

**Second Addendum: Pre-Treatment for Per- and
Polyfluoroalkyl Substances
Focused Feasibility Study for 1,4-Dioxane North of
Los Reales Road**

**Tucson Airport Remediation Project
Tucson International Airport Area Superfund Site, Area A**

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List of Acronyms and Abbreviations

ADEQ	Arizona Department of Environmental Quality
AFP44	Air Force Plant 44
AOP	advanced oxidation process
ARAR	Applicable or Relevant and Appropriate Requirements
AWWA	American Water Works Association
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMF	ceramic membrane filter
EPA	U.S. Environmental Protection Agency
FFS	focused feasibility study
GAC	granular activated carbon
gpm	gallons per minute
gpm/sf	gallons per minute per square foot
GWTS	groundwater treatment system
HA	Health Advisory
IX	ion exchange
LLR	liquid loading rates
MCL	Maximum Contaminant Level
µg/L	micrograms per liter
NWF	North Well Field
O&M	operations and maintenance
PCA	packed column aeration
PFAS	per- and polyfluoroalkyl substances
PFHpA	Perfluoroheptanoic acid
PFHxS	perfluorohexanesulfonic acid
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
ppt	parts per trillion
RAO	remedial action objective
RI/FS	remedial investigation/feasibility study
RO	reverse osmosis
ROD	Record of Decision
SCADA	supervisory control and data acquisition
SDWA	Safe Drinking Water Act
SPAC	submicron powdered activated carbon
SWF	South Well Field
TARP	Tucson Airport Remediation Project
TBC	To Be Considered Criteria
TCE	trichloroethene
TIAA	Tucson International Airport Area
USAF	United States Air Force
VOC	volatile organic compound
WTP	water treatment plant

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1.0 Introduction

1.1 Site Background

1.1.1 Tucson International Airport Area Superfund Site

The Tucson International Airport Area (TIAA) Superfund Site was established by the United States Environmental Protection Agency (EPA) in 1983 as a National Priorities List (NPL) site to address groundwater contamination, principally by trichloroethene (TCE), in the vicinity of the Tucson International Airport (TIA) and adjacent industrial areas. The TIAA Site is shown on **Figure 1**.

Groundwater contamination at the TIAA Superfund Site is divided into Areas A and B. The Area A groundwater contamination plume is the larger plume located on the west side of the TIAA Site. As described in EPA's 1988 Record of Decision (ROD), the remedial investigation (RI) of the Area A plume identified two principal source areas of groundwater contamination, Air Force Plant 44 (AFP44) and the Three Hangars located on TIA property (EPA, 1988a). Groundwater contamination occurred from solvent use and land disposal of spent industrial solvents at these facilities as far back as the 1940s, allowing for hazardous substances, pollutants, and contaminants to migrate in groundwater for several decades. The migration of volatile organic compounds (VOCs) in groundwater resulted in a contaminant plume extending approximately 5.5 miles northwest from the source areas, near Hermans Road and Nogales Highway, to the vicinity of Irvington Road and South 12th Avenue in Tucson, Arizona.

Area B includes several smaller TCE contamination plumes in shallow groundwater underlying the east-central portion of the TIAA Site. Area A and Area B Plumes have separate remedial actions. The Tucson Airport Remediation Project (TARP) facility addresses the Area A Plume north of Los Reales Road. Area B sub-areas are being addressed by other response efforts.

1.1.2 Tucson Airport Area Remediation Project

The TARP was implemented to address contamination in Area A groundwater north of Los Reales Road. Area A groundwater contamination south of Los Reales Road is being addressed by the United States Air Force (USAF) at AFP44.

The TARP groundwater remediation system was placed into service in September 1994. The system currently includes three major components (**Figure 2**):

- The North Well Field (NWF) located north of Irvington Road, and well R-127A located south of Irvington Road;
- The South Well Field (SWF), located south of Drexel Road; and
- The TARP Water Treatment Plant (WTP), located northwest of Irvington Road and Interstate 19.

The NWF is operated primarily to contain the Area A Plume. Well R-127A is operated primarily for mass reduction of the Area A Plume. The NWF is comprised of four remediation wells

screened in the deep regional Undivided Aquifer. These remediation wells are used to provide containment of the TCE plume, preventing further downgradient migration. The NWF remediation wells currently operate between approximately 1,150 and 1,300 gallons per minute (gpm).

The SWF is operated primarily to reduce the mass of contaminants in the Area A Plume. The SWF is comprised of five remediation wells that operate between approximately 40 and 350 gpm. The SWF remediation wells are screened in the Upper Divided Aquifer in the area historically having the greatest mass of TCE. The original purpose of the SWF was to reduce the mass of contaminants in the Upper Divided Aquifer, thus reducing downgradient migration of contaminants into the regional Undivided Aquifer. The SWF has not been in operation since June 2021 due to high concentrations of per- and polyfluoroalkyl substances (PFAS).

The TARP WTP was initially designed and constructed with a packed column aeration (PCA) treatment process to remove VOCs from groundwater extracted by the NWF and SWF remediation wells, as required by the 1988 ROD. In accordance with the ROD and 1991 Consent Decree, treated groundwater from the TARP WTP was delivered to the City of Tucson drinking water distribution system.

The TARP remediation system has reduced concentrations of TCE in the southern portion of the plume from over 300 micrograms per liter ($\mu\text{g/L}$) TCE in 1987 to between 5 and 30 $\mu\text{g/L}$ TCE in 2017. Most of the plume has significantly reduced levels of TCE contamination compared to pre-remediation concentrations, and most of the TCE contamination currently occurs in the regional Undivided Aquifer in the vicinity of the NWF.

In 2002, 1,4-dioxane was discovered in groundwater samples collected from TARP monitoring and remediation wells. Tucson Water (City of Tucson Water Department) has monitored the concentrations of 1,4-dioxane in water at the TARP WTP since 2002, to ensure the water delivered to the drinking water system remained below the EPA Safe Drinking Water Act (SDWA) Health Advisory (HA) of 3 $\mu\text{g/L}$ for 1,4-dioxane in effect prior to 2011. In order to meet the HA for drinking water, treated water from the TARP WTP was blended with drinking water from the distribution system, and the combined flow was then conveyed through a pipeline to the entry point to the distribution system (EPTDS) at Tucson Water's Santa Cruz Lane Reservoir.

In 2011, EPA lowered the SDWA HA for 1,4-dioxane to 0.35 $\mu\text{g/L}$. Because of elevated concentrations of 1,4-dioxane in the SWF, TARP-treated water could not achieve the 2011 HA, even with blending. Subsequently, Tucson Water shut down the SWF and began design and construction of an upgrade to the TARP WTP to remove 1,4-dioxane from the TARP-treated water. Pilot testing results supported the application of advanced oxidation process (AOP) using ultraviolet (UV) light and hydrogen peroxide to effectively treat 1,4-dioxane to levels at or below the HA for drinking water. The AOP facility at the TARP WTP began routine operation in February 2014.

Between February 2014 and May 2020, treatment was performed by processing contaminated groundwater through the AOP facility and then through the PCA facility. Throughout this period, water quality data indicated that the AOP facility effectively treated both TCE and 1,4-dioxane prior to the PCA facility, consistently meeting treatment goals. In June 2020, Tucson Water completed construction of piping, valve and control system modifications at the TARP WTP to implement a PCA Retirement Demonstration authorized by EPA and the Arizona Department of Environmental Quality (ADEQ). Accordingly, the PCA system was bypassed, and treated water from the AOP facility, with a free chlorine disinfection residual added at the TARP WTP, was conveyed directly to the drinking water distribution system as part of the demonstration. The 2023 Interim ROD Amendment approved elimination of the PCA system from the remedy (EPA, 2023).

1.1.3 Focused Remedial Investigation/Feasibility Study for 1,4-Dioxane

In July 2007, EPA issued USAF an Administrative Order for Response Action pursuant to Section 1431 of the SDWA which required USAF to install a new treatment system at AFP44 and mitigate the impact of TCE and 1,4-dioxane in groundwater from AFP44 on TARP and public drinking water supplies. Previously, in 2004, USAF conducted treatability studies to identify treatment processes and technologies to remove 1,4-dioxane from groundwater, selecting an AOP system using ozone and hydrogen peroxide to oxidize 1,4-dioxane and TCE in groundwater at AFP44 (APT, 2005). USAF completed the design and construction of the ozone-peroxide AOP system at AFP44, which became operational in September 2009. USAF reinjects groundwater treated by the AOP at AFP44 into the underlying aquifer.

USAF conducted a focused remedial investigation/feasibility study (RI/FS) to characterize the nature and extent of 1,4-dioxane in the entire Area A plume, both north (TARP) and south (AFP44) of Los Reales Road. The *Focused Remedial Investigation and Feasibility Study for 1,4-Dioxane North of Los Reales Road* (ECG, 2016) was issued in March 2016 and is comprised of three volumes. Volume III, the Focused Feasibility Study (FFS), evaluated six alternatives for remediation of 1,4-dioxane in Area A groundwater, including TARP. The purpose of the 2016 FFS was to address the treatment of 1,4-dioxane contained in the extracted groundwater. The 2016 FFS includes an evaluation of the management of TARP-treated water and required that *ex situ* (pump and treat) remediation technologies include management of the treated water.

In relation to pump and treat remediation technology alternatives, the 2016 FFS evaluated five methods for management of TARP-treated water:

- Reinjection into the aquifer within the TARP plume area;
- Discharge to the Santa Cruz River;
- Delivery to the Pima County wastewater collection and treatment facilities;
- Delivery to the City of Tucson municipal water distribution system (status quo at the time of the study); and
- Industrial, irrigation, and recreational uses.

The 2016 FFS retained aquifer reinjection and delivery to the City of Tucson municipal water distribution system as viable methods for management of TARP-treated water. Delivery of treated water to the Pima County wastewater collection and treatment systems was eliminated from consideration because it was deemed inconsistent with the Tucson Groundwater Active Management Area's Management Plan, difficult to implement based on impacts to operations at the wastewater treatment plants, and too costly due to the need to construct a two-mile pipeline to connect to the wastewater collection interceptor. Commercial/industrial, irrigation, and recreational use were removed from consideration, because construction of a distribution system was considered cost prohibitive and the water demand for these users would be inconsistent with the goals of the Tucson Active Management Area's Management Plan. Discharge of treated water from the TARP WTP to the Santa Cruz River was removed from consideration, because it was assumed that recharge to the aquifer may not be effective due to evaporation and may have an adverse impact on the capture zone of the TARP NWF.

The 2016 FFS recommended that treatment of 1,4-dioxane and TCE in groundwater from the TARP remediation well fields should continue via the existing AOP facility at the TARP WTP, with delivery of treated water to the municipal drinking water system. The 2016 FFS evaluation did not consider delivery to the existing City of Tucson recycled water system as an alternative method for management of TARP-treated water; however, a 2021 addendum (First Addendum) to the FFS evaluated alternative end uses of treated water from TARP (Carollo, 2021). Details on the First Addendum are provided in Section 1.1.5.

1.1.4 Proposed Plan 2017

In consideration of the 2016 FFS, EPA prepared a Proposed Plan (EPA, 2017) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) for the preferred remedy for 1,4-dioxane and VOCs at the TIAA Superfund Site Area A plume north of Los Reales Road, also known as TARP. The 2017 EPA Proposed Plan did not address treatment of PFAS, which were newly being detected in Area A groundwater.

1.1.5 FFS First Addendum 2021

The 2021 addendum (First Addendum) to the FFS evaluated alternative end uses of treated water from TARP other than as drinking water (Carollo, 2021). Potential uses included discharge to the Tucson Water recycled water system and discharge to the Santa Cruz River. The addendum concluded that these treated water management options would increase the ability of the TARP remedy to continue operating in the event of future limitations on the use of TARP-treated water for drinking water. The First Addendum also evaluated the construction and operation of a new extraction well (R-127A) for the TARP system.

1.1.6 Remedy Modifications 2021-2023

In September 2021, EPA signed a Minor Changes Memorandum to remove the specification of the end use of treated water from TARP (EPA, 2021). EPA approved further changes to the remedy in the 2023 Interim ROD Amendment, including treating the groundwater at TARP for 1,4-dioxane using the ultraviolet light-hydrogen peroxide advanced oxidation process (UV-AOP) system, which was already in place at TARP, elimination of the PCA system, construction and

operation of well R-127A to further reduce contaminant mass, and additional options for beneficial use of the water other than as drinking water, including discharge to the Tucson recycled water system (EPA, 2023).

1.2 FFS Second Addendum Purpose, Objectives, and Scope

The purpose of this FFS Second Addendum is to supplement the 2016 FFS and 2021 First Addendum by evaluating the treatment of PFAS at the TARP WTP. This FFS Second Addendum evaluates alternatives for treatment of PFAS. This Addendum does not affect any elements of treated water management, such as well-pumping and conveyance of extracted groundwater to the TARP WTP, or the management of water after it has been treated by the AOP facility. Because the nature and extent of PFAS in groundwater have not yet been determined and are the subject of multiple ongoing remedial investigations, this FFS does not address aquifer restoration. The existing TARP system was designed to remediate the Area A TCE groundwater plume.

Groundwater extracted for TCE remediation also contains elevated levels of 1,4-dioxane and PFAS. The purpose of the 2016 FFS was to address the treatment of 1,4-dioxane contained in the extracted groundwater. The purpose of this FFS is to address the treatment of select PFAS contained in the extracted groundwater for the TARP WTP.

PFOS and PFOA were initially detected in groundwater in the TARP system in 2013. Monitoring indicated increasing concentrations over time. In June 2021, TARP was shut down to retrofit the system to accommodate alternative discharge options for the treated water. In November 2021, The TARP system returned to service; however, Tucson Water did not resume operating the SWF wells. The SWF wells remain out of service due to high concentrations of PFAS.

Modifications to the existing TARP WTP are necessary because:

- The SWF has not been in operation since June 2021 due to concentrations of PFAS that are too high to treat with the current system;
- The system needs to be able to operate with all current (and any future) extraction wells to treat contaminants effectively;
- Concentrations of several PFAS are greater than their Maximum Contaminant Levels (MCLs) (Carollo, 2024a);
- PFAS concentrations are projected to increase by 2 to 5 times from the current concentrations (Carollo, 2024b);
- PFAS are not treated by the AOP plant;
- PFAS are being removed by the granular activated carbon (GAC) contactor vessels after the water leaves the AOP; and
- While the GAC contactor vessels (to quench excess hydrogen peroxide) do remove PFAS, the GAC vessel capacity for removing PFAS is quickly exhausted, and the system is not operating effectively or as designed.

As noted above, the containment of the Area A plume is achieved by operation of the NWF. Although operation of the SWF and R-127A are not required for plume containment, these remediation wells are important for contaminant mass removal, and the TARP system does not operate to its full capacity without them. Contaminant mass removal from the TARP plume affects migration and how long the TARP remedy will be in operation. The SWF has not been in operation since June 2021 due to elevated concentrations of PFAS in the wells. Adding PFAS treatment to the TARP WTP will potentially enable the SWF to be utilized, thus reducing contaminant migration, the overall cleanup cost, and the expected time to achieve cleanup.

2.0 Nature and Extent of Contamination

The current knowledge of the nature and extent of PFAS in groundwater is based on the analytical results from approximately 305 wells, including 157 wells and 148 wells from the Area A and Area B plumes, respectively. Both plumes contain groundwater exceeding the April 2024 Safe Drinking Water Act (SDWA) MCLs for the following PFAS compounds: perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA), perfluorohexanesulfonic acid (PFHxS), perfluorononanoic acid (PFNA), and the SDWA Hazard Index (HI) criteria. **Table 1** presents the PFAS compounds with SDWA MCLs and a mixture of PFAS with a SDWA Hazard Index. In the following paragraphs, a single compound (PFOS) was selected to illustrate the currently known nature and extent of the PFAS contamination. PFOS is highly prevalent and detected at high concentrations in the groundwater.

Area A groundwater contamination extends from Los Reales Road to the TARP NWF, a distance of approximately 4.5 miles. Within Area A, PFOS concentrations in groundwater in 2023 ranged from less than 1.6 parts per trillion (ppt) to 400 ppt, with an average concentration of 64 ppt. The MCL for PFOS is 4 ppt. PFOS was detected in 67 of the 157 samples analyzed, a prevalence of 43%. PFOS was detected at concentrations above the MCL in 64 of the 157 samples analyzed, a prevalence of 41%. The results of PFOS analysis (2023) are presented in **Figure 3** with the Area A TCE plume shown to provide a more complete depiction of the current understanding of the groundwater contamination at TIAA.

The results of PFOS analysis (2023) are presented in **Figure 3**. The full extent of PFAS contamination at TIAA has not been defined. Any potential PFAS contribution from the Area B plume to the TARP system is currently unknown. The nature and extent of PFAS in the Area B plume and in the portion of the Area A plume that is south of Los Reales Road and within the shallow groundwater of the Tucson Airport Property (i.e., Three Hangars Area) are not considered in this study, because these areas are the subjects of separate remedial actions.

Figure 3 shows the concentrations of PFOS at the TARP extraction well system and nearby monitoring wells at TIAA (2023). Within the SWF, PFOS concentrations ranged from 116 ppt to 244 ppt. Within the NWF, PFOS concentrations ranged from 2.44 ppt to 48.5 ppt, and PFOS was detected at 90 ppt in R-127A. PFOS concentrations are greatest at the SWF, lower in R-127A and lowest in the NWF. As previously indicated, due to the higher levels of PFOS, the SWF has

been shut down since June 2021 and will remain shut down until the TARP system is upgraded to treat higher concentrations of PFAS.

The existing TARP system is designed to capture and treat the Area A TCE plume. In doing so, it also captures elevated levels of 1,4-dioxane and PFAS. The purpose of the 2016 FFS was to address the treatment of 1,4-dioxane contained in the extracted groundwater. Similarly, the purpose of this Second Addendum to the FFS is to address the treatment of select PFAS in the extracted groundwater influent to the TARP WTP. The effectiveness of the TARP system to address aquifer restoration of PFAS in the Area A and B plumes has not been determined.

3.0 Remediation Goals

3.1 FFS Remedial Action Objectives

Five remedial action objectives (RAO) for evaluating remedial alternatives to address contamination in Area A were identified in the 2016 FFS (ECG, 2016) and restated in the 2017 Proposed Plan. This FFS further suggests refining the RAOs as follows:

1. Prevent migration of VOCs, 1,4-dioxane and PFAS in groundwater beyond Area A that would pose an unacceptable risk to human receptors.
2. Prevent exposure (ingestion, inhalation, and/or dermal absorption) to VOCs, 1,4-dioxane and PFAS in groundwater that would pose an unacceptable risk to human receptors.
3. Restore Area A groundwater at TARP to beneficial use (i.e., drinking water) within a reasonable timeframe.

3.2 Identification of ARARs and To Be Considered Criteria

Section 121 of CERCLA requires that remedial actions must be protective of human health and the environment while complying with all ARARs (Applicable or Relevant and Appropriate Requirements).

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance at a CERCLA site.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not “applicable” to a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well-suited to the particular site.

In addition to legally binding laws and regulations, many Federal and State environmental and public health programs also develop criteria, advisories, guidance, and proposed standards that

are not legally binding, but that may provide useful information or recommended procedures. To Be Considered Criteria (TBCs) are not potential ARARs but are evaluated along with ARARs, as part of the risk assessment to set protective cleanup level targets. Chemical-specific TBC values such as health advisories and reference doses will be used in the absence of ARARs or where ARARs are not sufficiently protective to develop cleanup goals. Other TBCs, such as guidance or policy documents developed to implement regulations, may be considered and used, where necessary to ensure protectiveness. No additional TBCs have been identified for the alternatives discussed in this Second Addendum.

ARARs for the treatment of water for PFAS at the TARP WTP are described below. The ARARs identified in this addendum are supplemental to the ARARs identified in the 2016 FFS (ECG, 2016) and the 2023 Interim ROD Amendment (EPA, 2023) and are specific to the treatment of PFAS at TARP.

3.2.1 Chemical-specific ARARs

Chemical-specific ARARs are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the environment. Cleanup of groundwater at the TARP WTP to established MCLs for PFAS (**Table 1**) is considered an additional ARAR for this Addendum.

3.2.2 Location-specific ARARs

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations. No additional location-specific ARARs have been identified for this Addendum.

3.2.3 Action-specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous substances. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Since there are usually several alternative actions for any remedial site, different requirements can come into play. These action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how a selected alternative must be achieved. No additional action-specific ARARs have been identified for this Addendum.

4.0 Screening of Remedial Action Technologies

This section briefly describes treatment technologies that could be used to remove PFAS from groundwater. Technologies that would be difficult to incorporate with the existing TARP system are identified as incompatible with the project parameters. The treatment technologies evaluated as part of the TARP PFAS treatability study included: granular activated carbon (GAC), ion exchange (IX) resin, foam fractionation, submicron powdered activated carbon (SPAC) and reverse osmosis.

4.1 Granular Activated Carbon (GAC)

GAC, a form of carbon, is porous material with a high volumetric surface area that effectively adsorbs many contaminants, including varieties of PFAS. Raw materials used to make GAC are typically coal, peat, wood, and/or coconut shells. Carbon life for PFAS removal can vary widely depending on the carbon type, target contaminant concentrations, background water quality, and PFAS carbon chain length. In general, GAC adsorbs longer-chain PFAS (e.g., PFOS and PFOA) better than shorter-chain PFAS (e.g., PFHxA and PFBS). Once active absorption sites become exhausted, the GAC media must be replaced with new media and the spent media sent for off-site thermal regeneration. For groundwater treatment, GAC is typically implemented in a fixed bed system (non-fluidized) within multiple pressure vessels that are connected in series (lead/lag). Flow rates through these systems can range from 5 gpm to greater than 1,000 gpm.

Due to the large range in operational flow rates and effectiveness of removing PFAS, GAC is an applicable treatment technology for TARP.

4.2 Ion Exchange (IX)

Ion exchange (IX) resin is a synthetically manufactured product that consists of a gel or macroporous polymer matrix with affixed functional groups that can be positively or negatively charged. Typically, IX resins with positively charged functional groups are deployed for PFAS treatment because PFAS of concern are negatively charged at environmentally relevant pH conditions. The negatively charged functional groups (i.e., carboxylate and sulfonate ions) of the PFAS compounds exchange with the chloride counter-ion, becoming affixed to the positively charged functional group on the resin. The hydrophobic portion of the PFAS compound also adsorbs to the resin polymer matrix, which provides a dual mechanism of removal for PFAS, greatly increasing the removal kinetics when compared to GAC.

Like GAC, IX resin is most effective at removing long-chain PFAS compounds and is less effective at removing short-chain PFAS compounds. However, in general, IX resin is more effective at removing short-chain PFAS compounds than GAC. For water treatment, IX is typically implemented in the same orientation as GAC, that is, in a fixed bed system (nonfluidized) within multiple pressure vessels that are connected in series (lead/lag). Flow rates through these systems can range from 5 gpm to greater than 1,000 gpm. Pre-treatment for IX typically requires filtration of suspended solids down to 5 microns. Unlike GAC, IX cannot be backwashed because the mass transfer zone for IX can be disrupted during this process. Unlike with GAC, IX regeneration technology for resins used in PFAS treatment is not yet commercially available.

Due to the large range in operational flow rates and effectiveness of removing PFAS, IX is an applicable treatment technology for TARP.

4.3 Foam Fractionation

Foam fractionation treats water impacted with PFAS via multiple mechanisms by employing a series of columns in which a gas (air or ozone) is injected into contaminated water, creating bubbles that facilitate gas-liquid interface partitioning of dissolved PFAS into a foam fractionate

waste stream. The foam fractionate is collected as a concentrated waste. Foam fractionate waste stream destruction technologies are generally limited by the volume they can treat and may have a high cost per gallon to operate. Recent studies indicate that foam fractionation is ineffective in removing short-chain PFAS, and research into the efficacy of foam fractionation systems with flow rates greater than 100 gpm has not been sufficiently conducted.

Because foam fractionation has been shown to be ineffective in removing short-chain PFAS and insufficient information is currently available for systems with flow rates over 100 gpm, foam fractionation is not an appropriate technology for TARP at this time.

4.4 Submicron Powdered Activated Carbon (SPAC)

SPAC employs an activated carbon-based adsorbent medium that is manufactured to a mean particle diameter of less than 1 micron. Compared to GAC, which has a mean particle diameter ranging between 300 and 1,600 microns, SPAC has an increased surface area per unit of mass and a higher volume of mesopores, resulting in increased adsorption kinetics. For PFAS applications, the SPAC is mixed with the influent water in a vessel, resulting in a slurry, and the slurry is held in suspension through constant mechanical mixing. The slurry is then pumped to a ceramic membrane filter (CMF) with a 0.1-micron nominal pore size membrane. The CMF system would incur high capital costs. The CMF separates the PFAS-laden SPAC from the influent water. The water leaving the CMF, referred to as filtrate, is free of PFAS and is the treated effluent from the process. The SPAC that is separated by the CMF is returned to the reactor vessel where it continues treatment until it is ultimately exhausted of capacity. Once the SPAC is at capacity, the adsorbent is removed from the vessel and placed in a thickening tank to remove excess water from the waste stream. The effectiveness of PFAS removal when using SPAC is a function of residence time, SPAC dosing, and PFAS speciation. Similar to GAC, spent SPAC media would require reactivation or disposal.

Due to the high capital costs of the CMF system that complements the SPAC treatment, SPAC is not considered a cost-effective treatment technology at TARP at this time.

4.5 Reverse Osmosis (RO)

Reverse osmosis (RO) is a technology used to remove a large majority of contaminants (including PFAS) from water by forcing water, under pressure, across a semi-permeable membrane. A typical RO system consists of three streams: the untreated water (feed), the treated water (permeate), and the residual reject water (concentrate). The most common membrane module configuration is spiral-wound, which consists of flat sheet membrane material wrapped around a central permeate collection tube. Like many treatment technologies, RO is typically used as part of a treatment train. Most efficient RO performance may require pretreatment. RO-treated effluent (permeate) may require supplemental management to mitigate the corrosivity of demineralized water. Because of the anticipated high pumping rates, use of RO would require handling and disposal of a large volume of concentrate liquid.

Because RO would produce a large volume of concentrate liquid that would need to be disposed and the considerable costs of disposal, RO is not a cost-effective treatment technology for TARP at this time.

5.0 Analysis of PFAS Treatment Alternatives

This section establishes and evaluates the treatment alternatives considered in this study. The PFAS alternatives considered are limited to the evaluation of alternatives for treatment of PFAS in extracted groundwater for the TARP WTP. The screening described in Section 4.0 concluded that GAC and IX were determined to be potentially applicable treatment technologies for TARP.

5.1 Conceptual Design Criteria

This section reviews the design criteria for the treatment alternatives. During the conceptual design process, different configurations of IX and GAC were evaluated. The IX design criteria for Alternatives 1 through 7 are summarized in **Table 2**. The IX Alternatives 1 through 5 were evaluated by changing the number of lead/lag trains such that the following three different liquid loading rates (LLR) maximums are not exceeded:

- Maximum 12 gallons per minute per square foot (gpm/sf), American Water Works Association (AWWA) guidance maximum LLR for IX treatment.
- Maximum 14 gpm/sf, approximate midpoint LLR between AWWA guidance and vendor recommendation.
- Maximum 18 gpm/sf, vendor recommended maximum LLR for IX treatment.

Simplified process schematics for each treatment alternative are presented in **Appendix A** (from Carollo, 2024b). For Alternatives 1 and 2, one lead/lag train is sufficient to be under the AWWA's maximum recommended LLR for IX treatment. However, for Alternatives 3 through 5, the number of trains required to be under AWWA's maximum recommended LLR was calculated, and the number of treatment trains were reduced by one train and two trains, to be under, at the approximate midpoint LLR, and at the vendor-recommended LLR, respectively. The site layouts include the footprint of the vessels for all three LLR options, but for the development of the cost opinions in Section 5.4, the approximate midpoint LLR design criteria are considered for these treatment alternatives since it is only slightly greater than the AWWA guidance and less aggressive than the vendor-recommended LLR.

The GAC design criteria for Alternative 6 are: Max LLR: 8 gpm/sf and empty bed contact time greater than 5 minutes per vessel.

The lead-GAC and lag-IX design criteria for Alternative 7 are: Max LLR: 12 gpm/sf, lead-GAC empty bed contact time: 4 to 5 minutes per contactor for quenching, and lag-IX empty bed contact time: 3 minutes per contactor for PFAS removal.

5.2 Treatment Alternatives

The increase in PFAS concentrations at TARP emphasized the need to evaluate alternative well operation combined with water treatment approaches to address increasing PFAS levels in raw water delivered to the TARP WTP. **Table 3** summarizes the seven alternatives developed and evaluated, in addition to the No Action alternative.

The treatment alternatives are summarized as follows:

- **Alternative 0 – No Action.** Under Alternative 0, no changes to the current TARP system would be made. PFAS is nominally removed as AOP effluent passes through the existing quench GAC system (twelve lead-only contactors) used for quenching excess hydrogen peroxide. Because of the additional load to remove PFAS, the existing quench GAC system requires changeout multiple times per year. If the existing system did not need to be utilized for PFAS removal, the changeout frequency would be from between three and five years. The TARP system will not operate effectively or as designed without operation of the SWF wells.
- **Alternative 1** consists of wellhead treatment for PFAS at TARP extraction well R-127A. Groundwater is extracted from R-127A at a rate of 1,300 gpm and would pass through a two-stage sediment removal followed by a new single IX lead/lag train (two contactors). The treated groundwater would then be conveyed to the TARP WTP via the combined NWF pipeline and blended with water from the NWF and SWF. Because concentrations of PFAS in the blended water would still be above the MCLs, the existing GAC system would still be required to fully treat PFAS, and changeout of the GAC would still be required multiple times per year.
- **Alternative 2** consists of treating the SWF for PFAS with IX. Groundwater extracted from the SWF at 890 gpm would pass through a two-stage sediment removal followed by a single new IX lead/lag train (two contactors). The treated groundwater would then be blended with water from the NWF at the TARP WTP. Because concentrations of PFAS in the blended water would still be above the MCLs, the existing GAC system would still be required to fully treat PFAS, and changeout of the GAC would still be required multiple times per year.
- **Alternative 3** consists of treating the NWF for PFAS with IX. Groundwater extracted from the NWF at 6,000 gpm would pass through two-stage sediment removal followed by five new IX lead/lag trains (10 new contactors). The treated groundwater would then be blended with water from the SWF and sent through the AOP. Because concentrations of PFAS in the blended water would still be above the MCLs, the existing GAC system would still be required to fully treat PFAS, and changeout of the GAC would still be required multiple times per year.

- Alternative 4 consists of treating groundwater from the combined flow from the NWF and SWF for PFAS with IX prior to the AOP. Groundwater extracted at a combined rate of 7,200 gpm would pass through a two-stage sediment removal followed by six new IX lead/lag trains (12 contactors setup). Because PFAS would be removed from the groundwater prior to passing through the AOP, the changeout frequency of the existing GAC system would significantly decrease, and the AOP quench system would be able to operate as designed.
- Alternative 5 consists of treating groundwater from the combined flow from the NWF and SWF for PFAS with IX, by passing the effluent at 7,200 gpm through six new IX lead/lag trains (12 contactors) after treatment by the AOP and the existing GAC system. Changeout of the GAC would still be required multiple times per year. This alternative would not include additional sediment removal.
- Alternative 6 consists of treating groundwater from the combined flow from the NWF and SWF for PFAS with GAC lead/lag after AOP. This alternative would not include additional sediment removal. The existing contactors would be retrofitted with piping and valve manifolds to allow operation, and four new lead/lag trains would be added.
- Alternative 7 consists of treating groundwater from the combined flow from the NWF and SWF for PFAS with lead-GAC for peroxide quenching and lag-IX for PFAS treatment after AOP. This alternative would not include additional sediment removal, since GAC upstream of IX would act as both sediment removal filter and peroxide quencher, thus, protecting the IX media downstream. The existing contactors would be retrofitted with piping and valve manifolds to allow operation, and four lead/lag trains and two new IX vessels would be added. The lag vessels of the retrofitted vessels would handle the IX resin, with a feed distributor and modified underdrain to retain IX resin.

5.3 Treatment Cost Opinions

Capital and annual operation and maintenance (O&M) cost opinions were developed for each of the seven treatment alternatives and are presented in **Appendix B**.

The capital cost opinions are expressed in March 2022 dollars, based on a 20-Cities Average Engineering News Record Construction Cost Index that accounts for materials and common labor on construction projects. This level of cost estimating is generally made with limited information (e.g., process block diagrams, preliminary equipment lists, and conceptual layouts), and accuracy is anticipated to be in the range of minus 30 to plus 50 percent.

The cost opinions do not include any costs for additional supervisory control and data acquisition (SCADA) and communications equipment. The alignment of SCADA and communications hardware and software will be determined when new treatment facilities are constructed. The basis of this cost opinion is presented in **Table 4** and in **Appendix B**.

Appendix B shows the assumptions for the media changeout frequency and cost calculations. Since the next 20-year projections of PFAS concentrations at TARP WTP inlet show variable concentrations, the following assumptions were made for media changeout projections and cost:

- Best- and worst-case TARP WTP inlet PFAS concentrations at end of fifth year was assumed for every five-year interval: interval 1, 2, 3 and 4.
- Changeout frequency:
 - GAC: Changeout frequency for each five-year interval was calculated based on the inlet PFAS concentrations for the respective interval and the media usage rate of Calgon F400, or similar product, based on both TARP full scale and rapid small scale column test (RSSCT) breakthrough data.
 - IX: Changeout frequency for each five-year interval was calculated based on the inlet PFAS concentrations for the respective interval and the media usage rate of Purolite PFA694E, or similar product, based on TARP RSSCT breakthrough data.
 - For two stage PFAS removal (Alternatives 1, 2 and 3):
 - First stage treats partial flow to ND (less than 2 ppt)
 - Second stage treats the full/blended flow to the three different operational goals
- Three different operational goals were evaluated to outline the potential media changeout cost implications due to Tucson Water's operational strategy and potential regulatory scenarios. The goals correspond to the concentrations measured in the TARP WTP finished water outlets to the recycled water system and/or Santa Cruz River Discharge point: less than 2 ppt, less than 18 ppt, and less than 70 ppt.

Table 5 and **Table 6** summarize the media changeout frequency of GAC and IX media for the 2 ppt treatment goal for worst- and best-case scenarios, respectively.

5.4 Economic Analysis of Cost Opinions

An economic analysis was performed for the seven treatment alternatives. The values introduced in this section represent the sum of capital cost opinions and the present worth of annual O&M cost projections, assuming a discount rate of four percent and term of 20 years.

Table 7 and **Table 8** summarize the conceptual level cost opinions for the seven alternatives targeting PFAS treatment to less than 2 ppt at TARP WTP outlet for "worst" and "best" case inlet PFAS concentrations, respectively.

The cost analysis indicates:

- Based on capital costs: Alternative 2 is the most cost-effective treatment alternative but is only a partial flow treatment and would need two-stage PFAS removal. Among the full flow (NWF and SWF) treatment alternatives (Alternatives 4 through 7), Alternatives 6 and 7 have similar costs and are the most cost-effective options. Alternatives 0, 1, 2, 3 and 5 would require frequent GAC changeouts and the associated costs.

- Based on average annual O&M and present worth costs: Alternative 6 is the most cost-effective treatment alternative, as all other alternatives have both GAC and IX media changeout costs included in the annual O&M costs.

The detailed cost opinions are provided in **Appendix B**.

6.0 Evaluation of Alternatives

The approach for evaluating alternatives is presented under National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR 300.430(e)(9)(iii)) and CERCLA FS guidance (EPA, 1988b). The nine criteria fall under the categories:

- Evaluation of Threshold Criteria
- Evaluation of Balancing Criteria
- Evaluation of Modifying Criteria

The evaluation shall reflect the scope and complexity of site problems and alternatives being evaluated and consider the relative significance of the factors within each criterion. For this FFS Second Addendum, the scope of the alternatives is to provide for the removal of PFAS from the TARP system prior to discharge. Additionally, the alternatives must be able to be incorporated into the existing TARP system with all extraction wells operating. Because of the difficulty of removing high concentrations of PFAS extracted from the groundwater through the SWF, operation of the SWF will not resume until the TARP system is upgraded with additional PFAS treatment capabilities.

6.1 Threshold Criteria

Threshold criteria are requirements described in the CERCLA statute and include protection of human health and the environment and compliance with ARARs. All alternatives must pass these two threshold criteria to be considered for further evaluation.

6.1.1 Criteria 1: Overall protection of human health and the environment

All alternatives in this FFS Second Addendum are protective of human health and the environment by removing PFAS from treated water to below target treatment levels. The No Action alternative (Alternative 0) does not allow for the operation of the SWF, and therefore the system is not operating as designed nor is it consistent with the 2023 Interim ROD Amendment.

Alternatives 1, 2, and 3 do not treat PFAS from all of the extraction wells. Rather, in Alternatives 1, 2, and 3, PFAS treatment is conducted only at R-127A, SWF, and NWF respectively. The treated water is then blended with non-treated water from the other wells and the subsequent blended water has PFAS concentrations in the range of tens to hundreds of parts per trillion. Therefore, to achieve target treatment levels, AOP effluent is passed through the existing GAC system (12 contactors). With the additional PFAS treatment, protection of human health and the environment is achieved.

Alternatives 4, 5, 6 and 7 treat PFAS from all of the extraction wells to levels below the target treatment levels, thereby achieving protection of human health and the environment.

6.1.2 Criteria 2: Compliance with ARARs

All alternatives considered for this FFS Second Addendum comply with ARARs defined in Section 3.2 of this Addendum.

6.2 Balancing Criteria

The balancing criteria identify trade-offs between alternatives and are scored relative to one another for each of the balancing criteria. Ultimately, the balancing criteria analysis results in the identification of a preferred alternative.

6.2.1 Criteria 3: Long-term effectiveness and permanence

Maintaining current operations over the long-term, Alternative 0 would be inefficient and ineffective due to the large volume of GAC needed, the frequency and costs of changeouts, and the volume of used GAC that is generated. In addition, the TARP system cannot operate at its full capacity or as it was designed until the SWF resumes operation.

Alternatives 1 through 7 are effective over the long-term; however, the frequency and costs of GAC changeouts are considerable in Alternatives 1, 2, 3 and 5. Although the risk from residual PFAS in the aquifer is beyond the scope of this report, under all alternatives, the magnitude of PFAS contamination in the aquifer would be reduced as the treatment sequesters PFAS from the environment. Because Alternatives 1, 2 and 3 require using the current system to fully remove PFAS, the service and material difficulties associated with Alternative 0 will also be present.

Alternatives 4 through 7 provide for full-capacity operation of the treatment facility. The system needs to be able to operate with all current (and any future) extraction wells operating to treat contaminants effectively and to operate as designed.

The long-term risk from treatment residuals is minimal, because residuals will be contained and removed off-site for recycling, destruction and/or disposal. There is insufficient information at this time to fully assess long-term effectiveness of recycling, destruction and/or disposal of treatment residuals.

A benefit of Alternative 4 placing IX treatment upstream of the AOP process is having GAC downstream of the IX treatment for redundant PFAS treatment. Alternative 4 does not consider the existing GAC as part of the PFAS treatment approach, but the existing GAC will also adsorb PFAS compounds that are downstream of the IX vessels. Only Alternative 4 has this redundancy.

6.2.2 Criteria 4: Reduction of toxicity, mobility, or volume through treatment.

In all alternatives, PFAS will be removed from the water and adsorbed onto IX and or GAC materials. The toxicity of the PFAS is not reduced; however, the risk of exposure is reduced by sequestering the PFAS from the environment.

As long as breakthrough does not occur, PFAS's mobility is reduced as it is sequestered from the environment by adsorption to IX and or GAC. The volume of contamination is reduced by concentrating the PFAS during removal. PFAS adsorbed to IX/GAC is assumed to be removed from the environment and to be subject to further treatment, disposal, and/or destruction.

6.2.3 Criteria 5: Short-term Effectiveness

Under Alternative 0, there will be no changes or modifications to the existing AOP system. Alternative 0 can be immediately implemented; however, there is the short-term risk that the system will not operate effectively without extraction from the SWF wells. Under Alternatives 1 to 7, short-term impacts may include additional traffic, noise from construction, and additional dust during construction. It is anticipated that there will be minimal impact to workers and the environment. Time for construction is likely between several months and a year.

6.2.4 Criteria 6: Implementability

Alternative 0 is currently being implemented; however, it will be less implementable in the long-term, because of the continued inefficiencies resulting from the large volume of GAC needed, the frequency and costs of changeouts, and the volume of used GAC that is generated. In addition, the SWF will not be able to be restored to operation without additional GAC changeouts and increased volume of contaminated materials. Alternatives 1 to 7 are technically feasible and implementable; however, the frequency and costs of GAC changeouts are considerable in Alternatives 1, 2, 3 and 5.

The administrative feasibility of Alternative 0 is difficult long-term as noted above. The Administrative feasibility for Alternatives 1 to 7 is similar. All would require the time and costs for finalizing design plans, coordinating construction activities, obtaining permits, and addressing regulatory concerns and oversight. All can be implemented with minimal impact to the current operations.

No additional services and materials, beyond what is currently being performed, are required for Alternative 0 (no action); however, current operations are inefficient because of the large volume of GAC needed, the frequency and costs of changeouts, and the volume of generated used GAC. Alternatives 1 through 7 require design plans, materials determinations, construction services and equipment purchases (e.g., contactors) and implementation, testing and operations shakedown. Additionally, Alternatives 1 through 4 will require purchasing equipment for sediment removal. Because Alternatives 1, 2 and 3 require using the current PFAS removal system to fully remove PFAS, similar service and material difficulties as those associated with Alternative 0 will also be present. The number and size of contactors to be

purchased will vary among Alternatives 1 through 7; however, schedules for equipment manufacturing are variable and subject to outside market forces.

6.2.5 Criteria 7: Costs

As previously discussed in this Addendum, based on capital costs, Alternative 2 is the most cost-effective treatment alternative, but it is only a partial flow treatment, and would need two-stage PFAS removal. The TARP system does not operate to its full capacity without the SWF and does not operate as designed without extracting from the SWF. Among the full flow (NWF and SWF) treatment alternatives, i.e., Alternatives 4 through 7, Alternatives 6 and 7 have similar costs and are the most cost-effective options.

Based on long-term O&M and present worth costs, Alternative 6 is the most cost-effective treatment alternative, as all other alternatives have both GAC and IX media change-out costs included in the annual O&M costs.

Although Alternative 6 (full-flow GAC treatment at TARP) appears to be the most cost-effective, full-flow option based on capital and annual O&M costs, because Alternative 4 places the IX treatment upstream of the AOP process, the downstream GAC in Alternative 4 provides redundant PFAS treatment. Only Alternative 4 has this redundancy. From a long-term operational and regulatory compliance perspective, Alternative 4 may be the most cost-effective alternative.

6.3 Modifying Criteria

The modifying criteria include State Acceptance and Community Acceptance. These criteria are addressed qualitatively and may not be considered fully until after agency and public review of the FFS Second Addendum is completed.

6.3.1 Criteria 8: State Acceptance

The existing AOP system has been implemented with EPA oversight and state (ADEQ) concurrence. Because Alternatives 0 to 7 do not fundamentally alter the current TARP system, state acceptance is anticipated. The state acceptance criterion addresses any comments to EPA from ADEQ. ADEQ's input has been included in the evaluation of the alternatives.

6.3.2 Criteria 9: Community Acceptance

The Community Acceptance criterion provides an assessment of the community response to the alternatives presented in this FFS Addendum. The Unified Community Advisory Board has been meeting with the parties, regulators, and representatives on a quarterly basis over the past 30 years to monitor progress of the remedy, provide input, and educate the public. Community concerns about potential exposure to contaminants at TARP and disruptions to surrounding neighborhoods from remedial activities routinely dominate public comments at Unified Community Advisory Board meetings.

Because minimal changes will be made to the current TARP system, Alternatives 0 through 7 are likely to continue to have the same community acceptance. Furthermore, the community is

in favor of the removal of PFAS from the environment. Final community acceptance will be evaluated based on input received from the public.

7.0 Focused Feasibility Study Summary and Conclusions

The purpose of this FFS Second Addendum is to supplement the 2016 FFS and 2021 First Addendum with an evaluation of the feasibility of treating water entering the TARP WTP for PFAS. PFAS is currently being removed by the GAC contactors whose primary purpose is to quench excess hydrogen peroxide that is used in the AOP facility to treat VOCs and 1,4-dioxane. Continuing to use the existing GAC contactors for the removal of PFAS is prohibitively expensive and results in loss of efficiency of the TARP WTP. Pretreating incoming raw water for PFAS using IX will allow the TARP WTP to be utilized at full capacity and reduce the overall cost and the expected time to achieve cleanup.

This FFS Second Addendum identifies seven alternatives for treating water for PFAS as it enters the TARP WTP. Based on the comparative analysis, although Alternative 6 appears to be the most cost-effective alternative, the preferred alternative is Alternative 4.

Alternative 4 is the only alternative that provides redundancy for treatment by having GAC downstream of the IX treatment to be used for quenching hydrogen peroxide as designed. From a long-term operational and regulatory compliance perspective, Alternative 4 may be the most cost-effective in the long term.

Alternative 4 has an estimated net present value of approximately \$55,860,000 (Carollo, 2024b). Alternative 4, IX Media Before AOP Treatment, provides full-flow capacity from all TARP remediation wells and would:

- Increase treatment media bed life;
- Provide longer term effective removal of short-chain PFAS compounds;
- Reduce overall media replacement requirements; and
- Allow the existing GAC contactors to serve as a redundant treatment for PFAS, further ensuring continuous achievement of treated water quality goals and allowing the AOP facility's GAC system to return to its original purpose of hydrogen peroxide quenching only, thus reducing the current level of maintenance with respect to GAC media replacement frequency.

This FFS Second Addendum applies the nine evaluation criteria required by 40 CFR §300.430(e) and described in EPA guidance (EPA, 1988b and 1990) to evaluate and score alternatives. All alternatives meet the Threshold Criteria of protection of human health and the environment and are expected to comply with ARARs because the alternatives employ treatment to remove contaminants in extracted groundwater to achieve the ARARs for all water uses described in the alternatives.

Alternative 4, the preferred alternative, is anticipated to meet the criterion of State acceptance due to anticipated input from supporting agencies indicating that the alternative may be permitted under State law and that they support it. The preferred alternative is anticipated to meet the criterion of Community acceptance due to community understanding and acceptance of the TARP remediation system.

The preferred alternative is feasible and implementable as an additional treatment module of the TARP WTP.

8.0 References

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FIGURES



FIGURE 1 SITE MAP

TUCSON INTERNATIONAL AIRPORT
TUCSON, ARIZONA

NOTES:

TARP = Tucson Airport Remediation Project

WTP = Water Treatment Plant

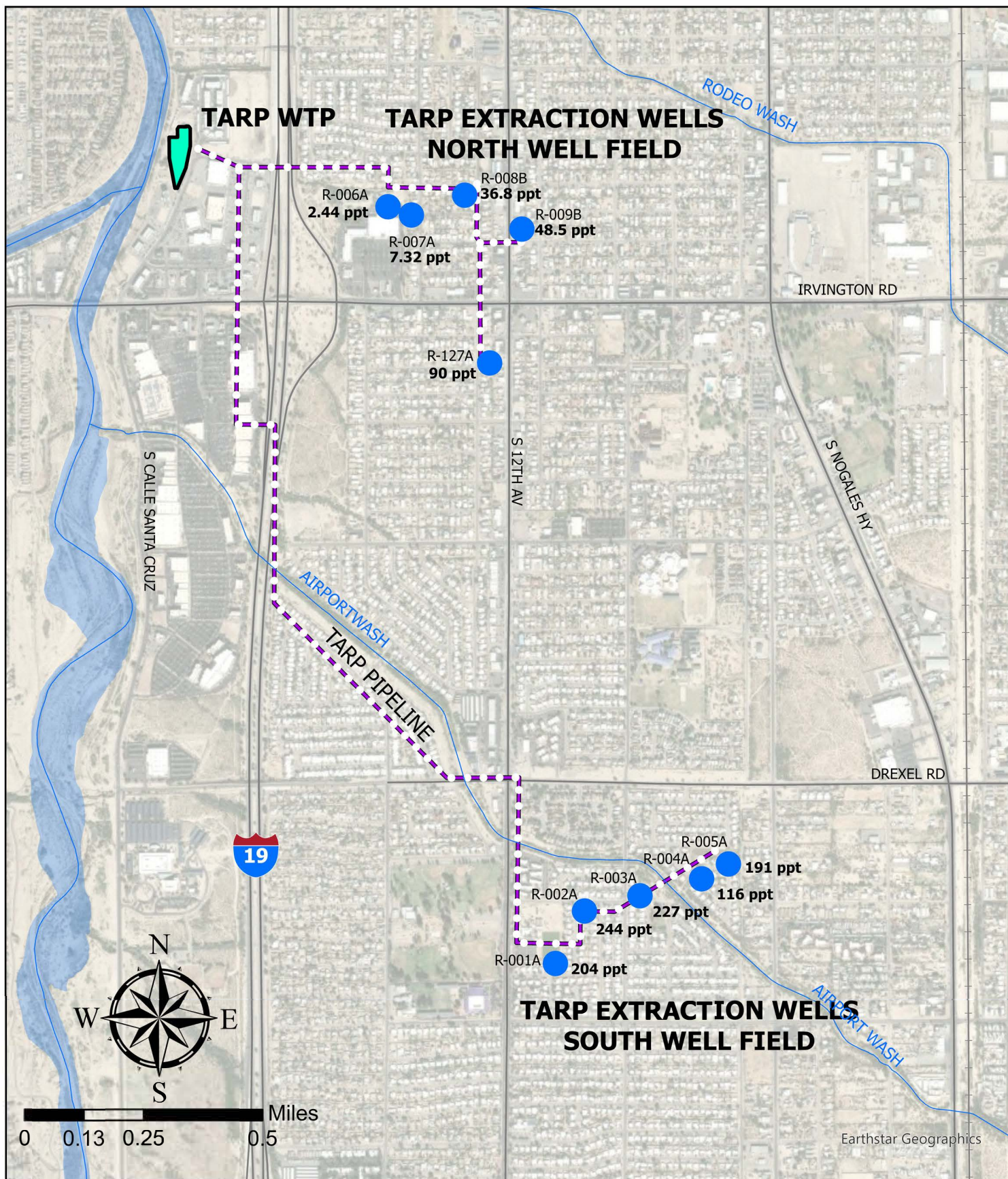


FIGURE 2 TARP REMEDIATION SYSTEM

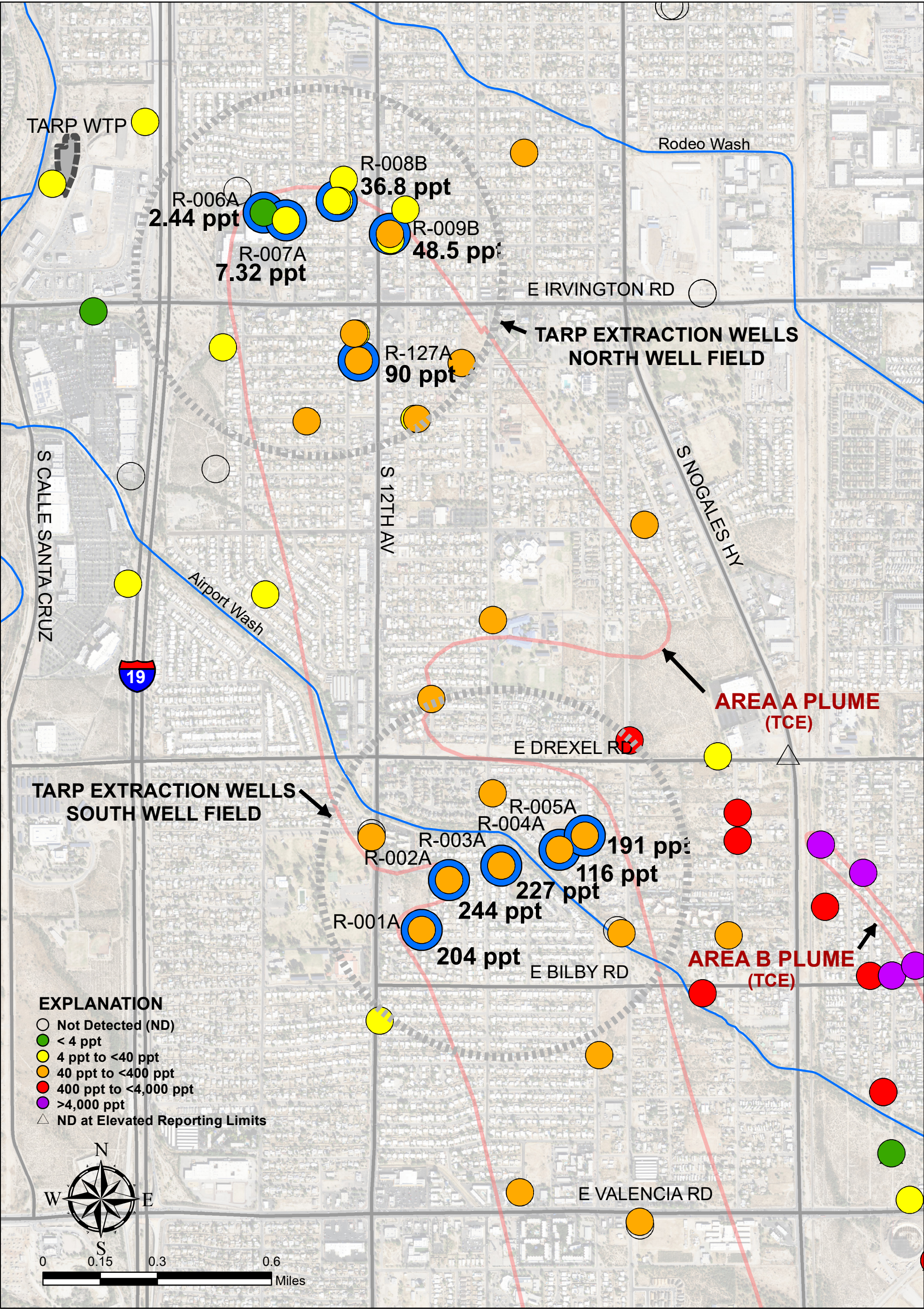
NOTES:

ppt = Parts per Trillion
TARP = Tucson Airport Remediation Project
WTP = Water Treatment Plant
PFOS = Perfluorooctanesulfonic Acid

TUCSON INTERNATIONAL AIRPORT
TUCSON, ARIZONA

NOTES:

● R-001A TARP Extraction Well ID
204 ppt PFOS Concentrations (2023)



EXPLANATION

- R-001A TARP Extraction Well ID
- 204 ppt PFOS Concentrations (2023)

NOTES:

- ppt = Parts per Trillion
- TARP = Tucson Airport Remediation Project
- WTP = Water Treatment Plant
- PFOS = Perfluorooctanesulfonic Acid
- TCE = Trichloroethene

FIGURE 3 PFOS IN GROUNDWATER
TUCSON INTERNATIONAL AIRPORT AREA
Tucson, Arizona

TABLES

Table 1
PER- AND POLYFLUOROALKYL SUBSTANCES
MAXIMUM CONTAMINANT LEVEL

TARP FFS ADDENDUM 2

COMPOUND	Maximum Contaminant Level
PFOA	4 ppt
PFOS	4 ppt
PFHxS	10 ppt
PFNA	10 ppt
HFPO-DA (GenX Chemicals)	10 ppt
Mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS.	Hazard Index of 1 (unitless)

Notes:

HFPO-DA = Hexafluoropropylene Oxide Dimer Acid

PFBS = Perfluorobutane Sulfonic Acid

PFHxS = Perfluorohexane Sulfonic Acid

PFNA = Perfluorononanoic Acid

PFOA = Perfluorooctanoic Acid

PFOS = Perfluorooctanesulfonic Acid

ppt = Parts per Trillion

Source: <https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas> (accessed 4/14/25)

Table 2
PER- AND POLYFLUOROALKYL SUBSTANCES
TREATMENT ALTERNATIVES
TARP FFS ADDENDUM 2

Parameter	ALTERNATIVES						
	1	2	3	4	5	6	7
Wells Treated	R-127A	SWF	NWF and R-127A	SWF, NWF, and R-127A	SWF, NWF, and R-127A	SWF, NWF, and R-127A	SWF, NWF, and R-127A
Additional PFAS Treatment Process	IX Lead/Lag Add 1 Train	IX Lead/Lag Add 1 Train	IX Lead/Lag Add 1 Train	IX Lead/Lag Add 1 Train	IX Lead/Lag Add 1 Train Existing GAC	GAC Lead/Lag Add 4 Trains Retrofit Existing GAC Lead/Lag 10 trains	GAC Lead IX Lag Add 2 Trains Retrofit Existing GAC Lead/Lag 10 trains
Location of Treatment Process	Well Head Before AOP	Before AOP	Before AOP	Before AOP	After AOP	After AOP	After AOP
Additional Sediment Removal	Yes	Yes	Yes	Yes	No	No	No
Design Flow (mgd)	1.9	1.3	8.7	10.4	10.4	10.4	10.4
Design Flow (gpm)	1,300	890	6,000	7,200	7,200	7,200	7,200

Notes:

mgd = million gallons per day

gpm = gallons per minute

SWF = South Well Field (Wells: R-001A, R-002A, R-003A, R-004A, R-005A)

NWF = North Well Field (Wells R-006A, R-007A, R-008B, R-009B)

GAC = Granular Activated Carbon

IX = Ion Exchange

AOP = Advanced Oxidation Process

Table 3
COMPARISON OF REMEDIAL ALTERNATIVES
TARP FFS ADDENDUM 2

Evaluation Criteria	Alternative 0 No Action	Alternative 1 R-127A IX Treatment Wellhead	Alternative 2 SWF IX Treatment Before AOP	Alternative 3 NWF IX Treatment Before AOP	Alternative 4 SWF and NWF IX Treatment Before AOP	Alternative 5 SWF and NWF IX Treatment After AOP and GAC	Alternative 6 SWF and NWF GAC Treatment After AOP	Alternative 7 SWF and NWF GAC and IX Treatment After AOP
1. Overall Protection of Human Health and the Environment	PROTECTIVE Current operations remove PFAS by passing water through the quenching contactors. Discharge levels are below MCLs.	PROTECTIVE Treats groundwater from R-127. Blended water exceeds 100 ppt total PFAS. This alternative would require continuation of the existing treatment at TARP (No Action Alternative); same comment for Alt 2 & 3.	PROTECTIVE Treats groundwater from SWF. Blended water exceeds 300 ppt total PFAS. This alternative would require additional PFAS treatment at TARP Plant.	PROTECTIVE Treats groundwater from NWF. Blended water still contains elevated total PFAS. This alternative would require additional PFAS treatment at TARP Plant.	PROTECTIVE Treats groundwater to below MCLs.	PROTECTIVE Treats groundwater to below MCLs.	PROTECTIVE Treats groundwater to below MCLs.	PROTECTIVE Treats groundwater to below MCLs.
2. Compliance with ARARs/TBC	COMPLIANT	COMPLIANT	COMPLIANT	COMPLIANT	COMPLIANT	COMPLIANT	COMPLIANT	COMPLIANT
3. Long-Term Effectiveness	UNCERTAIN EFFECTIVNESS.	EFFECTIVE	EFFECTIVE	EFFECTIVE	EFFECTIVE The only alternative that provides redundancy for treatment by having GAC downstream of the IX treatment.	EFFECTIVE	EFFECTIVE	EFFECTIVE
4. Reduction in Toxicity, Mobility, or Volume	PFAS adsorbed onto media (GAC/IX) is not reduced in toxicity. However, it does reduce mobility and volume in groundwater. Adsorbed media needs to be recycled or disposed off-site.	PFAS adsorbed onto media (GAC/IX) is not reduced in toxicity. However, it does reduce mobility and volume in groundwater. Adsorbed media needs to be recycled or disposed off-site.	PFAS adsorbed onto media (GAC/IX) is not reduced in toxicity. However, it does reduce mobility and volume in groundwater. Adsorbed media needs to be recycled or disposed off-site.	PFAS adsorbed onto media (GAC/IX) is not reduced in toxicity. However, it does reduce mobility and volume in groundwater. Adsorbed media needs to be recycled or disposed off-site.	PFAS adsorbed onto media (GAC/IX) is not reduced in toxicity. However, it does reduce mobility and volume in groundwater. Adsorbed media needs to be recycled or disposed off-site.	PFAS adsorbed onto media (GAC/IX) is not reduced in toxicity. However, it does reduce mobility and volume in groundwater. Adsorbed media needs to be recycled or disposed off-site.	PFAS adsorbed onto media (GAC/IX) is not reduced in toxicity. However, it does reduce mobility and volume in groundwater. Adsorbed media needs to be recycled or disposed off-site.	PFAS adsorbed onto media (GAC/IX) is not reduced in toxicity. However, it does reduce mobility and volume in groundwater. Adsorbed media needs to be recycled or disposed off-site.
5. Short-Term Effectiveness	EFFECTIVE Risk that the system will not operate effectively without extraction from the SWF wells.	EFFECTIVE Treatment for PFAS should be effective as the system comes online. Several weeks to months needed for construction.	EFFECTIVE Treatment for PFAS should be effective as the system comes online. Several weeks to months needed for construction.	EFFECTIVE Treatment for PFAS should be effective as the system comes online. Several weeks to months needed for construction.	EFFECTIVE Treatment for PFAS should be effective as the system comes online. Several weeks to months needed for construction.	EFFECTIVE Treatment for PFAS should be effective as the system comes online. Several weeks to months needed for construction.	EFFECTIVE Treatment for PFAS should be effective as the system comes online. Several weeks to months needed for construction.	EFFECTIVE Treatment for PFAS should be effective as the system comes online. Several weeks to months needed for construction.
6. Implementability	IMPLEMENTABLE Is currently in operation. Technically and administratively feasible. Services and materials available. Note: IX/GAC disposal and or recycling technologies are under research.	IMPLEMENTABLE Technically and administratively feasible. Services and materials available. Note: IX/GAC disposal and or recycling technologies are under research.	IMPLEMENTABLE Technically and administratively feasible. Services and materials available. Note: IX/GAC disposal and or recycling technologies are under research.	IMPLEMENTABLE Technically and administratively feasible. Services and materials available. Note: IX/GAC disposal and or recycling technologies are under research.	IMPLEMENTABLE Technically and administratively feasible. Services and materials available. Note: IX/GAC disposal and or recycling technologies are under research.	IMPLEMENTABLE Technically and administratively feasible. Services and materials available. Note: IX/GAC disposal and or recycling technologies are under research.	IMPLEMENTABLE Technically and administratively feasible. Services and materials available. Note: IX/GAC disposal and or recycling technologies are under research.	IMPLEMENTABLE Technically and administratively feasible. Services and materials available. Note: IX/GAC disposal and or recycling technologies are under research.
7.	Cost - Best Case							
	Capital Cost: ^{1,2,3,4,5,6,7}	\$0	\$5,630,000	\$4,860,000	\$19,490,000	\$23,510,000	\$19,130,000	\$11,010,000
	Ave Total Annual O&M Cost (NPV) ^{8,9,10}	\$0	\$3,130,000	\$3,620,000	\$2,430,000	\$2,380,000	\$2,360,000	\$1,190,000
	Total Present Worth ¹¹	\$0	\$48,170,000	\$54,060,000	\$52,510,000	\$55,860,000	\$51,200,000	\$27,180,000
	Total Estimated Cost (NPV)	\$0	\$53,800,000	\$58,920,000	\$72,000,000	\$79,370,000	\$70,330,000	\$38,190,000
	Cost - Worst Case							
	Capital Cost: ^{1,2,3,4,5,6,7}	\$0	\$5,630,000	\$4,860,000	\$19,490,000	\$23,510,000	\$19,130,000	\$11,010,000
	Ave Total Annual O&M Cost (NPV) ^{8,9,10}	\$0	\$4,250,000	\$5,110,000	\$3,190,000	\$3,250,000	\$3,230,000	\$1,660,000
	Total Present Worth ¹¹	\$0	\$63,390,000	\$74,310,000	\$62,840,000	\$67,680,000	\$63,030,000	\$33,570,000
	Total Estimated Cost (NPV)	\$0	\$69,020,000	\$79,170,000	\$82,330,000	\$91,190,000	\$82,160,000	\$44,580,000
	State Acceptance:	TBD based on future State review.	TBD based on future State review.	TBD based on future State review.	TBD based on future State review.	TBD based on future State review.	TBD based on future State review.	TBD based on future State review.
	Community Acceptance	TBD based on future public review.	TBD based on future public review.	TBD based on future public review.	TBD based on future public review.	TBD based on future public review.	TBD based on future public review.	TBD based on future public review.

Notes:

AOP = Advanced Oxidation Process

ARARs/TBC = Applicable or relevant and appropriate requirements/To be considered

GAC = Granular Activated Carbon

IX = Ion Exchange

NPV = net present value

NWF = North Well Field

O&M = Operation and Maintenance

ppt = Parts per trillion

RAO = remedial action objective

SWF = South Well Field

TARP = Tucson Airport Remediation Project

TCE = Trichloroethene

Operational Goal = Less than 2 ppt

PFAS Contingency Modeling and Treatment Evaluations: Worst Case Inlet PFAS Concentrations Conceptual Cost Opinion

¹ Cost opinions correspond to March 2022 dollars (ENR 20-Cities Average Construction Cost Index).

² Applied to equipment costs.

³ Applied to equipment costs and installation.

⁴ Applied to direct costs.

⁵ Applied to direct costs with contingency.

⁶ A.R.S. §42-5061(B)(6) tax deduction for pipes and fittings four inches in diameter or greater. Applied to piping cost.

⁷ Applied to total construction cost. For alternative 6 only, 16% is assumed due to design effort already completed 2019 and priced for construction.

⁸ Based on worst case influent PFAS concentrations from Clear Creek particle tracking model.

⁹ Based on historical TARP changeouts for peroxide quenching.

¹⁰ Based on lead-lag modeling of TARP full scale and rapid small scale column test (RSSCT) breakthrough data of operational goals for combined PFOS, PFOA, PFHxS, and PFHpA.

¹¹ Assumes discount rate of 4% per year and term of 20 years.

Table 4
COST OPINION BASIS
TARP FFS ADDENDUM 2

Item	Comment
Capital Cost Assumptions	
Process Equipment	• Updated vendor quotes for pressure contactors and sediment removal equipment.
O&M Cost Assumptions	
Media Unit Cost	• Calgon GAC F400 unit cost from TARP 2021 changeout (\$2.7/lb). • Purolite PFA694 unit cost from updated vendor quote (\$9.3/lb).
Media Changeout Frequency	• Inlet PFAS concentrations based on Clear Creek modeling. • For lead/lag trains, assumes change out in one vessel at a time. • GAC: used TARP full scale+RSSCT breakthrough data. • IX: used TARP vendor breakthrough projections. • For media changeouts, assumed 3 combined concentrations of combined PFOS, PFHxS, PFOA, and PFHpA: 2 ppt, 18 ppt, and 70 ppt. • For quenching-only, GAC change out frequency of 45 months assumed. • Duty cycle of 85% assumed for wells and treatment plant.
Present Worth Assumptions	• Discount rate of 4%. • 20-year term

Notes:

/lb = Per Pound
 GAC = Granular Activated Carbon
 IX = Ion Exchange
 PFAS = Per- and polyfluoroalkyl substances
 PFHpA = Perfluoroheptanoic acid
 PFHxS = Perfluorohexane Sulfonic Acid
 PFOA = Perfluorooctanoic Acid
 PFOS = Perfluorooctanesulfonic Acid
 ppt = Parts per Trillion
 RSSCT = Rapid Small Scale Column Test
 TARP = Tucson Airport Remediation Project

Table 5
CHANGEOUT FREQUENCY SUMMARY
2 PPT TREATMENT GOAL (WORST CASE SCENARIO)

TARP FFS ADDENDUM 2

Changeout Frequency	Alternative 1	Alternative 2	Alternative 3	Alternative 4 ¹	Alternative 5 ¹	Alternative 6 ²	Alternative 7
	R-127A	SWF	NWF	SWF and NWF	SWF and NWF	SWF and NWF	SWF and NWF
	IX Treatment	IX Treatment	IX Treatment	IX Treatment	IX Treatment	GAC Treatment	GAC and IX Treatment
	Wellhead	Before AOP	Before AOP	Before AOP	After AOP and GAC	After AOP	After AOP
Ion Exchange Media Changeout Frequency in Months							
Interval 1 (0 to 5 years)	4.8	5.1	9.7	9	9	N/A	5.1
Interval 2 (5 to 10 years)	2.7	6.1	6.5	6.6	6.6	N/A	3.8
Interval 3 (10 to 15 years)	1.4	8.1	3.8	4.2	4.2	N/A	2.4
Interval 4 (10 to 20 years)	1.4	8.1	3.5	3.9	3.9	N/A	2.2
GAC Media Changeout Frequency in Months							
Interval 1 (0 to 5 years)	3.5	3	10.4	45	45	3.7	45
Interval 2 (5 to 10 years)	3.1	2	12.4	45	45	3.2	45
Interval 3 (10 to 15 years)	2.3	1.2	16.2	45	45	2.7	45
Interval 4 (10 to 20 years)	2	1.1	16.1	45	45	2.2	45

Notes:

N/A = Not Applicable

¹ The GAC trains are assumed for peroxide quenching only.

² This is GAC-only treatment alternative and does not have any IX changeout requirements

Table 6
CHANGEOUT FREQUENCY SUMMARY
2 PPT TREATMENT GOAL (BEST CASE SCENARIO)
TARP FFS ADDENDUM 2

Changeout Frequency	Alternative 1	Alternative 2	Alternative 3	Alternative 4 ¹	Alternative 5 ¹	Alternative 6 ²	Alternative 7
	R-127A	SWF	NWF	SWF and NWF	SWF and NWF	SWF and NWF	SWF and NWF
	IX Treatment	IX Treatment	IX Treatment	IX Treatment	IX Treatment	GAC Treatment	GAC and IX Treatment
	Wellhead	Before AOP	Before AOP	Before AOP	After AOP and GAC	After AOP	After AOP
Ion Exchange Media Changeout Frequency in Months							
Interval 1 (0 to 5 years)	5.1	3.4	9.8	8.2	8.2	N/A	4.6
Interval 2 (5 to 10 years)	4.2	10.8	8.7	9.3	9.3	N/A	5.2
Interval 3 (10 to 15 years)	2.9	22.1	6.4	7.3	7.3	N/A	4.1
Interval 4 (10 to 20 years)	2.3	42	5.1	5.9	5.9	N/A	3.4
GAC Media Changeout Frequency in Months							
Interval 1 (0 to 5 years)	3	3	7	45	45	3.3	45
Interval 2 (5 to 10 years)	4	2.7	21.2	45	45	3.5	45
Interval 3 (10 to 15 years)	3.4	2	40.4	45	45	3.8	45
Interval 4 (10 to 20 years)	2.9	1.6	68.8	45	45	3.4	45

Notes:

N/A = Not Applicable

¹ The GAC trains are assumed for peroxide quenching only.

² This is GAC-only treatment alternative and does not have any IX changeout requirements

Table 7
COST OPINION SUMMARY
2 PPT TREATMENT GOAL (WORST CASE SCENARIO)
TARP FFS ADDENDUM 2

COST OPINIONS	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	R-127A	SWF	NWF	SWF and NWF	SWF and NWF	SWF and NWF	SWF and NWF
	IX Treatment	IX Treatment	IX Treatment	IX Treatment	IX Treatment	GAC Treatment	GAC and IX Treatment
	Wellhead	Before AOP	Before AOP	Before AOP	After AOP and GAC	After AOP	After AOP
Capital Cost	\$5,630,000	\$4,860,000	\$19,490,000	\$23,510,000	\$19,130,000	\$11,010,000	\$10,830,000
Average Annual O&M ¹	\$425,000	\$5,110,000	\$3,190,000	\$3,250,000	\$3,230,000	\$1,660,000	\$4,670,000
Present Worth							
Present worth of annual O&M ¹	\$57,759,000	\$68,447,000	\$43,353,000	\$44,169,000	\$43,897,000	\$22,560,000	\$63,467,000
Total present worth ¹	\$63,390,000	\$74,310,000	\$62,840,000	\$67,680,000	\$63,030,000	\$33,570,000	\$74,300,000
Equivalent Annual and Unit Treatment Cost							
Annualized capital cost ¹	\$414,000	\$358,000	\$1,434,000	\$1,703,000	\$1,408,000	\$810,000	\$797,000
Total equivalent annual cost	\$4,664,000	\$5,468,000	\$4,624,000	\$498,000	\$4,368,000	\$2,470,000	\$5,467,000
Cost per 1,000 gallons treated	\$1.45	\$1.70	\$1.44	\$1.55	\$1.44	\$0.77	\$1.70

Notes: ¹ Assuming a discount rate of 4 percent annually and a term of 20 years.

Table 8
COST OPINION SUMMARY
2 PPT TREATMENT GOAL (BEST CASE SCENARIO)
TARP FFS ADDENDUM 2

COST OPINIONS	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6	Alternative 7
	R-127A	SWF	NWF	SWF and NWF	SWF and NWF	SWF and NWF	SWF and NWF
	IX Treatment	IX Treatment	IX Treatment	IX Treatment	IX Treatment	GAC Treatment	GAC and IX Treatment
	Wellhead	Before AOP	Before AOP	Before AOP	After AOP and GAC	After AOP	After AOP
Capital Cost	\$5,630,000	\$486,000	\$19,490,000	\$23,510,000	\$19,130,000	\$11,010,000	\$10,830,000
Average Annual O&M ¹	\$3,130,000	\$362,000	\$2,430,000	\$2,380,000	\$2,360,000	\$1,190,000	\$3,360,000
Present Worth							
Present worth of annual O&M ¹	\$42,538,000	\$49,197,000	\$33,024,000	\$32,345,000	\$32,073,000	\$16,172,000	\$45,663,000
Total present worth ¹	\$48,170,000	\$54,060,000	\$52,510,000	\$55,860,000	\$51,200,000	\$27,180,000	\$56,490,000
Equivalent Annual and Unit Treatment Cost							
Annualized capital cost ¹	\$414,000	\$358,000	\$1,434,000	\$1,703,000	\$1,408,000	\$810,000	\$797,000
Total equivalent annual cost	\$3,544,000	\$3,987,000	\$3,864,000	\$4,110,000	\$3,768,000	\$2,000,000	\$4,157,000
Cost per 1,000 gallons treated	\$0.94	\$1.05	\$1.02	\$1.09	\$1.00	\$0.53	\$1.10

Notes: ¹ Assuming a discount rate of 4 percent annually and a term of 20 years.

APPENDIX A
Simplified Process Schematics

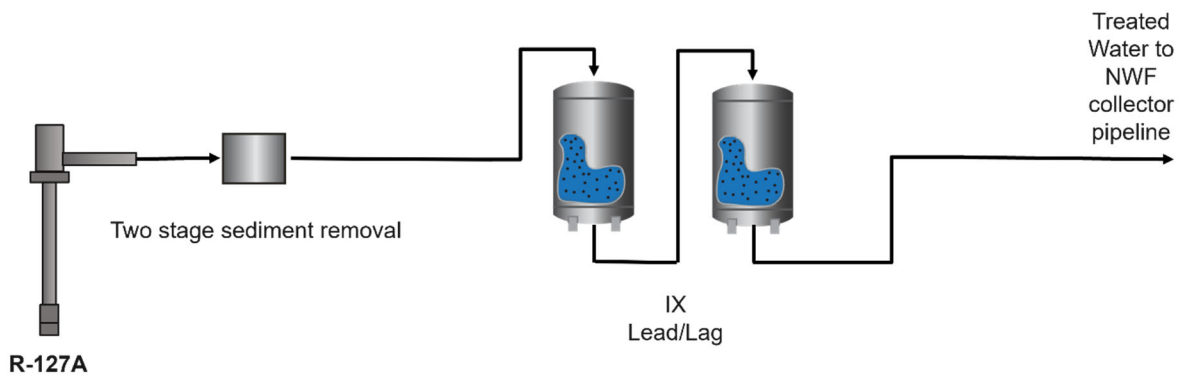


Figure B.1 Alternative 1: R-127A Wellhead Treatment

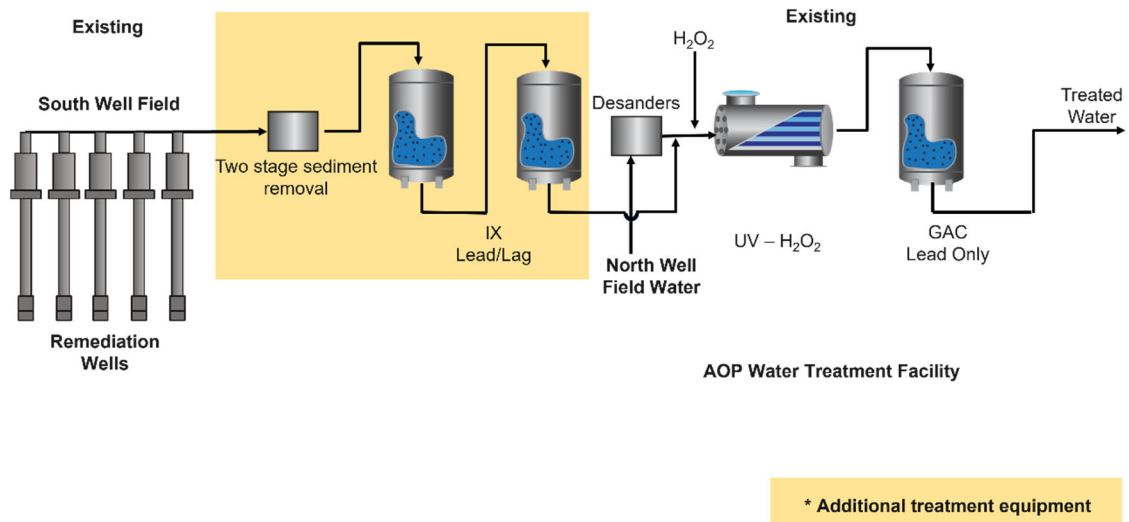


Figure B.2 Alternative 2: SWF IX Treatment Before AOP

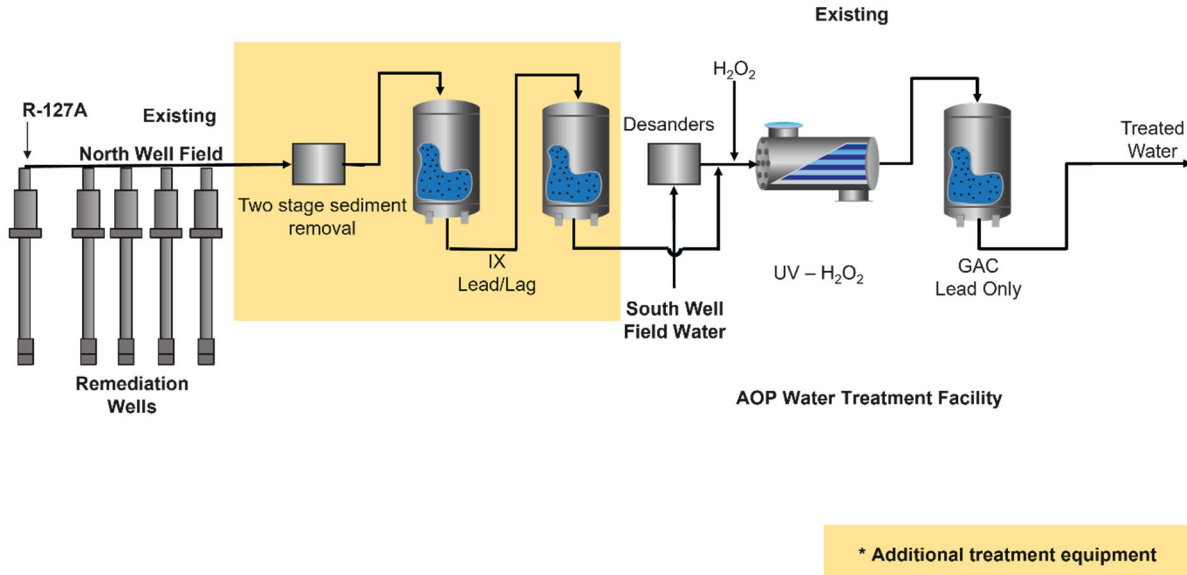


Figure B.3 Alternative 3: NWF IX Treatment Before AOP

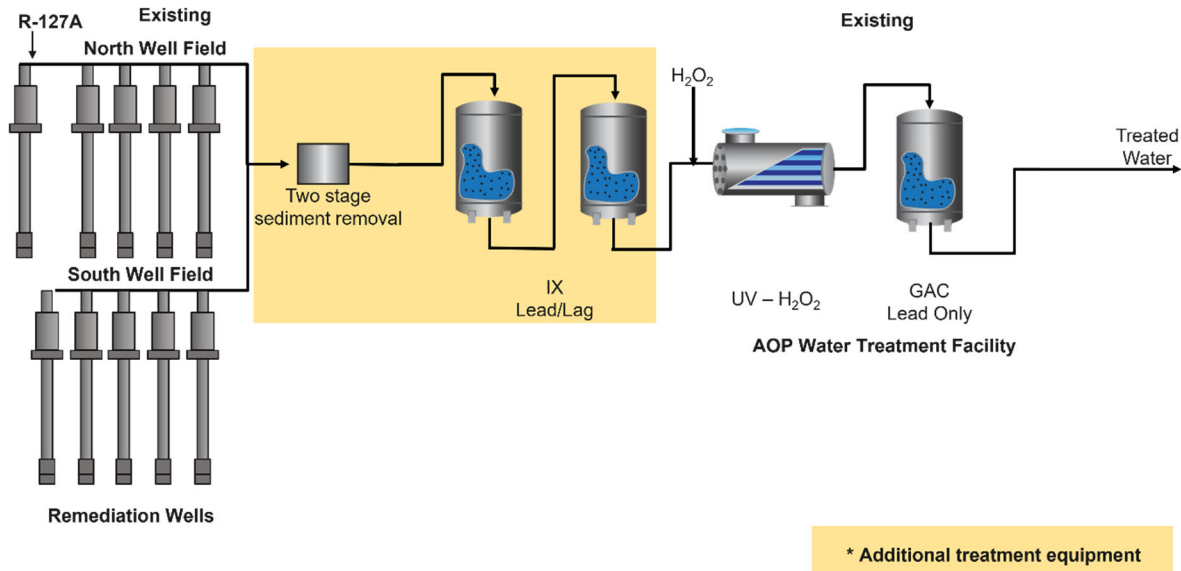


Figure B.4 Alternative 4: SWF and NWF IX Treatment Before AOP

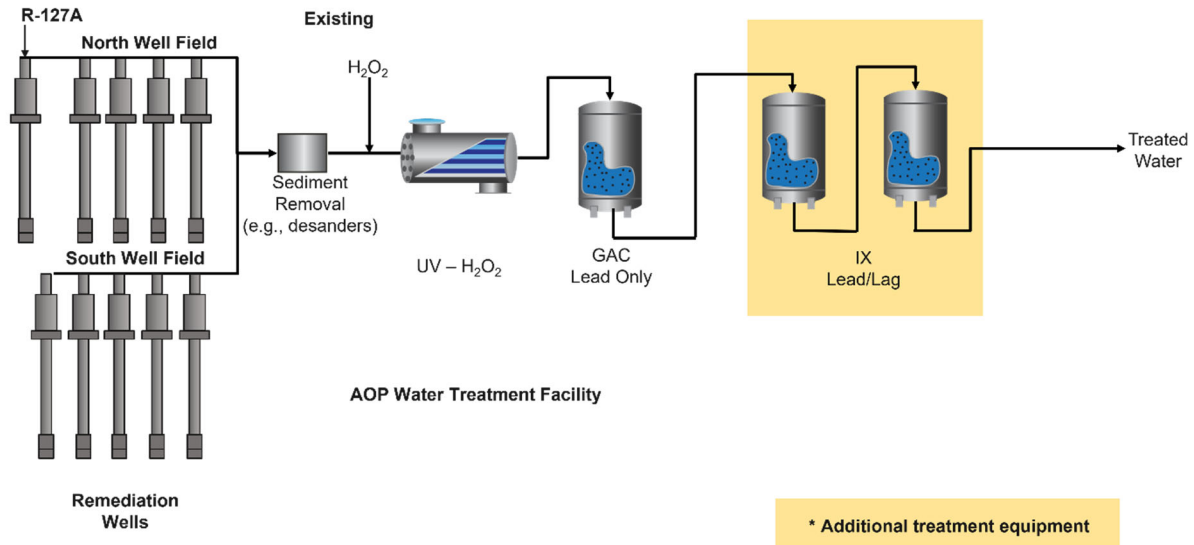


Figure B.5 Alternative 5: IX Treatment After AOP and GAC

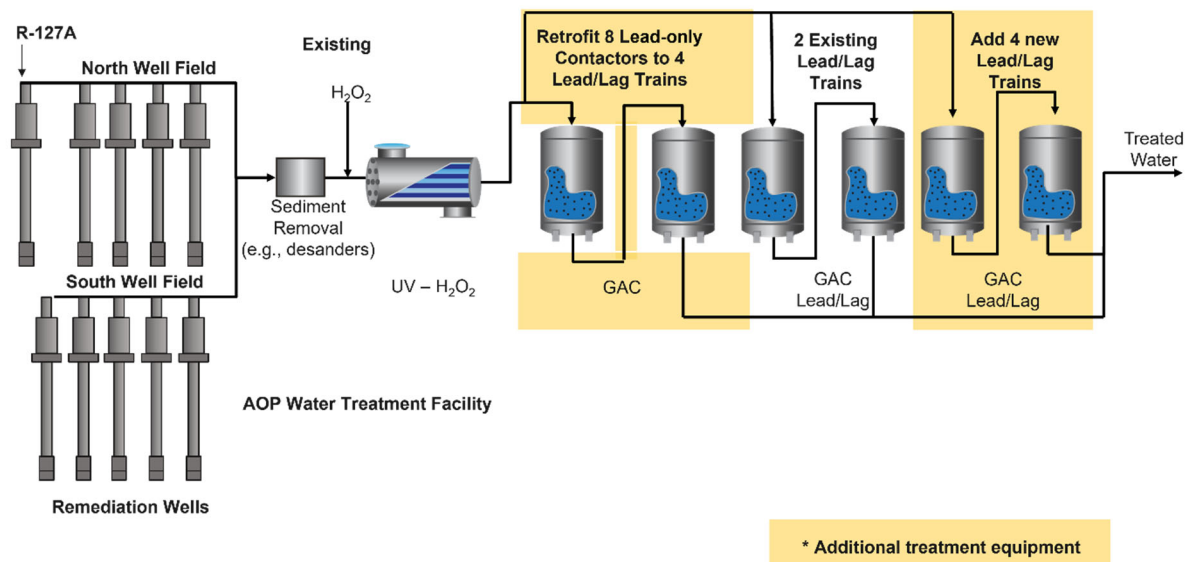


Figure B.6 Alternative 6: GAC treatment After AOP

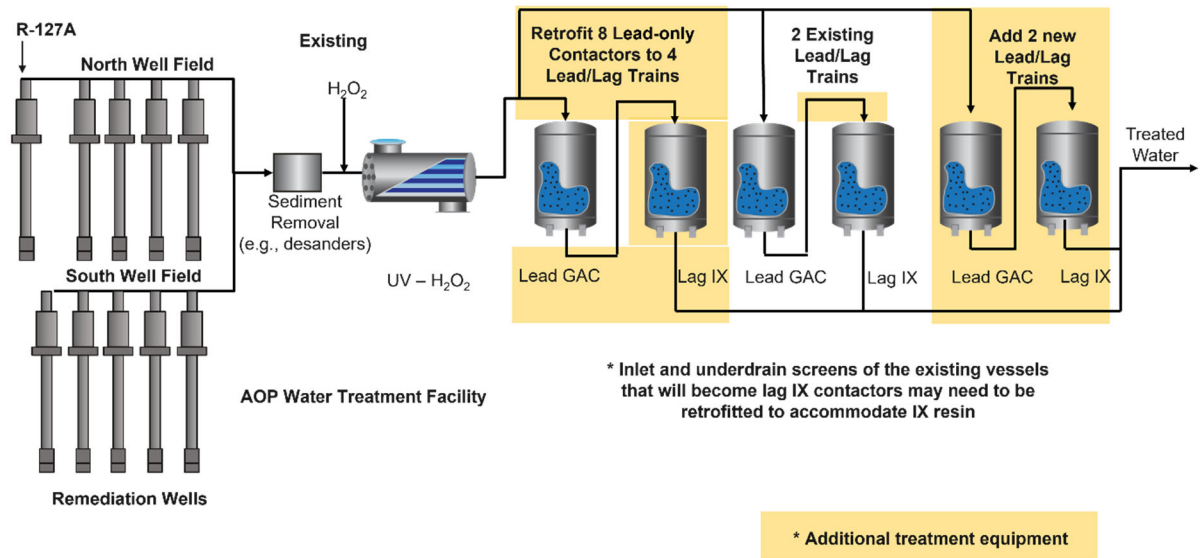


Figure B.7 Alternative 7: GAC and IX Treatment After AOP

APPENDIX B
Cost Opinions

Conceptual Cost Opinion

²Applied to equipment costs.³ Applied to equipment costs.

⁴ Applied to direct costs.

⁵ Applied to direct costs.

Applied to direct costs with contingency.

^a A.R.S. § 42-5061(B)(6) tax deduction for pipes and fittings four inches in diameter or greater. Applied to piping cost.

Applied to total construction cost. For alternative 6 only, 16% is assumed due to design effort already completed 2019 and priced for construction.

¹¹Based on worst case influent PFAS concentrations from Clear Creek particle tracking model.

⁹Based on historical TARP changeouts for peroxide quenching

¹⁰Based on lead-lag modeling of TARP full scale and RSSCT breakthrough data of operational goals for combined PFOS, PFOA, PFHxS, and PFHpA.

¹¹ Assumes discount rate of 4% per year and term of 20 years

Assumes discount rate of 4% per year and term of 20 years.

TARP Amendment 10
PFAS Contingency Modeling and Treatment Evaluations: Best Case Inlet PFAS Concentrations
Conceptual Cost Opinion

AACE International Class 4 Estimate (Expected Accuracy Range of -30% to +50%)	Factor	Alternative 1: R-127A IX Treatment Wellhead	Alternative 2: SWF IX Treatment Before AOP	Alternative 3: NWF IX Treatment Before AOP	Alternative 4: SWF and NWF IX Treatment Before AOP	Alternative 5: SWF and NWF IX Treatment After AOP and GAC	Alternative 6: SWF and NWF GAC Treatment After AOP	Alternative 7: SWF and NWF GAC and IX Treatment After AOP
CAPITAL COST ¹								
DIRECT COST								
PFAS Treatment								
Site Work ²	10%	\$137,000	\$117,000	\$461,000	\$570,000	\$463,000	\$283,000	\$264,000
Yard Piping and Valves ³		\$37,000	\$62,000	\$307,000	\$251,000	\$165,000	\$179,000	\$96,000
Foundation		\$46,000	\$41,000	\$276,000	\$194,000	\$194,000	\$135,000	\$77,000
Process Equipment								
GAC								
Contactors							\$1,874,000	\$937,000
Retrofit Existing Contactors							\$399,000	\$646,000
Media		\$323,000	\$323,000	\$323,000	\$323,000	\$323,000	\$554,000	\$219,000
Anion Exchange								
Contactors		\$469,000	\$438,000	\$1,874,000	\$2,343,000	\$2,343,000		
Media		\$344,000	\$246,000	\$1,572,000	\$1,965,000	\$1,965,000		\$835,000
Backwash Return Pump		\$14,000	\$14,000					
Automatic Backwash Filtration System		\$124,000	\$83,000	\$581,000	\$795,000			
Backwash Tank		\$27,000	\$14,000	\$122,000	\$136,000			
Bag Filters		\$72,000	\$51,000	\$133,000	\$133,000			
Installation ⁴	30%	\$412,000	\$351,000	\$1,382,000	\$1,709,000	\$1,389,000	\$848,000	\$791,000
Electrical ³	25%	\$446,000	\$380,000	\$1,497,000	\$1,851,000	\$1,505,000	\$919,000	\$857,000
Instrumentation & Control ³	15%	\$268,000	\$228,000	\$898,000	\$1,111,000	\$903,000	\$551,000	\$514,000
SUBTOTAL DIRECT COST		\$2,720,000	\$2,350,000	\$9,430,000	\$11,380,000	\$9,250,000	\$5,740,000	\$5,240,000
Contingency ⁴	30%	\$816,000	\$705,000	\$2,829,000	\$3,414,000	\$2,775,000	\$1,722,000	\$1,572,000
TOTAL DIRECT COST		\$3,540,000	\$3,060,000	\$12,260,000	\$14,790,000	\$12,030,000	\$7,460,000	\$6,810,000
INDIRECT COST								
General Conditions, Overhead, Profit & Risk ⁵	22%	\$779,000	\$673,000	\$2,697,000	\$3,254,000	\$2,647,000	\$1,641,000	\$1,498,000
Bonds and Insurance ⁵	3%	\$106,000	\$92,000	\$368,000	\$444,000	\$361,000	\$224,000	\$204,000
Tax (65% of 8.7% Tucson Rate) ⁵	6%	\$78,000	\$66,000	\$260,000	\$322,000	\$262,000	\$160,000	\$149,000
A.R.S. § 42-5061(B)(6) Tax Deduction ⁶	5%	-\$2,000	-\$3,000	-\$16,000	-\$13,000	-\$9,000	-\$9,000	-\$5,000
TOTAL INDIRECT COST		\$960,000	\$830,000	\$3,330,000	\$4,020,000	\$3,270,000	\$2,030,000	\$1,850,000
TOTAL CONSTRUCTION COST		\$4,500,000	\$3,890,000	\$15,590,000	\$18,810,000	\$15,300,000	\$9,490,000	\$8,660,000
Engineering, Administration, and Legal ⁷	25%	\$1,125,000	\$973,000	\$3,898,000	\$4,703,000	\$3,825,000	\$1,518,000	\$2,165,000
TOTAL CAPITAL COST		\$5,630,000	\$4,860,000	\$19,490,000	\$23,510,000	\$19,130,000	\$11,010,000	\$10,830,000
ANNUAL OPERATION & MAINTENANCE COST ⁸								
GAC Changeout Frequency For Peroxide Quenching ⁹					3.75	3.75		3.75
Average GAC Changeout Frequency - 2ppt Operational Goal (years) ¹⁰		0.28	0.19	1.15			0.26	
Average GAC Changeout Frequency - 18ppt Operational Goal (years) ¹⁰		0.31	0.22	1.27			0.28	
Average GAC Changeout Frequency - 70ppt Operational Goal (years) ¹⁰		0.59	0.41	2.43			0.51	
Average Anion Exchange Resin Changeout Frequency - 2ppt Operational Goal (years) ¹⁰		0.30	1.63	0.62	0.64	0.64		0.36
Average Anion Exchange Resin Changeout Frequency - 18ppt Operational Goal (years) ¹⁰		0.67	3.59	1.38	1.41	1.41		0.80
Average Anion Exchange Resin Changeout Frequency - 70ppt Operational Goal (years) ¹⁰		0.88	4.73	1.81	1.85	1.85		1.05
GAC Changeout for Peroxide Quenching (Including spent media management)					\$163,000	\$163,000		\$111,000
Average GAC Changeout - 2ppt Operational Goal (Including spent media management)		\$2,254,000	\$3,375,000	\$552,000			\$1,153,000	
Average GAC Changeout - 18ppt Operational Goal (Including spent media management)		\$2,026,000	\$3,034,000	\$497,000			\$1,071,000	
Average GAC Changeout - 70ppt Operational Goal (Including spent media management)		\$1,062,000	\$1,591,000	\$261,000			\$591,000	
Average Anion Exchange Resin Changeout - 2ppt Operational Goal (Including spent media management)		\$848,000	\$227,000	\$1,815,000	\$2,136,000	\$2,136,000		\$3,212,000
Average Anion Exchange Resin Changeout - 18ppt Operational Goal (Including spent media management)		\$385,000	\$103,000	\$823,000	\$969,000	\$969,000		\$1,456,000
Average Anion Exchange Resin Changeout - 70ppt Operational Goal (Including spent media management)		\$292,000	\$78,000	\$626,000	\$736,000	\$736,000		\$1,105,000
Backwash Return Pump Power and Maintenance		\$5,000	\$5,000	\$5,000	\$5,000			
General ⁷	0.5%	\$18,000	\$15,000	\$61,000	\$74,000	\$60,000	\$37,000	\$34,000
AVERAGE TOTAL ANNUAL O&M COST - 2ppt OPERATIONAL GOAL		\$3,130,000	\$3,620,000	\$2,430,000	\$2,380,000	\$2,360,000	\$1,190,000	\$3,360,000
AVERAGE TOTAL ANNUAL O&M COST - 18ppt OPERATIONAL GOAL		\$2,430,000	\$3,160,000	\$1,390,000	\$1,210,000	\$1,190,000	\$1,110,000	\$1,600,000
AVERAGE TOTAL ANNUAL O&M COST - 70ppt OPERATIONAL GOAL		\$1,380,000	\$1,690,000	\$950,000	\$980,000	\$960,000	\$630,000	\$1,250,000
ECONOMIC ANALYSIS								
Present Worth of Annual O&M - 2ppt Operational Goal ¹¹		\$42,538,000	\$49,197,000	\$33,024,000	\$32,345,000	\$32,073,000	\$16,172,000	\$45,663,000
Present Worth of Annual O&M - 18ppt Operational Goal ¹¹		\$33,024,000	\$42,945,000	\$18,891,000	\$16,444,000	\$16,172,000	\$15,085,000	\$21,745,000
Present Worth of Annual O&M - 70ppt Operational Goal ¹¹		\$18,755,000	\$22,968,000	\$12,911,000	\$13,319,000	\$13,047,000	\$8,562,000	\$16,988,000
TOTAL PRESENT WORTH - 2ppt Operational Goal		\$48,170,000	\$54,060,000	\$52,510,000	\$55,860,000	\$51,200,000	\$27,180,000	\$56,490,000
TOTAL PRESENT WORTH - 18ppt Operational Goal		\$38,650,000	\$47,810,000	\$38,380,000	\$39,950,000	\$35,300,000	\$26,100,000	\$32,580,000
TOTAL PRESENT WORTH - 70ppt Operational Goal		\$24,390,000	\$27,830,000	\$32,400,000	\$36,830,000	\$32,180,000	\$19,570,000	\$27,820,000
Annualized Capital Cost		\$414,000	\$358,000	\$1,434,000	\$1,730,000	\$1,408,000	\$810,000	\$797,000
Total Equivalent Annual Cost - 2ppt Operational Goal		\$3,544,000	\$3,978,000	\$3,864,000	\$4,110,000	\$3,768,000	\$2,000,000	\$4,157,000
Total Equivalent Annual Cost - 18ppt Operational Goal		\$2,844,000	\$3,518,000	\$2,824,000	\$2,940,000	\$2,598,000	\$1,920,000	\$2,397,000
Total Equivalent Annual Cost - 18ppt Operational Goal		\$1,794,000	\$2,048,000	\$2,384,000	\$2,710,000	\$2,368,000	\$1,440,000	\$2,047,000
COST \$/1,000 Gallons Treated - 2ppt Operational Goal		\$1.10	\$1.24	\$1.20	\$1.28	\$1.17	\$0.62	\$1.29
COST \$/1,000 Gallons Treated - 18ppt Operational Goal		\$0.88	\$1.09	\$0.88	\$0.91	\$0.81	\$0.60	\$0.75
COST \$/1,000 Gallons Treated - 70ppt Operational Goal		\$0.56	\$0.64	\$0.74	\$0.84	\$0.74	\$0.45	\$0.64

¹Cost opinions correspond to March 2022 dollars (ENR 20-Cities Average Construction Cost Index).

²Applied to equipment costs.

³Applied to equipment costs and installation.

⁴Applied to direct costs.

⁵Applied to direct costs with contingency.

⁶A.R.S. § 42-5061(B)(6) tax deduction for pipes and fittings four inches in diameter or greater. Applied to piping cost.

⁷Applied to total construction cost. For alternative 6 only, 16% is assumed due to design effort already completed 2019 and priced for construction.

⁸Based on worst case influent PFAS concentrations from Clear Creek particle tracking model.

⁹Based on historical TARP changeouts.

¹⁰Based on lead-lag modeling of TARP full scale and RSSCT breakthrough data of operational goals for combined PFOS, PFOA, PFHxS, and PFHpA.

¹¹Assumes discount rate of 4% per year and term of 20 years.