Jim Morrows Report used in Donald's Assessment

DRAFT

GEOTHERMAL SUBZONE
HYDROGEN SULFIDE IMPACT ASSESSMENT

1. INTRODUCTION

Geothermal research and development in Hawaii to date has indicated that hydrogen sulfide (H2S) is the air pollutant of primary concern due to its relatively high concentration in the Puna geothermal fluid, its inherent toxicity at high concentration and its very low odor threshold. The existing geothermal well, HGP-A, produces a fluid which contains approximately 900 parts per million by weight (ppmw) of H2S which is about 4 times that found at the Geysers geothermal area in California [1]. In this brief report, an effort has been made to assess the potential air quality impact of H2S emissions from future geothermal power plant development.

2. EXISTING H2S LEVELS

Air sampling data collected as part of ongoing monitoring in the area around the HGP-A well [2] and a special baseline study for the East Rift, Puna and Ka'u Districts [3] all indicate relatively low ambient levels of H2S. In the HGP-A area, the May 1981 - May 1982 annual average H2S level was 4.7 ug/m3 at a distance of approximately 1.1 miles southwest of the well

(Schroeder residence). The maximum 1-hour concentration at the same location was 66.8 micrograms per cubic meter (ug/m3), but this could not be related to well activity since the winds were coming from the northwest. The highest 1-hour concentration which could be related to well activity on the basis of wind direction (northeast) was 45.9 ug/m3. Monitoring data for 1983 indicated an even lower maximum hourly concentration (11.1 ug/m3) and an annual average of 2 ug/m3 [4]. This may be at least partially due to improved abatement facilities and operating efficiency of the HGP-A plant [5]. The Kilauea East Rift baseline study [3] reported H2S levels in a range of 0.06 to 1.8 ug/m3. It should be noted, however, that these were based on one to two week integrated samples rather than continuous monitoring as occurs in the HGP-A monitoring network.

3. H2S IMPACT ANALYSIS

a. Complex Terrain. Maximum estimated H2S concentration based on a 25 megawatt (MW) power plant scenario were extracted from the Dames & Moore report and used to generate estimates for four additional plant scenarios. A 1,000 ppmw H2S content in the geothermal fluid and an overall H2S removal efficiency for both power plant and well (steam stacking) of 98% were assumed. The remaining design parameters used in this analysis may be found in Reference 1 Table 9.2-1.

The four additional plant sizes considered were 55, 80, 110, and 250 megawatts (MW). The 25 MW size was picked because it is the size most likely to be built initially based on short-term electrical demand on the Big Island. The rationale for the others may be summarized as follows:

- 55 MW: the next most likely size after 25 MW
- 80 MW: a feasible large capacity plant
- 110 MW: the largest built single plant
- 250 MW: the maximum projected scenario for the Big Island

A single 250 MW plant is highly unlikely, but a more likely worst case scenario might involve three 80 MW plants about 2 kilometers apart each with its own well field providing the geothermal fluid [6].

Estimated maximum 1-hour H2S concentrations are presented in Table 1. Although the State has not promulgated an ambient air quality standard for H2S, proposed standards [7] have been cited in the table for comparative purposes. The "increment" is the allowable amount of additional H2S from manmade sources. The "ambient standard" is the sum of natural background levels of H2S plus the H2S contributed by manmade sources. Both are 1-hour average values. Under the proposed rules, one exceedance per year of those values is permitted; thus, in reviewing Table 1 for possible violations, one should look at the "second highest" values rather than the "highest."

The results suggest that single power plants up to 80 MW could meet both the increment and the ambient standard under normal operating conditions. When their is a plant malfunction, however, and steam stacking occurs, only the 25 MW plant seems able to meet the increment, while the 55 MW and 80 MW plants can only meet the less restrictive ambient standard. It should be noted that these maximum concentrations generally occurred at terrain elevations approximately the same as the effective plume height from the plant. This is normally the case in so-called complex terrain where nighttime plumes moving in stable air with low wind speed come in contact with hillsides at the same height as the stack or the plume itself. It should also be noted that the assumed H2S removal efficiency for steam stacking was 98% when experience at the existing HGP-A well has found 95% removal to be a more realistic upper limit of control [6]. With 95% control the concentrations for steam stacking in Table 1 would be 2.5 times greater in magnitude.

b. Flat Terrain. An EPA-developed air quality simulation model, PTMAX [8], was used for demonstrating the range of maximum groundlevel 1-hour H2S concentrations under a variety of meteorological conditions in flat or gently rolling terrain. The 25 Mw plant parameters were again taken from the Dames & Moore report [1]. Estimated maximum 1-hour H2S concentrations for normally operating power plants and wells under steam stacking conditions are presented in Tables 2 and 3,respectively. In this example, a 95% H2S removal efficiency was assumed for steam stacking conditions. The results in Table 3 can be converted to 98% control for comparison with Table 1 by dividing the concentrations by 2.5. It should be noted that these tables contain maximum values, not second highest, and thus are not directly comparable to the proposed increment and standard. They can serve as an indication of potential problems, however.

The results for normally operating individual plants (Table 2) suggest that the previously proposed 1-hour increment of 35 ug/m3 would be met under virtually all meteorological conditions in flat terrain. It can thus also be implied that the proposed ambient standard of 139 ug/m3 would also be met provided that unusually high natural background levels did not coincide with the maximum concentrations associated with the larger plant sizes.

Under steam stacking conditions with 95% H2S removal efficiency, however, the larger size facilities (> 25 MW) would appear to have difficulty complying with an increment of 35 ug/m3 and, based on previous data on the range of naturally occurring H2S levels in the Puna area, might also have trouble meeting an ambient standard of 139 ug/m3. Higher removal efficiencies appear to be necessary to insure compliance with the proposed increment and standard.

4. DISCUSSION & CONCLUSIONS

The foregoing analysis was an attempt to characterize the possible hydrogen sulfide (H2S) impacts associated with geothermal development in Hawaii. It was based on existing data and studies with only a brief screening analysis of flat terrain impacts introduced as new material. It was not intended to be exhaustive or to address specific impacts of specific projects in specific locales. This will have to be done at the time such projects are proposed and when detailed design data are available.

One area not quantified in this screening analyis was fugitive H2S emissions. Leaking valves and joints in the system can result in release of what are referred to as "fugitive" emissions. Good design and maintenance can largely eliminate such emissions, but the lack thereof could result in low height emission sources which could effect nearby properties. Also, H2S emissions from the liquid phase of the geothermal resource after gas-liquid separation (partitioning) could be significant if not abated in some manner. Experience at HGP-A indicates approximately 98% partitioning which means about 2% of the H2S goes with the liquid (brine) and can escape to the atmosphere if not retained in solution by physical or chemical means.

An approximation of the concentrations that may be expected from 2% uncontrolled fugitive emissions would be the results found in Tables 1 and 2 because they represent the outcome of 98% control (which means 2% are released). In fact, they may be on the low side because (1) they represent 98% control of 98% of the total H2S and (2) fugitive emissions would likely be released at a lower height and with little or no dilution air as occurs in a forced draft cooling tower.

From this brief screening analysis, the following conclusions may be drawn:

- a 25 MW plant with at least 98% H_2S removal efficiency appears capable of meeting the previously proposed state increment and ambient standard under normal and abnormal (steam stacking) operating conditions.

- larger plant sizes may need higher efficiency H_2S control systems and or adequate buffer zones in order to meet the proposed increment and standard.

- maximum H_2S impacts appear to be associated with terrain elevations at or above the stack height.

- fugitive H_2S emissions from low height release points within a facility have the potential for creating significant H_2S concentrations near the source if not adequately addressed in design and maintenance of the facility.

- release of exhaust gases from the control system into the cooling tower can further reduce ambient H_2S concentrations by dilution.

- although smaller plants seem capable of meeting the proposed increment and standard, the cumulative impact of several such plants might encounter compliance problems depending on their relative locations and control efficiencies.

TABLE 1

ESTIMATED 1-HOUR HYDROGEN SULFIDE
CONCENTRATIONS

SOURCE	Concentration (ug/m^3) 25 MW	55 MW	80 MW	110 MW	250 MW
POWER PLANT:					
Highest	12.3	27.1	39 *	54 *	123 **
2nd Highest	9.4	20.7	30	41 *	94 *
STEAM STACKING:					
Highest	38 *	84 *	122 *	167 **	380 **
2nd Highest	31	68 *	99 *	136 *	310 **

Notes: 1. Based on 25 MW estimates from Dames & Moore report dated 30 January 1984. Other plant sizes based on linear extrapolation.

2. * - denotes exceeds proposed 35 ug/m^3 increment
** - denotes exceeds proposed 139 ug/m^3 standard

TABLE 2

MAXIMUM ESTIMATED H2S CONCENTRATIONS
IN FLAT OR GENTLY ROLLING TERRAIN
FROM GEOTHERMAL POWER PLANTS

Atmospheric Stability	Wind Speed (m/sec)	Downwind Distance (km)	1-Hour H2S Concentration (ug/m^3) 25 Mw	55 Mw	80 Mw	110 Mw
	0.5	1.4 (2)	1.2	2.5	3.7	5.1
	0.8	1.1 (2)	1.4	3.0	4.4	6.1
Very Unstable	1.0	1.0 (2)	1.5	3.3	4.8	6.6
	1.5	0.8 (2)	1.7	3.8	5.6	7.7
	2.0	0.7 (2)	1.9	4.2	6.2	8.5
	2.5	0.7 (2)	2.1	4.6	6.6	9.1
	3.0	0.6	2.2	4.8	7.0	9.7
	0.5	6.3 (2)	0.4	0.8	1.2	1.7
	0.8	4.1 (2)	0.6	1.2	1.8	2.4
	1.0	3.4 (2)	0.7	1.4	2.1	2.9
	1.5	2.4 (2)	0.9	1.9	2.8	3.9
Unstable	2.0	1.9 (2)	1.1	2.4	3.5	4.8
	2.5	1.5 (2)	1.3	2.8	4.0	5.5
	3.0	1.3	1.4	3.1	4.6	6.3
	4.0	1.0	1.7	3.8	5.5	7.5
	5.0	0.9	2.0	4.3	6.3	8.6
	2.0	3.8 (2)	0.8	1.8	2.6	3.6
	2.5	3.0 (2)	1.0	2.2	3.1	4.3
	3.0	2.5	1.1	2.5	3.7	5.0
Slightly Unstable	4.0	1.9	1.4	3.2	4.6	6.3
	5.0	1.5	1.7	3.7	5.4	7.5
	7.0	1.1	2.1	4.7	6.8	9.4
	10.0	0.8	2.6	5.8	8.4	11.6
	12.0	0.7	2.9	6.3	9.2	12.7
	15.0	0.6	3.2	6.9	10.1	13.9

TABLE 2 (Con't)

	0.5	209 (2)	0.0	0.1	0.1	0.1
	0.8	84 (2)	0.1	0.1	0.2	0.3
	1.0	55 (2)	0.1	0.2	0.3	0.4
	1.5	27 (2)	0.2	0.4	0.6	0.8
	2.0	17 (2)	0.3	0.6	0.9	1.2
	2.5	12 (2)	0.4	0.8	1.2	1.6
Neutral	3.0	8.9	0.5	1.1	1.5	2.1
	4.0	5.9	0.7	1.5	2.2	3.0
	5.0	4.2	0.9	2.0	2.8	3.9
	7.0	2.7	1.3	2.8	4.1	5.6
	10.0	1.7	1.8	3.9	5.7	7.8
	12.0	1.4	2.0	4.5	6.6	9.0
	15.0	1.1	2.4	5.3	7.7	10.6
	20.0	0.8	2.7	6.0	8.7	12.0
	2.0	7.1	1.8	4.1	5.9	8.1
Slightly Stable	2.5	6.3	1.8	3.9	5.7	7.8
	3.0	5.8	1.7	3.7	5.4	7.5
	4.0	5.1	1.6	3.5	5.1	7.0
	5.0	4.6	1.5	3.3	4.8	6.5
	2.0	13.7	1.6	3.4	5.0	6.9
	2.5	12.0	1.5	3.3	4.9	6.7
Stable	3.0	10.8	1.5	3.2	4.7	6.5
	4.0	9.2	1.4	3.1	4.5	6.2
	5.0	8.1	1.4	3.0	4.3	6.0

Notes:

1. Based on 25 MW estimates from Dames & Moore report dated 30 January 1984. Other plant sizes based on linear extrapolation.

2. Plume height is of sufficient height that extreme caution should be used in interpreting the results as this stability may not exist to this height. Also, wind speed variations with height may exert a dominating influence.

TABLE 3

MAXIMUM ESTIMATED H2S CONCENTRATIONS
IN FLAT OR GENTLY ROLLING TERRAIN
FROM STEAM STACKING AT GEOTHERMAL WELLS

Atmospheric Stability	Wind Speed (m/sec)	Downwind Distance (km)	1-Hour H2S Concentration (ug/m^3) 25 Mw	55 Mw	80 Mw	110 Mw
Very Unstable	0.5	1.3 (2)	5.2	11.5	16.7	22.9
	0.8	1.0 (2)	6.3	13.8	20.1	27.6
	1.0	0.9 (2)	6.9	15.1	21.9	30.2
	1.5	0.8 (2)	8.0	17.6	25.6	35.2 *
	2.0	0.7 (2)	8.9	19.6	28.5	39.1 *
	2.5	0.6	9.6	21.2	30.8	42.4 *
	3.0	0.6	10.3	22.7	33.0	45.4 *
Unstable	0.5	5.5 (2)	1.8	4.0	5.9	8.1
	0.8	3.6 (2)	2.6	5.8	8.5	11.7
	1.0	2.9 (2)	3.1	6.9	10.1	13.8
	1.5	2.1 (2)	4.3	9.4	13.7	18.8
	2.0	1.6 (2)	5.3	11.7	17.0	23.4
	2.5	1.3	6.3	13.8	20.0	27.5
	3.0	1.1	7.1	15.7	22.8	31.4
	4.0	0.9	8.7	19.1	27.8	38.3 *
	5.0	0.7	10.1	22.2	32.3	44.3 *
Slightly Unstable	2.0	3.1 (2)	4.1	9.0	13.1	18.0
	2.5	2.5	5.0	11.0	16.0	22.0
	3.0	2.1	5.9	12.9	18.8	25.9
	4.0	1.5	7.5	16.5	24.1	33.1
	5.0	1.2	9.0	19.9	28.9	39.7 *
	7.0	0.9	11.7	25.8	37.5 *	51.6 *
	10.0	0.6	15.1	33.1	48.2 *	66.2 *
	12.0	0.5	16.9	37.1 *	54.0 *	74.3 *
	15.0	0.4	19.1	42.1 *	61.2 *	84.2 *

TABLE 3 (Con't)

	0.5	156 (2)	0.2	0.4	0.5	0.8
	0.8	62 (2)	0.4	0.8	1.2	1.6
	1.0	41 (2)	0.5	1.2	1.7	2.3
	1.5	20 (2)	1.0	2.2	3.2	4.4
	2.0	13 (2)	1.5	3.4	4.9	6.7
	2.5	8.9	2.1	4.6	6.7	9.2
Neutral	3.0	6.7	2.7	5.9	8.6	11.8
	4.0	4.4	3.9	8.6	12.5	17.2
	5.0	3.1	5.2	11.4	16.6	22.9
	7.0	2.0	7.7	16.8	24.5	33.7
	10.0	1.2	11.1	24.5	35.6 *	49.0
	12.0	1.0	13.2	29.0	42.2 *	58.1
	15.0	0.8	15.4	33.8	49.1 *	67.5
	20.0	0.6	18.1	39.9 *	58.0 *	79.7
	2.0	5.6	9.9	21.9	31.8	43.7
Slightly	2.5	5.0	9.5	20.9	30.4	41.9
Stable	3.0	4.5	9.2	20.2	29.3	40.3
	4.0	3.9	8.6	19.0	27.6	38.0
	5.0	3.5	8.2	18.1	26.3	36.2
	2.0	10.0	9.1	20.0	29.1	40.0
	2.5	8.7	8.9	19.7	28.6	39.3
Stable	3.0	7.7	8.8	19.4	28.2	38.7
	4.0	6.5	8.5	18.7	27.2	37.4
	5.0	5.7	8.2	18.0	26.2	36.0

Notes:

1. Based on 25 MW estimates from Dames & Moore report dated 30 January 1984. Other plant sizes based on linear extrapolation.

2. Plume height is of sufficient height that extreme caution should be used in interpreting the results as this stability may not exist to this height. Also, wind speed variations with height may exert a dominating influence.

3. * = exceeds proposed increment of 35 ug/m^3.