

**Air Treatment Facility (ATF) Review
Draft Final Report
Comments by the Independent Odor Expert – Dirk Apgar
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Introduction

This paper is intended to provide a constructive critique of the City of Los Angeles' Air Treatment Facility Technical Draft Final Report (Report). The Report summarizes the technical memoranda produced during the City's Air Treatment Facility (ATF) Review Study, which was conducted to develop an understanding of the causes of odor problems originating from the City's wastewater conveyance system and reach conclusions on methods of controlling those nuisance odor problems.

Under the original Collection System Settlement Agreement (CSSA), the City had planned to construct seven new ATFs to help control odors from the wastewater conveyance system. Of the seven, two have almost been completed (Jefferson & La Cienega and 6000 Jefferson), but design and construction of the remaining five was placed on hold pending the outcome of the ATF Review. As part of the review, the City reevaluated the location and necessity of the five remaining proposed ATFs based on the effect of changing wastewater flows through its interceptors and the associated effect on sewer headspace air pressure, measured performance of the interim carbon scrubber based ATFs, and continued odor complaints. Final recommendations on the location and technologies to be used in a single ATF at the Mission and Jesse site were reported as a result of the ATF Review. The determination of the size of the ATF will be made during the design process for the new facility utilizing information the City will obtain through testing of a drop structure scale model similar to the structure at Mission and Jesse.

The City has undergone a significant level of work in an attempt to develop an understanding of the airflow and air pressurization within its wastewater conveyance system. It is rare that this level of effort is seen within the United States or, for that matter, worldwide. While the City and its consulting engineering firms have many capable technical experts, it is important to understand that estimating the causes and effects of the airflow dynamics in complex sewer systems and the resulting likelihood of odor emissions and impacts can only be done within a broad range of accuracy. It is possible that while odor impacts may be diminished, communities may continue to experience odors even with the activation of the two ATFs currently nearing completion, modification of wastewater flow patterns, and the implementation of the recommended ATF at Mission and Jesse. As the ATFs at Jefferson & La Cienega and 6000 Jefferson are brought up to their design airflow capacities, neighboring citizens should be able to assess their ability to control odor emissions and impacts in their community.

Below is a summary of the major components of the ATF Review Study. Each has been discussed previously in comments by the Independent Odor Expert with input by Community Liaison, The City Project.

Airflow Modeling Study

The Airflow Modeling Study (Modeling Study) was conducted by the City in an attempt to better understand how flowing wastewater influences the movement of the free air in the sewer system and better predict where odor emissions may occur. The model created in this instance relied on major assumptions regarding the City's existing sewer system. As with all models, the conclusions of the study can only be as good as the assumptions upon which it is based. The usefulness of the Modeling Study results should not be summarily discounted, however, they should be viewed as being within a broad range of accuracy and should not be viewed as precise or as the only information that should be used to locate and size ATFs for odor control.

The movement of air above wastewater in a sewer is largely dependent on the viscous drag of the liquid on the gas. Viscous drag is the force exerted on the air by the moving water due to friction. Air movement is also influenced by the ambient air pressure and movement outside the sewer, heating or cooling of the air, and obstructions within the sewer. As moving air meets an obstruction it can be compressed, resulting in increased sewer air pressure. If the air pressure internal to the sewer is higher than that of the surrounding atmosphere, there is the potential for foul air to escape and cause nuisance odor impacts in the community.

The stated scope of the Modeling Study was to create a model that could identify odor "hot spots" under several potential wastewater flow scenarios. These hot spots are not points of actual or even modeled odor impacts, but locations in the sewer system where the model indicates airflow is likely to be restricted. According to the Study, past experience has shown that airflow restrictions are the primary cause of high air pressure in the sewer. Since we know high sewer pressure (in comparison to lower atmospheric pressure) can cause foul air to escape, being able to predict possible locations of sewer airflow obstruction/high air pressure, is one way to predict the location of odor impacts in the community.

To estimate where these hot spots could occur, the City's engineering team used a pair of computer models to understand wastewater flow conditions and developed a third model to estimate how flowing wastewater would cause air to move within the sewer and where that movement may become restricted. It was explicitly stated that the airflow model is not intended to model air differential pressure, but only to identify hot spots as defined above.

Modeling Methodology

The City used commercially available computer software to model and analyze wastewater flows under various conditions. They developed an additional computer program that used the output of the wastewater flow predicting software to estimate where the characteristics of the sewers and the flowing wastewater could result in a location where the capacity of the system to carry air would become restricted. In that case, a "hot spot" was identified.

The Modeling Study explains that the airflow model was developed assuming only that the movement of the wastewater is responsible for air movement within the sewer. The airflow model calculates the airflow capacity within a segment of the sewer based on the wastewater velocity, the depth of wastewater, and the geometry of the pipe. Based on that information, the airflow velocity is estimated as a fraction of the wastewater velocity. That fraction varies with depth of the wastewater and the diameter of the sewer. The volumetric airflow is calculated by

multiplying the air velocity by the cross section of the free air space. The airflow is similarly calculated for the next downstream sewer segment. If the first segment's airflow is greater than the second segment's, it is assumed that the potential for compression of the air exists. If the difference in airflows in the two segments is greater than 2,000 cubic feet per minute (cfm) a hot spot is identified.

Modeling Assumptions and Accuracy

The City's model is based on the assumption that flowing wastewater is the only influence causing air to move within the sewer. This phenomenon is well documented and could provide a reasonable first estimate of airflow. However, while the drag of flowing wastewater has a significant influence on sewer airflow, air pressure up and downstream of the sewer segment modeled can also have a profound effect on air movement as can the effects of air buoyancy and friction between the moving air and the sewer wall. A stated limitation of the model is that it does not account for back pressure effects from siphons, drop structures, slope reductions or junction structures. The effect of air treatment facilities on airflow is also ignored by the model.

All models predict reality with some degree of error and the absolute accuracy of the City's model is difficult to gage. Field data was collected in an attempt to determine if the model was predicting those areas where pressurization of the sewer air was occurring. Air pressure was monitored at six locations where hot spots were predicted by the model. Data from one of the locations was discounted due to the strong effect of the air treatment facility at the Hyperion wastewater treatment plant. Data from the remaining five locations did show good correlation between the modeled and real-world conditions. However, only locations identified by the model to have a build-up of pressure were sampled. It would have been helpful if locations that the modeled airflows indicated lower or neutral pressure were also monitored. This would have provided additional insight to the model's accuracy.

Model Analysis and Hot Spot Identification

Analysis to identify hot spots and estimate the airflow within certain sewer sections was performed using three different wastewater flow scenarios. These represented the current and possible future sewer configurations that would divert flows from the North Outfall Relief Sewer (NORS) to the North Outfall Sewer (NOS) and from the NOS to the Central Outfall Sewer (COS). For each of these three scenarios, the airflow model was used to identify hot spots based on a 48-hour period using typical weekday and weekend wastewater flows.

The Study states that the airflow rate within the sewer is one of the design criteria for any future air treatment facility. This is a reasonable statement. Knowledge of the sewer airflow is necessary to determine the rate of air extraction by an ATF to lower the pressure in the sewer to prevent odor emissions. Current airflow rates were estimated at several locations that appear to be associated with known odor problems. Airflows at the upstream ends of the North Central Outfall sewer (NCOS) and NORS siphons near the I-405 freeway and five drop structures were modeled. The Study states that actual airflow rates can differ from the model-estimated rates due to the disregard of ATF ventilation and airline effects. The Study reports the modeled airflows for eleven locations near the NCOS, NORS, and the drop structures for each of the three wastewater flow scenarios.

Some of the model-identified hot spots were dismissed due to known actual conditions. Those locations that were dismissed were those known or assumed to be affected by ATFs and therefore not sources of odor problems. Under the current wastewater conveyance system configuration, nine hot spot locations identified by the model were considered valid. Six of these hot spots were located on the East Central Interceptor Sewer (ECIS), one was on the NORS/ECIS Junction, and the remaining two were on the NCOS and NORS siphons at I-405. When modeling the two potential future sewer configurations, three additional hot spots were identified on the ECIS, one at the NOS siphon and one immediately downstream of the North Outfall Treatment Facility (NOTF) on the NOS.

General Remarks and on the Airflow Modeling Study

The City's engineering team has produced a model to estimate airflows and hot spot sites of potentially high pressure within the sewer system. The model estimates the airflow based on the assumption that air movement is only due to the viscous drag on the air by moving wastewater and ignores several other significant parameters. However, given the state of the art of sewer airflow modeling, it is not an unreasonable way to gain insight into the potential for air pressure increases, potential locations of odorous emissions, and to understand the magnitude of the air volumes moving within the sewer. The estimate of the volumetric airflow is important to quantify so that air treatment facilities can be sized to neutralize the potential for high air pressure at the model identified hot spots.

Given the current state of the art of modeling airflow within sewers, it is important to corroborate modeled information with real world data and observations. The City's team has conducted some field data collection that indicates their model is capable of identifying points of air pressurization within the sewer. These locations are compared with odor complaint locations in the ATF Study (discussed later in this paper) to further verify the validity of the model.

From the information in the Modeling Study, one can conclude that, as a first estimate, the airflow model provides a reasonable estimate within a broad range of accuracy. The model was used in the ATF Study along with field data and observations as an aid to determining the need, location, and size of ATFs.

Sewer Siphon Duct Connection Study

The stated purpose of the Sewer Siphon Duct Connection Study (Siphon Duct Study) was to examine the effect that existing interceptor siphons located under the I-405 freeway have on airflow dynamics in the interceptor collection system. The interceptor collection system discussed in the Siphon Duct Study is made up of the North Outfall Relief Sewer (NORS), East Central Interceptor Sewer, North Central Outfall Sewer (NCOS) and the North Outfall Sewer (NOS).

The focus of the Siphon Duct Study was to examine the potential benefit of adding a duct to connect the air spaces of the NORS and NCOS. Because the NORS airspace has been shown to have consistently higher than atmospheric pressure and the NCOS lower than atmospheric pressure, it was hoped that the two could be connected, allowing air to flow from the high to low pressure sewers and decrease the odorous emissions from the NORS. Earlier investigation on this topic was described in the City's NORS Siphon Air Line Feasibility Study. After that work was

produced, additional investigatory tasks were accomplished and documented in the Sewer Duct Study that reports on the findings and conclusions based on an analysis of the data collected.

In addition to examining the effects of joining the NORS and NCOS air spaces, the Siphon Duct Study also reports on the affects of blocking an existing permanent air duct that joins the NCOS and the NOS. This was done in an attempt to understand why the NCOS is at a consistently low pressure.

Rational and Methodology of Siphon Study

The City and its consulting engineers formulated the Siphon Study to perform air pressure measurements in the as-built (no NORS/NCOS air duct connection) to establish a baseline data set. The air duct would then be installed and air allowed to flow freely between the NORS and NCOS while additional air pressure data and airflow measurements through the duct were recorded. After the free airflow data was collected a fan would be place in the air duct forcing air from the NORS into the NCOS to determine if that scenario would provide positive results with respect to controlling odors. In order to gain an understanding of the affect the existing air treatment facilities' extraction of air from the sewers had on air pressure and flow within the sewer system under these various scenarios they would be cycled on and off during the data gathering period.

Baseline Data Collection Phase

The baseline air pressure measurements were taken over approximately three week's time beginning in early June of 2009. During that time the NORS was consistently pressurized between approximately 0 to 0.4 inches water column with an average of approximately 0.2 inches water column. There were almost daily excursions of the NORS pressure below 0 inches water column, but for the most part it was positively pressurized with respect to the atmosphere.

The NCOS baseline pressure measurements were taken simultaneously with the measurements in the NORS. The NCOS data showed that that sewer's air space was consistently lower in pressure than the surrounding atmosphere with an average pressure of approximately -0.39 inches of water column.

The pressure of 1 inch of water column is literally the pressure exerted by water one inch below its surface. This may seem slight but the ventilation of air requires very slight pressure differences. Pressure in heating and air conditioning systems are typically measured in these units. Significant air volumes can be moved with differential pressures in the 0 to 1 inch water column range and the pressures measured in the NORS and NCOS could reasonably be assumed to have the capability to transfer large volumes of air between the two sewers. This justified the further investigation of the efficacy of allowing that to occur with the air duct connection.

Further baseline data collection was taken while the NORS/ECIS ATF system was turned off so that its 10,000 cfm capacity was not being extracted from just upstream of the NORS/ECIS junction. During that time the data revealed that the pressure in the two sewers was higher than it was when the AFT was turned on as one would expect. The pressure measurement data taken from the NCOS showed that the ATF's influence could be detected miles from the point at which

the air was extracted from near the NORS/ECIS junction. This data could prove useful in the locating and sizing of future AFT facilities.

Passive Air Duct Connection Data Collection Phase – Description and Critique

A 36-inch duct was used to connect maintenance holes on the NORS and NCOS. This allowed the higher pressure in the NORS to be relieved while causing air in the range of 3,000 to 3,500 cfm to flow into the NCOS and raising the pressure in that sewer. The increase in pressure in the NCOS was significant, rising from an average of -0.39 to +0.03 inches water column, while the pressure in the NORS decreased by only 0.06 inches wc from 0.20 to 0.14 inches wc. The decrease in pressure in the NORS could result in fewer odor emissions but the increasing pressure in the NCOS could result in odor emissions from that sewer.

During the passive air duct connection pressure monitoring, the NORS/ECIS and Jefferson ATFs were cycled on and off. When the scrubbers (rated at 10,000 cfm each) were extracting air from the sewers, the airflow from the NORS into the NCOS was from 3,000 to 3,500 cfm as mentioned above. With those interim ATFs turned off, the airflow dropped to approximately half those values and the pressure increased by 0.1 and 0.17 in the NORS and NCOS respectively. This would indicate that the effect of the air extraction by the ATFs has a more profound effect on the NCOS than on the NORS in the vicinity of the duct connection.

Active Air Duct Connection (Forced Ventilation) Data Collection Phase – Description and Critique

During the active air duct data collection phase, an axial flow fan was placed in the 36 inch diameter duct to extract air from the NORS and force it into the NCOS. The apparent intention of this phase was to determine if mechanically extracting air would relieve more pressure from the NORS than during the passive ventilation phase and what affect would be seen in the NCOS. The fan was operated to achieve target airflows of 5,000, 7,500, 10,000 and 12,500 cfm.

As a result of the active ventilation described above, three significant and related issues became evident. First, and most importantly, the average pressure in the NCOS became very high at 1.5 inches wc above that found in the passive ventilation test. Second, the pressure in the NCOS fluctuated extremely between the positive and negative pressure values indicating that very unpredictable odorous emissions could come from the NCOS with the forced ventilation option. Third, there was only a minor benefit to the pressure condition in the NORS with the average pressure decreasing by only about -0.03 inches wc in that sewer.

The fact that the active ventilation led to only a small reduction in the NORS average pressure while the NCOS became so highly and erratically pressurized leads to the conclusion that the active air duct connection is not a viable option for controlling odors in the NORS/NCOS system.

Air Duct Isolation between NOS and NCOS – Description and Critique

With the information obtained from the investigation and data gathering described above, the reason for the consistent negative pressure in the NCOS still remained unclear. The City's team determined that additional sampling would be needed to determine the cause. It was decided to

block the airflow in the permanent air duct that connects the NCOS to the NOS near their respective siphons under the I-405 freeway. It was reasoned that this would allow the team to determine if the low pressures in the NCOS were influenced by the NOS.

The permanent air duct was blocked and pressure monitors were used to record pressure data for a period of approximately two weeks. Pressure in the NCOS was observed to not change appreciably while the pressure in the NOS markedly increased. This would indicate that the NCOS was not influenced by the NOS but that the opposite was true. The NCOS influenced the NOS pressures, keeping them lower as a result of the air duct being open.

One additional conclusion was noted in the Siphon Duct Study. That was that the low flow conditions in the NCOS at the time the data was being collected were the cause of the negative pressures in that sewer. It would be reasonable to assume that the lack of high pressure would result from the low flow conditions but there are likely additional factors that lead to negative pressure in the NCOS. These lower than atmospheric pressures could be caused by wind passing over maintenance holes causing air to flow out of openings in their lids, temperature differences between the sewer air and the surrounding atmosphere or sewer conditions upstream of the pressure data collection area that may influence the NCOS near the I-405 freeway siphon.

General Remarks on the Siphon Duct Study

Understanding the dynamics of airflow and pressure distribution is necessary to effectively control wastewater conveyance system odors. Good real-world data helps engineers locate, and size air treatment facilities for appropriate foul air extraction and treatment to minimize odor emissions from sewers and adequately treat the air prior to its discharge to the neighborhood. The Siphon Duct Study provides some of the fundamental information that will aid with the final design of odorous air management and control systems.

Complete understanding of the airflow characteristics in a sewer system is never achievable but it is possible to move forward with good designs based on limited knowledge. Information regarding the way wastewater flow influences airflow and pressure distributions in the sewers was not included in the Siphon Duct Study. That topic was covered in the Airflow Modeling Study (discussed above).

In a separate NORS Siphon Air Line Feasibility Study, the City concluded that installing a permanent duct between the NORS and NCOS could provide partial relief of the high pressure in the NORS and that an attractive aspect of this alternative is its simplicity and relatively low cost. That study indicates that it would cost approximately \$200,000 to install the permanent duct. The work in the Sewer Siphon Duct Connection Study would support this conclusion.

Drop Structure Study

The purpose of the Drop Structure Study was to develop a better understanding of how wastewater flowing through drop structures influences the pressure of the free air space in the structure and connecting sewers. The Drop Structure Study also examined the affect turning on and off various interim air treatment facilities had on the sewer air pressure.

A drop structure is necessary when the elevation of a sewer must change abruptly. This can be required at the confluence of two sewers when one is higher than the other. Air above the flowing wastewater is dragged in the approach sewer and with the flow falling into the drop structure. This action can cause high pressures to develop if the moving air is obstructed from traveling downstream from the drop structure. To help alleviate this problem an air return line connecting the bottom and top of the drop structure is often included in the design. The City had observed that drop structures with these air return lines often had high pressures in their approach sewers and that at least one drop structure without a return line operated with an approach sewer having air pressure lower than atmospheric. Those sewers with high pressures could cause odors to escape and impact the local community while the low air pressure sewer would be unlikely to be offensive.

Due to the observed air pressures in and around the drop structures, the City performed a series of tests to measure the effects of (1) blocking the air return lines, (2), modifying wastewater flows, and (3) cycling the relevant interim carbon scrubber ATFs off and on to measure the effects on air pressures upstream and downstream of five drop structures.¹

The Drop Structure Study's additional stated objective was to identify potential changes to the planned odor control strategies and methods to control odorous air releases in the proximity of the drop structures.

Investigation Procedures

The City's team conducted a series of experiments in the field that first involved measuring the air pressure in the sewers as they are currently built and operated to obtain baseline data. Data was gathered in the North Outfall Sewer (NOS) and Eagle Rock Interceptor Sewer (ERIS) approaches to the drop structures, in the drop structures, and in the North Outfall Relief Sewer (NORS), East Central Interceptor Sewers (ECIS) and North East Interceptor Sewer (NEIS) on the downstream side of the drop structures.

The air return lines were then blocked with inflatable plugs to prevent airflow from the bottom of the drop structures from flowing back to the top of the drop structures. As this was done, additional air pressure data was collected. Then, wastewater flows through the drop structures were manipulated by removing barriers known as stop logs within diversion structures in the sewers. These diversion structures, as the name implies, are used to divert flow from one sewer to another. Finally, while the air return lines were blocked and the flows manipulated in the drop structures, the interim ATFs at the Humboldt and Mission and Jesse locations were cycled on and off. Air pressure data was collected to determine if the air they extracted from the sewer would influence the air pressures in the drop structures as well as the upstream and downstream sewers.

¹ The drop structures tested were located at Division, Humboldt, Mission & Jesse, and 23rd San Pedro and the University of Southern California (USC).

General Remarks on the Drop Structure Study

The City of Los Angeles has gone to considerable effort to understand how sewer air pressure is influenced by drop structure design, wastewater flow, and operation of interim ATFs. While there is good information that can be derived from the data collected, there is no one obvious conclusion from the information obtained that will allow a clear decision to be made regarding the solution to the problem of air emissions from the sewers and the odor impacts that result. This is not to say that the information is not valuable; the information should reasonably lead to better informed engineering decisions. What can be gleaned from the data is that a number of changes that each contribute a little to the solution could be made to lower the probability of odor emissions.

The most significant conclusion that can be drawn from examining the Drop Structure Study is that it will likely be necessary to use more appropriately sized and located ATFs to remove air from the sewers and thus reduce the high pressures that result in uncontrolled odor emissions. As long as such high pressures exist in the sewers, uncontrolled emissions are virtually certain. Because none of the methods investigated in the Drop Structure Study (including blocking air return lines and manipulating wastewater flows), could dependably achieve a substantial and consistent reduction in air pressure, the only real alternative is to remove more sewer air with ATFs.

The information obtained in the Drop Structure Study was used to help initially size and locate ATFs. Final ATF locations and sizes should be determined after scale drop structure model testing in the City's hydraulics laboratory and through a formal pre-design and design process.

Total Non-Methane Hydrocarbon Study

The City is required under the terms of the CSSA to install and operate interim and permanent ATFs for the control of odors from the sewers. These ATFs must have permits issued by the South Coast Air Quality Management District (SCAQMD) that will allow the City to build and operate the facilities. Permits of this type place limits on ATF pollutant emissions that could have nuisance or human health effects. As part of its ATF Review, the City monitored total non-methane hydrocarbons (TNMHC) and odorous compounds in the sewer air and produced a technical memorandum summarizing its finding.

Some organic² pollutants that may be emitted from the ATFs can react in the atmosphere forming ozone (O₃), which is one of the first pollutants regulated under the Clean Air Act. The concentration of O₃ in the City's air is higher than the regulatory limit. As a result, the City is considered a non-attainment area for that pollutant by the United States Environmental Protection Agency (US EPA). The SCAQMD limits emissions of these organic pollutants as a way to limit the production and concentration of O₃. The existing interim ATFs are required to meet SCAQMD TNMHC and hydrogen sulfide (H₂S) emission concentration limits described in their permits. Future permanent ATFs will certainly have limits on these pollutants as well.

² Substance whose molecules contain one or more carbon atoms with the exception of carbonates, cyanides, carbides, and a few others.

As part of the City's ATF Review, the City wanted to gain knowledge about the pollutants in the sewer air that the new ATFs would be treating and about the ability of the interim ATFs to control these pollutants. This would allow the City to determine if the interim ATF technology (carbon bed scrubbers) could be used as part of the new ATF systems. The purpose of the work was the following:

- Understand the characteristics of the air pollutants in the sewer air that would be treated by the new ATFs;
- Determine if the concentrations of the various organic compounds in the sewer air summed to a similar value as that determined by the SCAQMD TNMHC testing method;
- Determine if there were organic compounds in the sewer air that should not be included in the calculation of the TNMHC concentration;
- Compare the measured pollutant concentrations in the interim ATF exhaust against the SCAQMD permit limits;
- Assess the pollutant removal efficiency of the interim ATFs; and
- Determine if a handheld device could be used to measure TNMHC concentrations

Sampling and Analysis of Sewer Air Pollutants

The City simultaneously extracted air samples for analysis by several laboratory methods. Two EPA methods, TO-12 and TO-15, were used to determine the concentration of specific organic compounds, SCAQMD Method 25.3 was used to quantify TNMHC concentration, and American Society for Testing and Materials (ASTM) Method D5504 was used to quantify sulfur compound concentrations in the sewer air. In addition to these methods, H₂S data monitors were used to spot check and collect concentration data over extended periods. A handheld photo-ionization detector (PID) was also used with hopes that it could be used as an alternative to Method 25.3 for measuring TNMHC concentrations.

Pollutants in the Air Stream

The two EPA methods yielded a great deal of information about which organic compounds are present in the sewer air that made up the interim ATF inlet airstream and in the exhaust air streams. The information about the individual compounds is valuable in that it could be used in the evaluation of future ATF technologies for controlling their emission into the atmosphere at concentrations acceptable to the SCAQMD. The pollutants identified by these methods probably contribute only slightly to the total sewer odor given the concentrations reported. The sulfurous compounds identified by the ASTM method are likely the main cause of sewer odors in these air streams.

The City was interested if the EPA methods would find some compounds that do not cause O₃ production in the atmosphere, but could influence the TNMHC value determined by the SCAQMD method. If the EPA methods *did* find such compounds, that could call into question the permit limit on TNMHC concentration that SCAQMD uses to limit atmospheric O₃ levels. Ultimately, discounting the influence of those non-O₃ producing compounds did not appreciably change TNMHC concentration, so the SCAQMD method appears to be a reasonable way of finding the concentration.

Using the information obtained by the EPA methods, the total carbon in the organic compounds was summed and compared to the TNMHC value obtained by the SCAQMD Method 25.3. The values determined by the two methods differed by as much as a factor of five and were not consistent between sites. Examination of the Method 25.3, TO-12, and TO-15 did provide information on which compounds most influenced the TNMHC concentrations. This information could be used in the selection of ATF technology if it is deemed necessary to lower the concentration of those most influential compounds to meet the permit limits.

The interim ATFs were able to control the emission of H₂S and TNMHC to their individual permit limits at all locations with the exception of the Humboldt interim ATF. The concentration of TNMHC in the exhaust stream was measured at 18.4 parts per million as carbon (ppmC). This exceeded the permit limit of 18 ppmC. The Technical Memorandum states that the relatively high exhaust concentration was likely due to the fact that the carbon was spent, which means that it was past the end of its useful life. This is a reasonable conclusion since the other interim ATFs sampled were able to adequately control the TNMHC emissions to levels below the permit limits. Simply installing fresh carbon should allow the Humboldt interim ATF to meet the permit limit.

A handheld PID was used to sample the sewer air to determine if that type of device could be used to measure TNMHC concentrations rather than the more cumbersome SCAQMD method 25.3. The handheld PID would have the advantage of providing almost instantaneous values at the ATF locations, whereas the SCAQMD method requires that samples be taken to a laboratory for analysis and it can take weeks to obtain results. Unfortunately, the information from the two methods compared poorly so it is not likely that use of the PID will provide its desired advantage unless a suitable correction factor could be used to convert the PID readings. The SCAQMD would have to accept such a methodology.

General Remarks on the TNMHC Study

The City conducted a substantial effort and developed an understanding of the types and concentrations of pollutants that are treated by the interim ATFs that have been installed for odor control. Because the SCAQMD places permit limits on the emission of TNMHC and hydrogen sulfide, the City monitored the inlet and outlet airstreams of the existing interim ATFs. It was shown that these current systems, based on carbon bed scrubbers, can be effective in meeting the permit requirements.

The monitoring and analysis did show that there were some organic compounds that influence the TNMHC concentrations but do not contribute to O₃ production in the atmosphere, which is what the permit limit is intended to prevent. However, this influence was slight and will not likely change the requirement to limit the TNMHC emissions.

The interim ATFs were shown to be capable of removing pollutants with sufficient efficiency to meet their permit requirements. This is not to say that the currently installed interim ATFs have provided adequate relief from odor impacts on the community, but only that the permit conditions can be met. In one case the permit limit for TNMHC was exceeded and was likely due to the need for new carbon. In a similar manner, hydrogen sulfide and other odorous compounds can be emitted if the carbon in these devices is not changed with adequate frequency.

A handheld PID was tested as a simple means of determining TNMHC concentrations. The initial conclusion of the draft TNMHC Technical Memorandum was that the PID was not likely an adequate tool for determining permit compliance. However, the final version raises the possibility of using a PID with an appropriate calibration curve that would allow the instrument's output to be correlated to SCAQMD Method 25.3 results, but it also recommends further work to determine if this is feasible and that an alternative but unnamed hand-held device may provide better service.

The City was able to gain some useful information regarding the composition of the sewer air and the various testing methods for organic air pollutants and TNMHC concentrations that are available. It also verified that the interim ATF carbon bed scrubber technology was adequate for meeting its current permit limits.

Air Treatment Facility Study

The Air Treatment Facility Technical Memorandum (ATF Tech Memo) was produced to justify the selection of future ATF locations, technologies, and foul air treatment volumes. The ATF Tech Memo is based on the earlier work (and related technical memoranda) on sewer drop structure air pressure studies, airflow modeling, and analytical testing of non-methane hydrocarbons and inorganic odorous compounds such as hydrogen sulfide (H₂S), all of which comprise the broader ATF Review Study and are discussed in detail above.

Under the original CSSA, the City had planned to construct seven new ATFs to help control odors from the wastewater conveyance system. Of these seven, two have almost been completed, but design and construction of the remaining five was placed on hold pending the outcome of the City's ATF Review. The City has continued to treat foul air from the sewers with interim ATFs based on carbon filtration while the ATF Review has been conducted. As a result of the work, the City is recommending proceeding with only one of the originally planned but yet un-built ATFs.

Field Testing of Sewer Air Pressure

The City has conducted what could be considered a very large scale set of tests to characterize the air pressure within its sewer system in its study on differential air pressure at drop structures. In that study the City conducted measurements on sewer air pressure to determine how it was influenced by the changing of wastewater flows through and around drop structures, installation of airflow blocking devices in and near drop structures, and the operation of existing interim ATFs. The pressure data collected provided some insight to how each of these influenced air pressure in and around the drop structures. While the City was able to draw some general conclusions about how each of these might influence air pressures, there was no one clear solution that would lower sewer air pressure to the point that odor emissions would be completely eliminated. This should not be viewed as an unreasonable result. Due to the complex network of sewer connections and the dynamic character of wastewater flow, air pressures vary widely and significantly within sewers. It would indeed be the rare case where any sewer operator could completely eliminate the potential for odor emissions.

Sewer Airflow Modeling

The City developed a model to estimate where odor emissions from the sewers might occur. The model used by the City to predict wastewater flows was used to estimate the velocity and depth of water in connecting segments of the sewers. Based on the information provided by this model, a second model was developed to predict where changes in the air space geometry from one segment to another indicated a reduction in the amount of air that could be conveyed from an upstream to a downstream segment. Where this occurred, the potential for odor emission was predicted. This was a reasonable method of arriving at a first estimate of odor emission locations. That said, the modeling of airflow in sewers and the points of emissions has proven to be difficult and, at best, only a rough estimate of each can be expected.

The odor emission locations were overlaid on a map in the ATF Tech Memo with the location of odor complaints received between the months of October 2008 to September 2009. There appeared to be some correlation between the predicted points of emissions and the registered odor complaints. However, not all clusters of complaints corresponded to predicted emission points. Also, it is not possible to show how all real odor emissions and impacts correlate to the predicted emission points because not all true impacts result in complaints formally registered with the City.

ATF Locations Recommendations

Based on the results of the airflow modeling discussed above, the City developed recommendations on the methods of reducing air pressure within the various sewers in the vicinity of drop structures. Of the four ATFs originally recommended for installation at drop structures, only the ATF at the Mission and Jesse site is now being recommended for construction by the City. No mention of the originally planned ATF at NORS/ECIS is made in the draft ATF Tech Memo.

In addition to the ATF at the Mission and Jesse site, modifications in the drop structures and adjacent sewers are being recommended. These include the use of flow diversion devices known as stop logs to modify the flow patterns in the sewers to minimize pressure in and around the drop structures. They also include the installation of airflow prevention devices that would be installed in the drop structure air return lines and plastic curtains in the sewers to prevent pressurization of the air spaces downstream of the drop structures.

The ATF Tech memo also recommends that air pressure tests be conducted in the sewer in the vicinity of the newly constructed ATF treating air from the East Central Interceptor Sewer (ECIS) Jefferson Siphon. It is further recommended that if the operation of that ATF does not result in satisfactory pressure reductions along the North Outfall Relief Sewer (NORS) that the city should initiate a fan test along the NORS between the siphon at the Fox Hills Mall and the Culver City Park. The purpose of that test would be to determine how much air would need to be extracted from the NORS to reduce the air pressure within the sewer and thereby control odor emissions.

Determining ATF Airflows Required to Control Odor Emissions

The ATF Tech Memo projects that it would be necessary to extract 20,000 cubic feet per minute (cfm) of air at Mission and Jesse to lower sewer air pressure and control odors at that location. It further recommends that the City conduct airflow tests on a scale model of a sewer drop structure in its hydraulics laboratory to better estimate the actual airflow necessary. This should provide a deeper understanding of what ATF airflows would be required and result in a more efficient ATF design to be developed. At this writing the City is modifying a physical scale model of a drop structure in its hydraulics laboratory to conduct this testing.

Identification of Air Emission Control Technologies

The ATF Tech Memo describes commonly applied air pollution control devices used for controlling wastewater odors. Using the information gained in the TNMHC study, the City evaluated the ability of various air emission control technologies to control odors from the wastewater conveyance system. With the exception of biotrickling filters and carbon adsorbers, all of the technologies are eliminated from consideration as viable for the normally unstaffed wastewater conveyance facility locations such as the Mission and Jesse site.

Recommendations of the ATF Tech Memo

The ultimate recommendation set forth in the ATF Tech Memo is that a combination of a biotrickling filter and a carbon adsorber be used to control odors from the Mission and Jesse drop structure and surrounding sewers near that location. Information in the ATF Tech Memo indicates that high levels of hydrogen (H_2S) sulfide gas can be present in the foul air from this part of the sewer. A biotrickling filter should be capable of removing virtually all of H_2S from the foul air stream. Use of a carbon adsorber to remove most of the residual odors that are not removed by the biotrickling filter should provide very good control of odors that are introduced to the ATF.

General Remarks on the ATF Tech Memo

The City's engineering team has developed recommendations to construct one additional ATF at Mission and Jesse. Odor control technologies and methods for estimating foul air treatment volumes are also recommended for that single location that should provide good odor control based on the City's findings and assumptions are correct. Of the remaining four sites originally proposed for ATFs, it has been recommended that only wastewater flow patterns be modified and air flow prevention devices be placed in the sewers to prevent the build-up of high air pressures.

With the information assembled by the City's team, it is not possible to definitively state that the reduced number of ATFs, changes to wastewater flow patterns, and installation of airflow prevention devices will or will not adequately control odors from the sewers. One could not make such a definitive statement even if all five of the originally proposed ATFs were determined to be necessary by the City's team. The state of the art of odor control from sewers is not yet sufficient to make such strong conclusions even with the large amount of information and knowledge gained in the process of the City's ATF Review Study. However, it would be safe to

say that five well designed, carefully located and adequately maintained ATFs would provide better odor control than a single ATF.

The City has constructed and is near final completion of ATFs at Jefferson and La Cienega and 6000 Jefferson. The City's team has recommended that sewer air pressure monitoring be conducted after these are completed to determine air pressures along the North Outfall Relief Sewer. This would be a prudent course of action to determine how much the high air pressures have been relieved in that sewer and how far away from the ATF the air pressures remain acceptably low within the sewer. It would also be prudent to measure air pressures in the sewers connected to the new ATFs to obtain additional knowledge that could be used in the design of future ATFs.

Of the seven originally proposed conveyance system ATFs, two are nearing completion and one is being proposed. It will be possible to determine if these are adequate to control odors that have been impacting the surrounding communities after they are fully operational. Typical public works projects in the size range of the ATF design and installation can be expected to take between three and five years to move from initial authorization to completion. Because these timelines can be considered long, the City should move forward soon with design and installation of the recommended ATF at the Mission and Jesse site. With the completion of the two newly constructed ATFs, the City should quickly test how the airflow extracted from the sewers influences pressures in the conveyance system.

Recommendations of the ATF Review Study Draft Final Report

The ATF Review Study Draft Final Report (Report) pulls together the findings of and makes recommendations based upon the previously discussed airflow modeling, drop structure, siphon, TNMHC, and ATF technical memorandum. The most significant recommendation set forth in the Report is that of the seven originally planned ATFs four will not be built. These were at the drop structures located at Division, Humboldt, Richmond and 23rd & San Pedro. The City's justification for building only an ATF at the Mission and Jesse site is that it is the drop structure through which the NEIS/ECIS tunnel appeared to relieve pressure back into the NOS.

The installation of the ATF at the Mission & Jesse site would likely not be sufficient in and of itself to alleviate odor emissions from the drop structure and the connecting sewers. Modifications to the drop structure are also being recommended to prevent air from being carried away from the structure by the flowing wastewater and to allow the interim and future ATF to efficiently capture foul air from the structure. Plastic curtains are recommended to prevent airflow from the bottom of the drop structure into the downstream NEIS. A damper at the top of the drop structure air return line will prevent the air movement induced by the water falling in the drop structure to pressurize the upstream NOS. A new foul air pick-up point that is being recommended at the bottom of the drop structure will, in conjunction with the damper, allow the ATF to efficiently capture air from the structure. Final decisions regarding these recommended modifications will be made by the City with information obtained from testing water and airflow in a scale model drop structure in its hydraulics laboratory.

Changes to wastewater flow patterns in the NOS and NEIS are also being recommended. The City found that air pressures were lower when more of the wastewater was allowed into the NOS past the Division, Humboldt and Richmond drop structures and into the ECIS through the drop at

Mission & Jesse. Removing stop logs in the diversion structures to accomplish this has been recommended. This would seem a reasonable conclusion based on what is known about the airflow and pressurization dynamics in and around drop structures. The recommendation has been made to revisit these conclusions after the physical testing of the drop structure testing in the City's hydraulics laboratory.

General Remarks and Conclusions of the Independent Odor Expert

The City of Los Angeles Bureau of Sanitation has undergone a large study of the cause of odor emissions from its wastewater conveyance system. Conclusions have been drawn based on air pressure data gathered during physical manipulation of the system to change wastewater flow patterns and change potential airflow pathways in the sewers. Computer modeling based on wastewater flow and sewer geometry has been conducted to estimate where airflow restrictions could cause the air to be pressurized and emitted to the neighborhoods above the sewers. Foul air testing has been conducted to determine the chemical species that need to be controlled by air treatment facilities. Studies of this breadth and depth are indeed rare and can yield good information regarding the cause and effects of odor emissions and impacts. However, the state of the art in modeling of airflow dynamics in sewers will only allow for general conclusions to be drawn on results that lie within a broad range of accuracy. There is much art left in the science of wastewater conveyance system odor control and solutions must still be made based on inference by those with real world experience and knowledge based on past successful and unsuccessful attempts to control sewer odor emissions and impacts.

The City's plan forward is to complete the two ATFs currently under construction at Jefferson and La Cienega and at 6000 Jefferson and to construct only one of the originally recommended five additional ATFs. Given the information provided in the ATF study technical memorandums on the various studies this does not appear to be an unreasonable approach. However, as mentioned above, because these conclusions are based on a range of accuracy is very broad, only the installation and operation of these improvements will allow the neighbors and the City to determine if they will be successful in preventing odor impacts in the community. With the full scale operation of the two ATFs currently in construction, the community should soon be able to determine if these projects will provide relief from sewer odors. It remains to be seen if these efforts will be sufficient or if additional measures will be required to provide the community with sufficient relief from sewer odors.