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INTERIM REPORT: STUDIES OF BORON DEPOSITION NEAR GEOTHERMAL POWER PLANTS

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INTERIM REPORT:

STUDIES OF BORON DEPOSITION NEAR GEOTHERMAL POWER PLANTS

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The summer and fall of 1979 were an intense period of field research at the Geysers geothermal area. Environmental Sciences Division personnel made measurements in the Geysers area from April until October 1979 when the onset of seasonal rains limited field work and some of the measurements being made.

Field studies involved three basic types of measurements which are listed below.

Cooling Tower Drift Deposition

A. Phytometer studies of drift deposition on botanical test organisms.
   1. Field-grown barley in pots.
   2. Lichens in cheesecloth bags.

B. Passive integrating air samplers - cheesecloth bags on frames.

C. Drift deposition and composition studies - conducted at Unit 12 in cooperation with Environmental Systems Corp. group.

Plant Ecological Studies

- Plant foliage collections and measurements which were correlated with deposition onto passive integrating samplers and barley pot study.

Animal Population Studies

- Small collections were made at Units 12, 15, and 7/8 and in a suitable control area to the west of the Geysers area.

Brief summaries of the data obtained in most of these work areas will be made to demonstrate the type of information being obtained in this program.

Drift Deposition Studies

Phytometer Methods. Two test organisms were used in the cooling tower drift studies conducted primarily at Units 12 and 7/8. Previous studies by P.G.&E. scientists (1) have shown that the vegetation damage is apparent at most of the geothermal units in operation except the most recently commissioned ones (Units 15 and 12). The damage pattern often extends in a southerly direction and downslope. Since this is the direction (south) to which nighttime mesoscale and microclimatic air masses move, there is a suggestion that nighttime conditions may be the most effective in producing the phytotoxic effect evident. Since the psychrometric conditions change during the night, it is possible that nighttime deposition of cooling tower drift involves the actual deposition of droplets of drift onto the leaves. Stomatal resistance would be high during the early nighttime and stomatal openings would be closed. Deposition of drift droplets onto the leaves during nighttime conditions could reach sensitive leaf protoplasm by diffusion through cuticle and epidermis, or through stomatal openings when the stomata open late at night or early in the morning. Since the Mediterranean sclerophyllous vegetation indigenous to the Geysers area will experience water stress late in the summer season as droughty conditions prevail, it is quite possible that most of the damage occurs from drift in the early part of the growing season and at night, or from nighttime deposition. It is apparent that physiologically significant concentrations of boron and other drift constituents enter the leaf and are within the mesophyll of the leaf or else tightly complexed to cuticular and epidermal macromolecules. For example, the boron concentrations observed in leaves collected at the Geysers geothermal units cannot be eluted from the leaves with distilled water and a surfactant, and are tightly held within or on the leaf.

It may be possible to test some of the hypotheses described above during the early operational period of Unit 13 which is an isolated unit that will be commissioned during the summer of 1980. There will be less cross-talk from other operational units at Unit 13 and some of the questions concerning the mechanism of the phytotoxic response may be answered with a few simple experiments and measurements in that area.

Some preliminary results are shown in Tables 1 through 6. These data have not been subjected to intensive study and have been compiled primarily for this Interim Report.

The composition of cooling tower water from Unit 12 is shown in Table 1. It is apparent from these analyses that boron, iron, potassium, and sulphates are the major elements released to the environment from the cooling towers. The daily flux of these elements can be estimated by using the concentrations in Table 1 and the daily water loss from the unit's cooling system. Material balance measurements should be made at these units to provide a useful value for estimating potential environmental effects. It is possible that the sulphates released have as great a phytotoxic effect as the boron which has previously been cited as the causal agent for plant damage in the Geysers area.

During the latter part of June, an intensive study was conducted at Unit 12 by LLL personnel and the Environmental Systems Corp. under contract to LLL. Some of the drift deposition data obtained at that time are shown in Table 2. Three days of measurements were made and the values in Table 2 show that a distance profile of boron deposition existed on two of the three days. On June 28, an unusually high deposition of boron was observed at the 120 m station which may be related to greater wind shear of the drift plume and higher levels of ground deposition at the station.

The 50-hour integrated deposition values are unexpectedly low based on the daily, short-term (4.5 h) data. It is possible that losses occur from the sampling devices with longer exposures. Other depositional data will be compared to these and the method will be re-evaluated.

Another method of estimating deposition used in the Unit 12 study was the cheesecloth bag sampler. This sampler approximates foliage deposition more closely than a ground area deposition. Data from six cheesecloth samplers and a blank of the cloth material are shown in Table 3. It is apparent that the major elemental effluents in cooling tower drift are well-represented in the elements extracted from the samplers after three weeks of exposure. The high concentrations of nitrates cannot be explained at this time but may be related to airborne algal spores or pollen or some other contaminant which have a measurable nitrogen content. The sampler in a sense integrates the aerosols moving through it and possesses a moderate cation exchange capacity. Maximum boron, sulphate, nitrate, iron, and potassium were observed on the same sampler. The Cobb Mountain sampler data suggest that low levels of some effluent elements may be leaving the Geysers valley.

In Table 4, data from a wider geographic series of cheesecloth samplers is shown. The four elements chosen were boron, chlorine, potassium, and sulphates. The sampler placed at Unit 7/8 (south side) yielded data which suggests that the most effective deposition of cooling tower drift was toward the south. Vegetation in this area shows the greatest foliage damage and have high concentrations of boron (200-600 ppm). It is possible that the sulphate levels measured by these methods would exert as great a phytotoxic effect at the boron levels observed. The two measurements on Sawmill Flats Road on the north side of Cobb Mountain, as the road drops to Bottle Rock Road and Putah Creek Valley, suggest also that some drift or well-site effluents are moving over Cobb Mountain into the adjacent airshed to the east. The levels are low but still easily detectable. No values for air moving into the Geysers development area from the west have been obtained but will be to provide an adequate baseline for comparison with these data.

In addition to the passive cheesecloth samplers, a series of pots of young barley plants were placed in the field at study sites where other sampling methods and devices were used. All plants received the same cultural methods and being potted in a standard soil, eliminated root uptake of previously deposited boron. Table 5 contains the barley pot data and the boron concentrations in barley leaves is contrasted with data obtained by two other samplers.

The lichens with their high affinity for airborne materials complexed the largest amount of total boron. The total boron complexed by the barley plants could not be calculated because of losses of biomass from the pots in the field. The three methods agree relatively well, however, the barley values suggest greater deposition at the 120 m station which also was evident in data in Table 2.

Small mammals were live-trapped around Units 12, 7/8, 9/10, and 15 in the summer of 1979. A sample of the same species of rodents was also obtained 18 miles west of the Geysers area.

The ranges of values obtained for boron in animal organs and animals collected at the three units and the control area are shown in Table 6. The G.I. tract, liver, and kidney data are shown. The data are not completely conclusive and suggest that regional geochemical levels of boron may be high in the soil and vegetation and which are entering small mammal food chains. The kidney which is the major organ of accumulation for boron as excretion takes place has levels which may indicate that elevated concentrations occur in the Geysers area. Values higher than the maxima shown in Table 6 have recently been determined (greater than 200 ppm) and it is apparent that when compared to the control values, these data are significantly higher and point to higher local levels of boron in animal populations in the Geysers development area.

Additional analytical work must be done to complete the 1979 studies, and a total analysis of the data base by standard statistical methods. A small series of pre-operational samples was obtained at the newly commissioned Unit 13 and these data will have to serve as the baseline for the unit which has recently become operational.

In conclusion, the preliminary data presented here demonstrate deposition of cooling tower drift effluent in adjacent environments to the operational units in the Geysers area. Phytotoxicity may be caused by several constituents of the cooling tower water, such as boron, sulphates, chlorine, and possibly a trace metal such as copper. The major evidence points to boron or sulphates. A considerable amount of analytical data on foliage samples, not presented here, is available and may yield an answer to the question of the primary causal factor in plant damage evident in the Geysers area. Total sulphur measurements will be made on a selected series of vegetation foliage samples, especially those that show high boron concentrations.

The integrated effect of cooling tower drift deposition upon ecosystems adjacent to geothermal power plants cannot be described from these preliminary studies. It is apparent that measurable deposition of cooling tower effluents occurs onto the landscape and the major point requiring elucidation is whether or not the integrated annual (or longer) deposition will have cumulative, deleterious effects on adjacent or contiguous terrestrial or aquatic ecosystems.

With a seasonal rainfall regime such as that which occurs in California, it is possible that heavy pulses of rainfall may elute significant quantities of geothermal effluents deposited on the landscape into surface hydrological systems. The potential dilution is large under such conditions, and, unless the effluent is highly toxic such as arsenic or mercury, the expected effects may not perturb ecosystem function or the physiology of component organisms. The major question remaining is the effect of the deposited pool of effluent elements on the surrounding ecosystems and their biota.

Sites sampled and studied during the spring and summer of 1979 are shown in Figure 1.

REFERENCE

1. B.S. Malloch, M.K. Eaton, and N.L. Crane. 1979. "Assessment of Vegetation Stress and Damage near the Geysers Power Plant Units," P.G. & E. Company Department of Engineering Research Report 420-79.3, February 13, 1979.

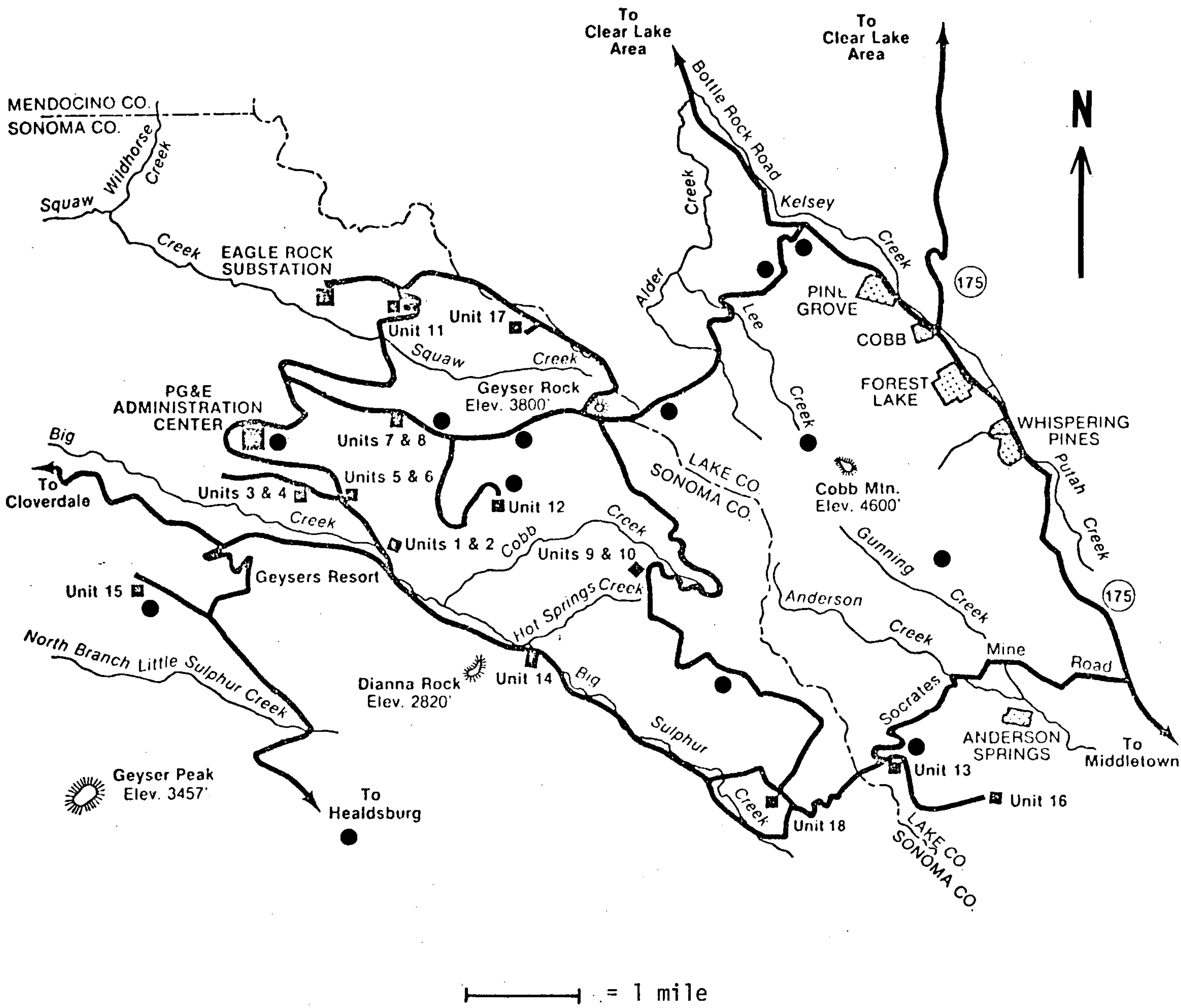

Figure 1. Map of the Geysers area.
Sites sampled and studied during summer 1979, Environmental Sciences Division. ●

Table 1. Composition of Unit 12 Cooling Water (June 28, 1979)

	3:20 p.m.	6:10 p.m.
Cations:*		
As	0.06 ppm	0.03 ppm
B	77.4 ppm	82.3 ppm
Fe	29.6 ppm	25.9 ppm
Mn	1.04 ppm	0.65 ppm
P	0.14 ppm	0.17 ppm
Pb	0.04 ppm	0.05 ppm
Zn	0.08 ppm	0.04 ppm
Ca	1.46 ppm	1.75 ppm
K	68.8 ppm	284.0 ppm
Mg	0.28 ppm	0.42 ppm
Na	4.45 ppm	7.91 ppm
Anions: †		
F	0.55 ppm	No data
Cl	10.0 ppm	6.8 ppm
SO_4	1425.0 ppm	700.0 ppm

* Analyzed by inductively coupled argon plasma spectroscopy.

† Analyzed by anion chromatography.

Table 2. Boron Deposition From Cooling Tower Drift at Unit 12, Geysers Area, June 26-28, 1979.

	Downwind Sector of Plume (46°-51° E. of N.)		
June 26, 1979			
Station	4	5	6
Distance	41 m	83 m	120 m
B(μg/m²)	545.1	225.6	142.2
B(μg/m²/h)	121.1	50.1	31.6
June 27, 1979			
Station	4	5	6
Distance	41 m	83 m	120 m
B(μg/m²)	343.2	235.3	155.2
B(μg/m²/h)	76.3	52.3	34.5
June 28, 1979			
Station	4	5	6
Distance	41 m	83 m	120 m
B(μg/m²)	451.3	179.3	448.0
B(μg/m²/h)	100.3	39.8	99.5
Mean Deposition (4.5 h period)	99.2 ± 22.4	47.4 ± 6.7	55.2 ± 38.4

Table 3. Anion and Cation Concentrations on Cheesecloth Samplers Exposed in the Geysers Area, June-July, 1979. (21 Days Exposure)

	Total µg on Sampler										
Sample Location	F	Cl	PO_4	NO_3	SO_4	B	P	Ca	Na	K	Fe
Blank	5.5	90	---*	---	---	---	12	38	108	17.5	2.3
Unit 12, 120 m	37.5	425	75	1000	800	140	27.5	246.5	413	122.0	2.8
Unit 12, 41 m	45.0	850	---	1475	3050	165	15.0	264.0	959	540.0	68.0
Unit 12, 1200 m	40.0	850	160	1400	500	105	48.0	255.0	482	459.0	11.0
Unit 9/10, 60 m	7.0	180	---	250	240	121	43.0	181.0	200	45.0	3.0
Unit 9/10, 130 m	8.0	525	1125	460	460	116	27.0	188.0	324	104.0	35.0
Cobb Mtn., at Geyser Rock	---	92	---	70	82	27	29.0	122.0	56	422	9.0

* Not Detected

Table 4. Boron, Chlorine, Potassium, and Sulphate Concentrations on Cheesecloth Samplers Exposed in the Geysers Area, June-July, 1979 (21-22 Days Exposure).

	Total μg of Element on Sampler			
Location	B	Cl	K	SO_4
Unit 12, 1200 m S.E.	105	---*	497.0	---
Unit 12, 83 m S.E.	82	800	555.0	1850
Unit 15, 150 m E.	130	500	130.5	365
Unit 9/10, 60 m E.	121	840	520.0	1250
Unit 7/8, 75 m N.E.	65	290	408.0	270
Unit 7/8, 150 m S.	423	750	905.0	2000
Adm. Bldg.- P.G. & E.	32	1850	384.5	1450
Cobb Mtn. near Geysers Rock	27	---	422.2	---
Sawmill Flats Rd.-0.4 m from Bottle Rock Rd.	14	235	113.5	165
Sawmill Flats Rd.-1.4 m from Bottle Rock Rd.	15	280	94.5	260
Blank Cheesecloth	0	90	15.0	0

* Not analyzed.

Table 5. Deposition of Boron on Test Plants, Cheesecloth Bags, and Lichen Bags (Passive Collectors at Unit 12, Geysers Area, California, June 26 - July 11, 1979.

	Boron (ppm dry wt.) Barley Plants*	Total B(μg) on Collector Cheesecloth Bags	Total B(μg) on Collector Lichen Bags
LLL Greenhouse Grown Plants N = 3	5.7	NA**	NA**
Unit 12 Exposed Plants† N = 4 per station			
42 m from plant	52.7 (28-75)††	190	902.3
83 m from plant	22.6 (19-26)	127	140.1
120 m from plant	38.5 (35-45)	72.0	86.3

* All plants grown in pots in same soil in LLL greenhouse; test plants exposed to Unit 12 environment for June 26 - July 11, 1979 period.

** Not applicable

† Pots placed in field and watered; soil uptake was elimated and only foliar deposition is believed to have occurred. Dry weights of barley leaves are from 7-10 gm.

†† Range of measurements.

Table 6. Boron Concentrations in Small Mammals Collected in the Geysers Area and in a Control Area West of the Geysers.

Location	Kidney	Liver	GI Tract
Control Area	14 - 63	1.9 - 10.5	2.9 - 24
Unit 12	5.5 - 70.4	3.6 - 5.4	5 - 34
Unit 7/8	22 - 108.3	5.2 - 11.4	9 - 59
Unit 9/10	6.4 - 126.9	2.1 - 12.8	7 - 56

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