San Antonio Water System

Six Mile Creek 72-inch Siphon Air Jumpers Project

30% Design Technical Memorandum

SAWS Job No. 17-6503

March 2017

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SIX MILE CREEK 72-INCH SIPHON AIR JUMPERS PROJECT

Technical Memorandum

Prepared for:

San Antonio Water System

San Antonio, TX

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EXECUTIVE SUMMARY

The San Antonio Water System (SAWS) currently owns and operates two sewer siphons which cross under a concrete tributary channel feeding Six Mile Creek within the City of San Antonio. The siphon diameters are 84- and 72-inches and were installed in 1985 and 2010, respectively. The siphons have a combined wet weather flow of 170 MGD and dry weather peak flow of 60 MGD.

SAWS retained Arcadis U.S., Inc. (Arcadis) to provide technical assistance in evaluating methods for alleviating malodorous gas discharge from upstream of the siphons by providing modifications to the sewer siphons. This technical memorandum presents an assessment of the existing siphon system, its operational efficiencies, key findings, and recommendations for its improvement.

Arcadis evaluated four alternatives for mitigating the discharge of malodorous gases from upstream of the sewer siphons which were as follows:

1. Eliminate the siphon by deepening the line downstream of the siphon to a point at which it could connect to an existing invert further downstream.
2. Eliminate the siphon by routing and "daylighting" the sewer pipe through the Six Mile Creek tributary channel.
3. Provide an air jumper structure that connects the pipe from upstream to downstream of the siphon over the Six Mile Creek tributary channel.
4. Provide modifications to the existing Apollo Drive odor control unit for reducing malodorous discharge.

Alternatives 1 through 3 all involve allowing the sewer gases to travel downstream of the siphons; while Alternative 4 continues to have gases expelled from the sewer and treated upstream of the siphons. Results of the evaluation indicated that of Alternatives 1 through 3, which all involved allowing sewer gases to travel downstream, the air jumper (Alternative 3) was the most feasible.

The modifications presented in Alternative 4 are consistent with recommendations provided in the *Memorial Stadium Odor Control Unit* technical memorandum provided by Arcadis in 2016. In that memorandum, Arcadis recommended further evaluation of installation of an electro-oxidation polishing unit for reducing odors. As part of this technical memorandum, Arcadis conducted a present worth evaluation to compare the value of installing the proposed air jumper associated with Alternative 3, to modifications presented in Alternative 4. The cost to construct the air jumper was estimated to be $1,611,000, which would provide a 25-year present worth value of $1.78 million dollars. In comparison, an electro-oxidation polishing unit, as proposed in Alternative 4, would cost approximately $158,000 to construct and provide a 25-year present worth value of $731,000. Additionally, SAWS requested that a present worth evaluation be conducted for a dilution fan associated with ongoing SAWS Job No. 17-6502, which includes the addition of a dilution fan and stack modifications to the existing odor control unit. The 25-year present worth value of a dilution fan alternative would be $728,000.

Based on the findings of the evaluations performed by Arcadis, it is recommended that SAWS further evaluate the electro-oxidation polishing technology presented in the *Memorial Stadium Odor Control Unit* technical memorandum for reduction of the discharge of malodorous sewer gases. However, if SAWS desires to construct the air jumper to provide a means for the gases to continue traveling downstream (Alternative 3), Arcadis recommends that airflow measurements be conducted prior to moving into detailed design.

1. INTRODUCTION

1.1 Background

The San Antonio Water System (SAWS) currently operates two sewer siphons which cross under a concrete tributary channel feeding Six Mile Creek within the City of San Antonio and maintained by Bexar County Flood Control. Each siphon is fed by a sewer which runs parallel to Roosevelt Avenue (also known as State Highway 536), on the east side. The sewers feeding the siphons are 84-inch and 72-inch diameter reinforced concrete pipe installed in 1985 and 2010, respectively. Flows to each pipe are directed through a junction box approximately 1,500 feet upstream of the siphons where the flows are split. **Figure 1** shows the approximate locations of the pipelines, junction box and siphons.

Figure 1 - Sewer Siphon Layout

1.2 Purpose

SAWS has received numerous odor complains stemming from the sewers and junction box in this area. The odor complaints have been attributed to the build-up of sewer gases caused by the siphons which do not permit airflow to continue down the sewer. In attempts to remedy the odor complaints, SAWS installed an odor control unit adjacent to the junction box in 2012. The odor control unit pulls noxious gases from the sewer, through the junction box, and treats it within a tower type bioscrubber. Despite repeated attempts to reduce the malodorous gases by SAWS, through means such as sealing of manholes, and improvements to the odor control unit, the complaints persist. Arcadis, U.S. Inc. (Arcadis) has been retained by SAWS to provide technical assistance in evaluating options for transporting the noxious gases downstream from the siphon areas and provide recommendations for solutions.

2. EXISTING SYSTEM

SAWS provided Arcadis with flow data coming into the junction box which is presented in **Table 1**.

Table 1 - Flow Rates Into Junction Box

Flow Rate	Average Dry Flow (MGD)	Max Dry Flow (MGD)	Peak Wet Flow (MGD)
West 84"	31	44	100
East 84"	6	16	70
Combined	37	60	170
Expected flow rates are based on model predicted data for both 84" lines upstream of junction box			

The flow data provided by SAWS, and presented in **Table 1,** was utilized for development of alternatives presented in the following sections. In addition to the flow data SAWS provided, Arcadis was provided record drawings for both the 72- and 84-inch sewer lines. Based on information provided in the record drawings, **Table 2** was generated, which summarizes the key features of each line between the junction box and siphon.

Table 2 - Sewer Siphon Pipes

Parameter	72-inch Pipe	84-inch Pipe
Construction Material	Reinforced Concrete Pipe	Reinforced Concrete Pipe
Pipe Slope from Junction Box to Beginning of Siphon	0.84%	1.03%
Invert Elevation Leaving Junction Box (ft. msl.)	571.27	571.25
Invert Elevation at Start of Siphon (ft. msl.)	558.40	556.78
Lowest Invert Elevation in Siphon (ft. msl)	540.00	541.64

Each siphon has a slightly different configuration: the 84-inch pipe reduces to a 66-inch pipe through the siphon before returning to 84-inch pipe at a manhole downstream. The 72-inch siphon remains a 72-inch pipe through the entire siphon. The cross section of both pipes are shown in **Figure 2** for reference.

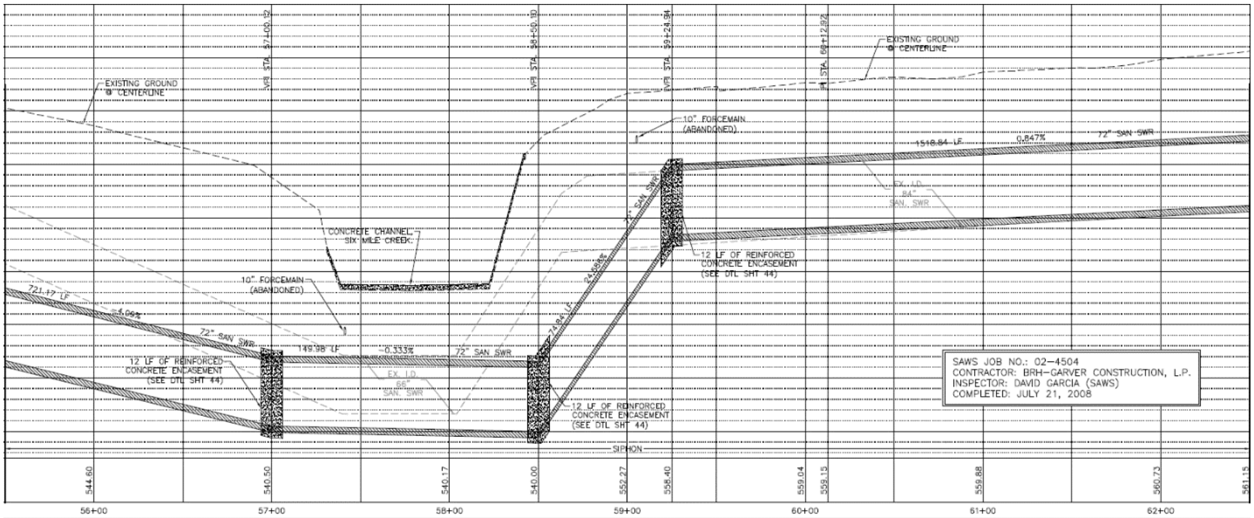


Figure 2 – Existing Siphon Cross Section

Based on data provided by FEMA on its flood insurance rate map for Bexar County, Panel 0580G, the 100-year floodplain elevation within the area of the siphons is about 573 feet mean sea level.

SAWS recently cleaned debris out of both siphons. Along with the cleaning, a sonar and closed circuit television (CCTV) video was recorded on the 66-inch siphon. From discussions with SAWS, the 66-inch siphon had approximately 21 tons of material removed. Assuming most of the material removed was grit or small debris, it can be estimated that approximately 16 cubic yards of material was removed (assuming 2,600 lb/cubic yard of sandy-grit for the material). Assuming the entire siphon was completely cleaned out, this corresponds to a buildup of approximately two feet of debris inside the bottom of the siphon prior to cleaning. This sort of buildup within the bottom of the siphon indicates that the cross-sectional area of the siphon was approximately 30% reduction in flow area by the time it was cleaned.

SAWS indicated that the siphons are currently scheduled to be cleaned out every ten years. Based on Arcadis' experience, a ten-year interval of cleaning is typical. A buildup of two feet of sediment within the bottom of the pipe over ten years is an acceptable rate of accumulation indicating the siphon is operating properly. SAWS should continue to maintain its servicing of the siphons at a minimum interval of every ten years to ensure continued operation.

3. EVALUATION OF ALTERNATIVES

Three alternatives were evaluated for stopping the impediment of sewer gases at the existing siphons; a fourth alternative is presented for reducing odors without allowing sewer gases to continue down the sewer. The alternatives that were evaluated are as follows:

1. Eliminate the siphon by deepening the line downstream of the siphon to a point at which it could connect to an existing invert further downstream.
2. Eliminate the siphon by routing and "daylighting" the sewer pipe through the Six Mile Creek tributary channel.

3. Provide an air jumper structure that connects the pipe from upstream to downstream of the siphon over the Six Mile Creek tributary channel.
4. Provide modifications to the existing odor control unit for reducing odorous discharge.

3.1 Alternative 1 – Eliminate the Siphon by Replacing Downstream Pipe

The first alternative replaces the piping downstream of the siphons to prevent formation of the siphon. Both the 72- and 84-inch sewer pipes connect to a junction box approximately 5,800 feet downstream of the siphon at an invert elevation of 565.50 feet msl. Based on the bottom invert elevations of the siphons presented in **Table 2**, the 72- and 84-inch pipe siphons are respectively 25.5 feet and 23.86 feet lower than the invert of the junction box to which they connect. To replace the pipe downstream of the siphon, the piping would need to be replaced for miles until a common invert could be accomplished. If no common invert exists, the piping would need to be replaced all the way to the treatment plant. It is approximately 6.5 miles to the Leon Creek WRC and 8.5 miles to Dos Rios WRC by road. Based on the distance of pipe that would need to be replaced this alternative was determined to be infeasible from a cost perspective and was not evaluated further.

3.2 Alternative 2 – Eliminate the Siphon by Rerouting Sewer Lines Through the Tributary Channel

The second alternative eliminates the siphon by rerouting the sewer lines to cross directly through the tributary channel instead of under it. To accomplish this, both the 72- and 84-inch pipes would need to be rerouted between the junction box and downstream manholes. The total vertical drop between the junction box at the beginning of the siphon and downstream manhole for the 72- and 84-inch pipes are 1.27 and 2.25 feet, respectively. This drop corresponds to a slope of 0.05% and 0.09%, respectively. Based on the flow data provided by SAWS presented in **Table 1**, the 72-inch pipe would become surcharged in a maximum flow event with this alignment. Therefore, the 72-inch pipe would need to be replaced with a larger pipe, approximately 84-inches in diameter. Utilizing two 84-inch pipes would allow the lines to be routed through the stream as shown in **Figure 3** below with the red line.

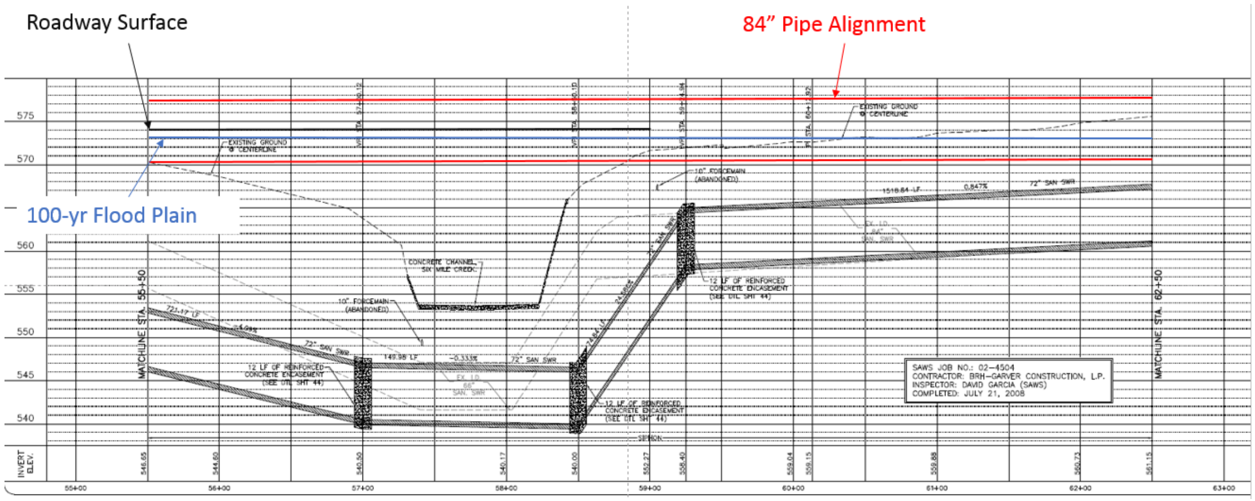


Figure 3 - Rerouted Sewer Alignment

As shown in **Figure 3** the sewer lines would be partially submerged during a 100-year storm event. Additionally, the alignment shown in the figure above would result in an elevation of the top of pipe higher than the adjacent highway roadway deck, which is at an elevation of approximately 574 feet msl. For the alignment shown in **Figure 3,** there would be approximately 1,275 feet of exposed pipeline between the upstream junction box and manholes downstream based on existing ground surface elevations.

During a 100-year storm event, the sewer lines would impede stormwater flow through the channel. This could have an impact on the hydraulics of the channel and would require much more detailed analysis. In addition to the hydraulic implications of routing the pipes through the tributary channel, there are also structural and environmental considerations that would need to be evaluated.

To route the two pipes through the flow path of the tributary, the pipes would need to be extremely well reinforced as flood water would impart large amounts of lateral forces when the channel filled. Determination of the exact amount of lateral loading would require stream flow modeling efforts which are not within the scope of this work. However, it is assumed that the forces would great enough to require additional reinforcing beyond just that of the pipe. Additionally, during a site visit it was noticed that large trees were strewn across the channel indicating that during flood events large debris are also washed down the channel would could become hung up or damage the pipe. As shown below in **Photo 1**, a large tree limb was caught on the roadway bridge guardrails adjacent to the siphons, further indicating that flood water in the area have historically be very high and strong.

Photo 1 - Bridge Debris

Along with the structural and stream impediment implications of routing the pipes through the tributary channel, there is also the potential for the pipe to break or leak. If either sewer line were to leak into the tributary, raw sewage would have the potential to flow into the San Antonio River.

Based on the hydraulic, environmental, aesthetics, and structural implications associated with rerouting the sewer lines through the flow path of the tributary channel this alternative is not recommended.

The Association for the Advancement of Cost Engineering (AACE) Class V (Concept Screening) for 1% to 15% Project Definition cost estimate to demolish the existing pipes between the junction box and downstream manhole and install two new 84-inch pipes at the alignment presented above, is approximately $8.5 million dollars.

3.3 Alternative 3 – Installation of Air Jumper System

The third alternative included installation of an 'air jumper' or a pipeline which allows air from upstream of a siphon to travel downstream of the siphon by interconnecting manholes. This allows for sewer gases to continue to travel down the sewer, and away from target areas. As a starting point for preliminary sizing and design concepts Arcadis utilized a paper published in WEFTEC 2006 entitled *Sewer Siphon Assessment and Air Jumper Design* by Deering, Jepsen, Acevedo, and Taylor, henceforth referred to as 'Air Jumper Design'.

3.3.1 Design Calculations

There are numerous aspects which need to be accounted for in design of an air jumper. Of particular importance are the hydraulics of the flow, along with the airflow and headspace within the sewer upstream of the siphon. Air jumpers are designed based on the flow rate of the air within the sewer which is directly related to the flowrate of the sewer. Based on flow data presented in **Table 1** Arcadis performed hydraulic calculations to determine the percentage of the flow split into the 72 and 84 sewer pipes at the upstream junction box. Determination of the flow split was done utilizing a variation of the Chezy-Manning equation shown in **Equation 1**.

$$\boldsymbol{Eq.1}: \; v = \left(\frac{1.49}{n}\right) R^{\frac{2}{3}} \sqrt{S}$$

Equation 1 was utilized along with the nomograph for open channel circular channels shown in **Figure 4** in an iterative approach to get the unit headloss between the 72 and 84-inch pipes the same.

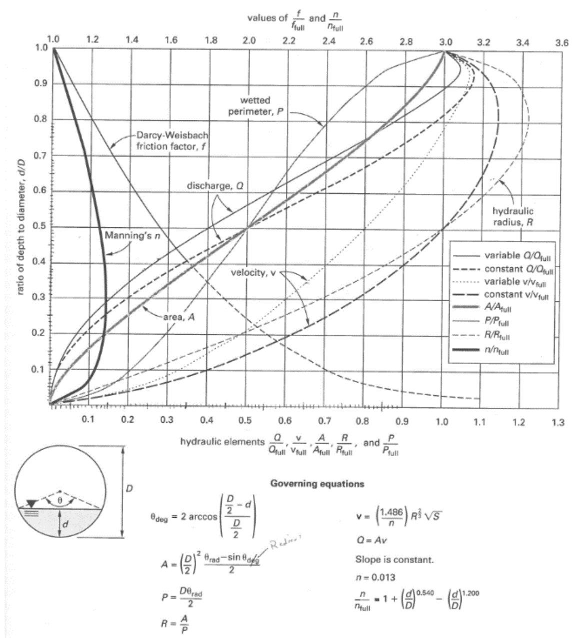


Figure 4 - Circular Channel Nomograph

The unit headloss equation (**Equation 2**) for a partially full circular pipe was also utilized to perform the headloss calculations.

$$\boldsymbol{Eq.2}: hf = \frac{Ln^2v^2}{2.208R^{\frac{4}{3}}}$$

The flow split percentage to each pipe was varied until the difference in unit headloss was within 15%. Results of the flow splitting calculations at the different flow rates are presented in **Table 3** below.

Table 3 - Sewer Flow Split

Event	Flow Split (%)	
	72" Pipe	84" Pipe
Avg Dry Flow (37 MGD)	32	68
Max Dry Flow (60 MGD)	40	60
Peak Wet Flow (170 MGD)	40	60

Note: Slide gates in junction box were assumed to be fully open utilizing frictional headloss as flow split control.

Utilizing the flow split presented in **Table 3**, and corresponding normal water depth, headspace in a cross section of the sewer was calculated. Results of this calculation are presented **Table 4**.

Table 4 - Sewer Headspace

Event	Headspace Area (ft^2)	
	72" Pipe	84" Pipe
Avg Dry Flow (37 MGD)	25.1	33.4
Max Dry Flow (60 MGD)	23.2	31.8
Peak Wet Flow (170 MGD)	17.5	24.6

To determine the airflow rate in each sewer, Air Jumper Design recommends the use of the **Equation 3**:

$$\boldsymbol{EQ.3}: Q_{air} = RF * V * A$$

Where RF is a reduction factor based on the size of the sewer. Based on the data presented in Air Jumper Design a reduction factor of 0.2 was selected for both pipes. The airflow rate in each sewer was determined and is presented in **Table 5** utilizing **Equation 3**.

Table 5 - Sewer Airflow Rates

Event	Airflow (scfm)		
	72" Pipe	84" Pipe	Combined
Avg Dry Flow (37 MGD)	2080	3249	5329
Max Dry Flow (60 MGD)	2078	3364	5443
Peak Wet Flow (170 MGD)	2065	3439	5504

As can be seen from **Table 5,** the largest combined airflow takes place during peak wet weather events, culminating in approximately 5,500 scfm of airflow which needs to bypass the siphon.

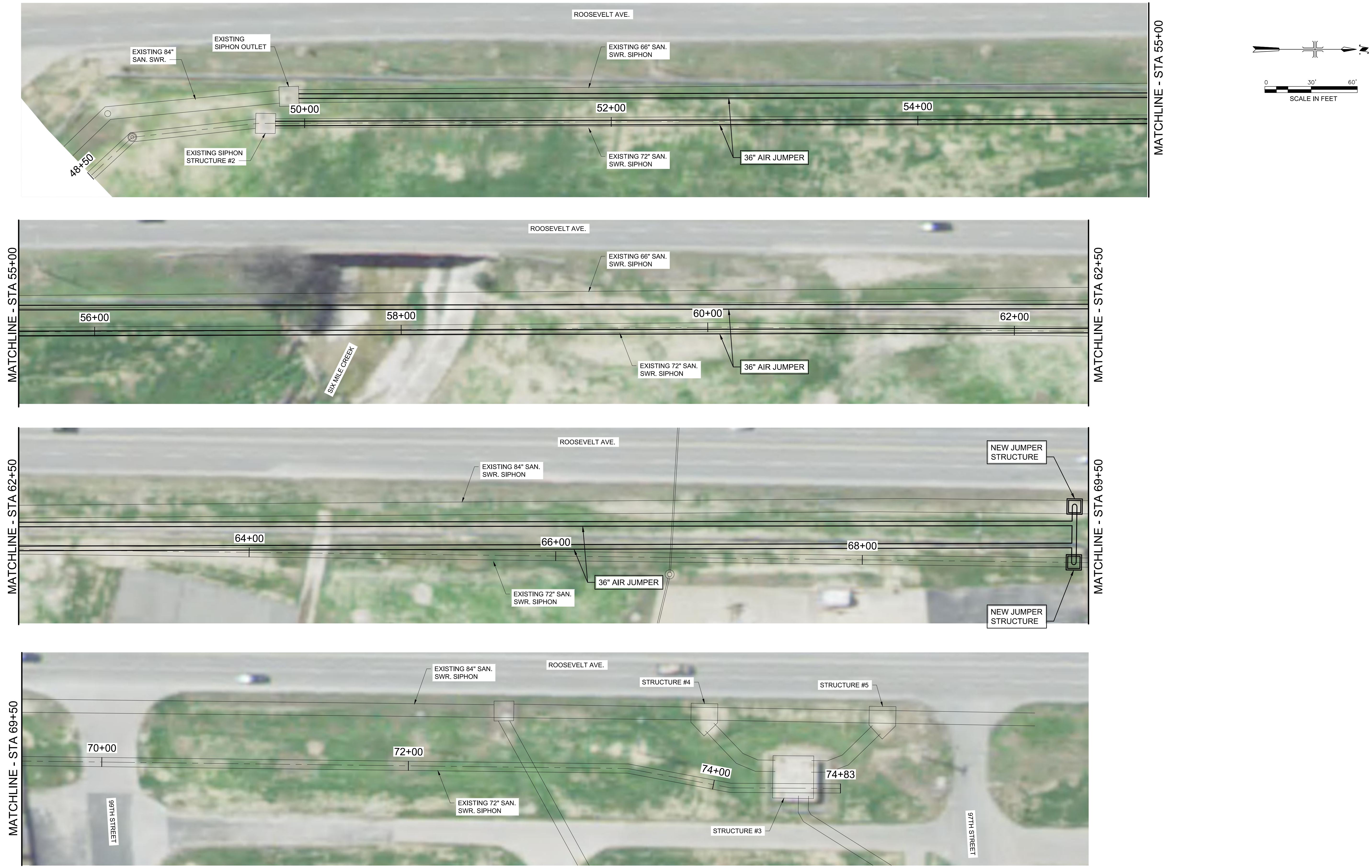
Based on record drawings provided to Arcadis for the alignment of the existing siphons, the invert of the siphon outlet structures are at 569.00 feet MSL and 569.84 feet MSL for the 84- and 72-inch sewers respectively. Based on the hydraulic calculations presented above, during peak wet weather events, the static water surface elevations are at 571.73 feet MSL and 572.27 feet MSL for the 84- and 72-inch sewers respectively. To allow for the air jumper line to have continuous airflow without being submerged, the air jumper invert would need to therefore be at a minimum of 574.00 feet MSL. However, to utilize the existing siphon outlet manholes downstream of the siphons as connection points, the invert of the air jumper will need to be at an invert of 577.00 feet MSL. To provide an air jumper with an invert at 577.00 feet MSL, the air jumper will need to be approximately 1,980 feet long.

Sizing of the air jumper pipe was based off the recommended headloss for an air jumper at the peak flow rate of 5,500 scfm presented in **Table 5**. Air Jumper Design recommends no more than 0.01 inches of headloss per 100 feet of air jumper pipe, which is what was used for this evaluation. Therefore, for an air jumper that is 1,980 feet long, no more than 0.198 -inches of headloss in a water column was permitted.

The calculation of the airflow headloss utilized an equivalent length methodology for all fittings and a friction factor headloss associated with pipe roughness. Results of the analysis indicated two feasible air jumper alternatives: a single 48-inch pipe or two 36-inch pipes.

3.3.2 Air Jumper Alignment

The alignment of the air jumper is shown in **Figure 5 and 6** in plan and profile. The alignment shows the two 36-inch pipe alternative; however a similar alignment would be used for the single 48-inch alternative.



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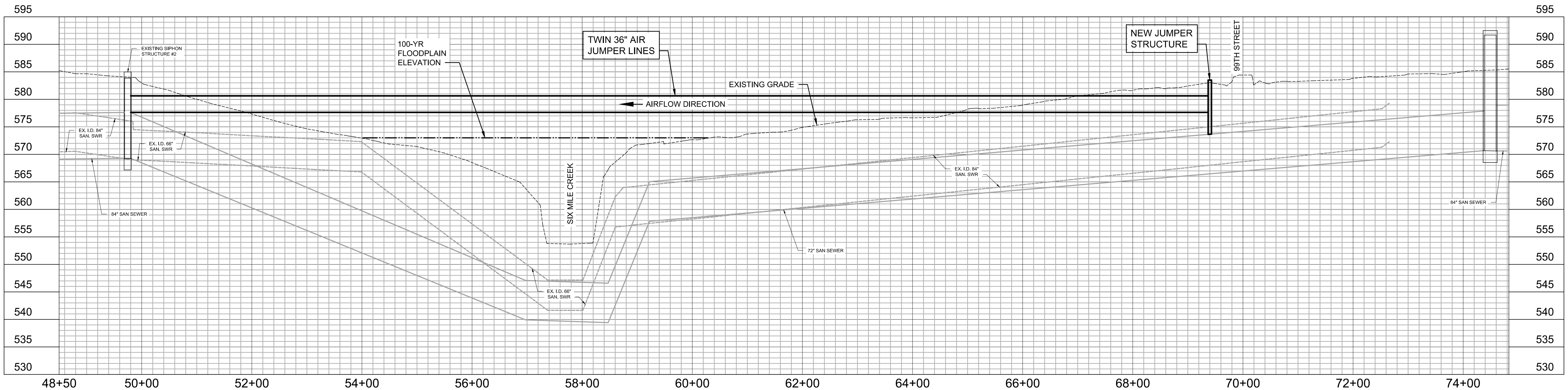
SAN ANTONIO WATER SYSTEM

SIX MILE CREEK 72" SIPHON AIR JUMPER PROJECT

ALIGNMENT PLAN

MARCH 2017

FIGURE 5



PROFILE

0 100' 200' SCALE IN FEET HORIZONTAL

0 10' 20' SCALE IN FEET VERTICAL

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SAN ANTONIO WATER SYSTEM

SIX MILE CREEK 72" SIPHON AIR JUMPER PROJECT

ALIGNMENT PROFILE

MARCH 2017

FIGURE 6

As can be seen from **Figures 5 and 6** the air jumper would not be within the 100-year flood water surface elevation located at elevation 573 feet MSL. However, the air jumpers would be above the roadway elevation of 574 feet MSL and quite visible to the public.

The air jumper line would require pipe supports to be installed within the tributary channel. The supports would be much smaller than those required for Alternative 2 associated with rerouting of the sewer lines. The smaller supports would have less impact on the flow patterns within the channel as well as reduced costs.

There are three possible pipe materials which could be utilized for the air jumper: steel, stainless steel, or fiberglass reinforced pipe (FRP). Advantages and disadvantages associated with each material are presented in **Table 6**. Arcadis recommends that the pipe be made of epoxy lined steel pipe, however Type 316 stainless steel would also be a viable alternative if SAWS prefers, but would be more expensive. The cost estimates presented in **Section 3.3.5** assumes epoxy lined steel pipe.

Table 6 - Pipe Material Comparison

Material	Advantages	Disadvantages
FRP	Low Cost Highly Corrosion Resistant Lighter	Recent SAWS projects have had quality problems with FRP. Difficult to work with and repair.
Epoxy Lined Steel	Easy to Work With Can Span Large Distances	Will Require Repainting
316 Stainless Steel	No Painting or Coating Required Can Span Large Distances	Most Expensive

3.3.3 Air Jumper Permitting

Arcadis conducted an evaluation for possible permits and approvals from regulatory agencies which will be needed for the proposed air jumper. The following list details regulatory agencies and permitting requirements that would be required for installation of the air jumper.

1. Texas Department of Transportation (TxDOT): Proposed air jumper lines are too large to be installed on the existing roadway bridge. A traffic construction entrance and traffic plan will need to approved by TxDOT if determined to be required for construction.
2. City of San Antonio (CoSA): All requirements of the City of San Antonio Tree Protection Act.
3. San Antonio River Authority (SARA): Not within SARA jurisdiction and no permitting necessary.
4. Federal Aviation Administration (FAA): If a crane is used for installation of the pipe within the vicinity of the runway the FAA will need to approve the plan. This submission will need to be completed by the contractor selected to perform the work and approval made by the FAA.
5. Bexar County: Approval will be needed from the Bexar County Public Works department. They will not be providing a permit just review of the plans and approval.
6. Federal: Permitting and approval for impact to Waters of US. This will be handled through Army Corp of Engineers permitting.
7. U.S. Fish and Wildlife Services (USFWS): Sensitive species evaluation due to the tributary.
8. Texas Park and Wildlife Department (TPWD): Sensitive species evaluation due to the tributary.
9. Texas Historical Commission: Desktop evaluation of historical resources which may be impacted due to the presence and proximity to the tributary.
10. Texas Commission on Environmental Quality (TCEQ): If more than one acre of soil will be disturbed during the installation, a stormwater pollution prevention plan (SW3P) and Municipal Separate Storm Sewer System (MS4) permit will be needed under the TCEQ stormwater rules. Additionally, the proposed air jumper design should be submitted to the TCEQ as a courtesy for review.
11. Army Corp of Engineer: Approval and permitting will be necessary from the Army Corp of Engineers for impacting the area below the normal 100-yr floodplain elevation.

In addition to the permitting and approval requirements listed above, Arcadis determined that the Bexar County Flood District intends to complete major rehabilitation projects to improve the channel downstream of the Roosevelt Avenue bridge, as well as replacement of the bridge. The projects are referred to as “Sixmile Creek Drainage Improvements – CCR 4 SA 43” and “Sixmile Creek Drainage Improvements – Roosevelt Bridge SA 43” by Bexar County. Both projects are currently in the permitting stage with the Army Corp of Engineers and are not expected to begin construction until 2018. The intent of the bridge replacement project is to raise the bridge above the 100-year flood plain elevation, however no plans are currently available for review. The raising of the bridge may reduce the extent that the air jumper is visible to motorists on the roadways. If an air jumper pipe is installed, the supports for it would need to be coordinated with the redesign of the channel included as part of the CCR 4 SA 43 project to replace the concrete channel.

3.4 Alternative 4- Odor Control System Improvements

In a technical memorandum presented to SAWS in April 2016 entitled “*Memorial Stadium Odor Control Unit Evaluation*”, Arcadis conducted an evaluation on the existing odor control unit that serves the siphons. The objective of the evaluation was to determine the source of the persistent odors in the area surrounding the odor control unit (OCU), and provide recommendations to mitigate them. Upon completion of the evaluation, Arcadis recommended that further investigation be conducted to support installation of an electro-oxidation unit for polishing in lieu of the carbon unit currently installed. The recommendation was made as it was determined that the source of the odors was most likely due to five odorous compounds not being treated by the bioscrubber or the carbon polishing unit. The existing bioscrubber OCU shown in **Figure 1,** was designed for 4,500 scfm. Air flow calculations presented in **Section 3.3.1** show that the maximum airflow down the sewer is approximately 5,500 scfm, indicating the OCU is undersized by approximately 1,000 scfm. In the 2016 memorandum provided by Arcadis, it was estimated that an electro-oxidation unit would cost approximately $158,000 to construct. SAWS may wish to further consider this polishing treatment technology as a viable alternative to the installation of the air jumper line or siphon modifications.

3.5 Engineer's Opinion of Probable Construction Costs

Two separate cost estimates were prepared for the Air Jumper Alternative 3: one for two 36-inch pipes and another for the single 48-inch pipe. A detailed breakdown of the cost estimates are provided in **Appendix A**. Based on an Association for the Advancement of Cost Estimating (AACE) Class III Cost Estimate for 10% to 40% Project Definition, the following construction costs are anticipated for each alternative:

- One 48" Pipeline – $1,611,000
- Two 36" Pipelines - $2,206,000

A present worth evaluation was conducted to determine the potential value of the 48-inch air jumper compared to different alternatives which SAWS has considered for mitigating odors within the area. The alternatives evaluated were requested by SAWS as possible solutions that have been presented in this and other technical reports. Present worth evaluations were completed for the following alternatives:

1. Installation of a 48-inch air jumper.
2. Installation of a dilution fan as currently being designed by SAWS as part of Job Number 17-6502.
3. Installation of an electro-oxidation unit as presented in the technical memorandum *Memorial Stadium Odor Control Unit.*
4. Installation of both a dilution fan and electro-oxidation unit.

Results of the present worth analysis are shown in **Figure 7** below.

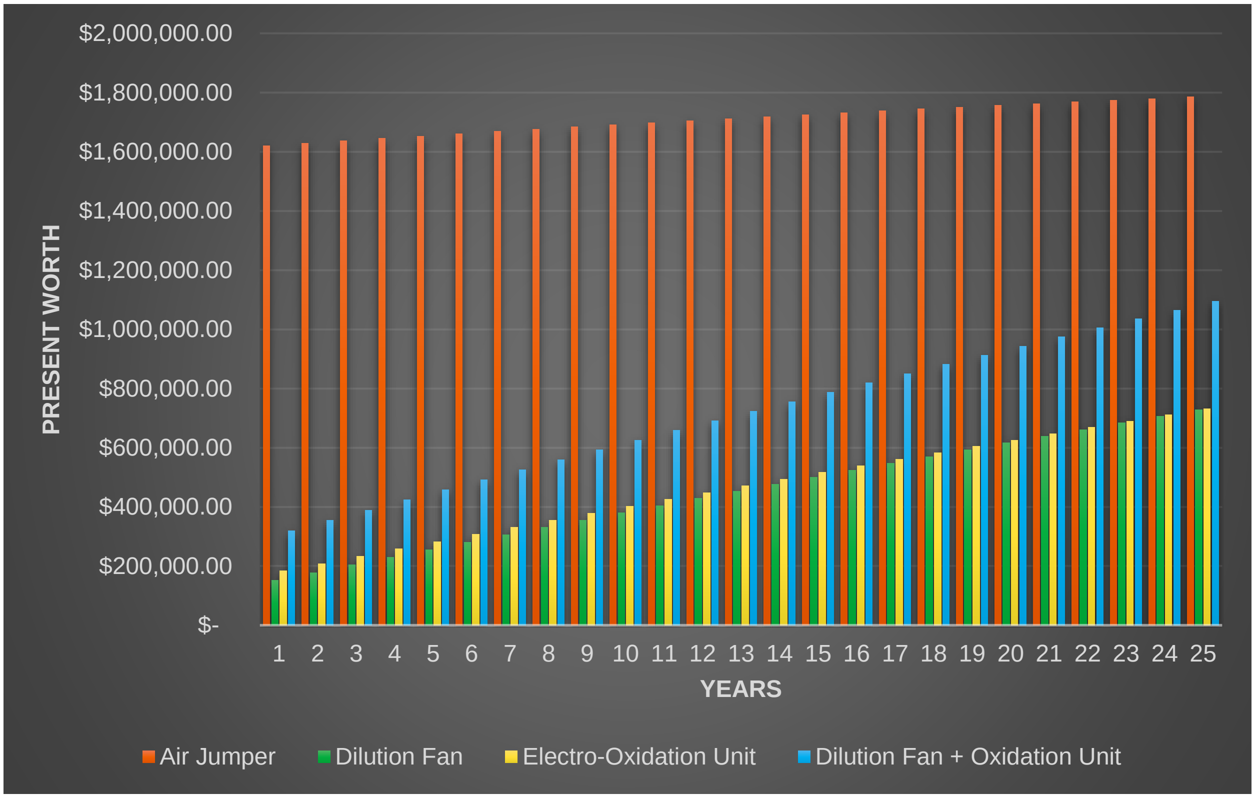

Figure 7 - Present Worth Analysis

Results of the present worth analysis indicate that for a 25-year life cycle an air jumper would have a present worth value of approximately $1.78 million. The dilution fan would have a present worth value of approximately $728,000, the electro-oxidation unit would have a present worth value of approximately $731,000 and the combination of an electro-oxidation unit and dilution fan would have a present worth value of $1.10 million. For reference, it would take 53 years for the dilution fan and electro-oxidation unit, 90 years for the dilution fan, and 99 years for the electro-oxidation unit to each respectively break even with the present worth values for the air jumper.

The following assumptions were utilized in the present worth analysis:

- The OCU feed blower is 85% efficient;
- The OCU feed blower needs to be replaced every 10 years;
- The 48” air jumper would need to be repainted every 20 years;
- The dilution fan would need to be replaced every 15 years;
- A 2% energy escalation factor and 2% present worth factor was utilized;
- Bioscrubber requires three hours per week of manpower and $1,000 per year in consumable materials for operation;
- Dilution fan would require one hour per month of manpower time for maintenance;

- Assumed $30 per hour rate for manpower;
- Electro-oxidation unit would require two hours per week of manpower time for inspection and maintenance;
- Electro-oxidation unit would require $300 per year in consumable components;
- Power rate is $0.10 kW-hr; and
- No odor control unit or polishing unit would be utilized in conjunction with the air jumper.

Table 7 summarizes the capital and present worth costs for each option.

Table 7 - Capital and Present Worth Costs

Alternative	Capital Cost	25-Year Present Worth	Years to Break Even with Air Jumper
48-inch Air Jumper	$1,611,000	$1,780,000	-
Dilution Fan	$125,600	$728,000	90
Electro-Oxidation Unit	$158,000	$731,000	99
Dilution Fan + Electro-Oxidation Unit	$283,600	$1,100,000	53

4. RECOMMENDATIONS

From the alternatives presented in this memorandum, Arcadis recommends that SAWS further evaluate installation of an electro-oxidation polishing unit, as presented in the 2016 *Memorial Stadium Odor Control Unit* technical memorandum. The electro-oxidation unit is recommended as it provides a method by which the remaining noxious gas constituents which are not treated in the stack bioscrubber can be removed prior to discharge. Additionally, installation of a dilution fan won't provide any treatment capabilities but may be able to reduce the complaints by diluting the air and forcing it higher into the atmosphere away from populated areas. However, if SAWS desires to reduce operations and maintenance costs associated with the odor control unit, as well as allow malodorous gases to travel further down the sewer, the best alternative would be installation of an air jumper.

There is nearly a $600,000 cost difference between the single 48-inch air jumper and the two 36-inch air jumpers. While the single 48-inch line is less expensive, it would also be more prominent to the public. The pipe supports and bridge to span the concrete tributary channel for a single 48-inch line versus two 36-inch lines are nearly the same from a cost and environmental impact perspective, making the 48-inch line a better option over the two 36-inch lines.

Prior to moving forward with detailed design of the air jumper, it is recommended that airflow measurements be conducted within the sewer lines to verify some of the assumptions made in the calculations included with this memorandum. By conducting airflow measurements prior to detailed design, Arcadis can further verify that the air jumper will be sufficiently sized for allowing sewer gases to pass through the siphon.

Finally, if SAWS desires to pursue the installation of the electro-oxidation polishing unit, Arcadis recommends that airflow measurements and air sampling be conducted as discussed in our 2016 technical memorandum.

APPENDIX A

Detailed Cost Estimate

Six Mile Creek 72-inch Siphon Air Jumpers - 30% Design					
Engineer's Opinion of Probable Construction Costs					
Alternative 2 - Rerouting Sewer Pipes					
Item No.	**Item Description**	**Unit**	**Quantity**	**Unit Cost**	**TOTAL COST**
General Requirements					
1	Bonds and insurance, mobilization, demobilization (5% of bid items)	LS	1	$ 268,600	$ 269,000
2	Silt Fence	LF	4,932	$ 3	$ 13,000
3	Permitting	LS	1	$ 10,000	$ 10,000
					$ 292,000
Site Work					
4	Demolition Existing 72"	CY	448	$ 50	$ 23,000
5	Demolition Existing 84"	CY	520	$ 50	$ 27,000
6	Repair of Concrete Channel After Pipe Demolition	LS	1	$ 100,000	$ 100,000
7	Roadway Repair	LS	1	$ 50,000	$ 50,000
					$ 200,000
Pipelines					
8	84" Concrete Sewer Pipe (18-20' deep)	LF	4,932	$ 975	$ 4,809,000
9	Connect to Existing Structures	EA	4	$ 10,000	$ 40,000
					$ 4,849,000
Mechanical and Instrumentation					
					$ -
					$ -
Structural					
10	Pipe Supports Across Channel	LS	1	$ 300,000	$ 300,000
					$ 300,000
Electrical					
					$ -
					$ -
Subtotal (without bonds, insurance, etc)					**$ 5,372,000**
SUBTOTAL					**$ 5,641,000**
Contractor OH & Profit				15%	$ 847,000
Contingency				30%	$ 1,693,000
GRAND TOTAL					**$ 8,450,000**

Six Mile Creek 72-inch Siphon Air Jumpers - 30% Design Engineer's Opinion of Probable Construction Costs Alternative 3 - Air Jumper - Two 36-inch Lines					
Item No.	**Item Description**	**Unit**	**Quantity**	**Unit Cost**	**TOTAL COST**
General Requirements					
1	Bonds and insurance, mobilization, demobilization (5% of bid items)	LS	1	$ 70,050	$ 71,000
2	Silt Fence	LF	4,932	$ 3	$ 13,000
3	Permitting	LS	1	$ 10,000	$ 10,000
					$ 94,000
Site Work					
4	Repair of Concrete Channel After Install of Pipe Supports	LS	1	$ 20,000	$ 20,000
5	Manhole	EA	2	$ 6,120	$ 13,000
					$ 33,000
Pipelines					
6	36" Steel Pipe, Epoxy lined, Std. Weight, Primed	LF	3,960	$ 237	$ 939,000
7	Connect/Core Into Existing Structures	EA	2	$ 10,000	$ 20,000
8	Paint Pipe	SF	37,322	$ 7	$ 262,000
					$ 1,221,000
Mechanical and Instrumentation					
					$ -
					$ -
Structural					
9	Pipe Supports Across Channel	LS	1	$ 46,000	$ 46,000
10	Pipe Supports Not in Channel	LS	1	$ 78,000	$ 78,000
					$ 124,000
Electrical					
					$ -
					$ -
Subtotal (without bonds, insurance, etc)					**$ 1,401,000**
SUBTOTAL					**$ 1,472,000**
Contractor OH & Profit				15%	$ 221,000
Contingency				30%	$ 442,000
GRAND TOTAL					**$ 2,206,000**

Six Mile Creek 72-inch Siphon Air Jumpers - 30% Design					
Engineer's Opinion of Probable Construction Costs					
Alternative 3 - Air Jumper - Single 48-inch Line					
Item No.	**Item Description**	**Unit**	**Quantity**	**Unit Cost**	**TOTAL COST**
General Requirements					
1	Bonds and insurance, mobilization, demobilization (5% of bid items)	LS	1	$ 51,100	$ 52,000
2	Silt Fence	LF	4,932	$ 3	$ 13,000
3	Permitting	LS	1	$ 10,000	$ 10,000
					$ 75,000
Site Work					
4	Repair of Concrete Channel After Install of Pipe Supports	LS	1	$ 20,000	$ 20,000
5	Manhole	EA	2	$ 6,120	$ 13,000
					$ 33,000
Pipelines					
6	48" Steel Pipe, Epoxy lined, Std. Weight, Primed	LF	1,980	$ 327	$ 647,000
7	Connect/Core Into Existing Structures	EA	2	$ 10,000	$ 20,000
8	Paint Pipe	SF	24,881	$ 7	$ 175,000
					$ 842,000
Mechanical and Instrumentation					
					$ -
					$ -
Structural					
9	Pipe Supports Across Channel	LS	1	$ 46,000	$ 46,000
10	Pipe Supports	LS	1	$ 78,000	$ 78,000
					$ 124,000
Electrical					
					$ -
					$ -
Subtotal (without bonds, insurance, etc)					**$ 1,022,000**
SUBTOTAL					**$ 1,074,000**
Contractor OH & Profit				15%	$ 162,000
Contingency				30%	$ 323,000
GRAND TOTAL					**$ 1,611,000**