TECHNICAL MEMORANDUM

To: Chino Desalter Authority **Date:** July 20, 2015

From: Jim Borchardt **Reference:**

Subject: Review of On-Site Solution for Archibald South Plume

This technical memorandum (TM) is prepared for the Chino Desalter Authority (CDA) to review the proposed on-site treatment solution at Chino Desalter II for trichloroethylene (TCE) originating in the Archibald South Plume.

CDA is currently implementing a Phase III Expansion Project to increase the capacity of their wellfield, transmission, and treatment capacity at the Chino II Plant. The proposed On-Site Solution would modify this current project by utilizing the new wells to intentionally intercept the TCE plume, modify the transmission piping to isolate the TCE from the remaining well water, and provide treatment using the Chino II reverse osmosis membranes and decarbonator facilities. The objective of this review is to evaluate the technical feasibility of the proposed solution, identify costs and other potential issues associated with the proposal, and compare the proposed solution to other wellhead treatment alternatives.

PHASE III FACILITIES

CDA is currently undertaking a Phase III Expansion Project. The objective of the expansion project is to increase domestic water supply and achieve net water production from the Chino II Plant of 20.5 mgd, or 14,236 gpm. This represents a net increase in production of 8.1 mgd, or 5,640 gpm.

The additional water supply will be provided by construction of three new wells to the west of the existing Chino II Wellfield. This is a productive part of the groundwater basin, and each well is anticipated to yield 2,000 gpm. The names and approximate locations of the three new wells are as follows:

Site A – Intersection of Merrill and Archibald Avenues
Site 1 – Intersection of Bellegrave and Turner Avenues
Site 2 – Intersection of Bellegrave and Archibald Avenues

New piping will connect these new wells to the existing Chino II wellfield transmission system along Bellegrave Avenue and convey the water to an expanded Chino II Plant.

PROPOSED ON-SITE SOLUTION

Groundwater data collected by the Santa Ana Regional Water Quality Control Board shows the presence of TCE within an area of approximately 3 square miles (the Archibald South Plume), and this plume is approaching existing and proposed CDA wells. The On-Site Solution provides a strategy to intercept the TCE and provide treatment at the Chino II Plant.

The Proposed On-Site Solution would utilize a dedicated pipeline to connect the new CDA Phase III wells directly to the reverse osmosis (RO) treatment process at the Chino II Plant. The RO process is expected to provide approximately 30% for removal of the TCE, with additional TCE removal achieved by modifying the existing decarbonators. This would provide air stripping of up to 95% of the TCE passing through the plant. The On-Site Solution is more fully described in the Remedial Action Alternative memorandum, dated July 8, 2014, prepared for CDA.

The Proposed On-Site Solution includes an alternative well configuration where the Site A well would be moved roughly one mile north in the vicinity of Edison Avenue and Cucamonga Creek. Thus, “Alternative 1” is defined by the current Phase III well locations, and “Alternative 2” is defined by the northerly location of Site A. The configuration of Alternative 2 in relation to existing CDA facilities is illustrated in **Figure 1** on the following page.

The TCE plume has been modeled, and future estimates of TCE concentrations at each well site have been prepared. The range of minimum to maximum TCE concentrations under future conditions are presented in **Table 1**, reproduced from the referenced Remedial Action Alternatives Memorandum.

Table 1 - Summary of Future TCE Concentrations for Proposed Wells (µg/L) (Range of Minimum to Maximum)

Alternative	Site A	Site 1	Site 2	CDA Well I-11
1	3 to 20	<0.5	<0.5 to 20	4 to 14
2	10 to 25	<0.5	<0.5 to 10	4 to 12

The future estimates vary between wells, reflecting spatial dispersion of TCE within the plume. Site A and possibly Site 2 are expected to have higher concentrations, while Site 1 is not expected to have appreciable amounts of TCE. Existing Well I-11, which is currently connected to the Chino I Plant, is expected to have moderate levels of TCE. For this reason, the On-Site Solution alternatives include the option to provide connecting piping to existing Well I-11 so it can be directed to the Chino II Plant for TCE treatment.

Note that the TCE values in **Table 1** exceed the (MCL) of 5.0 µg/L as well as the Public Health Goal (PHG) of 1.7 µg/L and the Detection Limit for Reporting (DLR) of 0.5 µg/L.

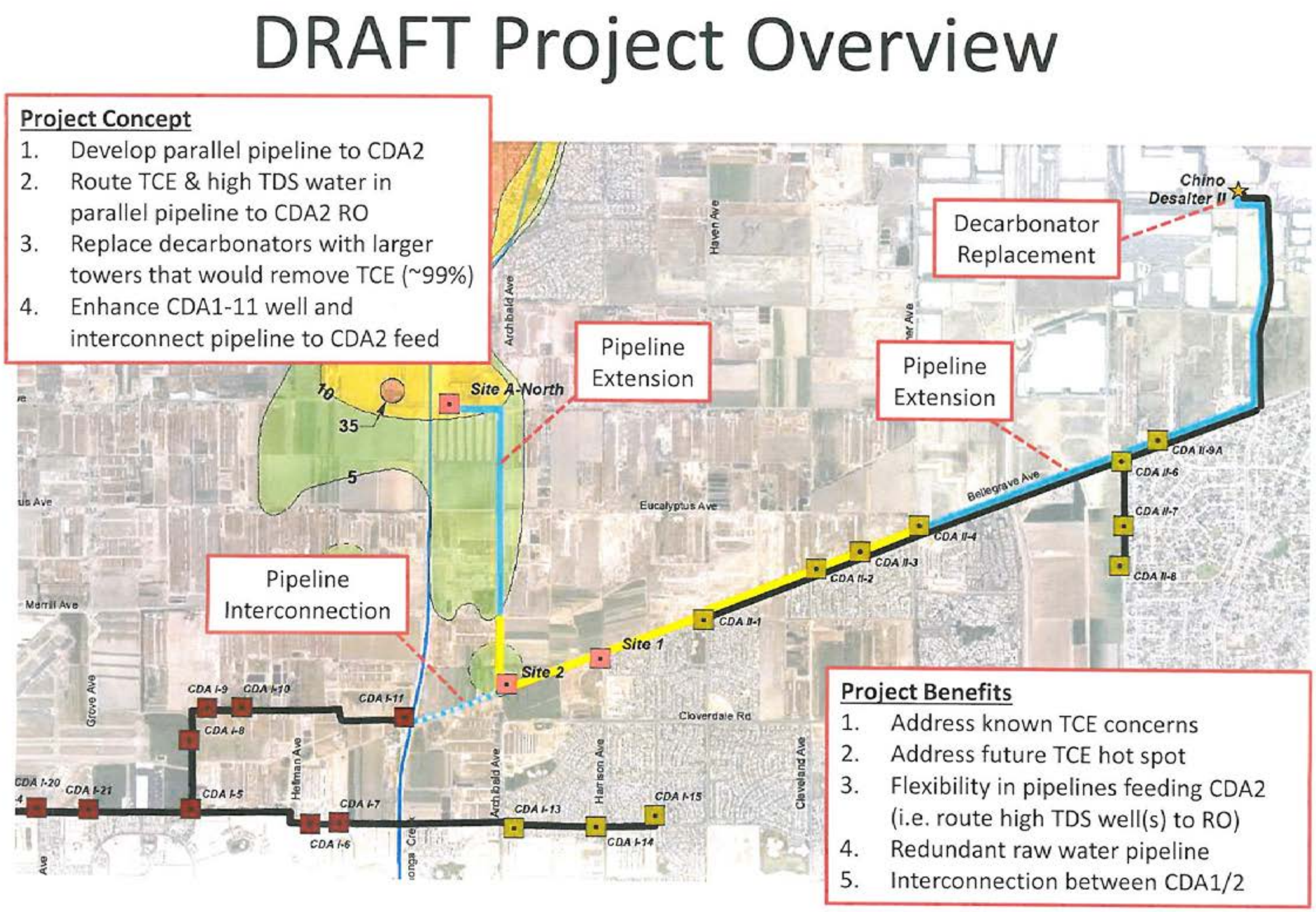

Figure 1 – Alternative 2 Configuration

GENERAL WELL WATER QUALITY

Water quality in the vicinity of the proposed wells was collected and summarized to characterize the water quality that may be expected from the Site A, Site 2, and Site 1 wells. This data is presented below in **Table 2**. This data was shared with treatment equipment vendors to help establish conceptual design requirements for wellhead treatment alternatives.

Table 2 - General Water Quality for Adjacent Wells

Parameter	CDA Well II-1	CDA Well I-11
TOC (mg/L)	N/A	1.0-1.4
Perchlorate (µg/L)	< 4.0	<1 to 1.6
Nitrate as NO3 (mg/L)	96 to 100	140 to 320
TDS (mg/L)	490 to 590	710 to 960
Alk (mg/L)	200 to 220	340 to 410
Bicarbonate (mg/L)	250 to 270	410 to 500
Calcium (mg/L)	94 to 100	150 to 180
Chloride (mg/L)	57 to 60	80 to 120
Magnesium (mg/L)	21 to 23	36 to 46
Potassium (mg/L)	2.0 to 2.4	2.7 to 3.3
Sodium (mg/L)	34 to 37	45 to 58
Sulfate (mg/L)	26 to 29	42 to 63
pH	7.3 to 7.8	7.1 to 7.3

ON-SITE TREATMENT CONSIDERATIONS

The existing Chino II Plant currently provides RO and decarbonation treatment, which can provide substantial TCE removal. The Proposed On-Site Solution would modify the decarbonators to provide enhanced removal. The feasibility and efficiency of TCE removal using these processes is discussed below.

TCE Removal by RO Membranes

The removal of volatile organic compounds such as TCE using RO is not a well-studied topic. The Mediation Parties noted several scientific papers that examined the removal of TCE using RO membranes. Rejection rates varied from the low 30% for clean membranes to almost 90% for fouled membranes. Dow Chemical lists a rejection rate of 30-43 % for its FILMTEC membranes. A pilot study can provide a means to estimate the performance of membranes for TCE removal. There are currently no plans to conduct a pilot study for TCE removal at Chino II, so results from other pilot studies can be reviewed to assess the performance of other RO membranes with TCE.

Irvine Ranch Water District (IRWD) conducted a groundwater pilot project that investigated the effectiveness of RO on VOC removal and associated VOC fouling potential. Three pilot sites were studied of which two contained TCE in the groundwater. One site, ET-1, had low levels (~12 µg/L) of TCE and another site, SGU, had much higher (220 µg/L) TCE levels. Koch TFC-4820HR membranes were used in the pilot study. These membranes offer similar rejection salt (~99.5%) and flux (10,500-11,000 gpd) to the existing Chino II FILMTEC membranes.

At the ET-1 site, TCE rejection averaged approximately 30% at a recovery rate of 77.5%. At SGU, TCE rejection again averaged about 30% at a lower recovery rate of 72.5 %. At the SGU pilot site, there was some indication, though not conclusive, that TCE may desorb from impacted membranes during periods of increased feed water quality (lower TCE levels). Multiple test runs were conducted at both ET-1 and SGU. TCE rejection rates varied from 26-42%, depending on test conditions. Based upon pilot data and scientific literature, a rejection rate of 30% is believed to be a reasonable assumption for TCE removal at the Chino II Desalter.

Long-term TCE effects on membrane life/fouling are not known, as only pilot study data was available. High levels of TCE (220 µg/L) at the IRWD SGU site was suspected of causing membrane fouling issues due to interaction with the materials of construction of the RO membranes. Other pilot data with TCE levels at 100 µg/L and below showed no membrane fouling issues. The TCE levels in the feed water to the Chino II Desalter RO membranes and concentrate recovery membranes are anticipated to be below 100 µg/L, which should not have an appreciable effect on membrane fouling.

TCE Removal by Decarbonators

The purpose of the Chino II Desalter post-treatment decarbonators is to remove dissolved carbon dioxide in the RO permeate water. This increases the pH and decreases the amount of post treatment chemicals, specifically sodium hydroxide, necessary to stabilize the product water.

The major equipment associated with the decarbonators includes the Decarbonator Tower and Decarbonator Tower Blower, shown in the photographs below in **Figure 2**.

Figure 2 - Chino II Desalter Decarbonator Tower and Blower

RO permeate is conveyed to the top of the Decarbonator Tower and flows downward through the tower, which contains a bed of high efficiency mass-transfer media or packing. The Decarbonator Tower Blower forces air upward through the packing countercurrent to the water flow. As the water flows downward, the packing promotes fluid distribution and greatly increases the liquid-to-gas-phase mass transfer area. Carbon dioxide then diffuses from the liquid to the gaseous phase and exits with the exhaust gas at the top of the Decarbonator Tower. Water drains to the base of the tower where it is collected in a sump for gravity flow to the product transfer wetwell.

Removal of TCE through the Decarbonator Tower occurs via mass transfer from the liquid phase to the gaseous phase, similar to carbon dioxide. However, the mass transfer of carbon dioxide from the liquid phase to the gaseous phase is more favorable than for TCE. The ability to strip a compound is related to its Henry's Law constant, which describes the relative tendency of a compound to volatilize from liquid to air. The higher a compound's Henry's Law constant, the more strippable it may be. Carbon dioxide has a Henry's Law constant that is more than 5 times the Henry's Law constant for TCE.

The key process parameters for design of an air stripping process (like the decarbonators) include water temperature, Henry's Law constant, influent concentration of compound to be removed, air to water ratio, packing type, and packing height.

The packing suppliers use software to assist with the design of decarbonators/air strippers and can vary the input parameters to identify optimum configurations. Simulations were conducted for TCE removal by the existing Chino II Desalter Decarbonator System (No Action Alternative) and modified Chino II Desalter Decarbonator System (Alternatives 1/2). **Table 3** summarizes the design criteria and results of these simulations.

For the No Action Alternative, the existing Decarbonator Towers with 8 feet of packing each can remove about 78% of the TCE in the RO Permeate. In order to achieve a target of 95% TCE removal, the Decarbonator Tower packing height would need to be increased to 12 feet of packing and the air flow in each tower would increase from 8,400 cfm to 27,300 cfm. Thus, Alternatives 1 and 2 require full replacement of the existing decarbonators with taller units and substantially larger blowers.

One significant concern with TCE removal using the decarbonators is whether off-gas treatment of the volatilized TCE will be required by the Air Quality Management District (AQMD). A determination of this is relatively complex and is beyond the scope of this memorandum. For this reason, options both with and without off-gas treatment are provided to illustrate the importance of this issue.

Table 3 - Decarbonator System Design for TCE Removal

Parameter	Existing Decarbonator System	Alternative 1 & 2 Decarbonator System
Decarbonator Towers		
Number of Decarbonator Towers	3	3
Type	Vertical, Cylindrical, Above Grade	Vertical, Cylindrical, Above Grade
Design Flow Rate, each (gpm)	3,400	3,400
Air-Water Ratio	18	60
Design Pressure	Atmospheric	Atmospheric
Material	FRP	FRP
Diameter, ft	12'-0"	12'-0"
Decarbonator Blowers		
Number	3	3
Type	General Purpose Fan	General Purpose Fan
Flow, each, cfm	8,400	27,300
Packing Media		
Nominal Diameter, inches	3.5	3.5
Depth of Packing, feet	8	12
Material	Polypropylene	Polypropylene
Manufacturer	Lantec	Lantec
Model	LANPAC	LANPAC-XL
TCE		
RO Permeate Concentration, µg/L	7.2	7.2
Decarbonator Effluent Concentration, µg/L	1.58	0.34
% Removal	78%	95%

Off-Gas TCE Treatment

Off-gas emitted from a decarbonator or air stripper may or may not require treatment before the air is exhausted to the atmosphere. If off-gas treatment is required, it will add a significant level of complexity and cost to the On-Site Solution. Treatment is typically accomplished using gas-phase carbon adsorption or direct combustion, but in either case, minimizing air flow is a key parameter. Air/water ratios for decarbonators or strippers should be at or below 20 for systems requiring off-gas treatment, as opposed to the air/water ratio of 60 used in the above decarbonator sizing for Alternatives 1 and 2. This means that taller columns with more packing are required to achieve the required removal efficiencies.

For gas phase GAC, bed life is highly dependent on humidity. The air emitted from the decarbonator or air stripper is fully saturated with water, and humidity must be reduced to 50% or less for the GAC to achieve a normal bed life of 6 to 12 months prior to replacement. This requires pre-heating of the air prior to entering the GAC vessels, and rough calculations indicate that approximately 200 kW of energy will be needed to pre-heat air for the optimally-sized replacement decarbonators (i.e. air/water ratio <20 and total air flow of 27,300 acfm) considered for Alternatives 1 and 2. More energy would be required if higher air/water ratios are used.

GAC bed depths typically range from 18 to 30-inches, with applied air velocity in the range of 50 to 100 ft/min. This would require 3 to 4 vessels, 12 ft diameter each, to treat the full air flow from the decarbonators. However, two vessels in series are required for operation, in a standard lead-lag (alternating) configuration. Thus, space must be provided for up to 8 vessels, 12 ft diameter each, plus additional space for the pre-heating equipment and access for changeout.

Should space become the limiting factor, it may be beneficial to consider steam regeneration of the gas phase GAC or direct combustion of VOCs in the air stream, either of which may reduce footprint. The investigation of these alternative technologies is beyond the scope of this report.

WELLHEAD TREATMENT OPTIONS

As opposed to treating the TCE at the Chino II site using the RO and decarbonator processes, the TCE could also be treated at the wellhead. A variety of treatment processes may be used for the control of TCE in well water. Four of the more common methods are presented below, including air stripping, granular activated carbon, ozone with peroxide, and ultraviolet light with peroxide. For comparison to the On-Site Solution alternatives, it is assumed that a single wellhead treatment system would be installed at Site A

Air Stripping

As discussed above for the decarbonators, air stripping is a common treatment system for the removal of volatile organic compounds, such as TCE. Multiple air stripping technologies can be considered, including Packed Tower Aeration (PTA), baffled tray aeration, bubble aeration, or aspiration systems. In cases where height restrictions are an issue, baffled tray aeration is often used due to its lower profile. For the purposes of this memorandum, air stripping using PTA is assumed.

For conceptual sizing purposes, it is assumed the well pump will discharge 2,000 gpm to a single packed tower. Using an air/water ratio of 20 for TCE, a packing height of 16 feet, diameter of 12 feet, and air flowrate of 5,400 acfm will achieve >99% removal efficiency. Optimal sizing is typically obtained from the equipment vendor, should this option be selected.

The well water at Site A is very hard, and PTA is susceptible to scaling with calcium carbonate. To address this issue, an acid feed system sized to provide a dose of 20 mg/L of mineral acid is assumed to be part of this treatment option. In addition, it is assumed that packing material will require replacement every three years due to degradation because of scaling or bio-fouling.

As discussed above, off-gas treatment of TCE may or may not be required by the AQMD, which is not addressed in this Study.

Figure 3 - Packed tower aerator with GAC off-gas treatment

If required, it is assumed that off-gas treatment would be provided by granular activated carbon (GAC) adsorbers. Assuming the 5,400 acfm flow rate described above, this suggests a 24-inch deep bed of GAC in a 10-ft diameter vessel. Two vessels in series are required for operation, in a standard lead-standby (alternating) configuration. Heating the off-gas to reduce humidity to less than 50% will achieve a GAC bed life of approximately one year before replacement is necessary. However, energy requirements are large, and estimated to be 45 kW for the 5,400 acfm air flow.

Granular Activated Carbon

Liquid-phase GAC contacting is an effective treatment technology for removal of TCE. It is widely used in wellhead treatment applications for adsorption of a wide variety of organic contaminants. For applications at this scale, GAC is typically provided in pre-fabricated steel vessels (**Figure 4**), which would be mounted on a concrete pad at the wellhead site.

Figure 4 – Typical prefabricated GAC vessels

As water contaminated with organic constituents passes through a bed of GAC, the organics partition out of the aqueous phase and are adsorbed onto the surface of the GAC. This process continues until the adsorptive capacity of the GAC bed is reached, at which point the GAC must be replaced or regenerated. Many organic compounds, including TCE, are readily adsorbed onto

GAC; however, compounds with highly solubility, high polarity, or low molecular weight may be poorly adsorbed (e.g. formaldehyde) or not appreciably adsorbed at all (e.g. 1,4-dioxane).

For conceptual sizing purposes, the GAC system would consist of 8 vessels arranged in four parallel lead-lag trains to treat the 2,000 gpm flow rate. Design criteria are shown in **Table 4**. The changeout frequency would be approximately one changeout per train per year, based on typical adsorption capacity data for TCE. However, if other organic contaminants are present at high level, they may break through more quickly and thereby control the life of the GAC beds.

Table 4 – Design criteria for a GAC system

Parameter	Unit	Value
Number of Vessels	ea	8
Vessel Diameter	ft	12
GAC Bed Depth	ft	6
Mass of GAC per Vessel	lb	20,000
Vessel Empty Bed Contact Time	min	10
Hydraulic Loading Rate	gpm/ft^2	4.4

The capital costs for this system includes the prefabricated vessels along with the piping, valves, and concrete pad. This is expected to be slightly more than $1 million based on typical data for in-vessel GAC systems. The major operating cost will be for GAC changeouts. Based on a predicted bed life of about one year, this annual GAC replacement costs are expected to be just over $100,000, based on a typical cost of $1.25 per pound for GAC.

Ultraviolet Light with Peroxide

The Ultraviolet Light / Peroxide (UV/H_2O_2) system is a widely-used advanced oxidation process for the removal of organics. UV/H_2O_2 equipment is generally provided as a skid-mounted package system with one or more UV reactors (**Figure 5**).

Figure 5 – Typical UV/H_2O_2 equipment

This system works by injecting H_2O_2 into the water, and exposing it to UV light. In the presence of UV light, the H_2O_2 forms free hydroxyl radicals. Most organic compounds (including TCE) are readily oxidized under these conditions. However, some constituents, including 1,2-dichloroethane and 1,2,3-trichloropropane, will not be removed by UV/H_2O_2 treatment.

A conceptual design for this site would include two 72-lamp UV reactor units plumbed in parallel, along with a 6,500 gal hydrogen peroxide storage tank and feed equipment. At a peroxide dose of 15 mg/L, this system would achieve around 95% removal of TCE. A potential limitation to this process is the formation of by-products – some organics will be oxidized to low-molecular-weight aldehydes. In waters with high levels of organics, additional GAC treatment may be required downstream to remove these by-products. However, with 25 μg/L of influent TCE, potential formaldehyde formation would be limited to about 16 μg/L.

The capital cost for a commercial system (UVPhoxD72AL75, manufactured by Trojan) would be around $930,000, for the two UV reactors along with a UV transmittance monitor, hydrogen peroxide feed equipment, and a control system. In terms of operating costs, the system will consume a little over 17,000 gal of peroxide per year, electricity consumption is estimated to be about 70kW, and replacement lamps would cost $62,000 annually. These costs assume the system runs continuously at 100% power.

Ozone with Peroxide

Another type of advanced oxidation process is ozone with peroxide. This process also forms hydroxyl radicals that provide powerful oxidation of a variety of contaminants, including TCE. In this process, water is dosed with both hydrogen peroxide and ozone, and the oxidation takes place in a skid-mounted reactor (**Figure 6**).

Figure 6 – Skid-mounted ozone/peroxide reactor

A system was conceptually sized for 2,000 gpm and 35 μg/L influent TCE, to achieve >97% TCE reduction and <1 μg/L in the effluent. Design criteria for this conceptual system are shown in **Table 5**. The capital cost for a commercial system (HiPOx, manufactured by Ultura Water) would be around $1.1 million, including the reactor, an on-site oxygen generator, and feed systems for ozone and peroxide. Annual operating costs will be around $300,000 for hydrogen peroxide delivery, electrical power, and maintenance.

Table 5 – Design criteria for an ozone/peroxide system

Parameter	Unit	Value
Design Flow	gpm	2000
Effluent TCE Concentration	μg/L	< 1
Ozone Dose	mg/L	9.4
Hydrogen Peroxide Dose	mg/L	9.4
Power Consumption	kW	89
Oxygen Consumption	scfm	18.5
Hydrogen Peroxide Consumption	gal/day (35% solution)	67
On-Site Oxygen Generator Power	kW	22

EVALUATION OF ALTERNATIVES

Four alternatives have been identified for evaluation in this review. Alternatives 1 and 2 were evaluated with and without the option to connect existing Well 1-11 to the Chino II Plant. The four alternatives are described below.

No Action Alternative

The "No Action" alternative assumes that the CDA Phase III Expansion Project is completed as originally envisioned and without any special provisions for TCE control. Conveyance piping from the three new wells would be interconnected with existing piping from the existing Chino II wellfield to provide fully blended raw water to the Chino II Plant. TCE removal by the existing RO membranes is estimated to be about 30%, while TCE removal by the existing decarbonators is estimated to be about 78%. No TCE removal is assumed for water that is by-passed or treated by Ion Exchange (IX), so the portion of TCE contained in these flow streams will enter the clearwell.

Alternative 1

Alternative 1 assumes that the three new wells proposed in the CDA Phase III Expansion Project are used for TCE capture. Water from the new wells would be conveyed to the Chino II Plant in a dedicated pipeline and be routed directly to the RO process train. Flow from the existing Chino II wellfield would be split between RO, IX and the by-pass. TCE removal by the RO membranes is again estimated to be about 30%, while TCE removal through the modified decarbonators is increased to an estimated 95%. Because the TCE is delivered only to the RO process, the IX and by-pass flows do not contain TCE.

Alternative 2

Alternative 2 is similar to Alternative 1, with the exception of the proposed location of Well Site A, which is moved further to the north to improve interception of the TCE plume. This results in the higher future TCE concentrations assumed in **Table 1**.

Alternative 3

Alternative 3 is similar to the "No Action" alternative, with the exception that one of the wellhead treatment options is installed to treat Well Site A. The level of treatment is assumed to be sufficient to reduce the TCE concentration entering the transmission system from Site A to less than 0.5 µg/L. Other wells containing TCE would not receive treatment, other than that afforded by the existing facilities at the Chino II Plant.

Mass Balance Analysis

Each alternative captures TCE in the new wells and conveys it to the Chino II Plant. However, the flows, blending ratios, treatment efficiency, TCE concentrations, and the inclusion of Well I-11 will vary. To evaluate the impact of these variables on TCE in the different flow streams at the Chino II Plant, a mass balance analysis was conducted. The assumptions for the analysis are summarized below:

Flow Rates: The mass balance includes the analysis of three differing flow conditions, each of which is presented in the following Tables:

- **Table 6** - Parallel, dedicated pipes to the Chino II Plant (Alternatives 1 and 2), excluding Well I-11.
- **Table 7** - A single, fully blended pipe to the Chino II Plant (No Action and Alternative 3), excluding Well I-11.
- **Table 8** - Parallel, dedicated pipes to the Chino II Plant (Alternatives 1 and 2), including Well I-11.

TCE Concentrations: The mass balance includes the analysis of two differing TCE concentrations from each proposed well, the minimum and maximum future estimates presented in **Table 1**.

Wellfield Operation: The mass balance includes the analysis of operation using only the new wells without contribution from the existing Chino II wellfield, or combined operation with using both the proposed wells and the existing wellfield.

Well I-11: The mass balances consider either excluding or including Well I-11 for Alternatives 1 and 2.

The detailed results of the mass balance analysis presenting all permutations of the above variables is included in two tables in **Appendix A**, each table summarizing the results of excluding or including Well I-11. An abbreviated summary of results are presented in **Tables 9**, **10**, **11**, and **12**.

Discussion

The mass balance analysis clearly shows that for all alternatives, the projected TCE levels in the clearwell at the Chino II plant are below the MCL of 5.0 µg/L. Furthermore, Alternatives 1 through 3 achieve projected TCE levels below the PHG of 1.7 μg/L, and the projected TCE levels for Alternatives 1 and 2 are below the DLR of 0.5 μg/L. Even without decarbonator improvements, TCE in the clearwell under Alternatives 1 and 2 would be below the PHG.

The water from the Chino II plant would be considered by the State of California to be safe to drink under any alternative, and under some scenarios, levels would be low enough that reporting to the State would not be required. The inclusion or exclusion of Well I-11 makes only a negligible difference in the final TCE levels entering the Clearwell for Alternatives 1 and 2.

The Concentrate Reduction Facility (CRF) will see some higher levels of TCE based on the mass balance projections. The highest expected concentration in the CRF influent will be around 20 to 30 μg/L, which is high enough to lead to some volatilization above open water surfaces. The brine from the CRF may see levels of TCE in the 25 to 50 μg/L range, which is acceptable for brine discharge.

Table 6 - Assumed Flow Rates for Alternatives 1 and 2 (Excluding CDA Well I-11)

Flow Stream, gpm	Chino II Wells	Proposed Wells	Combined Flow
Total Raw Water	8,887	6,000	14,887
RO Membrane Influent	4,851	6,000	10,851
RO Membrane Effluent	3,881	4,800	8,681
CRF Influent	970	1,200	2,170
CRF Brine	291	360	651
CRF Effluent	679	840	1,519
Decarbonator Effluent	4,560	5,640	10,200
IX Flow	2,261	0	2,261
Bypass Flow	1,775	0	1,775
Clearwell Influent	8,596	5,640	14,236

Table 7 - Assumed Flow Rates for "No Action" Alternative and Alternative 3 (Excluding CDA Well I-11)

Flow Stream, gpm	Chino II Wells	Proposed Wells	Combined Flow
Total Raw Water	8,887	6,000	14,887
RO Membrane Influent	6,478	4,373	10,851
RO Membrane Effluent	5,182	3,499	8,681
CRF Influent	1,296	874	2,170
CRF Brine	389	262	651
CRF Effluent	907	612	1,519
Decarbonator Effluent	6,089	4,111	10,200
IX Flow	1,350	911	2,261
Bypass Flow	1,060	715	1,775
Clearwell Influent	8,499	5,737	14,236

Table 8 - Assumed Flow Rates for Alternatives 1 and 2 (Including CDA Well I-11)

Flow Stream, gpm	Chino II Wells	Proposed Wells	Combined Flow
Total Raw Water	7,912	6,975	14,887
RO Membrane Influent	3,876	6,975	10,851
RO Membrane Effluent	3,101	5,580	8,681
CRF Influent	775	1,395	2,170
CRF Brine	233	419	651
CRF Effluent	543	977	1,519
Decarbonator Effluent	3,643	6,557	10,200
IX Flow	2,261	0	2,261
Bypass Flow	1,775	0	1,775
Clearwell Influent	7,679	6,557	14,236

Table 9 - Projected TCE Concentration Profile – New Wells Only (Excluding CDA Well I-11)

Chino II Flow Stream	No Action	Alternative 1	Alternative 2	Alternative 3
RO Influent	1.3 to 13.5	1.3 to 13.5	3.7 to 11.8	0.5 to 3.7
RO Effluent	0.9 to 9.5	0.9 to 9.5	2.6 to 8.3	0.4 to 2.6
CRF Influent	2.9 to 29.7	2.9 to 29.7	8.1 to 26.0	1.1 to 8.1
CRF Brine	5.0 to 50.5	5.0 to 50.5	13.7 to 44.3	1.9 to 13.7
CRF Effluent	2.1 to 20.8	2.1 to 20.8	5.6 to 18.2	0.8 to 5.6
Decarbonator Effluent	0.24 to 2.45	0.06 to 0.56	0.15 to 0.49	0.09 to 0.67
IX & Bypass	0	0	0	0
Clearwell Influent	0.24 to 2.45	0.06 to 0.56	0.15 to 0.49	0.09 to 0.67

Table 10 - Projected TCE Concentration Profile – Combined Flow (Excluding CDA Well I-11)

Chino II Flow Stream	No Action	Alternative 1	Alternative 2	Alternative 3
RO Influent	0.5 to 5.4	0.7 to 7.5	2.0 to 6.5	0.2 to 1.5
RO Effluent	0.4 to 3.8	0.5 to 5.2	1.4 to 4.6	0.1 to 1.0
CRF Influent	1.2 to 12.0	1.6 to 16.4	4.5 to 14.4	0.4 to 3.3
CRF Brine	2.0 to 20.3	2.8 to 27.9	7.6 to 24.5	0.8 to 5.5
CRF Effluent	0.8 to 8.4	1.1 to 11.5	3.1 to 10.1	0.3 to 2.3
Decarbonator Effluent	0.10 to 0.99	0.03 to 0.31	0.08 to 0.27	0.04 to 0.27
IX & Bypass	0.5 to 5.4	0	0	0.2 to 1.5
Clearwell Influent	0.22 to 2.25	0.02 to 0.22	0.06 to 0.19	0.08 to 0.61

Table 11 - Projected TCE Concentration Profile – New Wells Only (Including CDA Well I-11)

Chino II Flow Stream	Alternative 1	Alternative 2
RO Influent	1.7 to 13.6	3.7 to 11.9
RO Effluent	1.2 to 9.5	2.6 to 8.3
CRF Influent	3.8 to 29.9	8.2 to 26.1
CRF Brine	6.4 to 50.8	13.9 to 44.3
CRF Effluent	2.6 to 20.9	5.7 to 18.3
Decarbonator Effluent	0.07 to 0.56	0.15 to 0.49
IX & Bypass	0	0
Clearwell Influent	0.07 to 0.56	0.15 to 0.49

Table 12 - Projected TCE Concentration Profile – Combined Flow (Including CDA Well I-11)

Chino II Flow Stream	Alternative 1	Alternative 2
RO Influent	1.1 to 8.7	2.4 to 7.6
RO Effluent	0.8 to 6.1	1.7 to 5.3
CRF Influent	2.4 to 19.2	5.3 to 16.8
CRF Brine	4.1 to 32.6	8.9 to 28.5
CRF Effluent	1.7 to 13.4	3.7 to 11.7
Decarbonator Effluent	0.05 to 0.36	0.10 to 0.31
IX & Bypass	0	0
Clearwell Influent	0.03 to 0.26	0.07 to 0.23

COST ESTIMATES

Capital and O&M costs were estimated for all options considered. **Table 13** presents a summary of these costs.

Table 13 - Alternative System Costs

Parameter	Wellhead Treatment Options					On-Site Treatment Options	
	GAC (8 Vessels)	O3/H2O2 (HiPOx) (2 Units)	UV/H2O2 (2 Units)	Air Stripper (PTA)	Air Stripper with VGAC	New Decarbonators at Chino II	New Decarbonators at Chino II with VGAC
Capital Cost							
Vendor Quote	$1,080,000	$1,110,000	$935,000	$900,000	$1,080,000	$900,000	$1,625,000
Markup @ 20%	$1,296,000	$1,332,000	$1,122,000	$1,080,000	$1,296,000	$1,080,000	$1,950,000
Site Development	$200,000	$200,000	$200,000	$200,000	$300,000	$0	$200,000
Pad / Building	$100,000	$400,000	$400,000	$200,000	$250,000	$0	$150,000
Electrical / I&C	$100,000	$300,000	$300,000	$200,000	$250,000	$100,000	$300,000
Contractor OH&P[1]	$339,200	$446,400	$404,400	$336,000	$419,200	$236,000	$520,000
Total Capital Cost	$2,035,200	$2,678,400	$2,426,400	$2,016,000	$2,515,200	$1,416,000	$3,120,000
O&M Cost							
Labor[2]	$7,500	$30,000	$30,000	$7,500	$22,500	$0	$30,000
Energy[3]	$10,000	$136,000	$87,000	$41,000	$96,000	$25,000	$275,000
Chemicals	$110,000	$115,000	$87,000	$125,000	$135,000	$0	$30,000
Supplies	$5,000	$10,000	$62,000	$40,000	$45,000	$5,000	$15,000
Maintenance[4]	$20,400	$26,800	$24,300	$20,200	$25,200	$14,200	$31,200
Total O&M Costs[5]	$107,000	$222,500	$203,200	$163,600	$226,600	$44,200	$381,200
Present Worth							
Capital Cost	$2,035,200	$2,678,400	$2,426,400	$2,016,000	$2,515,200	$1,416,000	$3,120,000
Annual O&M Cost	$107,000	$222,500	$203,200	$163,600	$226,600	$44,200	$381,200
Net Present Value (NPV)[6]	$3,630,000	$5,990,000	$5,450,000	$4,450,000	$5,890,000	$2,070,000	$8,790,000

(1) Contractor OH&P assumed as 20%
(2) Labor rate assumed as 75$/hr
(3) Energy costs assumed as $0.14/kWh
(4) Maintenance costs assumed as 1% of capital costs
(5) Wellhead treatment options total O&M costs are based on an assumed 70% utilization of the facilities. On-Site treatment utilization is assumed as 100%.
(6) NPV assumes a 3% discount rate and 20 year period

WELL AND TRANSMISSION SYSTEM MODELING

Hydraulic models of the alternative piping configurations were developed based on available and assumed information on the wells, typical wellhead pressures, and pipeline size and dimensional data as provided by CDA. The No Action and each of the three proposed alternatives were modeled, including the option of including or excluding Well 1-11 and the possible inclusion of well 9A in the dedicated pipeline. The models were developed using Innovyze's InfoWater software. The models were not calibrated but were validated to roughly coincide to available static data. The models were delivered to CDA for future use.

FINDINGS

The reviews and evaluations completed in the course of this investigation suggest the following findings:

- Using maximum future TCE levels predicted for the proposed new wells, all of the alternatives, including the "No Action" alternative, are capable of reducing TCE levels in the Clearwell at the Chino II Plant to below the Maximum Contaminant Level (MCL) of 5.0 µg/L. Alternative 3 achieves TCE levels below the Public Health Goal (PHG) of 1.7 µg/L, and Alternatives 1 and 2 achieve levels below the Detection Limit for Reporting (DLR) of 0.5 µg/L.
- The inclusion or exclusion of Well I-11 makes only a negligible difference in the final TCE levels entering the Clearwell for all alternatives.
- Estimated TCE levels are expected to have no impact on long-tern fouling of the membranes in the Chino II Plant or in the Concentrate Reduction Facility (CRF).
- TCE removal by the RO membranes is anticipated to be about 30%.
- TCE removal by the existing decarbonators is anticipated to be about 78%.
- Alternatives 1 and 2, without decarbonator improvements, achieve TCE levels in the Clearwell at the Chino II Plant below the PHG of 1.7 µg/L.
- Replacement of the decarbonators at the Chino II Plant will require taller columns with more packing and larger blowers to achieve TCE removal of roughly 95%, as assumed in Alternatives 1 and 2.
- A separate investigation is needed to determine if decarbonator off-gas treatment is required to control TCE release. This effort is beyond the scope of this Study, but is critical to determining the feasibility of the On-Site Solution. Limited space is available on-site at the Chino II Plant, and off-gas treatment alternatives are relatively large and energy intensive.
- Maximum TCE levels of 20 to 30 µg/L may be expected in the CRF influent. Some volatilization may occur from open water surfaces, such as the clarifier.
- CRF brine may have maximum TCE levels in the range of 25 to 50 µg/L. This is not a current issue for brine discharge.
- Multiple wellhead treatment alternatives appear feasible for TCE removal, and may offer a different approach to achieving TCE control. Wellhead treatment may also become financially attractive depending on whether off-gas treatment is or is not required at the Chino II Plant. A decision between wellhead alternatives will depend on specific cost factors, such as the presence of other contaminants in the groundwater that may change

the assumptions presented herein. A more detailed investigation is needed if this alternative is pursued.

APPENDIX A

CHINO II DESALTER
ARCHIBALD PLUME STUDY - REVIEW OF ALTERNATIVES
(FUTURE WATER QUALITY, EXCLUDES WELL 1-11)

TCE Levels:	
MCL =	5 ug/l
1/2 MCL =	2.5 ug/l
PHG =	1.7 ug/l
DLR =	0.5 ug/l

OPERATIONAL SCENARIO	PARAMETER	WELL - SITE A	WELL - SITE 2	WELL - SITE 1	PROPOSED WELLS COMBINED	CHINO II EXISTING WELLFIELD	TOTAL RAW WATER COMBINED	RO MEMBRANE INFLUENT COMBINED	RO MEMBRANES EFFLUENT	CRF INFLUENT	CRF BRINE	CRF EFFLUENT	DECARBONATOR EFFLUENT	IX	BYPASS	CLEARWELL INFLUENT (ALL FLOWS)
FLOWS																
CURRENT OPERATION	**Existing Flowrate, gpm**															
	Chino II Wellfield					8887	8887	4851	3881	970	291	679	4560	2261	1775	8596
	RO Recovery							80		70						
PROPOSED OPERATION	**Proposed Flowrate, gpm**															
	New Wells Only	2000	2000	2000	6000	0	6000	6000	4800	1200	360	840	5640	0	0	5640
	Combined Flow	2000	2000	2000	6000	8887	14887	10851	8681	2170	651	1519	10200	2261	1775	14236
TCE																
No Action	**TCE Removal %**								30			30	78			
CDA Phase III Well Configuration with Parallel, Combined Pipeline to Desalter II (No Treatment Improvements).	**Minimum TCE Conc, ug/l**															
	New Wells Only	3	0.5	0.5	1.3	0	6000	1.3	0.9	2.9	5.0	2.1	0.24	0.0	0.0	0.24
	Combined Flow	3	0.5	0.5	1.3	0	14887	0.5	0.4	1.2	2.0	0.8	0.10	0.5	0.5	0.22
	Maximum TCE Conc, ug/l															
	New Wells Only	20	20	0.5	13.5	0	6000	13.5	9.5	29.7	50.5	20.8	2.45	0.0	0.0	2.45
	Combined Flow	20	20	0.5	13.5	0	14887	5.4	3.8	12.0	20.3	8.4	0.99	5.4	5.4	2.25
Alternative 1	**TCE Removal %**								30			30	95			
CDA Phase III Well Configuration with Dedicated Pipeline to Desalter II and VOC/Decarbonator Improvements for Enhanced TCE Removal.	**Minimum TCE Conc, ug/l**															
	New Wells Only	3	0.5	0.5	1.3	0	6000	1.3	0.9	2.9	5.0	2.1	0.06	0.0	0.0	0.06
	Combined Flow	3	0.5	0.5	1.3	0	14887	0.7	0.5	1.6	2.8	1.1	0.03	0.0	0.0	0.02
	Maximum TCE Conc, ug/l															
	New Wells Only	20	20	0.5	13.5	0	6000	13.5	9.5	29.7	50.5	20.8	0.56	0.0	0.0	0.56
	Combined Flow	20	20	0.5	13.5	0	14887	7.5	5.2	16.4	27.9	11.5	0.31	0.0	0.0	0.22
Alternative 2	**TCE Removal %**								30			30	95			
Move One CDA Phase III Well to the North with Dedicated Pipeline to Desalter II and VOC/Decarbonator Improvements for Enhance TCE Removal.	**Minimum TCE Conc, ug/l**															
	New Wells Only	10	0.5	0.5	3.7	0	6000	3.7	2.6	8.1	13.7	5.6	0.15	0.0	0.0	0.15
	Combined Flow	10	0.5	0.5	3.7	0	14887	2.0	1.4	4.5	7.6	3.1	0.08	0.0	0.0	0.06
	Maximum TCE Conc, ug/l															
	New Wells Only	25	10	0.5	11.8	0	6000	11.8	8.3	26.0	44.3	18.2	0.49	0.0	0.0	0.49
	Combined Flow	25	10	0.5	11.8	0	14887	6.5	4.6	14.4	24.5	10.1	0.27	0.0	0.0	0.19
Alternative 3	**TCE Removal %**								30			30	78			
Move One CDA Phase III Well to the North and Provide Wellhaed Treatment with Parallel, Combined Pipeline to Desalter II (No Treatment Improvements at Chino II).	**Minimum TCE Conc, ug/l**															
	New Wells Only	0.5	0.5	0.5	0.5	0	6000	0.5	0.4	1.1	1.9	0.8	0.09	0.0	0.0	0.09
	Combined Flow	0.5	0.5	0.5	0.5	0	14887	0.2	0.1	0.4	0.8	0.3	0.04	0.2	0.2	0.08
	Maximum TCE Conc, ug/l															
	New Wells Only	0.5	10	0.5	3.7	0	6000	3.7	2.6	8.1	13.7	5.6	0.67	0.0	0.0	0.67
	Combined Flow	0.5	10	0.5	3.7	0	14887	1.5	1.0	3.3	5.5	2.3	0.27	1.5	1.5	0.61

CHINO II DESALTER
ARCHIBALD PLUME STUDY - REVIEW OF ALTERNATIVES
(FUTURE WATER QUALITY, INCLUDING WELL 1-11)

TCE Levels:		
	MCL =	5 ug/l
	1/2 MCL =	2.5 ug/l
	PHG =	1.7 ug/l
	DLR =	0.5 ug/l

OPERATIONAL SCENARIO	PARAMETER	Well I-11	WELL - SITE A	WELL - SITE 2	WELL - SITE 1	PROPOSED WELLS COMBINED	CHINO II EXISTING WELLFIELD	TOTAL RAW WATER COMBINED	RO MEMBRANE INFLUENT COMBINED	RO MEMBRANES EFFLUENT	CRF INFLUENT	CRF BRINE	CRF EFFLUENT	DECARBONATOR EFFLUENT	IX	BYPASS	CLEARWELL INFLUENT (ALL FLOWS)
FLOWS																	
CURRENT OPERATION	Existing Flowrate, gpm																
	Chino II Wellfield						7912	7912	3876	3101	775	233	543	3643	2261	1775	7680
	RO Recovery								80		70						
PROPOSED OPERATION	Proposed Flowrate, gpm																
	New Wells Only	975	2000	2000	2000	6975	0	6975	6975	5580	1395	419	977	6557	0	0	6557
	Combined Flow	975	2000	2000	2000	6975	7912	14887	10851	8681	2170	651	1519	10200	2261	1775	14236
TCE																	
No Action	TCE Removal %									30			30	78			
CDA Phase III Well Configuration with Parallel, Combined Pipeline to Desalter II (No Treatment Improvements).	Minimum TCE Conc, ug/l																
	New Wells Only	4	3	0.5	0.5	1.7	0	6975	1.7	1.2	3.8	6.4	2.6	0.31	0.0	0.0	0.31
	Combined Flow	4	3	0.5	0.5	1.7	0	14887	0.8	0.6	1.8	3.0	1.2	0.15	0.8	0.8	0.33
	Maximum TCE Conc, ug/l																
	New Wells Only	14	20	20	0.5	13.6	0	6975	13.6	9.5	29.9	50.8	20.9	2.46	0.0	0.0	2.46
	Combined Flow	14	20	20	0.5	13.6	0	14887	6.4	4.5	14.0	23.8	9.8	1.15	6.4	6.4	2.63
Alternative 1	TCE Removal %									30			30	95			
CDA Phase III Well Configuration with Dedicated Pipeline to Desalter II and VOC/Decarbonator Improvements for Enhanced TCE Removal.	Minimum TCE Conc, ug/l																
	New Wells Only	4	3	0.5	0.5	1.7	0	6975	1.7	1.2	3.8	6.4	2.6	0.07	0.0	0.0	0.07
	Combined Flow	4	3	0.5	0.5	1.7	0	14887	1.1	0.8	2.4	4.1	1.7	0.05	0.0	0.0	0.03
	Maximum TCE Conc, ug/l																
	New Wells Only	14	20	20	0.5	13.6	0	6975	13.6	9.5	29.9	50.8	20.9	0.56	0.0	0.0	0.56
	Combined Flow	14	20	20	0.5	13.6	0	14887	8.7	6.1	19.2	32.6	13.4	0.36	0.0	0.0	0.26
Alternative 2	TCE Removal %									30			30	95			
Move One CDA Phase III Well to the North with Dedicated Pipeline to Desalter II and VOC/Decarbonator Improvements for Enhance TCE Removal.	Minimum TCE Conc, ug/l																
	New Wells Only	4	10	0.5	0.5	3.7	0	6975	3.7	2.6	8.2	13.9	5.7	0.15	0.0	0.0	0.15
	Combined Flow	4	10	0.5	0.5	3.7	0	14887	2.4	1.7	5.3	8.9	3.7	0.10	0.0	0.0	0.07
	Maximum TCE Conc, ug/l																
	New Wells Only	12	25	10	0.5	11.9	0	6975	11.9	8.3	26.1	44.3	18.3	0.49	0.0	0.0	0.49
	Combined Flow	12	25	10	0.5	11.9	0	14887	7.6	5.3	16.8	28.5	11.7	0.31	0.0	0.0	0.23
Alternative 3	TCE Removal %									30			30	78			
Move One CDA Phase III Well to the North and Provide Wellhaed Treatment with Parallel, Combined Pipeline to Desalter II (No Treatment Improvements at Chino II).	Minimum TCE Conc, ug/l																
	New Wells Only	4	0.5	0.5	0.5	1.0	0	6975	1.0	0.7	2.2	3.7	1.5	0.18	0.0	0.0	0.18
	Combined Flow	4	0.5	0.5	0.5	1.0	0	14887	0.5	0.3	1.0	1.7	0.7	0.08	0.5	0.5	0.19
	Maximum TCE Conc, ug/l																
	New Wells Only	12	0.5	10	0.5	4.8	0	6975	4.8	3.4	10.6	18.1	7.4	0.88	0.0	0.0	0.88
	Combined Flow	12	0.5	10	0.5	4.8	0	14887	2.3	1.6	5.0	8.5	3.5	0.41	2.3	2.3	0.94