and I-8 are temporarily off-line to reflect current Plant operations.

Table 6 - CDA Wells + Airport Wells Mass Balance Scenarios

Scenario #	Wells Treated with GAC	Wells ON (I-16 or I-17, and/or I-18)*	Clearwell TCP (ppt)	Notes
1	None (baseline scenario)	I-16 or I-17, I-18	>5	North Airport Wells treated by Air Stripper, South Airport Wells treated by RO/IX
2	Wells I-1 thru I-4 and North Airport Wells	I-16, I-18	>5	North Airport Wells treated by GAC and Air Stripper, South Airport Wells treated by RO/IX
3	Wells I-1 thru I-4, I-16, North Airport Wells, South Airport Wells	I-16, I-18	>5	South Airport Wells directed to GAC/Air Stripper.
4	Wells I-1 thru 4, I-17, I-18, North Airport Wells, South Airport Wells	I-17, I-18	1.0	North Airport Wells, Well I-17, I-18, and South Airport Wells sent directly to GAC/Air Stripper

*assumes all wells I-1 thru I-15, and I-20 to I-21 are on in all scenarios

Installing centralized GAC treatment at Chino I to treat Wells I-1 thru I-4, I-17, I-18, and the Airport Wells is recommended for Alternative 2. Assuming that Wells I-1, I-3, I-4, I-16 (higher capacity than I-17), I-18, and all airport wells would be all on-line simultaneously, a total combined flow of 2,086 gpm would be treated with GAC. I-2 is assumed off-line for system sizing purposes since at least one of the North wells must be turned off, and I-2 flow is the smallest.

GAC TREATMENT DESIGN

In this Section, GAC sizing, media selection, potential treatment sequences, and facility design are discussed.

GAC SYSTEM SIZING

GAC vessels are usually designed in series with two vessels per train, in a lead-lag configuration. This allows for monitoring of the constituent(s) of interest after the first vessel for any breakthrough concentrations. During normal operation, the flow is sent through both the first and second vessel in series. Once the contaminant exceeds a certain percentage of its MCL, the first vessel's media no longer has sufficient treatment capacity and requires replacement. The train's piping is configured so that when the first vessel's media is spent, flow is directed to the second vessel and the first vessel can be taken off-line for media replacement. Once the media is replaced, the first vessel becomes the lag unit and the train operates in series again.

GAC vessels are typically fabricated with the following sizes:

- 10 feet diameter vessel, 20,000 lbs of carbon
- 12 ft diameter vessel, 20,000 lbs of carbon
- 12 ft diameter, 40,000 lbs of carbon.

Design criteria for the recommended new facility are summarized in **Table 7**.

Table 7 – Recommended GAC System Design Criteria

Design Criteria	Units	Value/Range	
		Alt. 1	**Alt. 2**
Flow	gpm	1,186	2,086
GAC vessel size	lbs	20,000	
Vessel Diameter	ft	12	12
GAC Depth	ft	5.2	5.2
Number of Trains	-	2	4
Number of Vessels per Train	-	2	
Volume			
Design Empty Bed Contact Time (EBCT) - per Vessel	min	7 - 10	
GAC volume – per vessel	cf	593	593
Actual EBCT	min	7.5	8.5
Loading Rate			
Maximum Loading Rate	gpm/sf	7	
Vessel Area	sf	113	113
Actual Loading Rate	gpm/sf	5.2	4.6

GAC MEDIA SELECTION

One of two types of media is typically selected for GAC treatment: bituminous or coconut-based carbon media. Depending on field conditions and the raw water quality, one media type could potentially perform better than the other and have a longer bed life. There is insufficient industry-wide experience with the removal of TCP to provide any reliable guidance on the selection of media type. Column testing for side-by-side treatment performance comparison could be considered, but this would require a year or more of testing and is not recommended. Instead, it is recommended that both types be allowed to bid, allowing full-scale evaluation of performance for the selected bid. Depending on results at Chino I and elsewhere in the industry, the other media type could be installed at a subsequent change-out, and a comparison of results used to select the optimum media for the future. Alternatively, column testing of each GAC type could be completed in parallel with operation of the initial GAC installation, to allow an informed choice of media type when change out is required. The testing could also potentially serve as an early breakthrough detection system and inform the district that a media change is imminent.

TREATMENT SEQUENCE

GAC treatment could be installed before air stripping (Configuration A, **Figure 2**), after air stripping (Configuration B, **Figure 3**), or as a stand-alone treatment process (Configuration C, **Figure 4**). Pros and cons for each treatment configurations are listed in **Table 8**.

Table 8 – Treatment Configurations Pros and Cons

Configuration	Pros	Cons
Configuration A: GAC, then Air Stripper	- High GAC media bed life and no additional pumping required	- Additional air stripper required for Alternative 2 - SCAQMD permit required - Vapor phase carbon adsorber potentially required in the future - High power costs - Blower maintenance
Configuration B: Air Stripper, then GAC	- Highest GAC media bed life	- Additional air stripper required for Alternative 2 - Pumping required from Air Stripper to GAC - SCAQMD permit required - Vapor phase carbon adsorber potentially required in the future - Highest power costs - Blower maintenance
Configuration C: GAC Only (no Air Stripper)	- Least complex system - Lowest power cost - Minimal piping modification - No SCAQMD permit	- Lowest media bed life

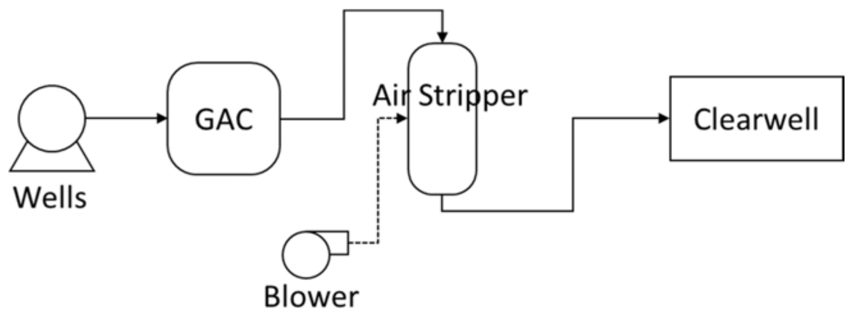

Figure 2 – Treatment Configuration A

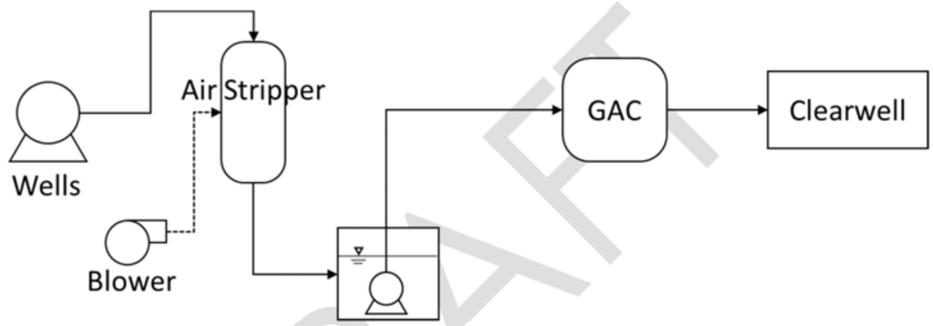

Figure 3 – Treatment Configuration B

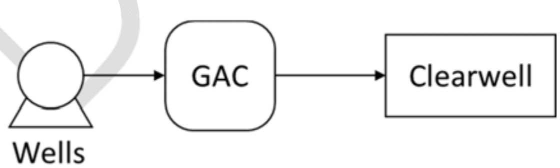

Figure 4 – Treatment Configuration C

FACILITY DESIGN

The proposed site plan for both Alternatives 1 and 2 is presented in **Figure 5.** The GAC treatment system will be located on a concrete pad in the Southeast corner of Chino I, near Well I-18. This location would require the existing storage structure to be relocated, and potentially some grading in order to level the area. This is an ideal site for the GAC system as it is convenient for piping connections and provides adequate access around the pad for system maintenance and truck access for GAC media replacement. Some relocation of yard piping may be required.

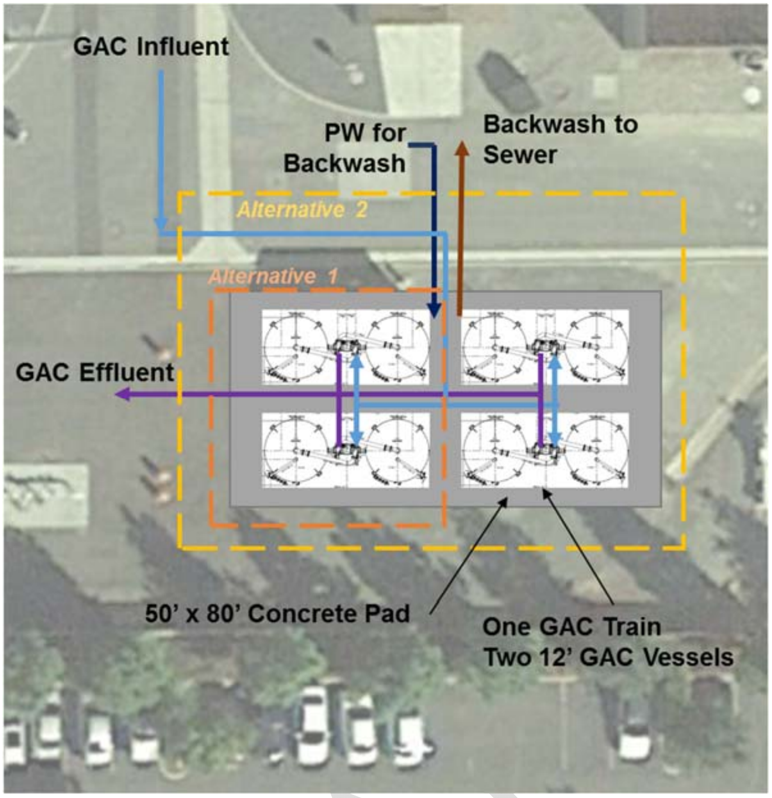

Figure 5 - GAC Treatment Site Plan

Raw water from the selected wells (or from the air stripper[s]) will enter the treatment system and be split between either two or four GAC trains, depending on Alternative 1 or 2, respectively. The treated product water from the GAC trains will be collected in one main pipe and discharged to the air stripper(s) for redundant treatment before the Clearwell. If the water is treated through the Air Strippers first, the GAC product water will be sent directly to the Clearwell.

One compressed air connection and one potable water connection may be required to slurry the new GAC into the vessel from the delivery truck during media replacement. One additional 8" connection with sufficient flow (1,700 gpm) is also required for backwash. The backwash line is ideally connected to treated water rather than raw water so no media is spent during backwash and no transfer zone develops in the vicinity of the vessel discharge line. It could be connected to either the RO effluent, or to one of the Clearwell effluent lines (within Chino I or on Kimball Avenue).

Even though the future GAC treatment system is located in the vicinity of the holding ponds, it is not recommended to use them to store backwash water: GAC fines could be reintroduced into the treatment system and clog cartridge filters. Once backwash is complete, the waste water can be sent to a sewer line. Two lines could be used: one belonging to IEUA north of the gate on Kimball Avenue, the other belonging to the City of Chino on Euclid Avenue. Connecting to the sewer on Euclid Avenue seems to be the less disruptive alternative at this stage. It would maintain access to Chino I through the Kimball avenue gate and is hence recommended. This new connection could also potentially be used to collect other sanitary flows currently connected to the brine line to free brine line capacity.

Proposed piping for Configurations A, B, and C are shown on **Figure 6**, **Figure 7**, and **Figure 8** respectively.

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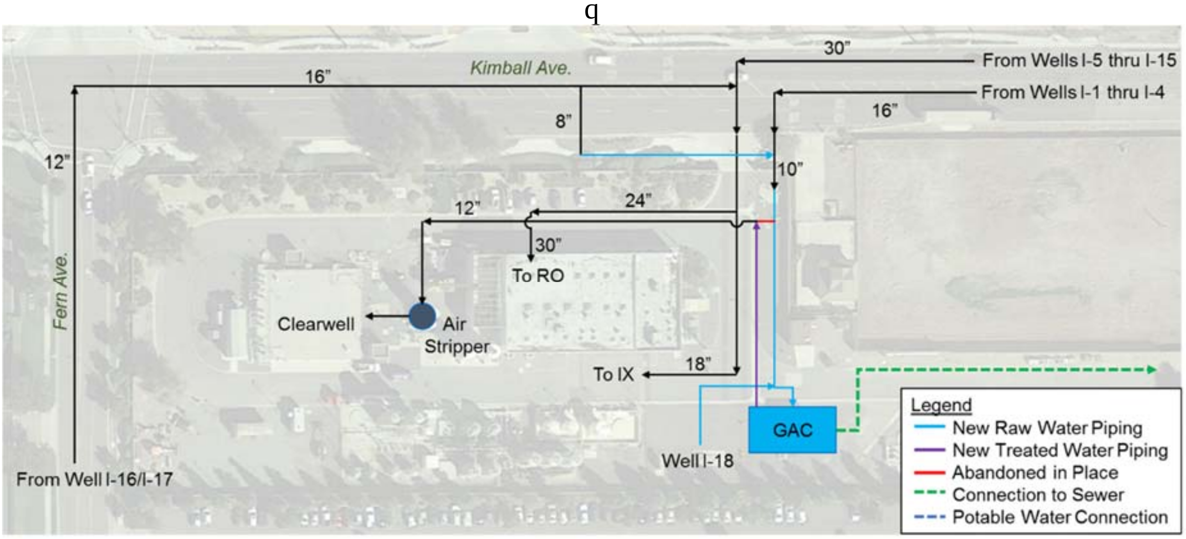

Figure 6 – Configuration A Piping

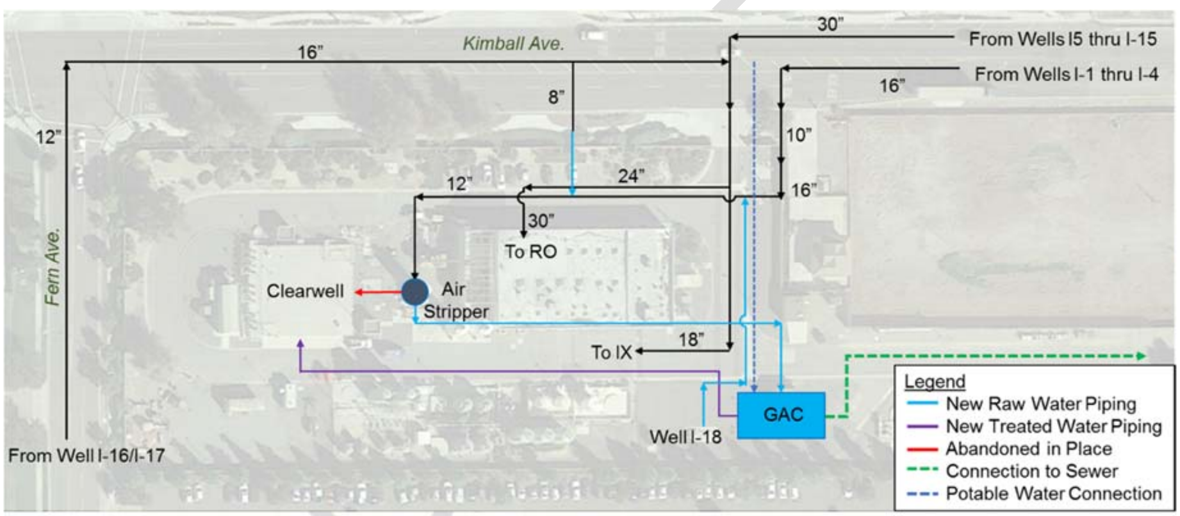

Figure 7 – Configuration B Piping

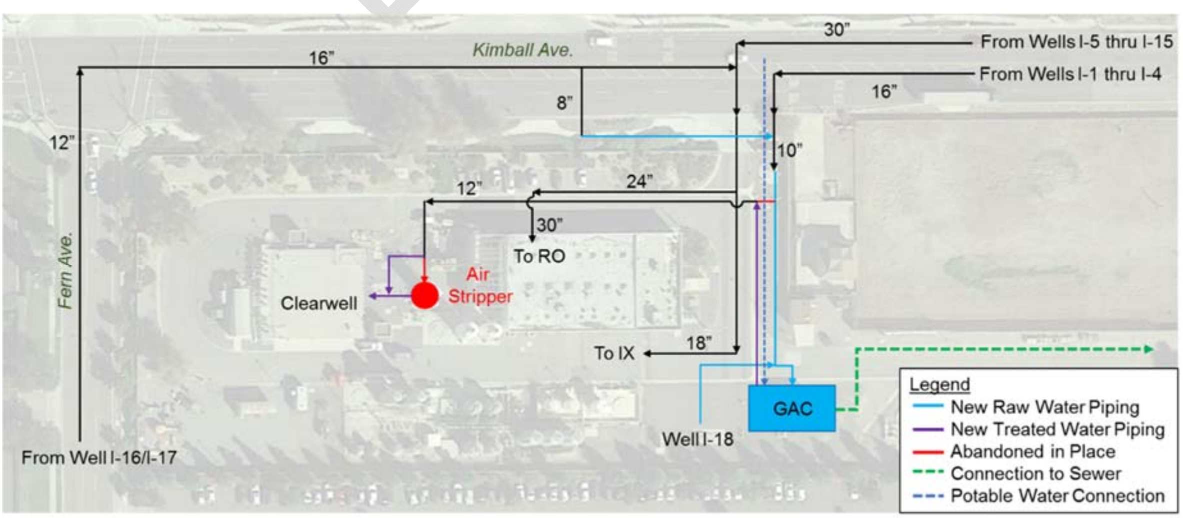

Figure 8 – Configuration C Piping

MEDIA REPLACEMENT FREQUENCY

GAC bed life predictions are helpful to estimate the Operation and Maintenance (O&M) cost for a GAC facility, since GAC media replacement is a significant O&M cost for the system. However, bed life predictions are based on isotherm data and do not take into account kinetic effects that are the true drivers of media bed life. Therefore, column testing with actual raw water through a full cycle would be the only way to accurately predict the expected bed life.

Predicted bed lives are also useful for determining the economical advantage of treating the water with air stripping before or after the GAC, or not at all. Anticipated usage rates for each of the constituents found in the raw water are summarized in **Table 9** for both alternatives (1 and 2) and all configurations.

Table 9 – Predicted GAC Media Bed Lives

Alternative	1			2		
Configuration	A	B	C	A	B	C
	Bed Life - days					
1, 2-Dichloroethene	1340	>10,000	1,300	1,400	>100,000	1,300
cis-1,2-Dichloroethene	364	6,700	360*	280	5,300	280*
1,2-Dichloroethane	535	5,200	530	400	4,100	400
1,2,3-Trichloropropane (TCP)	1875*	2,800*	1,900	930*	1,400*	930
Tetrachloroethylene	>10,000	>100,000	>10,000	>10,000	>100,000	>10,000
Trichloroethylene	444	5,600	430	550	640	300

*Actual media replacement frequency for the Alternative and Configuration considered.

Table 9 shows that the contaminants will breakthrough in different orders depending on the alternative and the configuration considered. For instance, for Alternative 1, Configuration A compounds would break through in the following order: cis-1,2-Dichloroethene, 1, 2-Dichloroethene, Trichloroethylene, 1, 2-Dichloroethene, TCP, and finally Tetrachloroethylene.

When air stripping is part of the treatment train (Configurations A and B), TCP breakthrough will trigger media replacement since the other compounds will be removed by air stripping. For instance, for Alternative 1, Configuration A, it is estimated that the media would need to be replaced in each duty vessel after 1,250 days of operation.

In the absence of air stripping (Configuration C), GAC media replacement would occur as the first compound breaks through. For instance, for Alternative 1, Configuration C, it is estimated that the media would need to be replaced in each duty vessel after 240 days of operation.

COMPOUND MONITORING

Based on the new regulation (State Water Resources Control Board, 2017), TCP monitoring at the Clearwell must be performed monthly starting January 1st, 2017 for at least six months. It is also recommended to monitor TCP at least once a month after the first GAC vessel of each train. For Configurations A and B, when the TCP concentration in the first vessel effluent exceeds the MCL it is recommended to schedule media replacement. This will ensure that the TCP concentration in the Clearwell does not exceed the MCL. For Configuration C, all compounds would need to be monitored, and the media replaced as soon as one compound concentration is detected near the MCL in the first vessel effluent.

ALTERNATIVES COST EVALUATION

This section provides conceptual cost estimates of the three treatment configurations considered for both alternatives.

PROJECT COST

Project costs are detailed in **Appendix C**, and include the following, as applicable:

- Equipment cost: GAC vessels and first batch of media, additional air stripper (Alternative 2), additional pumping (from stripper to GAC, Configuration B)
- Civil costs: piping, concrete pad, pavement
- Various electrical and I&C costs (30% of powered equipment cost)
- Scope contingency (10%), contractor contingency (30%), and project contingency (20%)

O&M COSTS

O&M Costs are summarized in **Appendix C** and include, as applicable:

- GAC media replacement costs
- Power costs for blowers and pumps

COST SUMMARY

In order to compare the three treatment configurations, a life-cycle analysis was performed and equivalent annualized cost presented in **Table 10.** Annualized costs are based on an inflation rate of 3% over 25 years of useful life.

Table 10 – Cost Summary

Alternative	Configuration	Description	Capital Cost ($)	O&M Cost* ($/year)	Total Annualized Cost ($/year)
1	A	GAC, then Air Stripper	$2,127,100	$37,000	$160,000
	B	Air Stripper, then GAC	$2,609,000	$54,000	$204,000
	C	GAC Only	$2,092,625	$81,000	$202,000
2	A	GAC, then Air Stripper	$4,449,100	$87,000	$343,000
	B	Air Stripper, then GAC	$4,980,000	$111,000	$420,000
	C	GAC Only	$3,619,625	$147,000	$385,000

*O&M costs assume a power cost of $0.13/kWh

SCAQMD may require additional gas-phase treatment of the air used for stripping with carbon adsorber. This was not taken into account in this analysis, but if enforced, could increase Configurations A and B annualized costs.

It should be noted that presented costs are preliminary and subject to change during detailed design. Overall, for both Alternatives, the different Configurations costs are very similar and additional considerations such as operational preferences may determine the configuration selected. Those cost estimates also heavily rely on preliminary bed life calculations that present an unknown level of uncertainty due to the complex raw water quality profile.

SENSITIVITY ANALYSIS

The sensitivity analysis below examines the impacts on the Total Annualized Cost of bed life variations within a 50% to 200% range of their currently estimated values. Potential costs are presented in **Table 11:**

Table 11 – Sensitivity Analysis Summary

Alternative	Configuration	Description	Total Annualized Cost ($/yr) % of calculated media bed life		
			50%	100%	200%
1	A	GAC, then Air Stripper	$176,000	$160,000	$153,000
	B	Air Stripper, then GAC	$214,000	$204,000	$198,000
	C	GAC Only	$283,000	$202,000	$162,000
2	A	GAC, then Air Stripper	$387,000	$343,000	$321,000
	B	Air Stripper, then GAC	$426,000	$397,000	$382,000
	C	GAC Only	$501,000	$355,000	$282,000

RECOMMENDATION

According to **Table 11,** Configuration A is the most cost effective, except for Alternative 2 Configuration C with a long bed life. This is because Configuration C becomes more cost effective as the media bed life and the treated flow (Alternative 2) increases. Configuration C (GAC only) would also be the easiest system to operate and maintain. It is hence recommended to select Configuration C, and keep the Air Stripper as a contingency plan. During the first several month of GAC operation, actual media bed life can be accurately evaluated and a decision made accordingly to either put the Air Stripping back online as part of the treatment process, or to turn it off indefinitely.

REFERENCES

2017, Tetra Tech, Final Feasibility Study, Chino Airport Groundwater Assessment

2017, State Water resources Control Board, Title 22, California Code of Regulations, Division 4, Chapter 15, Article 5.5

2003, Agenson, Oh, Urase, Retention of a wide variety of organic pollutants by different nanofiltration/reverse osmosis membrens: controlling parameters of process, Journal of Membrane Science, 225 91-103

APPENDIX A - CALCULATIONS

Chino Desalter Authority - TCP Study

Alternative 1

Well Blending Calcs

Goal: estimate TCP concentration in the Clearwell.

Background level **0.0025**

level below the MCL/ML that is not detected but may still be present

Flow split		Influent	Effluent	Recovery	
	RO gpm	5,800	4,640	80%	
	IX gpm	3,436	3,367	98%	**Conform to Plant operations**
	Total	9,236	8,007		
				RO rated capacity	5800
	TCP MCL	0.005	µg/L	IX rated capacity	3600

	Parameter	Unit	I-1	I-2	I-3	I-4	EW-1	EW-2	EW-3	EW-4	EW-5	I-5	I-6	I-7	I-8	I-9	I-10	I-11	I-13	I-14	I-15	I-20	I-21	I-16	I-17*	I-18	EW-6	EW-7	EW-8	EW-9	EW-10
Wellhead WQ	**Flow Rate**	**gpm**	**380**	**145**	**350**	**137**	**100**	**100**	**150**	**50**	**100**	**1100**	**350**	**175**	**954**	**1050**	**1134**	**574**	**1060**	**2174**	**1810**	**443**	**415**	**226**	**175**	**85**	**150**	**50**	**50**	**100**	**50**
	TOC	mg/L	0	0	0	0.13						1.2	1.2	1.4	1.7	2.1	2.4	1.4	0.96	1.2	0.86	0.88	1.2	0.17	0.86						
	1,1-Dichloroethene	µg/L																								7.8					
	cis-1,2-Dichloroethene	µg/L		3	3		3	3	3	3	3															17	3		3	3	
	1,2-Dichloroethane	µg/L	0.3	0.3	0.3		0.3	0.7	0.3	0.3	0.3															0.8	0.3		0.7	0.3	
	1,2,3-Trichloropropane	µg/L	0.01	0.30	0.27	0.0025	30	30	0.5	0.3	0.3	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	1.2	9.5	10	0.0025	30	10	0.0025
	Tetrachloroethylene	µg/L																								1.1					
	Trichloroethylene	µg/L		6	13		100	100	100	3	3					0.7	1	3.3	19						4.4	290	3		100	20	3
	Well Status	**on/off**	**OFF**	**ON**	**ON**	**ON**	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	**ON**	**OFF**	**OFF**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**
	GAC at Well Head	**yes/no**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Post Wellhead Treatment	**Flow Rate**	gpm	**0**	**145**	**350**	**137**	**0**	**0**	**0**	**0**	**0**	**0**	**350**	**0**	**0**	**1050**	**1134**	**574**	**1060**	**2174**	**1810**	**443**	**415**	**226**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	1,1-Dichloroethene	µg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.8	0	0	0	0	0
	cis-1,2-Dichloroethene	µg/L	0	3	3	0	3	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	3	0	3	3	0
	1,2-Dichloroethane	µg/L	0.3	0.3	0.3	0	0.3	0.7	0.3	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.3	0	0.7	0.3	0
	1,2,3-Trichloropropane	µg/L	0.005	0.3	0.27	0.0025	30	30	0.5	0.3	0.3	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	1.2	9.5	10	0.0025	30	10	0.0025
	Tetrachloroethylene	µg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	0	0	0	0	0
	Trichloroethylene	µg/L	0	6	13	0	100	100	100	3	3	0	0	0	0	0.7	1	3.3	19	0	0	0	0	0	4.4	290	3	0	100	20	3
Wells Combined and Treated	Influent TOC	mg/L	0.0282									1.36												0.170							
	GAC	**yes/no**	YES									NO												NO							
	Air Stripper	**yes/no**	YES									NO												NO							
	RO/IX	**yes/no**	NO									YES												YES							
	Flow Rate Combined	gpm	**632**									**9010**												**226**							
	Product Water Flow	gpm	**632**									**7811**												**196**							
	1,1-Dichloroethene	µg/L	0.000									0.0000												0.00000							
	cis-1,2-Dichloroethene	µg/L	0.000									0.0000												0.00000							
	1,2-Dichloroethane	µg/L	0.000									0.0000												0.00000							
	1,2,3-Trichloropropane	µg/L	0.000									0.0012												0.00120							
	Tetrachloroethylene	µg/L	0.000									0.0000												0.00000							
	Trichloroethylene	µg/L	0.000									1.2694												0.00000							
Clearwell	**Flow Rate Combined**	gpm	**8639**																												
	1,1-Dichloroethene	µg/L	0.0																												
	cis-1,2-Dichloroethene	µg/L	0.0																												
	1,2-Dichloroethane	µg/L	0.0																												
	1,2,3-Trichloropropane	µg/L	0.0011																												
	Tetrachloroethylene	µg/L	0.0																												
	Trichloroethylene	µg/L	1.1																												

Chino Desalter Authority - TCP Study

Alternative 2

Well Blending Calcs

Goal: estimate TCP concentration in the Clearwell.

Background level **0.0025**

level below the MCL/ML that is not detected but may still be present

Flow split		Influent	Effluent	Recovery	
	RO gpm	5,800	4,640	80%	
	IX gpm	3,210	3,146	98%	**Conform to Plant operations**
	Total	9,010	7,786		
				RO rated capacity	5800
	TCP MCL	0.005	µg/L	IX rated capacity	3600

	Parameter	Unit	I-1	I-2	I-3	I-4	EW-1	EW-2	EW-3	EW-4	EW-5	I-5	I-6	I-7	I-8	I-9	I-10	I-11	I-13	I-14	I-15	I-20	I-21	I-16	I-17*	I-18	EW-6	EW-7	EW-8	EW-9	EW-10
Wellhead WQ	**Flow Rate**	**gpm**	**380**	**145**	**350**	**137**	**100**	**100**	**150**	**50**	**100**	**1100**	**350**	**175**	**954**	**1050**	**1134**	**574**	**1060**	**2174**	**1810**	**443**	**415**	**226**	**175**	**85**	**150**	**50**	**50**	**100**	**50**
	TOC	mg/L	0	0	0	0.13						1.2	1.2	1.4	1.7	2.1	2.4	1.4	0.96	1.2	0.86	0.88	1.2	0.17	0.86						
	1,1-Dichloroethene	µg/L																								7.8					
	cis-1,2-Dichloroethene	µg/L		3	3		3	3	3	3	3															17	3		3	3	
	1,2-Dichloroethane	µg/L	0.3	0.3	0.3		0.3	0.7	0.3	0.3	0.3															0.8	0.3		0.7	0.3	
	1,2,3-Trichloropropane	µg/L	0.01	0.30	0.27	0.0025	30	30	0.5	0.3	0.3	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	1.2	9.5	10	0.5	30	10	0.5
	Tetrachloroethylene	µg/L																								1.1					
	Trichloroethylene	µg/L		6	13		100	100	100	3	3					0.7	1	3.3	19						4.4	290	3		100	20	3
	Well Status	**on/off**	**OFF**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**OFF**	**ON**	**OFF**	**OFF**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**OFF**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**
	GAC at Well Head	**yes/no**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Post Wellhead Treatment	**Flow Rate**	gpm	**0**	**145**	**350**	**137**	**100**	**100**	**150**	**50**	**100**	**0**	**350**	**0**	**0**	**1050**	**1134**	**574**	**1060**	**2174**	**1810**	**443**	**415**	**0**	**175**	**85**	**150**	**50**	**50**	**100**	**50**
	1,1-Dichloroethene	µg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.8	0	0	0	0	0
	cis-1,2-Dichloroethene	µg/L	0	3	3	0	3	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	3	0	3	3	0
	1,2-Dichloroethane	µg/L	0.3	0.3	0.3	0	0.3	0.7	0.3	0.3	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	0.3	0	0.7	0.3	0
	1,2,3-Trichloropropane	µg/L	0.005	0.3	0.27	0.0025	30	30	0.5	0.3	0.3	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	1.2	9.5	10	0.5	30	10	0.5
	Tetrachloroethylene	µg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1	0	0	0	0	0
	Trichloroethylene	µg/L	0	6	13	0	100	100	100	3	3	0	0	0	0	0.7	1	3.3	19	0	0	0	0	0	4.4	290	3	0	100	20	3

	Parameter	Unit	I-1 to EW-5	I-5 to I-21	I-16 to EW-10
Wells Combined and Treated	Influent TOC	mg/L	0.0157	1.36	0.228
	GAC	**yes/no**	**YES**	**NO**	**YES**
	Air Stripper	**yes/no**	**YES**	**NO**	**NO**
	RO/IX	**yes/no**	**NO**	**YES**	**NO**
	Flow Rate Combined	gpm	**1132**	**9010**	**660**
	Product Water Flow	gpm	**1132**	**7786**	**660**
	1,1-Dichloroethene	µg/L	0.000	0.0000	0.00010
	cis-1,2-Dichloroethene	µg/L	0.000	0.0000	0.00036
	1,2-Dichloroethane	µg/L	0.000	0.0000	0.00003
	1,2,3-Trichloropropane	µg/L	0.000	0.0012	0.00077
	Tetrachloroethylene	µg/L	0.000	0.0000	0.00001
	Trichloroethylene	µg/L	0.000	1.2300	0.00500

	Parameter	Unit	Value
Clearwell	**Flow Rate Combined**	gpm	**9578**
	1,1-Dichloroethene	µg/L	0.0
	cis-1,2-Dichloroethene	µg/L	0.0
	1,2-Dichloroethane	µg/L	0.0
	1,2,3-Trichloropropane	µg/L	0.0010
	Tetrachloroethylene	µg/L	0.0
	Trichloroethylene	µg/L	1.00

Chino Desalter Authority - TCP Study

Process Removal

	GAC	RO	IX	Air Stripper - Alt 1	Air Stripper - Alt 2
1,1-Dichloroethene	99.99%	90%	0%	99.9%	95.1%
cis-1,2-Dichloroethene	99.99%	90%	0%	99.9%	95.2%
1,2-Dichloroethane	99.99%	90%	0%	99.4%	91.1%
1,2,3-Trichloropropane	99.99%	90%	0%	78.2%	66.1%
1,4-Dioxane	99.99%	90%	0%	1.3%	1.1%
Carbon Tetrachloride	99.99%	90%	0%	99.9%	95.7%
Tetrachloroethylene	99.99%	90%	0%	99.9%	95.7%
Trichloroethylene	99.99%	90%	0%	99.9%	95.5%

Chino Desalter Authority - TCP Study

Alternative 1 - Existing Air Stripper

Design Basis

Flow rate = 1,012 gpm

Constituent	K_H (atm/M)	Concentration (µg/L) MCL	Removal Predicted
1,1-Dichloroethene	5.8	6	100%
cis-1,2-Dichloroethene	7.4	6	100%
1,2-Dichloroethane	1.18	0.5	99%
1,2,3-Trichloropropane	0.32	0.005	78%
1,4-Dioxane	0.00488	1	1%
Carbon Tetrachloride	29	0.5	100%
Tetrachloroethylene	26.9	5	100%
Trichloroethylene	11.6	5	100%

Design Assumptions

Mass transfer coeff. =	0.5	min^{-1}
Air temperature =	25	°C
	298.15	K
Ideal gas constant =	0.08206	L-atm/mol-K

Select Air Flow Rate

Air / liquid ratio =	63		
Air flow rate =	8500	cfm	blower rated capacity: 8,500 cfm

Existing Tower Configuration and Diameter

Number of towers =	1	
Diameter =	10	ft
Height =	24	ft
Cross-section area =	78.5	sf
Design loading rate =	23	gpm/sf
Actual loading rate =	12.9	gpm/sf
Loading rate OK?	YES	Y/N

Calculate Column Performance

Constituent	Stripping Factor	$\frac{C_f}{C_i}$	Predicted Removal
1,1-Dichloroethene	14.9	1.40E-03	9.99E-01
cis-1,2-Dichloroethene	19.0	1.29E-03	100%
1,2-Dichloroethane	3.0	6.31E-03	99%
1,2,3-Trichloropropane	0.8	2.18E-01	78%
1,4-Dioxane	0.0	9.87E-01	1%
Carbon Tetrachloride	74.5	1.02E-03	100%
Tetrachloroethylene	69.1	1.03E-03	100%
Trichloroethylene	29.8	1.15E-03	100%

Select Air Blower

Pressure drop =	0.43	psi
Back pressure =	1.0	ft water
Raw power =	16	hp
Efficiency =	75	%
Power required =	21	hp

Air Stack Sizing

Air Flow Rate =	8500	cfm
Min Settling Velocity =	2000	ft/min
Area =	4.3	ft^2
Diameter =	2.1	ft

Chino Desalter Authority - TCP Study

Alternative 2 - Existing and New Air Strippers

Design Basis

Flow rate =	2,223	gpm
Effluent target =	80	% of MCL

Constituent	K_H (atm/M)	Concentration (µg/L) MCL	Removal Predicted
1,1-Dichloroethene	5.8	6	95%
cis-1,2-Dichloroethene	7.4	6	95%
1,2-Dichloroethane	1.18	0.5	91%
1,2,3-Trichloropropane	0.32	0.005	66%
1,4-Dioxane	0.00488	1	1%
Carbon Tetrachloride	29	0.5	96%
Tetrachloroethylene	26.9	5	96%
Trichloroethylene	11.6	5	95%

Design Assumptions

Mass transfer coeff. =	0.5	min^{-1}
Air temperature =	25	°C
	298.15	K
Ideal gas constant =	0.08206	L-atm/mol-K

Select Air Flow Rate

Air / liquid ratio =	57	
Air flow rate =	8500	cfm

blower rated capacity: 8,500 cfm

Existing Tower Configuration and Diameter

Number of towers =	2	
Diameter =	10	ft
Height =	24	ft

One new stripper, identical to the existing one, is added.

Cross-section area =	78.5	sf
Design loading rate =	23	gpm/sf
Actual loading rate =	14.2	gpm/sf
Loading rate OK?	YES	Y/N

Calculate Column Performance

Constituent	Stripping Factor	$\frac{C_f}{C_i}$	Predicted Removal
1,1-Dichloroethene	13.6	4.93E-02	9.51E-01
cis-1,2-Dichloroethene	17.3	4.76E-02	95%
1,2-Dichloroethane	2.8	8.87E-02	91%
1,2,3-Trichloropropane	0.7	3.39E-01	66%
1,4-Dioxane	0.0	9.89E-01	1%
Carbon Tetrachloride	67.8	4.33E-02	96%
Tetrachloroethylene	62.9	4.34E-02	96%
Trichloroethylene	27.1	4.55E-02	95%

Select Air Blower

Pressure drop =	0.43	psi
Back pressure =	1.0	ft water
Raw power =	16	hp
Efficiency =	75	%
Power required =	21	hp

Air Stack Sizing

Air Flow Rate =	8500	cfm
Min Settling Velocity =	2000	ft/min
Area =	4.3	ft^2
Diameter =	2.1	ft

Pipes	Diameter (in)	Velocity ft/s	Total Capacity* (gpm)	Current Well Flow (gpm)	Current Velocity ft/s	Remaining Capacity (gpm)	Airport Well Flow (gpm)	Total Flow (gpm)
North Wells	16	6	3,800	632	1.01	3,168	500	1,132
East Wells	30	6	13,300	9,010	4.08	4,290	--	9,010
South Wells	16	6	3,800	226	0.36	3,574	400	626
TOTAL to GAC				**858**	5.47			**1,758**

$$V = 0.408\frac{Q}{D^2}$$

where:
V = Water velocity inside the pipe (ft/second)
Q = Flow rate of water inside pipe (gpm)
D = Pipe inside diameter (in)

10

CDA Pump Calcs				V (ft/s)	6	
Headloss	*psi*	*ft*		C	120	
Air Stripper to GAC	8.7	20		pump efficiency	75%	
Pressure Drop through GAC	14	32.3		$/hp	$5,000	*unit cost includes both pumps and lift station (concrete
GAC to Clearwell	1.3	3				
Hazen Williams		7.89				
TDH		**63.2**				
Q (gpm)		**1186**				
HP		**25**	$127,000			
kWh		**165,000**				

$$h_l = \frac{10.44 * L * Q^{1.85}}{C^{1.85} * d^{4.8655}}$$

Airport Pump Calcs			
Headloss	*psi*	*ft*	
Air Stripper to GAC	8.7	20	
Pressure Drop through GAC	14	32.3	
GAC to Clearwell	1.3	3	
Hazen Williams		9.23	
TDH		**64.6**	
Q (gpm)		**2086**	
HP		**45**	$227,000
kWh		**297,000**	

APPENDIX B - MAPS

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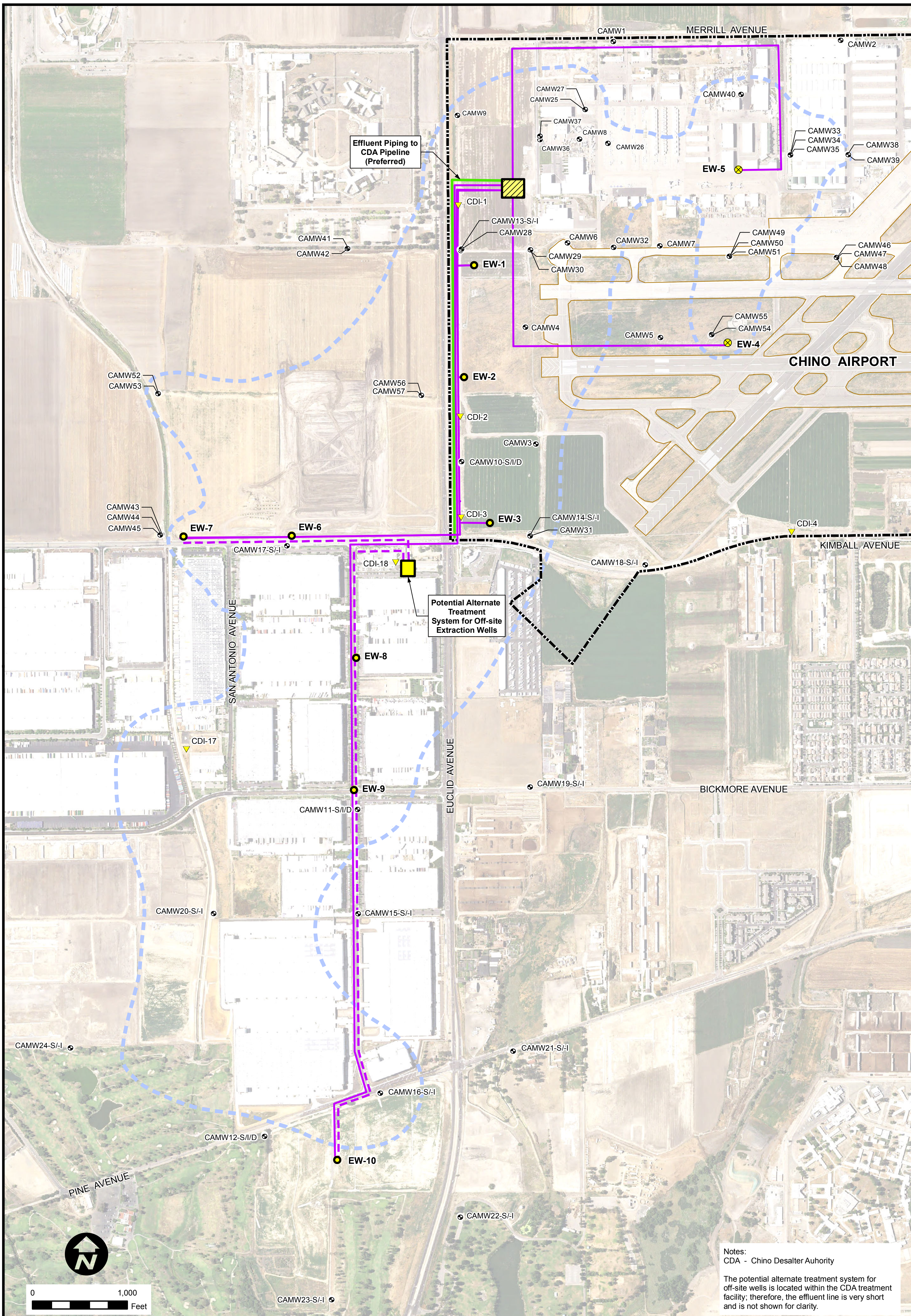


West Plume Groundwater Extraction Well

East Plume Groundwater Extraction Well

Chino Desalter Authority (CDA) Extraction Well

Groundwater Monitoring Well Location

Influent Piping to Groundwater Treatment System

Effluent Piping from Groundwater Treatment System to On-site CDA Collection Header

Potential Alternate Routing of Off-site Extraction Well Piping

On-site Groundwater Treatment System

Potential Alternate Groundwater Treatment System for Off-site Wells

Chino Airport Boundary

Areal Extent of Volatile Organic Compound Plumes in GroundwaterTargeted for Active Remediation

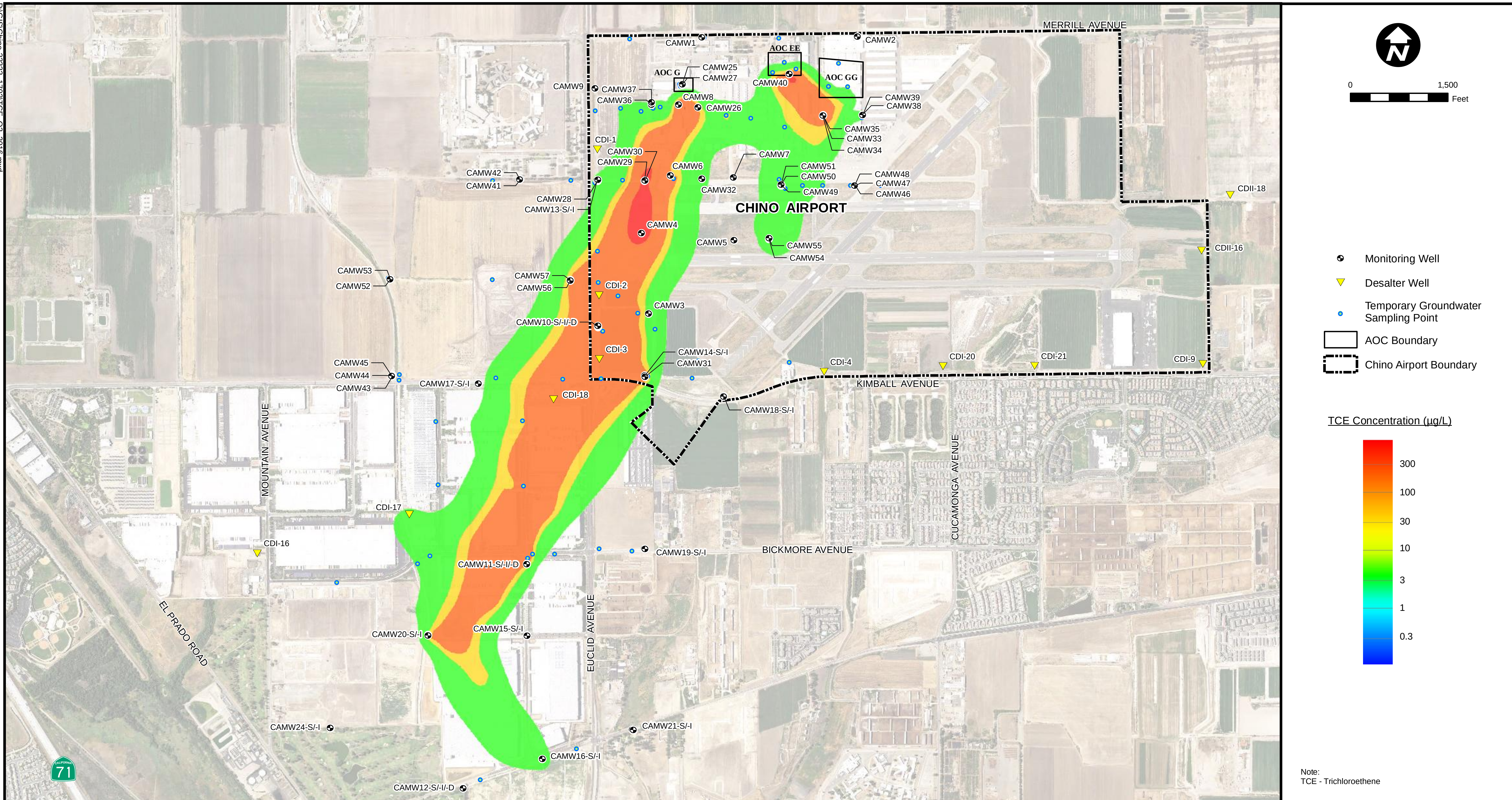
CHINO AIRPORT

Figure 25

Alternative 4A
West Plume Containment and East Plume Containment by Groundwater Extraction and *Ex Situ* Treatment

TETRA TECH

March 2017



Note:
TCE - Trichloroethene

CHINO AIRPORT

Figure 11

TCE at 5 µg/L, 50 µg/L, 100 µg/L, and 500 µg/L Isoconcentrations

TETRA TECH

March 2017

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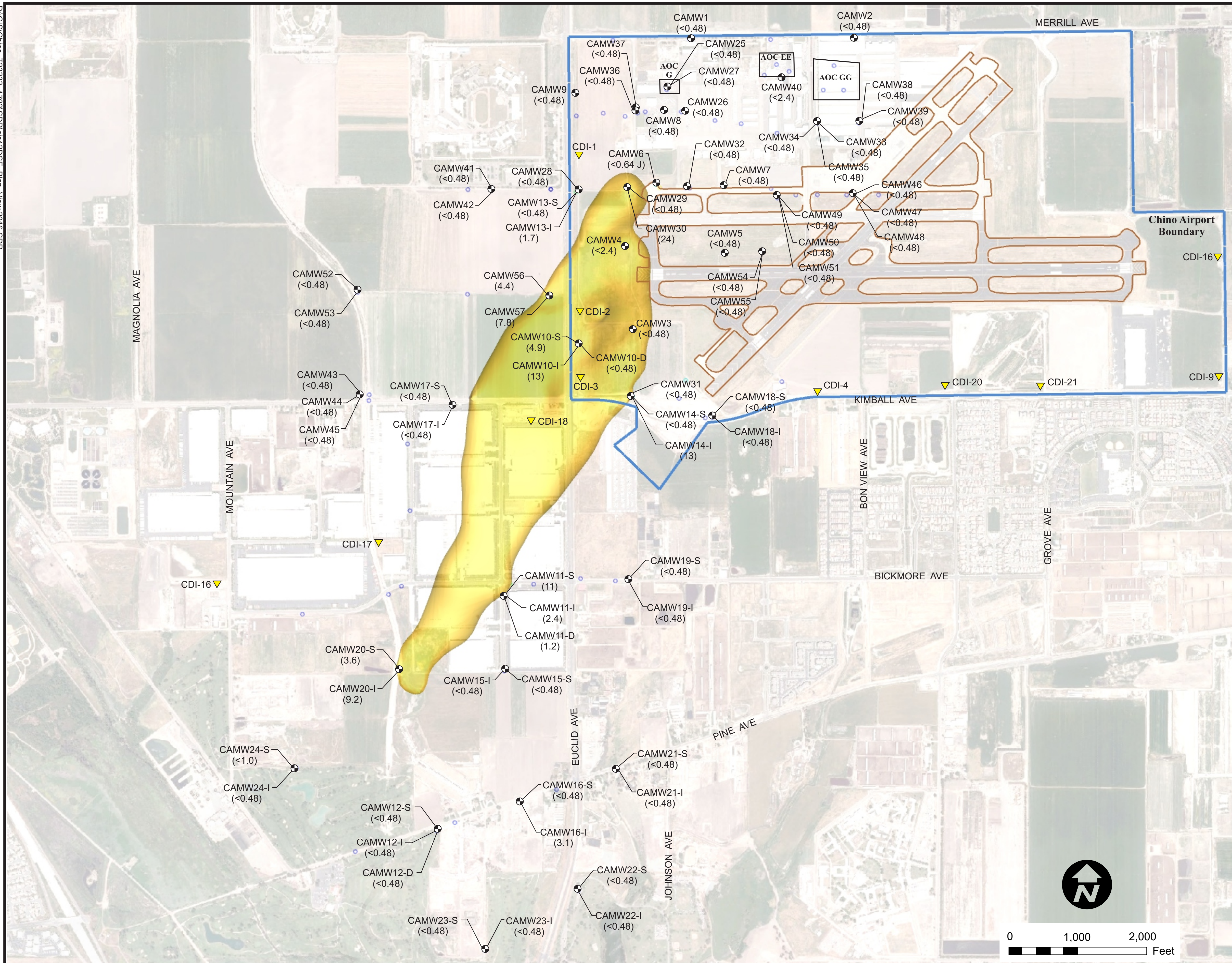

Monitoring Well (concentration in µg/L)

Desalter Well

Temporary Groundwater Sampling Point

cis-1,2-DCE Concentration

30 µg/L
10 µg/L
3 µg/L
0.1 µg/L
0.03 µg/L

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Figure 12

cis-1,2-DCE Above 6 µg/L Isoconcentration

TETRA TECH

March 2017

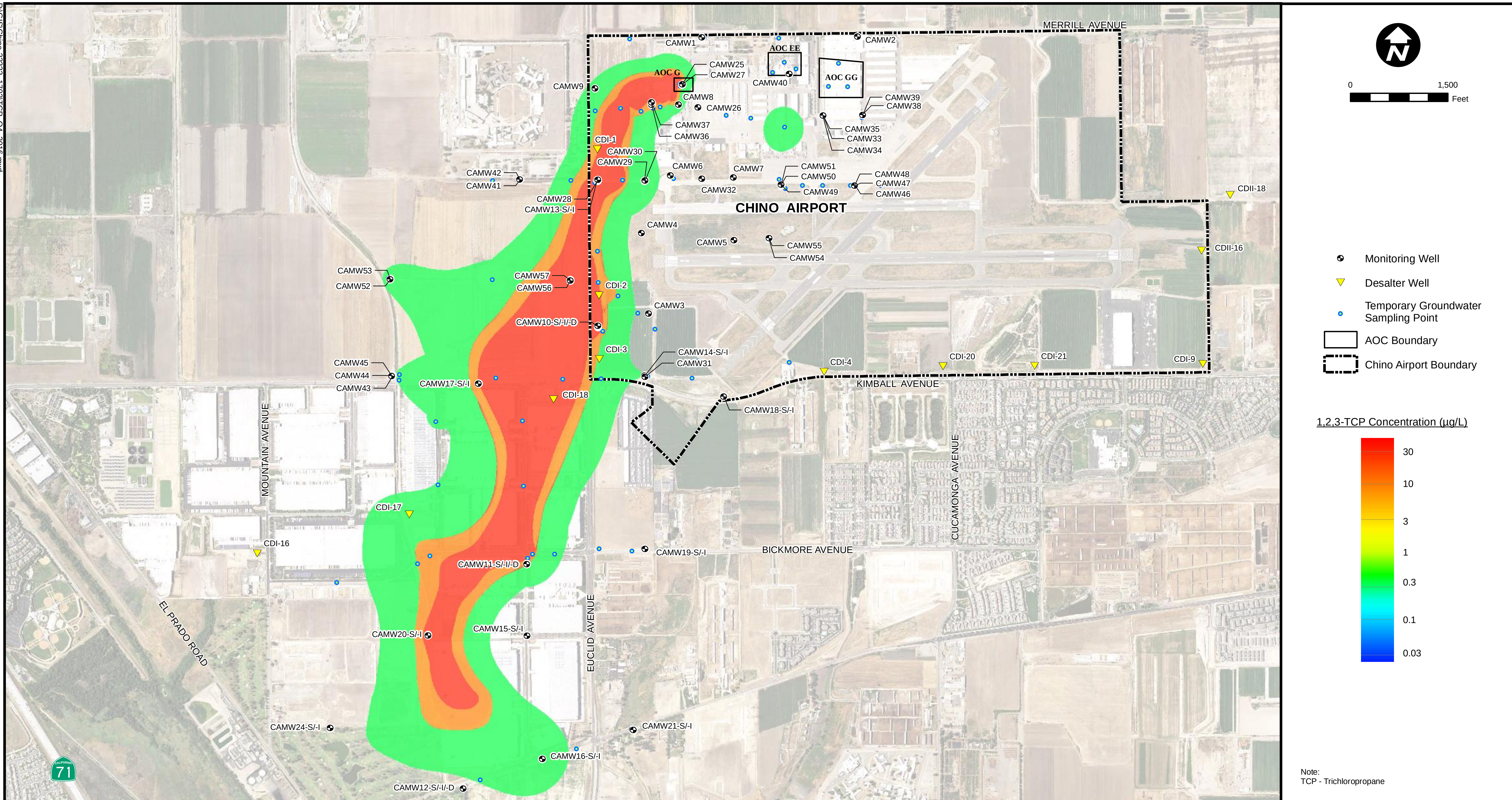

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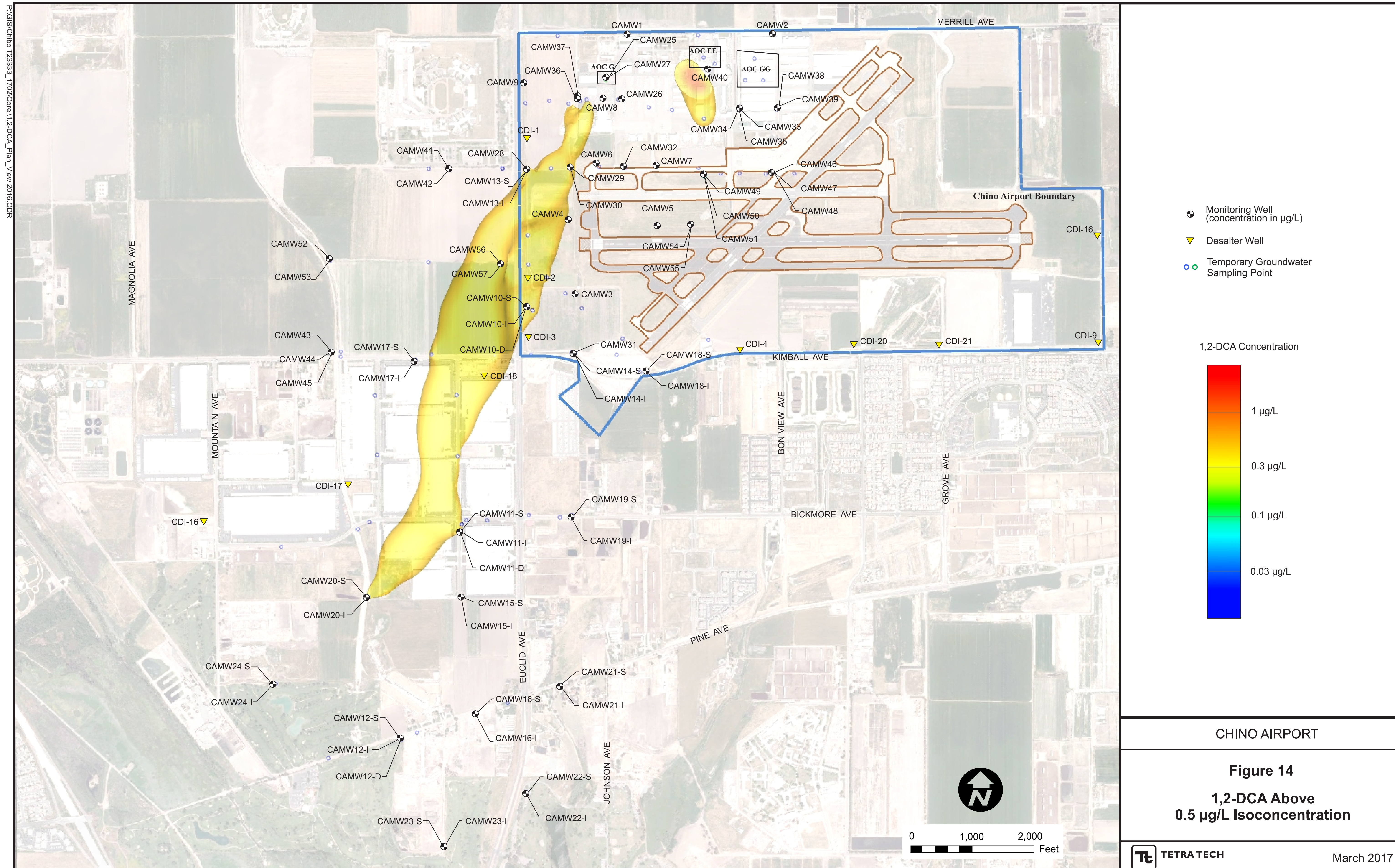
Figure 13

1,2,3-TCP at 0.5 µg/L, 5 µg/L, and 10 µg/L Isoconcentrations

TETRA TECH

March 2017



CHINO AIRPORT

Figure 14

1,2-DCA Above 0.5 µg/L Isoconcentration

TETRA TECH

March 2017

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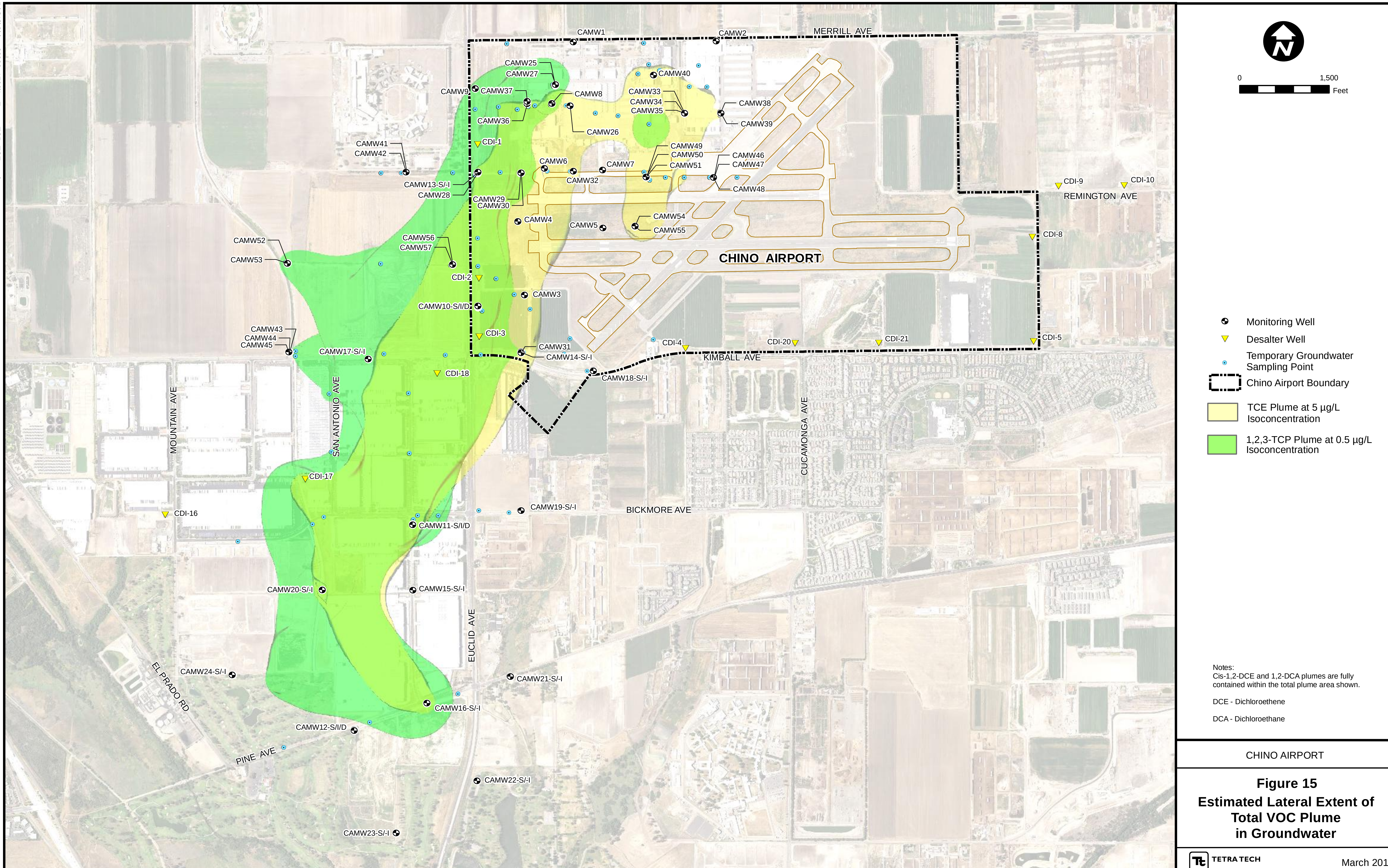

Monitoring Well

Desalter Well

Temporary Groundwater Sampling Point

Chino Airport Boundary

TCE Plume at 5 µg/L Isoconcentration

1,2,3-TCP Plume at 0.5 µg/L Isoconcentration

Notes:
Cis-1,2-DCE and 1,2-DCA plumes are fully contained within the total plume area shown.

DCE - Dichloroethene

DCA - Dichloroethane

CHINO AIRPORT

Figure 15
Estimated Lateral Extent of Total VOC Plume in Groundwater

TETRA TECH

March 2017

APPENDIX C – COST ESTIMATE

CDA GAC System Cost Estimate
SUMMARY

					Sensitivity Analysis - % of calculated bedlife		
					50%	100%	200%
Alternative	Configuration	Description	Capital Cost ($)	O&M Cost ($/year)	Total Annualized Cost ($/yr)	Total Annualized Cost ($/yr)	Total Annualized Cost ($/yr)
1	A	GAC, then Air Stripper	$2,127,100	$37,000	$176,000	$160,000	$153,000
	B	Air Stripper, then GAC	$2,609,000	$54,000	$214,000	$204,000	$198,000
	C	GAC Only	$2,092,625	$81,000	$283,000	$202,000	$162,000
2	A	GAC, then Air Stripper	$4,449,100	$87,000	$387,000	$343,000	$321,000
	B	Air Stripper, then GAC	$4,980,000	$111,000	$426,000	$397,000	$382,000
	C	GAC Only	$3,619,625	$147,000	$501,000	$355,000	$282,000

Model Inputs

Power cost ($/kWh)	0.13
Inflation Rate (%)	3%
Life of New Improvements (yr)	25

CDA GAC System Cost Estimate
CONFIGURATION A - GAC, then Air Stripper
Project and O&M

Project Cost

Item	Unit Cost Alt 1	Unit Cost Alt 2	Unit	Quantity Alt 1	Quantity Alt 2	Total Alt 1	Total Alt 2	Notes
Equipment								
GAC Vessels	$345,000		$/train	2	4	$690,000	$1,380,000	
GAC Media	$1.5		$/lbs	80,000	160,000	$120,000	$240,000	
Air Stripper				0	1	$0	$351,000	From 2015 quote adjusted for inflation and treatment capacity
Civil								
Piping Allocation	$24		$/LF/inch			$304,000	$312,000	
8" South Wells connection	$192	$192	$/LF	125	125	*$24,000*	*$24,000*	
16" to GAC	$384	$384	$/LF	180	180	*$70,000*	*$70,000*	
Well 18 to GAC	$96	$96	$/LF	100	100	*$10,000*	*$10,000*	
GAC to Air Stripper	$240	$288	$/LF	150	150	*$36,000*	*$44,000*	
8" Potable GAC Backwash	$192	$192	$/LF	250	250	*$48,000*	*$48,000*	
12" Sewer GAC Backwash	$288	$288	$/LF	400	400	*$116,000*	*$116,000*	
Concrete Pad	$600		$/cy	167	296	$101,000	$178,000	
Pavement Allocation	$20		$/LF	1205	1205	$24,100	$24,100	
Electrical/I&C Allocation - 30% of powered equipment cost	-		-			$0	$106,000	
Scope Contingency - 10%			-			$124,000	$260,000	
Contractor Contingency (profit, risk allocation) - 30%			-			$409,000	$856,000	
Project Contingency (Admin, CM, etc…) - 20%			-			$355,000	$742,000	
CONF. 1 - TOTAL PROJECT COST			-			**$2,127,100**	**$4,449,100**	
CONF. 1 - ANNUALIZED COST						**$123,000**	**$256,000**	

O&M Cost

	Unit	With Anticipated bed life Alt 1	With Anticipated bed life Alt 2	With 50% of anticipated bed life Alt 1	With 50% of anticipated bed life Alt 2	With 200% of anticipated bed life Alt 1	With 200% of anticipated bed life Alt 2
GAC							
GAC bed life	days	1394	990	697	495	2788	1980
Number of Trains	-	2	4	2	4	2	4
Carbon media unit cost	$/lbs	1.5		1.5		1.5	
Carbon Media Mass per Vessel	lbs	20,000		20,000		20,000	
GAC Replacement Costs	$/yr	$ 15,709	$ 44,240	$ 31,417	$ 88,480	$ 7,854	$ 22,120
Air Stripper							
Number of blowers	-	1	2				
Blower Size	HP	25					
Power Demand	kWh/yr	163,308	326,617				
Power Cost ($0.13/kWh)	$/yr	$ 21,230	$ 42,460				
O&M Total		**$ 37,000**	**$ 87,000**	**$ 53,000**	**$ 131,000**	**$ 30,000**	**$ 65,000**

TOTAL ANNUALIZED COST

Bed Life	Alt. 1	Alt. 2
100%	**$ 160,000**	**$ 343,000**
50%	**$ 176,000**	**$ 387,000**
200%	**$ 153,000**	**$ 321,000**

CDA GAC System Cost Estimate
CONFIGURATION B - Air Stripper, then GAC
Project and O&M

Project Cost

Item	Unit Cost Alt 1	Unit Cost Alt 2	Unit	Quantity Alt 1	Quantity Alt 2	Total Alt 1	Total Alt 2	Notes
Equipment								
GAC Vessels	$345,000		$/train	2	4	$690,000	$1,380,000	
GAC Media	$1.5		$/lbs	80,000	160,000	$120,000	$240,000	
Air Stripper				0	1	$0	$351,000	From 2015 quote adjusted for inflation and treatment capacity
Pumps	$5,000		$/hp	29	45	$145,000	$225,000	Includes vault/wetwell
Civil								
Piping Allocation	$24		$/LF/inch			$386,000	$425,000	
8" South Wells connection	$192	$192	$/LF	50	50	*$10,000*	*$10,000*	
Well 18 to Air Stripper	$96	$96	$/LF	200	200	*$20,000*	*$20,000*	
Air Stripper to GAC	$240	$288	$/LF	350	350	*$84,000*	*$101,000*	
GAC to Clearwell	$240	$288	$/LF	450	450	*$108,000*	*$130,000*	
8" Potable GAC Backwash	$192	$192	$/LF	250	250	*$48,000*	*$48,000*	
12" Sewer GAC Backwash	$288	$288	$/LF	400	400	*$116,000*	*$116,000*	
Concrete Pad	$600		$/cy	167	296	$101,000	$178,000	
Pavement Allocation	$20		$/LF	1700	1700	$34,000	$34,000	
Electrical/I&C Allocation - 30% of powered equipment cost	-		-			$44,000	$68,000	
Scope Contingency - 10%			-			$152,000	$291,000	
Contractor Contingency (profit, risk allocation) - 30%			-			$502,000	$958,000	
Project Contingency (Admin, CM, etc…) - 20%			-			$435,000	$830,000	
CONF. 2 - TOTAL PROJECT COST						**$2,609,000**	**$4,980,000**	
CONF. 2 - ANNUALIZED COST						**$150,000**	**$286,000**	

O&M Cost

	Unit	With Anticipated bed life Alt 1	With Anticipated bed life Alt 2	With 50% of anticipated bed life Alt 1	With 50% of anticipated bed life Alt 2	With 200% of anticipated bed life Alt 1	With 200% of anticipated bed life Alt 2
GAC							
GAC bed life	days	2110	1496	1055	748	4220	2992
Number of Trains	-	2	4	2	4	2	4
Carbon media unit cost	$/lbs	1.5		1.5		1.5	
Carbon Media Mass per Vessel	lbs	20,000		20,000		20,000	
GAC Replacement Costs	$/yr	$ 10,379	$ 29,274	$ 20,758	$ 58,548	$ 5,189	$ 14,637
Air Stripper							
Blowers							
Number of blowers	-	1	2				
Blower Size	HP	25					
Blower Power Consumption	kWh/yr	163,308	326,617				
Pumping							
Number of Pumps		2	2				
Pump Size	HP	25	45				
Pumps Power Consumption	kWh/yr	165,000	297,000				
Power Cost ($0.13/kWh)	$/yr	$ 42,680	$ 81,070				
O&M Total		**$ 54,000**	**$ 111,000**	**$ 64,000**	**$ 140,000**	**$ 48,000**	**$ 96,000**

TOTAL ANNUALIZED COST

Bed Life	Alt. 1	Alt. 2
100%	**$ 204,000**	**$ 397,000**
50%	**$ 214,000**	**$ 426,000**
200%	**$ 198,000**	**$ 382,000**

CDA GAC System Cost Estimate
CONFIGURATION C - GAC Only
Project and O&M

Project Cost

Item	Unit Cost Alt 1	Unit Cost Alt 2	Unit	Quantity Alt 1	Quantity Alt 2	Total Alt 1	Total Alt 2
Equipment							
GAC Vessels	$345,000		$/train	2	4	$690,000	$1,380,000
GAC Media	$1.5		$/lbs	80,000	160,000	$120,000	$240,000
Air Stripper				0	0	$0	$0
Civil	$24		$/LF/inch				
Piping Allocation						$280,000	$283,000
8" South Wells connection	$192	$192	$/LF	125	125	*$24,000*	*$24,000*
16" to GAC	$384	$384	$/LF	180	180	*$70,000*	*$70,000*
Well 18 to GAC	$96	$96	$/LF	100	100	*$10,000*	*$10,000*
GAC bypass Air Stripper	$240	$288	$/LF	50	50	*$12,000*	*$15,000*
8" Potable GAC Backwash	$192	$192	$/LF	250	250	*$48,000*	*$48,000*
12" Sewer GAC Backwash	$288	$288	$/LF	400	400	*$116,000*	*$116,000*
Concrete Pad	$600		$/cy	167	296	$101,000	$178,000
Pavement Allocation	$25		$/LF	1105	1105	$27,625	$27,625
Electrical/I&C Allocation - 30% of powered equipment cost	-		-			$0	$0
Scope Contingency - 10%			-			$122,000	$211,000
Contractor Contingency (profit, risk allocation) - 30%			-			$403,000	$696,000
Project Contingency (Admin, CM, etc…) - 20%			-			$349,000	$604,000
CONF. 3 - TOTAL PROJECT COST						**$2,092,625**	**$3,619,625**
CONF. 2 - ANNUALIZED COST						**$121,000**	**$208,000**

O&M Cost

	Unit	With Anticipated bed life Alt 1	With Anticipated bed life Alt 2	With 50% of anticipated bed life Alt 1	With 50% of anticipated bed life Alt 2	With 200% of anticipated bed life Alt 1	With 200% of anticipated bed life Alt 2
GAC							
GAC bed life	days	271	299	135	150	542	598
Number of Trains	-	2	4	2	4	2	4
Carbon media unit cost	$/lbs	1.5		1.5		1.5	
Carbon Media Mass per Vessel	lbs	20,000		20,000		20,000	
GAC Replacement Costs	$/yr	$ 80,881	$ 146,370	$ 161,762	$ 292,739	$ 40,441	$ 73,185
Air Stripper							
Number of blowers	-	0	0				
Blower Size	HP	25					
Power Demand	kWh/yr	-	-				
Power Cost ($0.13/kWh)	$/yr	$ -	$ -				
O&M Total		**$ 81,000**	**$ 147,000**	**$ 162,000**	**$ 293,000**	**$ 41,000**	**$ 74,000**

TOTAL ANNUALIZED COST

Bed Life	Alt. 1	Alt. 2
100%	**$ 202,000**	**$ 355,000**
50%	**$ 283,000**	**$ 501,000**
200%	**$ 162,000**	**$ 282,000**

Alternative 1 - no Airport Wells

Wells on*: I-1, 2, 3, 4, 17, and 18

Bed Life in days		WQ	GAC first, then Air Stripper		WQ	Air Stripper, then GAC		WQ	GAC Only	
			Evoqua	Stantec		Evoqua	Stantec		Evoqua	Stantec
Flow Rate*	gpm	1186			1186			1186		
TOC	mg/L	0.140			0.140			0.140		
1,1-Dichloroethene	µg/L	0.521	997	1809	0.001	19518	43761	0.521	997	1809
cis-1,2-Dichloroethene	µg/L	2.303	271	403	0.003	4983	6164	2.303	**271**	403
1,2-Dichloroethane	µg/L	0.260	398	682	0.002	3904	7375	0.260	398	682
1,2,3-Trichloropropane	µg/L	0.908	**1394**	3147	0.198	**2110**	5702	0.908	1394	3147
Tetrachloroethylene	µg/L	0.074	21292	9435	0.0001	526324	194797	0.074	21292	9435
Trichloroethylene	µg/L	24.245	620	323	0.028	21292	4226	24.245	620	323
Controlling bed life	**day**	**1394**			**2110**			**271**		

Alternative 2 - with Airport Wells

Wells on*: I-1, 2, 3, 4, 17, 18, EW-1, 2, 3, 4, 5, 6, 7, 8, 9, 10

Bed Life in days		WQ	GAC first, then Air Stripper		WQ	Air Stripper, then GAC		WQ	GAC Only	
			Evoqua	Stantec		Evoqua	Stantec		Evoqua	Stantec
Flow Rate*	gpm	2086			2086			2086		
TOC	mg/L	0.500			0.500			0.500		
1,1-Dichloroethene	µg/L	0.305	1463	2667	0.000	266326	64504	0.305	1463	2667
cis-1,2-Dichloroethene	µg/L	2.454	299	446	0.003	5667	6829	2.454	**299**	446
1,2-Dichloroethane	µg/L	0.290	430	736	0.002	4439	7960	0.290	430	736
1,2,3-Trichloropropane	µg/L	5.214	**990**	1810	1.135	**1496**	3280	5.214	990	1810
Tetrachloroethylene	µg/L	0.043	32558	13576	0.00004	918365	280303	0.043	32558	13576
Trichloroethylene	µg/L	34.019	592	323	0.039	683	4225	34.019	592	323
Controlling bed life	**day**	**990**			**1496**			**299**		

* for contaminant concentration, assume worst case concentration, i.e. 17 on and 16 off since 17 has higher contaminant concentrations. For flows (used for GAC sizing), assume 16 on and 17 off since 16 has higher flow than 17.

CDA Well I-18 GAC Treatment Evaluation

Utilization Rate Check

Design Basis

Flows		**Trains**
No Airport Wells	1186 gpm	2
Airport Wells	2086 gpm	4
Mass per vessel	20,000 lb	

Estimate GAC Utilization Rate - Stantec Model

			No Airport Well, Air Stripper			No Airport Well, no Air Stripper			With Airport Well, Air Stripper			With Airport Well, no Air Stripper		
Constituent	**Adsorption Parameters** K_f	**1/n**	**Influent (µg/L)**	**GAC Usage (lb/gal)**	**Bed Life (day)**	**Influent (µg/L)**	**GAC Usage (lb/gal)**	**Bed Life (day)**	**Influent (µg/L)**	**GAC Usage (lb/gal)**	**Bed Life (day)**	**Influent (µg/L)**	**GAC Usage (lb/gal)**	**Bed Life (day)**
1,1-Dichloroethene	470	0.52	0.00073	5.35E-07	43761	0.52123	1.29E-05	1809	0.00043	4.13E-07	64504	0.30525	9.99E-06	2667
cis -1,2-Dichloroethene	202	0.59	0.00297	3.80E-06	6164	2.30346	5.82E-05	403	0.00316	3.90E-06	6829	2.45396	5.97E-05	446
1,2-Dichloroethane	129	0.53	0.00164	3.18E-06	7375	0.25983	3.43E-05	682	0.00183	3.35E-06	7960	0.29029	3.62E-05	736
1,2,3-Trichloropropane	1080	0.61	0.19780	4.11E-06	5702	0.90841	7.44E-06	3147	1.13539	8.12E-06	3280	5.21432	1.47E-05	1810
Tetrachloroethylene	1066	0.56	0.00008	1.20E-07	194797	0.07351	2.48E-06	9435	0.00004	9.50E-08	280303	0.04305	1.96E-06	13576
Trichloroethylene	387	0.62	0.02790	5.54E-06	4226	24.24528	7.25E-05	323	0.03915	6.30E-06	4225	34.01934	8.25E-05	323
Controlling GAC usage - days					**5,702**			**3,147**			**3,280**			**1,810**
Controlling GAC usage GAC Only - days					**4,226**			**323**			**3,280**			**323**

Estimate GAC Utilization Rate - Evoqua Model Results

Constituent	**GAC Usage (lb/gal)**	**Bed Life (day)**	**GAC Usage (lb/gal)**	**Bed Life (day)**	**GAC Usage (lb/gal)**	**Bed Life (day)**	**GAC Usage (lb/gal)**	**Bed Life (day)**
1,1-Dichloroethene	1.20E-06	19518	2.35E-05	997	1.00E-07	266326	1.82E-05	1463
cis -1,2-Dichloroethene	4.70E-06	4983	8.65E-05	271	4.70E-06	5667	8.90E-05	299
1,2-Dichloroethane	6.00E-06	3904	5.89E-05	398	6.00E-06	4439	6.20E-05	430
1,2,3-Trichloropropane	1.11E-05	2110	1.68E-05	1394	1.78E-05	1496	2.69E-05	990
Tetrachloroethylene	4.45E-08	526324	1.10E-06	21292	2.90E-08	918365	8.18E-07	32558
Trichloroethylene	1.10E-06	21292	3.78E-05	620	3.90E-05	683	4.50E-05	592
Controlling GAC usage - days		**2,110**		**1,394**		**1,496**		**990**
Controlling GAC usage GAC Only - days		**2,110**		**271**		**683**		**299**

Estimate GAC Utilization Rate - Calgon Model Results

Constituent	**GAC Usage (lb/day)**	**Bed Life (day)**	**GAC Usage (lb/day)**	**Bed Life (day)**	**GAC Usage (lb/day)**	**Bed Life (day)**	**GAC Usage (lb/day)**	**Bed Life (day)**
1,1-Dichloroethene	9.20E+01	435	1.38E+02	290	-	-	4.88E+02	164
cis -1,2-Dichloroethene	4.97E+02	80	5.47E+02	73	1.46E+03	55	1.66E+03	48
1,2-Dichloroethane	2.64E+02	152	3.12E+02	128	8.22E+02	97	1.01E+03	79
1,2,3-Trichloropropane	4.20E+01	952	6.10E+01	656	2.56E+02	313	2.88E+02	278
Tetrachloroethylene	3.40E+01	1176	3.60E+01	1111	1.00E+02	800	1.00E+02	800
Trichloroethylene	5.60E+01	714	9.80E+01	408	3.00E+02	267	3.73E+02	214
Controlling GAC usage - days		**952**		**656**		**313**		**278**
Controlling GAC usage GAC Only - days		**80**		**73**		**55**		**48**