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MASTER

Project NOSAMP*

A Baseline Study of the Impact of Energy Development on Weather In The Northern Plains

by

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A. Possible Link Between Coal Development and Rainfall

The coal resources of Montana, Wyoming, and North Dakota, are now being developed at an increasing pace, as indicated by the present mine-mouth power plant construction (1, 2), applications for land leases by utility companies, and recent increases in railroad tonnage reaching eastern and midwest utility markets. That this use of coal would continue or even accelerate was an emphatic point of the recent President's energy message.

We now recognize that the coal development is not only necessary for the nation as a whole, but in some respects desirable for the Great Plains' economy. However, every effort should be made to minimize harmful side effects. Energy developments can adversely affect water supplies downstream and pollute the atmosphere downwind. Direct adverse effects on agriculture, animal life, and human health are now well known (3, 4). The possibility that energy development by-product emissions could change downwind rainfall is not as well known but, nevertheless, real. This statement cites the evidence for such effects and describes observations now being made to determine if changes in rainfall in downwind regions (principally the Dakotas) will accompany coal developments in Montana, Wyoming, and western North Dakota.

*Northern States Air Monitoring Program

Several states in the northern Great Plains have recently conducted intentional weather modification programs designed to add as much as 1 - 2 inches of precipitation per year to existing rainfall levels. The worth of a rainfall increase of this magnitude has been estimated at more than ten million dollars per year in South Dakota alone. These numbers illustrate the tremendous economic impact of even minor changes in rainfall patterns and suggest that states downwind of the proposed coal developments should examine the possibilities of downwind weather changes very closely.

B. Effect of Particulates on Cloud and Precipitation

All cloud droplets form around small particles called cloud condensation nuclei (CCN). The ability of a cloud to form rain by the coalescence of liquid droplets is related to the sizes and number concentration of the droplets which, in turn, are related to the CCN concentration present (5).

The operation of large mine-mouth power plants affects the local weather by adding heat, water vapor, carbon dioxide, and other gases to the atmosphere. However, the addition of solid particulate matter has perhaps the most impact because the particles enter the cloud processes along with the natural cloud condensation nuclei. In general, adding more particulates to the air leads to clouds consisting of many very small droplets (6, 7). Rain formation by coalescence tends to be slow in such clouds.

Formation of snow in winter clouds and in the upper, cold parts of summer clouds depends on the presence of insoluble particles called ice nuclei (IN) (8, 9). Most current cloud seeding procedures involve introduction of artificial IN, e.g., silver iodide crystals, into cold clouds. If particles produced by power plants or other industrial sources are active as ice nuclei, they may either seed or "overseed" the clouds they enter, causing increases or decreases, respectively, in precipitation, depending upon their type and concentration and the temperature structure and water content of the cloud.

The introduction of either extra CCN or IN into the atmosphere as a by-product of industrial processes amounts to an act of inadvertent weather modification. The particulates may travel hundreds of miles downwind from such sources as strip mines, open coal cars, and coal-fired generating plants, all the way exerting unknown, but possibly significant, effects upon the weather.

C. Types of Changes to be Expected

Evidence of effects of pollutants upon rainfall comes from many sources. For many years, observations have been made of the effect of pollutants from agricultural burning in the Caribbean, Hawaii, Africa, and Australia, which lead to the conclusion that rainfall is suppressed in the air mass containing the pollutants as it mixes with the cloud formations (10). In recent work in the midwest section of this country (the St. Louis "METROMEX" study, refs. 11, 12, 13, 14) several investigators have recognized both increases and decreases in rainfall, depending upon the details of the weather situations. Scientists at the University of Washington have observed an increase in rainfall due to the presence of large, hygroscopic particles in pulp mill plumes (15).

One of the significant differences between tropical islands, the coast of Washington and Oregon, and the St. Louis area in comparison to the northern Great Plains is the amount of moisture available for the local storm systems. In nearly all cases where an increase in precipitation due to pollution was observed, there was plentiful moisture.

In the northern Great Plains, moisture is not abundant. Some evidence from the METROMEX study (11) as well as computer modeling results by members of our staff (7) have indicated that a decrease in precipitation would be likely in the northern plains and other semi-arid regions because of the increase in cloud "stability" due to the large numbers of small particles introduced.

The METROMEX study also suggests that some combination of particulate, gaseous, and thermal pollution has increased the intensity and frequency of severe weather by as much as 20 - 30% over St. Louis (14). Such changes over the Great Plains due to energy development seem less probable, but climatology studies should still be considered in looking for such possibilities.

D. Suggested Program for Assessing the Effects

The particles discussed above are much smaller than those that degrade air quality as normally perceived, and special instruments are needed to detect them. There are several institutions in the northern Great Plains which are equipped, from the point of personnel as well as hardware and laboratory facilities, to conduct a systematic, careful study of the particulate and gaseous concentration levels in the environment prior to the development and operation of the anticipated coal-fired generators, as well as during such operation. This expertise can be pointed toward an understanding of the types of nuclei that will be released, their effect on cloud processes, and the resulting change in precipitation reaching the surface, both over the development site and downwind for several hundred miles into surrounding states. Numerical simulation of rainfall processes in clouds would be an important part of such a study.

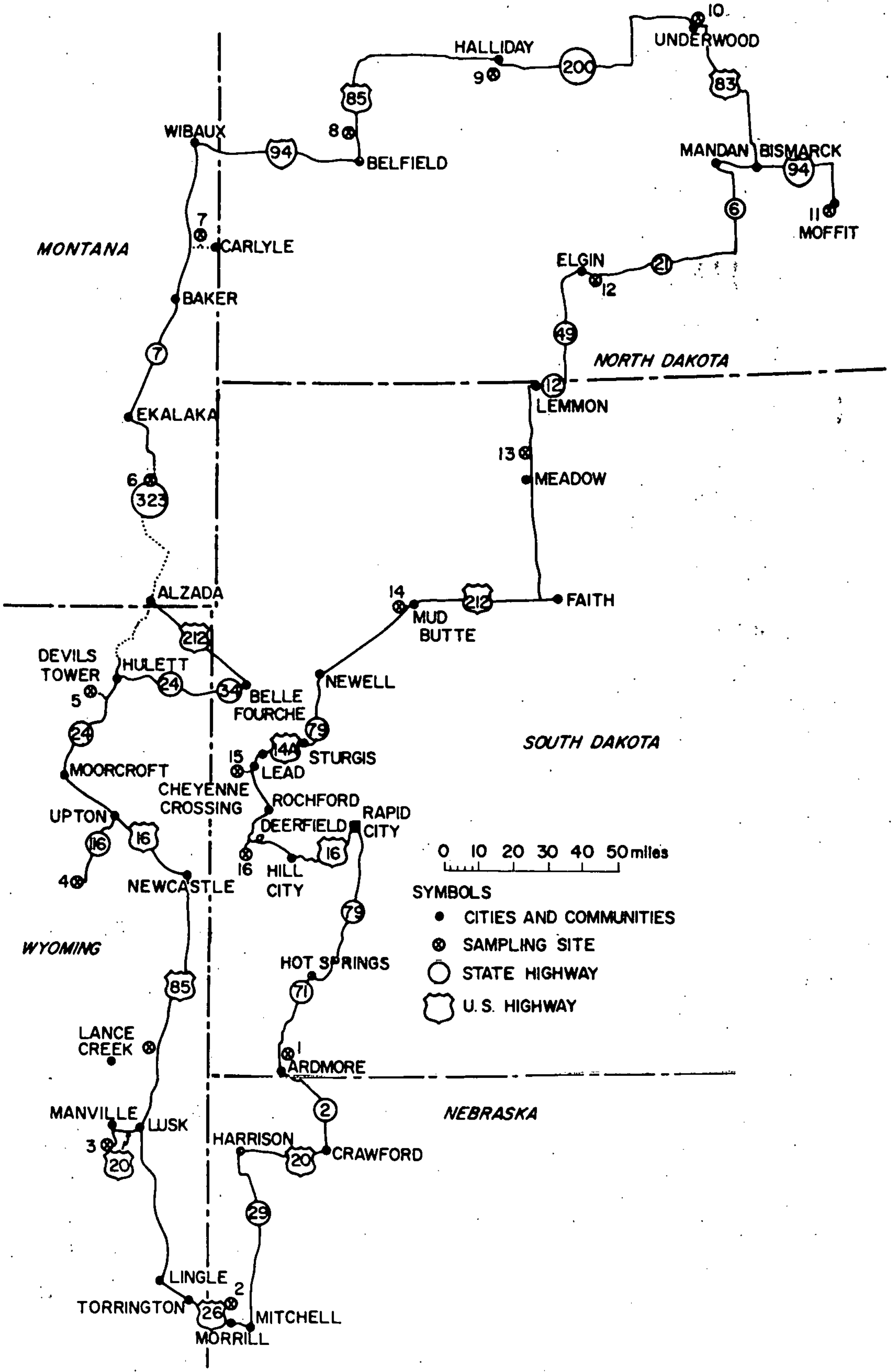
E. Current Baseline Studies Under Project NOSAMP

The Institute of Atmospheric Sciences' Cloud Physics Laboratory, South Dakota School of Mines and Technology, is currently conducting measurements of various air pollutants and meteorological parameters in a five-state area of the northern Great Plains. The study is supported by the Old West Regional Commission and the Energy Research and Development Administration. The project circuit is shown in Fig. 1 and is designed to obtain baseline readings of the various pollutants in downwind proximity to the major coal development areas of northeastern Wyoming, southeastern Montana, and western North Dakota. At this time, the term "baseline" is rather nebulous because several large coal-fired power plants have already come into operation (Dave Johnston near Casper, Wyoming, and part of a four-unit complex at Colstrip, Montana). In anticipation of even greater strip mining and coal development, these measurements constitute a baseline level from which a comparison can be made of effluent production in the future.

Table 1 presents the instrument package aboard the 27-ft motor home laboratory. Because of the distance around the circuit, each station is visited only once a month with funding for the initial baseline measurements scheduled for approximately 18 months from the time of first field operations. Data from these systems are compiled on an 18-channel magnetic tape data logger from which data reduction is accomplished using a PDP-8 minicomputer and CDC 6400 computer. At this stage, 16 separate variables are being measured either by automatic entry onto the tape logger system or from notebook entry. With 16 stations, 16 variables, and 18 visits, our three-dimensional data matrix contains 4,608 values. Present efforts are to achieve a data retrieval program such that column, row, or block segments of the matrix can be retrieved and analyzed for specific requirements.

F. Future Prospects

The present project does not, however, include support for future "post-operational" measurements nor significant analysis of data. In order for the program to reap the benefit for which it



10
UNDERWOOD
HALLIDAY
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200
85
83
8
WIBAUX
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BELFIELD
MANDAN
BISMARCK
94
6
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MOFFIT
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CARLYLE
MONTANA
ELGIN
21
12
BAKER
49
7
NORTH DAKOTA
12
LEMMON
EKALAKA
13
MEADOW
6
323
ALZADA
14
212
FAITH
MUD
BUTTE
212
DEVILS
TOWER
HULETT
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34
NEWELL
5
BELLE
FOURCHE
24
79
SOUTH DAKOTA
14A
15
STURGIS
LEAD
MOORCROFT
CHEYENNE
CROSSING
ROCHFORD
RAPID
CITY
UPTON
DEERFIELD
16
116
16
16
HILL
CITY
4
NEWCASTLE
0 10 20 30 40 50 miles
SYMBOLS
CITIES AND COMMUNITIES
SAMPLING SITE
STATE HIGHWAY
U. S. HIGHWAY
79
WYOMING
HOT SPRINGS
85
71
LANCE
CREEK
1
ARDMORE
2
NEBRASKA
MANVILLE
LUSK
3
HARRISON
20
CRAWFORD
20
29
LINGLE
2
TORRINGTON
26
MITCHELL
MORRILL

Figure 1

TABLE 1

Pollutant Species to be Monitored, Concentration Levels, and Inventory of Available Analytical Systems

Pollutant Parameters	Current Ambient Level	Wheatland Post-Op. Level Anticipation	Analytical System	In Mobile Lab
[1]SO_2	10 μg m^{-3}	50 μg m^{-3}	FID	✓
[1]NO_x	150 μg m^{-3}	5000 μg m^{-3}	O_3 Chemilumen	Needed[5]
[2]O_3	40 μg m^{-3}	May decrease	Ethylene Chemilumen	Needed
HC	No data	?	QMS	✓ (thermal desorber)
[2]CCN	500 cm^{-3}	600 - 10^3	Diffusion counter	✓
[2]CN (Aitken)	10^3 cm^{-3}	5 x 10^3 - 10^4	Expansion counter	✓
[2]IN	<10^{-3} cm^{-3}	?	Acoustical counter	✓
[3]Total Susp. Part.	20 μg m^{-3}	30 μg m^{-3}	Hi-Vol sampler and microbalance	Home labs
Meteorological Parameters:				
Wind S/D	--	--	Anem.-vane	✓
Dewpoint	--	Local increase near sites	Thermoelectric D.P. sensor	✓
T_D	--	Local nocturnal increase under cloud	Thermistor	✓
Raindrop size distribution and rainfall rate	?	?	Distrometer	✓
Special Parameters:				
pH, precipitation	6 - 7	4 - 5 (isolated cases)	pH-meter	✓
Total aerosol size	log-normal	Distribution narrowed	EAA, XRDS	✓
Aerosol compound anal.	--	--	XRDS	Home labs
Trace metals[4] (e.g., Pb)	0.20 μg m^{-3}	0.40 μg m^{-3}	AAS, QMS	Home labs

[1]24-hr mean

[2]Data for short-term sampling (<10 min)

[3]24-hr continuous sample

[4]See Section 3.4, Table 8

[5]Presently requested in proposal to a local utility company.

FID = Flame Ionization Detection

AAS = Atomic Absorption Spectrophotometry

QMS = Quadrupole Mass Spectrometry

EAA = Electric Aerosol Analyzer

XRDS = X-ray Diffraction and Scattering

was designed, additional studies must continue beyond the baseline measurement phase.

We urge that a strong research program be instituted in order to gain an advance step on the whole coal development scenario as it affects precipitation in the northern Great Plains. With this knowledge, we may be able to suggest needs in pollution control equipment for power plants or a corrective scheme which may be used to offset undesirable effects. We think that such a research program should be a major concern of every state within the affected region.

G. Summary

(1) Coal developments are likely to change precipitation patterns in regions as much as several hundred miles downwind, with decreases being judged more probable than increases in the semi-arid northern Great Plains.

(2) Such indicated rainfall changes would have significant economic effects.

(3) A baseline monitoring study of these effects is currently underway but anticipated large scale coal development suggests even more comprehensive research on inadvertent weather modification in the northern Great Plains region.

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