Comparison of Methods Used to Measure Odour at Wastewater Treatment Plant Fencelines

Jay R. Witherspoon and Jennifer L. Barnes
CH2M HILL, Inc.
777 108th Avenue NE, Suite 800
Bellevue, WA, USA 98004-5118

Abstract

In recent years, there have been new odour assessment tools available to help municipal wastewater treatment plants (WWTPs) understand their off-site odour impact, such as dispersion modelling, portable odour measurement panel equipment, electronic noses, air tracer compounds, and odour sensors that can be used to measure ambient odours at the plant fenceline. However, perception of odours is highly subjective, individuals might have different responses to an odour at various concentration and duration. Many WWTPs have serious concerns about off-site odour impacts that are causing them to look for viable odour controls to meet community needs for an odour-free environment. This paper presents ways to demonstrate compliance with community odour standards using dispersion modelling, direct fenceline ambient sampling, and portable odour measurement equipment. Hand-held ambient odour and hydrogen sulfide (H_2S) measurement devices were evaluated, and they compared favorably to odour dispersion modelling results for a mid-sized WWTP in the United States. Other methods, such as the electronic nose, were reviewed but not included in this paper because they are better suited for sampling at the odour emission source than for ambient sampling. Electronic noses also tend to have high detection limits for known odourous compounds emitted at a WWTP, which means that the typical WWTP odourous emission concentrations emitted may not be detected by the device.

This paper provides insight into ambient sampling approaches using hand-held devices instead of other methods or approaches, including dispersion modelling and/or direct emissions source testing, to determine a WWTP's off-site odour impacts. Results from this innovative approach, which relies on recent innovations in portable, odour measurement panel equipment, show that a simple strategy exists to prioritize odour sources for controls. The dispersion model results in the case study, using source-measured inputs, were verified at the fenceline using data gathered

with hand-held ambient odour measurement and metering devices.

1. Introduction

Odour-related complaints from communities surrounding wastewater treatment plants (WWTPs) have been increasing for many WWTPs. This increase is typically the result of new residential development at and near plant fencelines, sales resulting in new residents in existing communities, concerns about property devaluation and health impacts, and rising numbers of violations and impacts from regulatory agencies responding to these community complaints. More world-wide air quality regulatory agencies are setting regulations and permit conditions that establish odour standards, in dilutions to threshold (D/T) or odour units (OU/m^3) tied to allowable frequencies, at WWTP property boundaries. In addition, WWTPs are proactively setting their own odour standards to reduce the number of odour complaints, in order to avoid permit conditions and regulatory standards, as well as be a good neighbor to the surrounding community.

Currently, there are many ways to measure ambient odours at a WWTP's fenceline. Typically, two approaches are used: 1) direct ambient sampling using sampling containers, sampling masts (for vertical odour impact measurements), fenceline sampling containers (for horizontal odour impact measurements), analytical odour measurement equipment, and portable hand-held devices; and 2) indirect ambient concentration determinations using odour-emission factors or direct measurements from the odour source as inputs into odour dispersion models to determine odour concentrations and frequencies at various off-site locations.

However, there are limitations to each method. Using hand-held odour sensors, it is difficult to capture actual odour strength by relying on ambient odours because they are so transitory. Due to dispersion and meteorological conditions, the odours perceived by residents and regulators come and go at any given time. Dispersion modelling accounts for odour sources at the plant and for meteorological conditions, but it is only a prediction of off-site odour impacts.

A direct comparison of dispersion modelling and hand-held odour sensor methods conducted at a mid-size WWTP in the United States is presented and discussed in this paper. The mid-sized WWTP set 7 D/T for 99 percent of the year for its community-based odour threshold standard, which is consistent with its state's Odour Nuisance Standard. Because 7 D/T is well below the observed off-site odour concentration at which the surrounding community tends to complain (typically around 20 D/T), this standard provides a small protection factor to the WWTP. Existing and new residential housing and major roadways now surround the WWTP, which was originally built in a rural setting at the lowest point in its service area, along naturally occurring rivers/flood plains. The WWTP was isolated until five years ago, when the community and residences expanded into areas very near the plant's fencelines. This residential migration has caused the WWTP to receive odour complaints and demands from the community to resolve off-site odour impacts and to create an "odour-free" environment.

2. Methods

The air dispersion model is a tool accepted by the industry to approximate intensity, frequency, and pathway of odour releases, but it is not an exact replication of actual off-site odour impacts. Meteorological data from the nearest airport meteorological station was used for the dispersion model. This meteorological data may not be identical to site conditions, but it is adequate to provide a credible, defensible model.

In order to determine the odour strength using dispersion modelling at the plant boundary of the WWTP, odour baseline sampling was conducted at each major and minor odour-emitting source for hydrogen sulfide (H_2S) and total odour. In some cases, H_2S was used to determine total odour emissions by developing an H_2S equivalent curve to handle odour sources that have low H_2S emissions but high odours, such as solids processes. Odour and H_2S emissions inputs into the dispersion model were based on direct sampling at the emission source.

Odour samples taken from the WWTP processes, using the USEPA Flux Chamber approach, were analyzed using the European method that included an odour panel and butanol calibration. A presentation rate of 20 liters/minute was used during the odour panel analysis. Hydrogen sulfide and total reduced sulfur (TRS) compounds were also analyzed using ASTM D 5504, using Tedlar sampling bags and a GC/sulfur chemiluminescence detector (GC/SCD). USEPA Method 15 describes Tedlar bag detection, and US EPA Method 16 describes the analysis of sulfur compounds (without metal fittings) by GC/flame photometric detection.

For dispersion modelling, the Bowman Environmental Engineering's BEEST modelling package, Version 5.0, was used as an interface with a US Environmental Protection Agency (USEPA) air dispersion computer model, Industrial Source Complex Short-Term (ISCST3), Version 96113, to simulate off-site odour impacts in terms of D/T levels at the plant fenceline and into the community. ISCST3 predicts 1-hour average pollutant concentrations. However, odour nuisances are most associated with exposure times on the order of seconds or minutes, rather than hours. Averaging over an hour has the effect of smoothing out concentration peaks. To avoid this smoothing effect, the 1-hour concentrations predicted by ISCST3 were converted to peak 5-minute concentrations using the following power law [1]:

$$\chi_s = \chi_{1-hour}\left(\frac{60\ min}{t_s}\right)^p$$

Where x_S is the short-term concentration, $x_{1\text{-hour}}$ is the model-predicted 1-hour concentration, t_S is the desired short term averaging time (in minutes), and p is the power-law exponent. The value of the p varies by atmospheric stability class.

Using hand-held devices, ambient samples of both H_2S and odour units (OU) were measured simultaneously at regular distance intervals along the WWTP's fenceline. A Jerome 631-X H_2S analyzer and a nasal ranger field olfactometer (a new product by St. Croix Sensory, Inc.), were used to determine ambient H_2S concentrations and odour D/T values at the fenceline, respectively. The nasal ranger organoleptic instrument directly measures and quantifies odour strength in the ambient air by mixing odourous ambient air with odour-free filtered air in discrete volume ratios. The D/T values range from 0 to 60 D/Ts. The Jerome meter measures H_2S concentrations within a 30-second sampling period down to a 1 part per billion (ppb) detection limit.

3. Results and Discussion

The results from the field ambient odour sampling and odour dispersion modelling are provided in the following section, along with discussions and insights gained from the results. Figures 1 and 3 present the peak 1-hour H_2S concentrations (µg/m3) and odour (D/T) off-site contours, respectively, predicted by the odour dispersion model for all WWTP process sources. Predicted peak 1-hour H_2S concentrations (µg/m3) or odours (D/T) represent the single highest concentration predicted to occur over any 5-minute period in the entire year, assuming peak odour emission rates (summer loading rates) are applied year round. This is an extremely conservative approach, since the peak odour emission rates typically occur during warm seasons (i.e., summer and fall) and are not present during cold weather, rain events, or winter conditions. This approach also applies these warm-weather emission rates during the winter when the most negative meteorological conditions for dispersion modelling potentials (low to no air movement, inversions, etc.) occur. In the winter is also when WWTPs have the lowest odour emission potential.

Figures 2 and 4 present the average 1-hour H_2S concentrations and odour off-site contours, respectively, predicted by the odour dispersion model for all WWTP process sources. This is a more realistic approach for the average off-site odour impacts compared to peak loading conditions, as well as compared to ambient odour monitoring at the fenceline. In addition, these conditions were modelled based on actual source test data and meteorological conditions that are most likely to occur at the WWTP.

The WWTP's measured fenceline H_2S sample results for two sampling events that captured the two highest odour emitting periods experienced historically at the WWTP, fall and summer conditions, are shown in Table 1. For the same locations and sampling events, the WWTP's odour D/Ts measurement results are shown in Table 2.

The predicted, average 1-hour contours for both H_2S and odours seem to correspond very well with the field-measured ambient odour and H_2S results seen in Tables 2 and 3. For both H_2S and odour concentrations, the model predicts higher concentrations than observed during ambient sampling at the fenceline. This is to be expected due to the conservative approach used in the modelling combined with the fact that it is difficult to capture worst-case odour impacts during an ambient sampling event. However, for the H_2S concentration, the model predicted concentrations that are approximately 80 times higher than measured at the fenceline, making the odour field measurement approach more reliable. The field-measurement approach using a Nasal Ranger is simple and easy for the operator to implement on a routine basis or during periods of highest off-site odour impacts.

Both the average, fenceline ambient odour and H_2S results correlate well with individual odour emission sources that can be clearly defined both from the plant and along the fenceline during ambient sampling. Several traceable or recognized odour sources were observed during the ambient fenceline odour sampling events and were modelled to see if the identified odour source matched the field ambient sampling results. This is an excellent approach to help prioritize individual odour emissions sources that have the greatest off-site impacts, as well as to determine a needed odour control requirement to bring the odour contours back to the WWTP's fenceline.

Table 1: Fenceline H_2S Sample Results

Sample Location	**Location Description**	**Measured Results**				**Predicted Results**	**Ratio of Predicted Average to Peak Measured**
		Average (ppm)	**Max (ppm)**	**Average (µg/m^3)**	**Max (µ g/m^3)**	**Average (µg/m^3)**	
1	Fenceline at South Entrance to Headworks	0.12	0.62	173	877	20,302	23.2
2	Fenceline at manhole in driveway	0.26	1.5	372	2,121	29,881	14.1
3	Fenceline at rock in driveway	0.08	0.39	108	552	47,583	86.3
4	Fenceline at roadsign	0.08	0.28	119	396	41,020	103.6
5	Main gate	0.04	0.28	55	396	32,083	81.0
6	½ way up hill from gate	0.04	0.3	56	424	21,608	50.9
7	NW corner of fenceline	0.03	0.16	48	226	14,542	64.3
8	Fenceline behind power pole	0.03	0.11	42	156	15,534	99.8
9	Fenceline past last tree (from W)	0.04	0.45	51	636	17,245	27.1
10	Fenceline 1/2 way b/w tree and sludge tanks	0.02	0.14	27	198	18,670	94.3
11	Fenceline behind sludge tanks	0.01	0.063	16	89	14,729	165.3
12	Fenceline b/w sludge tanks and digesters	0.01	0.13	20	184	13,165	71.6
13	Fenceline due East of digester (north of flare)	0.00	0.079	7	112	13,569	121.4
14	Canal at road	0.02	0.14	34	198	11,118	56.2
15	Canal at 1st break in trees	0.02	0.18	23	255	10,327	40.6
16	Canal just past trees	0.02	0.119	28	168	9,903	58.8

17	Canal due N of light at sludge tanks	0.02	0.12	22	170	12,619	74.4
18	Canal b/w sludge tanks & digesters	0.01	0.066	10	93	9,412	100.8
19	Canal at NE corner of plant	0.01	0.021	7	30	6,278	211.4
20	Fenceline behind digesters	0.02	0.15	22	212	13,569	64.0
						Average	**80.4**

Table 2: Fenceline Odor Sample Results

Sample Location	**Location Description**	**Measured Results**		**Predicted Results**		**Ratio of Predicted to Measured**	
		Average (D/T)	**Max (D/T)**	**Average (D/T)**	**Max (D/T)**	**Average**	**MAx**
1	Fenceline at South Entrance to Headworks	4.1	15.0	1.79	62.1	0.44	4.1
2	Fenceline at manhole in driveway	4.2	30.0	1.94	84.54	0.46	2.8
3	Fenceline at rock in driveway	1.8	7.0	2.32	105	1.32	15.0
4	Fenceline at roadsign	2.7	7.0	1.98	135	0.74	19.3
5	Main gate	3.3	30.0	1.66	114	0.51	3.8
6	½ way up hill from gate	1.3	4.0	1.27	92.51	0.99	23.1
7	NW corner of fenceline	1.9	7.0	0.93	67.27	0.49	9.6
8	Fenceline behind power pole	1.1	2.0	1.14	55.88	1.05	27.9
9	Fenceline past last tree (from W)	2.2	15.0	1.46	53.34	0.68	3.6
10	Fenceline 1/2 way b/w tree and sludge tanks	3.5	30.0	1.62	72.05	0.46	2.4
11	Fenceline behind sludge tanks	1.3	2.0	1.77	41.72	1.33	20.9
12	Fenceline b/w sludge tanks and digesters	1.9	15.0	1.8	49.11	0.96	3.3
13	Fenceline due East of digester (north of flare)	1.0	1.0	2.07	73.96	2.07	74.0
14	Canal at road	1.3	2.0	0.77	50.94	0.62	25.5
15	Canal at 1st break in trees	1.5	7.0	0.83	42.53	0.54	6.1
16	Canal just past trees	3.2	30.0	0.97	36.06	0.30	1.2
17	Canal due N of light at sludge tanks	1.1	2.0	1.21	46.02	1.11	23.0
18	Canal b/w sludge tanks & digesters	1.7	7.0	1.19	32.51	0.70	4.6
19	Canal at NE corner of plant	1.3	2.0	0.75	29.58	0.60	14.8
20	Fenceline behind digesters	4.7	30.0	2.09	54.44	0.45	1.8
					Average	**0.79**	**14.34**

Taking a closer look at one of the WWTP’s most significant odour sources, the Aerated Grit area captures several odourous sources, including the effluent channel leaving the headworks building and aerated grit basin and effluent channel. The predicted, 1-hour peak odour contours for the Aerated Grit area compared to predicted, 1-hour peak odour contours for all sources

(Figure 3), shows that the Aerated Grit area makes up over 90 percent of the off-site contribution to the odour impact in the immediate area. Using that same relationship and comparing the fenceline average sampling location results that are directly downwind of the Aerated Grit area to the average odour contours from all sources (Figure 4) to, it shows that the ambient monitoring average results closely match the modelled results, as demonstrated by the average D/T results in Table 3 for sampling sites 1-8. The comparison results are within 30 percent of each other and have the same general shape and profile.

Therefore, based on odour modelling and ambient measurement, the Aerated Grit area has high potential for off-site odour impacts and will require odour control to bring the odour contours back onto the WWTP site and reduce the off-site odour impacts. Dispersion modelling can then be used to determine the amount of odour control needed. Alternatively, ambient odour measurements can be scaled to determine this same amount of odour control required or used to demonstrate that the off-site odour impact has been reduced.

4. Conclusions

As seen in this case study, using hand-held odour sampling and metering devices can result in understanding off-site odour impacts ranges and profiles that are similar to results generated using dispersion models with emission source testing data. This means that a simple ambient monitoring program can be set up and calibrated using direct odour source measurements and dispersion modelling (if available) to provide early warning of an upcoming off-site odour event, to track current off-site odour effects and ensure that they are not getting worse, and/or to track odour-free periods. In addition, once acceptable, ambient readings have been established at the fenceline, this approach eliminates the need to remodel or resample at the odour sources in order to show compliance with odour standards.

Dispersion modelling is a needed tool that greatly assists WWTPs in planning for new odour sources and their odour control requirements, in looking at and designing for worst-case operating and meteorological conditions, and in addressing other operating scenarios. However, once acceptable odour emission standards have been established at a WWTP’s fenceline, ambient odour measurement using hand-held devices should then be considered to track ongoing compliance.

5. References

[1] Wang, Jie and Kenneth J. Skipka, Dispersion Modelling of Odorous Emissions, RTP Environmental Associates, June 13, 1993.

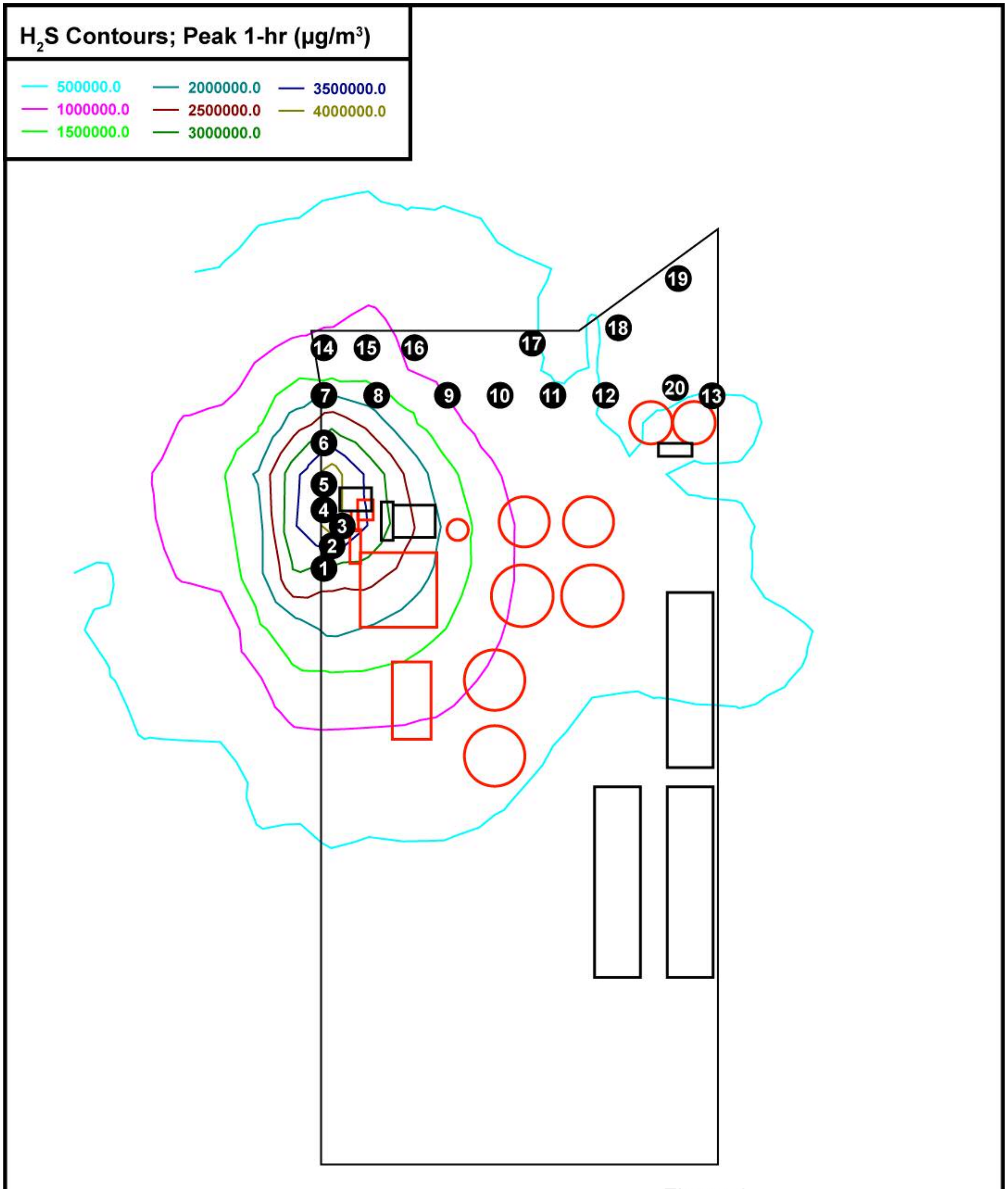

Figure 1
Hydrogen Sulfide Contours from All Sources

186740.WW.01_E082004007SEA_Fig 1 H2S Contours from All Sources Peak 1-hr _8/29/04_gm

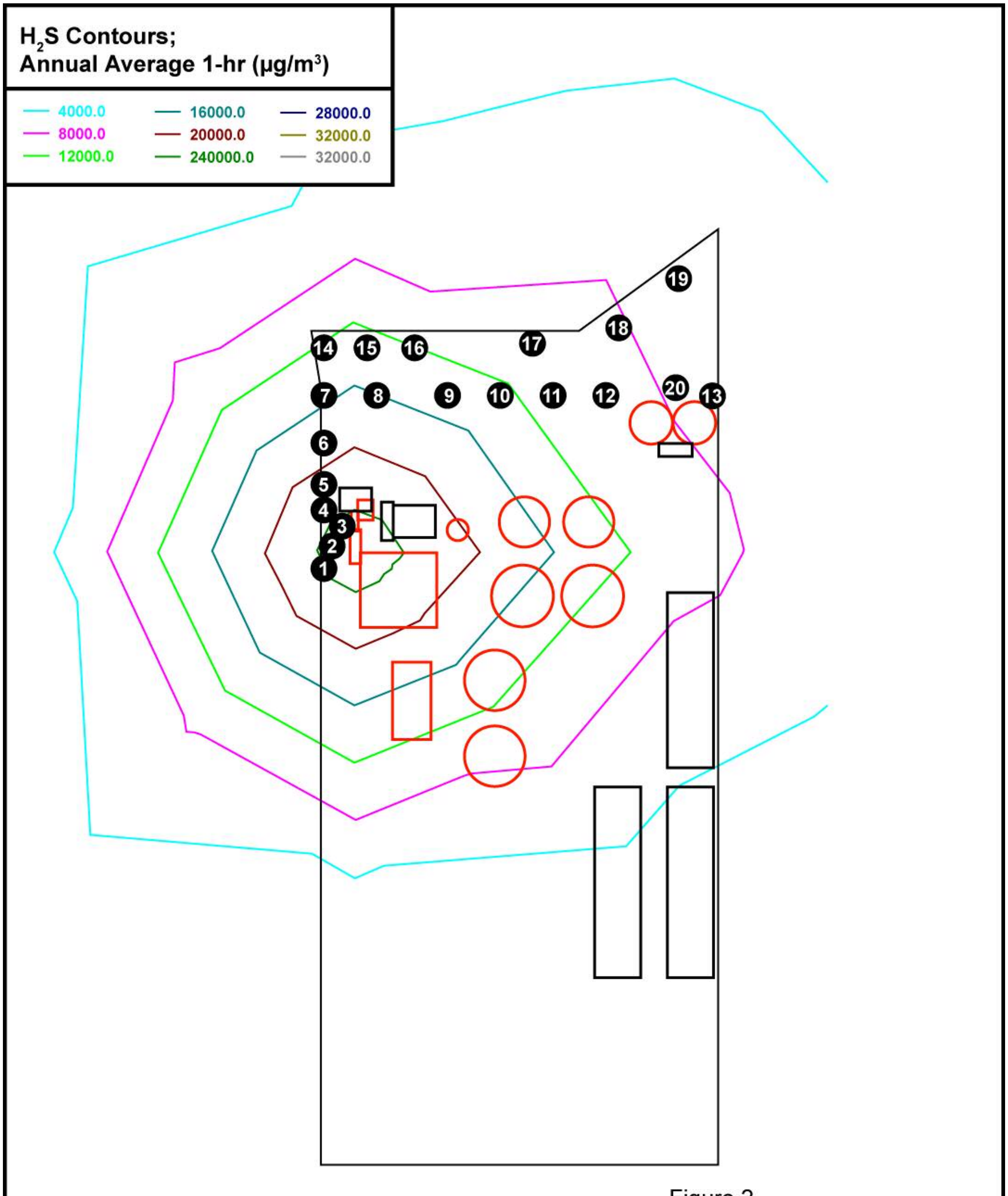

Figure 2
Hydrogen Sulfide Contours from All Sources

186740.WW.01_E082004007SEA_Fig 2 H2S Contours All Sources Annual Avg_8/29/04_gm

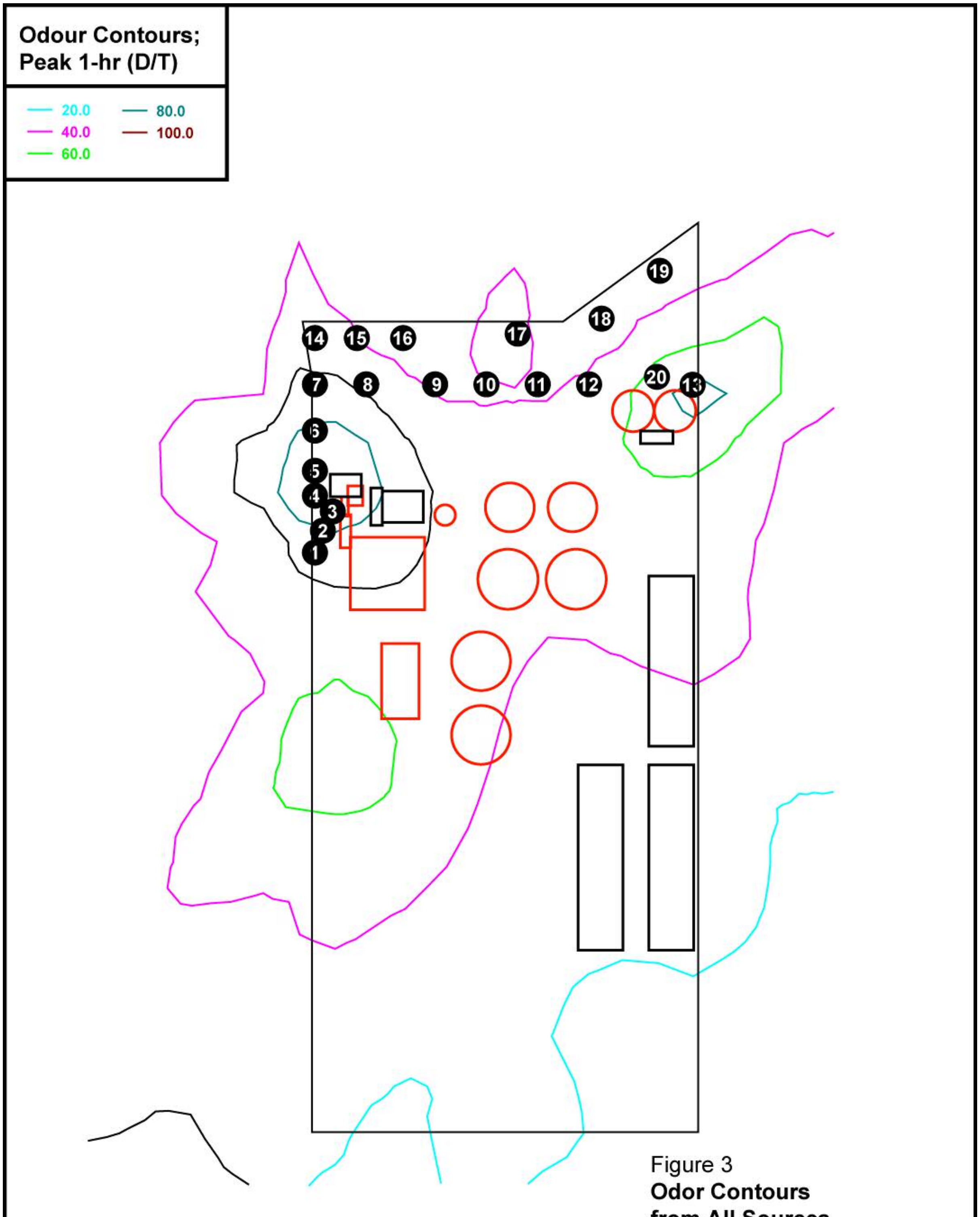

Figure 3
Odor Contours
from All Sources

186740.WW.01_E082004007SEA_Fig 3 Odor Contours All Sources Peak 1-hr DT_8/29/04_gm

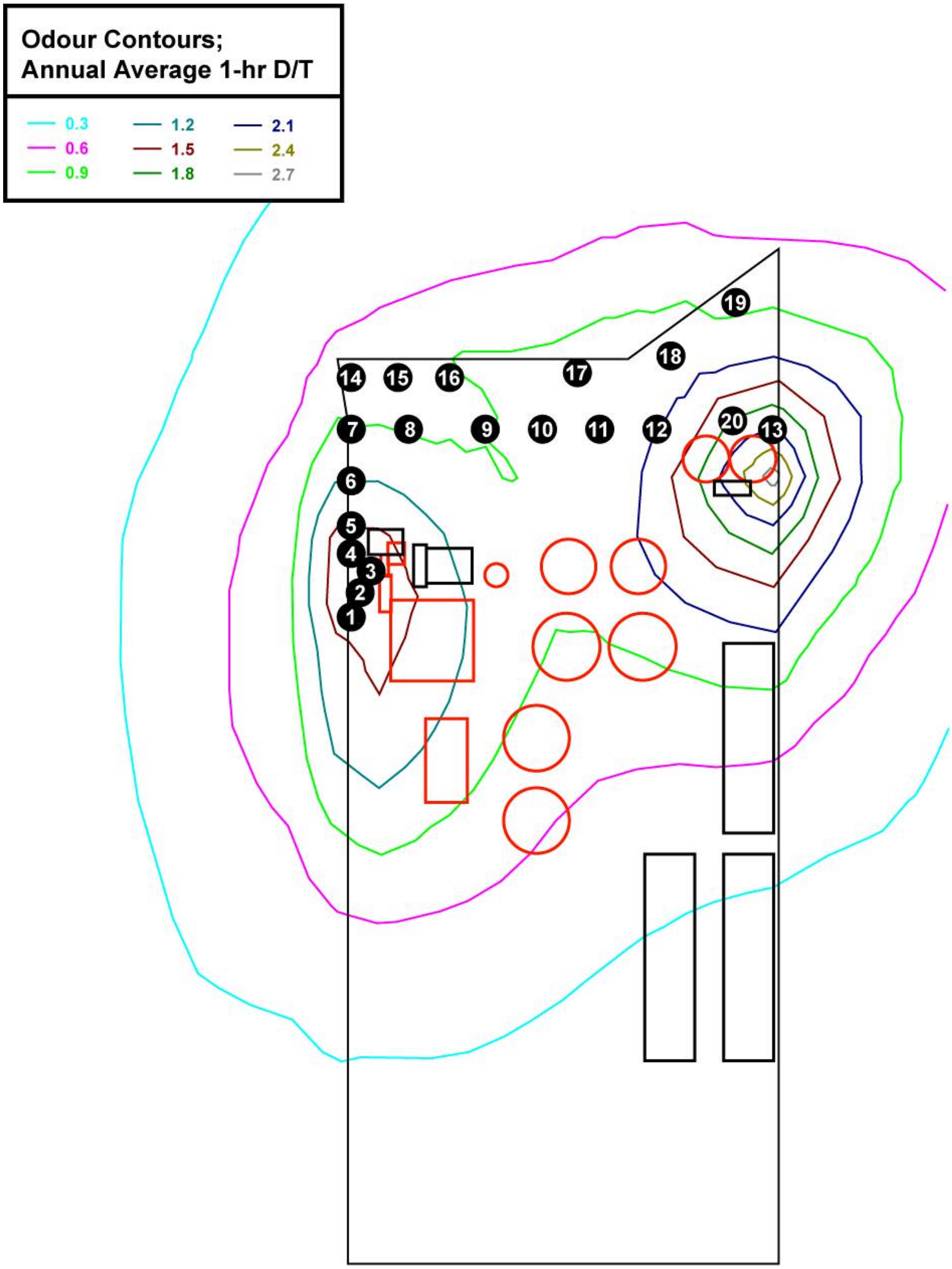

Figure 4
Odour Contours from All Sources

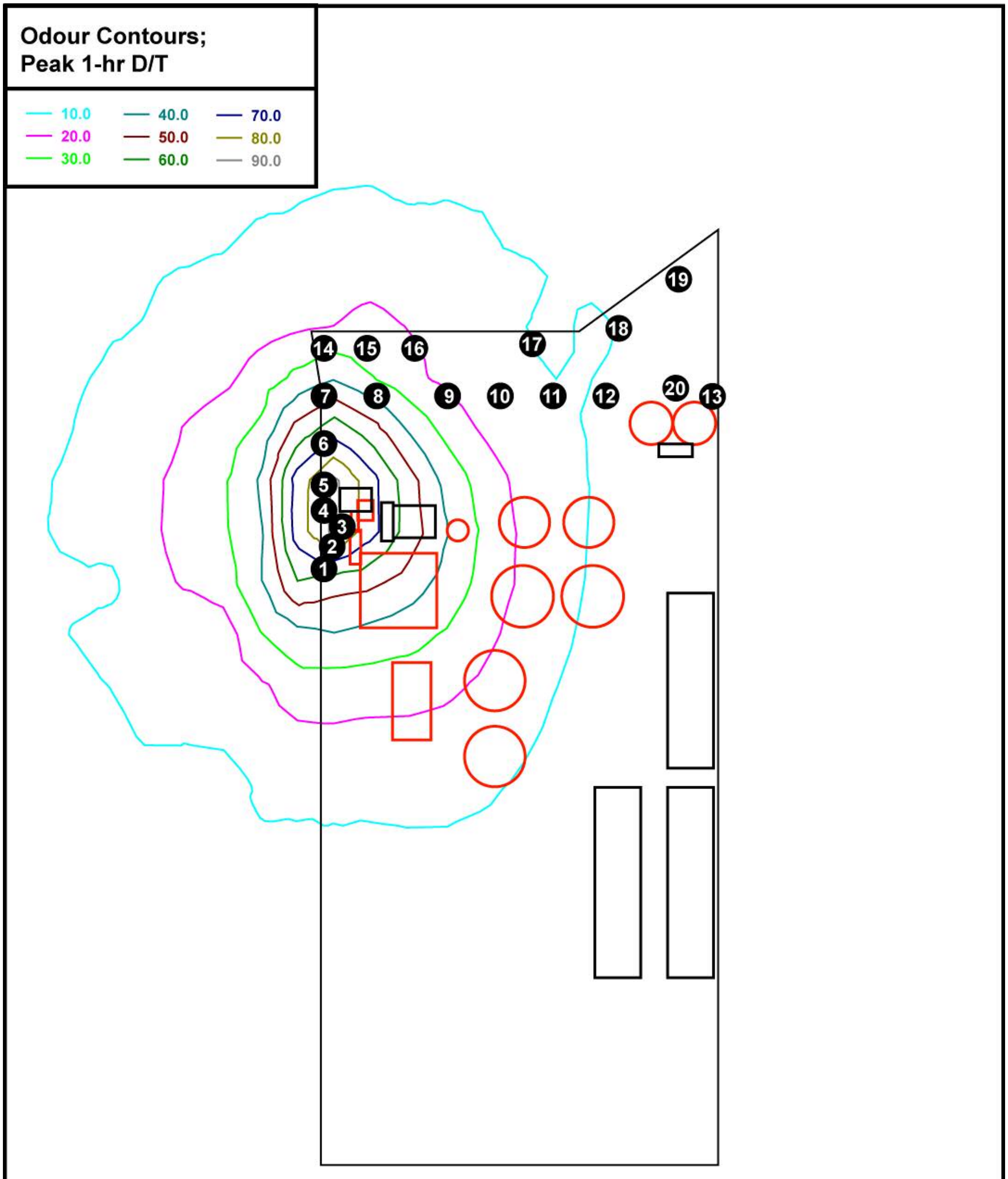

Figure 5
Odour Contours from Aerated Grit

186740.WW.01_E082004007SEA_Fig 5 Odour Contours Aerated Grit_8/27/04_gm