TECHNICAL SUPPORT DOCUMENT
FOR
INDEPENDENCE STEAM ELECTRIC STATION
Independence County, Arkansas

UNITED STATES · ENVIRONMENTAL PROTECTION AGENCY ·

VOL. I

ENVIRONMENTAL PROTECTION AGENCY
REGION VI
DALLAS TEXAS

906R77104

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Independence County, Arkansas

VOL. I

ENVIRONMENTAL PROTECTION AGENCY
REGION VI
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INTRODUCTION

This Technical Support Document (TSD) is one of two volumes that presents the environmental study for the application for certification of the Independence Steam Electric Station. The first volume, the Environmental Impact Statement (EIS), presents the major issues, significant features and summary analyses of the environmental study, description of plant and action, and alternatives considered. This volume presents the background information on the methodology used in the analysis and field efforts, pertinent regulations and other data utilized in the preparation of the EIS. This volume, in essence, is a reference document for the EIS.

The general organization of the TSD consists of a series of individual parts. Part 1 presents backup information for the need for power (Part 1.1) and for alternative actions (Part 1.2). Parts 2 through 8 each contain the reference information on a specific discipline investigated in the preparation of the EIS. In Part 9, Environmental Monitoring Program, the pre- and post-operational Environmental Monitoring Programs for the Independence Steam Electric Station are presented.

The scope of information appearing in the various parts of the TSD vary depending on the EIS presentation - from a list of species in an area to a detailed report from a consultant on the socioeconomic impacts expected from the Independence Steam Electric Station.

The format for cross references and internal references that appear in the TSD are as follows:

- References to EIS in a Part of the TSD - the "EIS" appears before section, table, and/or figure reference (i.e., EIS Table 2.1-1).
- References in the TSD to other TSD Parts - the "TSD" appears before the part, table, and/or figure references (i.e., TSD Figure 3.2-1).
- Reference in a Part of the TSD to other internal information - the number of the table, figure, and/or subpart is presented without prefix (i.e., Table 5.1-3).

It should be noted that the reverse is true of the references in the EIS to TSD parts, table, and figures. The indication "TSD" will appear before each TSD table, figure, and part referenced in the EIS. Internal EIS references to other sections of the EIS will appear without prefix.

Finally, please note that each part of the TSD is numbered sequentially by part (i.e., 4.0-1, 4.0-2, ...4.0-53) and that literature cited is included at the end of the individual part of the TSD.

PART 1
GENERAL MATERIAL

TECHNICAL SUPPORT DOCUMENT

PART 1

GENERAL MATERIAL

CONTENTS

TABLES

PART 1

GENERAL MATERIAL

1.1 POWER REQUIREMENTS

The City Water & Light Plant of the City of Jonesboro (CWL), Arkansas Electric Cooperative Corporation (AECC) and Arkansas Power & Light Company (AP&L) have through independent evaluations, determined the need for their participation in the Independence Steam Electric Station. The following sections present the individual evaluations plus a summary for the combined three utilities.

1.1.1 City Water & Light Plant of the City of Jonesboro

1.1.1.1 Purpose of Participation in the Facility

The City Water & Light Plant of the City of Jonesboro (CWL) will require additional generating capacity to meet the projected future loads of its service area. Engineering and economic analyses made by R. W. Beck and Associates show that future use of existing CWL generation facilities should be minimized because of the expected unavailability of natural gas, the high cost of oil, and the relative inefficiency of the existing generating units. This would also be in line with the President's National Energy Plan. Construction of a CWL-owned coal-fired generating unit was considered, but this alternative would be restricted to smaller size, because of CWL's load, and would not offer CWL the economies of scale available through participation in the larger, more efficient units of the 700 MW size proposed for the Independence Steam Electric Station. CWL will contract to participate in 5 percent of the total 1400 MW (net) that is proposed at Independence Steam Electric Station. The participation in this facility will not require any additional transmission facilities other than those already scheduled by CWL in conjunction with its participation in the White Bluff plant.

CWL is a publicly owned utility that operates and distributes electric power and energy to retail, commercial, and industrial customers and for municipal and public use within its service area. The CWL service area is approximately encompassed by the corporate limits of Jonesboro, with the exception of a few adjacent areas outside the city.

The power requirements of the system are met by CWL-owned generation and by purchases from AP&L and the Southwest Power Administration (SPA) which markets power from government-owned dams in the area.

SPA presently acts as CWL's load dispatch agent and schedules quantities of hydro power and purchases of power from AP&L, as necessary, to meet the requirements of the CWL system. CWL currently receives, at the CWL Northwest Substation, its entire SPA power and energy allocation and its entire AP&L purchases. Through its SPA contract, CWL utilizes up to 35 MW of SPA's surplus delivery point capacity at this station. SPA charges CWL $3.00 per kW/year, based on the 12-month peak purchase from AP&L, for use of its facilities at the Northwest Substation. This transmission service by SPA is available to CWL through June 30, 1979. SPA has indicated a willingness to renegotiate its contract with CWL for this service.

CWL currently purchases supplemental power from AP&L through terms of a contract which extends through June 1, 1980. This contract has provision for extensions on a year-by-year basis, with cancellation options by either party on 24-month advance written notice. This contract allows purchase of a maximum of 30 MW firm power and associated energy with a contract minimum of 10 MW.

Through contractual arrangements with SPA, standby capacity is presently provided for CWL generation in exchange for a 2 MW capacity dedication to SPA. This capacity dedication is based on 10 percent of the total capability of the CWL generating plant. Beginning with the operation of the White Bluff plant in 1980, SPA will provide standby capacity for all CWL generation in exchange for a dedication of 15 percent of the CWL generating capacity to SPA for reserves. CWL's contract with SPA expires on May 31, 1985, but it is anticipated that SPA will convert the firm power allocation to a peaking power allocation in the amount of 80 MW.

Because of the age of CWL generating facilities, the uncertainty of present fuel supplies, and the loss of firm power allocation from SPA after 1985, CWL must accomplish the following long-term power supply goals:

1. It must seek additional firm capacity sources of generation.

2. It must phase out aging inefficient generating units that use fuels that are in short supply.

3. It must seek to participate in ownership with other utilities in large fuel-efficient generating plants.

4. It must provide a program to participate with other utilities in development of alternate fuel sources.

To meet these objectives CWL has contracted to participate in ownership of 5 percent of the capacity of the 1400 MW (net) White Bluff plant and 5 percent of the capacity of the 1400 MW (net) Independence Steam Electric Station.

1.1.1.2 Future Need For Power

In 1974, a consultant prepared a long-range power supply study for CWL. In this study, an area load survey was made in conjunction with Jonesboro's long-range city plan. This study was used as a basis for projecting CWL's future electrical growth. At that time, a growth rate of 12 percent annually was determined from historical data since 1974. Other factors indicated an average rate of 10 percent per year was more realistic. Table 1.1-1 shows the actual growth from 1950 to 1977 and the projected growth from 1978 to 1986. A review of this table indicates that CWL load requirements have increased from a 6 MW peak demand in 1950 to 93 MW in 1977. This is an annual growth rate of 10 percent. The CWL forecast of future peak loads indicates a growth to 107 MW in 1978, 172 MW in 1983, 208 MW in 1985, and 229 MW in 1986; or an average growth rate of 10.0 percent between 1978 and 1986.

The energy requirement of the CWL service area is also shown in Table 1.1-1. This has been growing at approximately the same rate as the peak demand. Historically the energy requirements of CWL have grown from 24 GWH in 1950 to 331 GWH in 1976, or an annual growth rate of 10.6 percent. CWL forecasts an annual energy requirement of 401 GWH in 1978, 646 GWH in 1983, 781 GWH in 1985, and 859 GWH in 1986, or an annual growth of 10.0 percent between 1978 and 1986.

1.1.1.3 Generating Capacity Requirements To Meet Future Needs

In 1977, the CWL-owned generating capability totaled approximately 28.6 MW name plate rating which included three steam turbines and a 1 MW diesel unit. Because of age and poor operating efficiency, one of the three turbines is not considered as a reliable power source. The remaining two turbines and the diesel unit have a continuous capability of approximately 19.5 MW. However, due to frequent curtailment of the gas fuel supply, the high cost of oil as a fuel, and the relative inefficiency of these two turbines, CWL confines their use to operation during summer peak periods. The capacity of these units also is utilized to provide for generation reserve requirements.

New generating capacity will be available to CWL in 1980 and 1982 through its participation in ownership of 5 percent of each of the two 700 MW (net) units at the White Bluff plant, scheduled for completion in those years. CWL also will contract to participate in 5 percent of each of the two 700 MW (net) units at the proposed Independence Steam Electric Station scheduled for completion in 1983 and 1985.

The load and capability status of CWL in 1983 are shown on Table 1.1-2. This table shows that CWL will be deficient in capability to meet its load without purchase of additional supplemental power. Table 1.1-2 also indicates the same condition in 1985 without the Independence Steam Electric Station Unit Two.

In the 1974 engineering report, "Power Supply Study for the City Water and Light Plant, Jonesboro, Arkansas," it was pointed out that ownership participation in large coal-fired generating plants was the most economically attractive power supply alternative for CWL during the 1980s. More recent studies by a consultant in conjunction with CWL's financing of a 5 percent share of the White Bluff plant and specific evaluation of participation by CWL in the Independence Steam Electric Station have confirmed the results of the 1974 study.

1.1.2 Arkansas Power & Light Company

1.1.2.1 Purpose of Participation in the Facility

Arkansas Power & Light Company (AP&L) is part of the Middle South Utilities (MSU) System, which also includes the following operating companies: Arkansas Missouri Power Company, Louisiana Power & Light Company, Mississippi Power & Light Company, and New Orleans Public Service Inc. These companies supply the electric needs for portions of Arkansas, Missouri, Louisiana, and Mississippi. All generation is jointly planned, and through a contractual arrangement, reserves are shared by each of the five operating companies.

Historically, because of the availability of low-cost natural gas, AP&L has been a net importer of electric energy from other MSU companies. However, because of the nation-wide gas shortage, AP&L cannot rely, as it has in the past, on its sister companies for electrical energy. For this reason and also because of the uncertain future oil supply, AP&L is constructing generating units that will rely on fuels other than oil and gas. At this time, AP&L has a total owned generating capability of 2867 MW. Over 68 percent of this capability is oil fired, most of which has been converted from gas to oil.

Because of the natural gas shortage and the uncertain supply of oil, the Federal government has directed, as a part of the overall energy program, that the use of natural gas and oil in electric power generation be significantly curtailed or eliminated.

As a result of these considerations, AP&L must accomplish the following four objectives:

1. It must generate a larger portion of its current requirements for electricity.
2. It must construct additional generating capacity in order to take care of current and future requirements in its service area.

3. It must attempt to stabilize the rise in electric rates induced by massive price increases for oil and natural gas by switching to lower cost fuel.

4. It must diversify the types of fuels used so that its level of dependence upon natural gas and fuel oil is more in line with National energy policies.

To meet these objectives, AP&L has under construction Arkansas Nuclear One Unit Two, a 912 MW nuclear unit, and two 700 MW coal-fired units at White Bluff. About 420 MW of each of these coal units will be available to the AP&L customers. The Independence Steam Electric Station is also being developed to satisfy these four objectives.

1.1.2.2 Future Need For Power

AP&L prepares and continually updates the forecast of its power requirements. These forecasts are based on historical trends of electric use in its service area, plus a number of other factors such as population growth, forecast of industrial and commercial development, and other economic indicators. These forecasts showed that the Independence Steam Electric Station Units One and Two would be required in 1983 and 1985 respectively. AP&L also elected to obtain an independent forecast of its power needs before making the decision to apply for site and development permits. At the request of AP&L Management, National Economic Research Associates (NERA) developed an independent load and energy forecast for AP&L utilizing an economic methodology which incorporates into the predictions, important elements of the President's energy program, as well as effects of conservation, price elasticity, and load management. After considerable review, the Company adopted the NERA results as the AP&L official load forecast.

Peak Loads

Table 1.1-3 shows the historical and projected peak load requirements of AP&L. A review of this table indicates that these peak load requirements have grown from a demand of 1785 MW in 1968 to 3059 MW in 1977, or an annual growth rate of 6.2 percent. The NERA forecast of AP&L's peak loads show a growth up to 3314 MW in 1978, 4406 MW in 1983, 4738 MW in 1985, and 4841 MW in 1986, or an average growth rate of 4.9 percent between 1978 and 1986.

Historical peak loads of the MSU system without AECC and CWL (Table 1.1-3), have grown from 5066 MW in 1968 to 9523 MW in 1977 or an average annual growth rate of 7.3 percent. The MSU system projects peak loads of 10,333 MW in 1978, 13,781 MW in 1983, 15,561 MW in 1985, and 16,385 MW in 1986; or an average growth rate of 5.9 percent between 1978 and 1986. The peak load forecast of the MSU system is the sum of the forecasts of each company's forecast.

Overall Energy Requirements

Overall energy requirements of the AP&L service area and that of the MSU System have been growing at rates which are quite close to, but lower than, growth rates of peak load requirements. Historically the AP&L requirements grew from 8306 GWH in 1968 to 12,382 GWH in 1976, or average annual growth rate of 5.1 percent. AP&L predicts a growth to 13,919 GWH in 1978, to 19,832 GWH in 1983, to 21,976 GWH in 1985, and to 23,206 GWH in 1986, or an average annual growth of 6.6 percent between 1978 and 1986.

1.1.2.3 Generating Capacity Requirements To Meet Future Needs

In 1977, the AP&L-owned generating capability was 2867 MW. Included in this capability is 836 MW nuclear, 69 MW in hydroelectric, 76 MW in combustion turbine, and 1887 MW of gas-fired generation that has been converted to oil.

New capacity under construction and planned includes the second nuclear unit that will be operational in 1978 at 912 MW. Also, planned are two 700 MW coal-fired units at White Bluff that will be operational in 1980 and 1982, respectively. About 840 MW of this coal-fired capacity will be available to AP&L customers. It is expected that with the above units, including the potential retirement of obsolete oil burning units, AP&L will have available 4566 MW in 1982.

Expected AP&L load and generating capability in 1983, without and with Independence Unit One are presented in Table 1.1-4. This table shows the expected owned capability, purchases, and capability under contract, along with the projected load. It is apparent from this table that without Independence Unit One there will be a deficiency in capability to meet load responsibility plus 16 percent reserves. Without Independence Unit One AP&L will be deficient in generation by 265 MW.

The expected AP&L load and generating capability in 1985 without and with Independence Unit Two are also shown in Table 1.1-4. This table shows the expected owned capability, purchases, and capability under contract, along with the projected load. Even with Independence Unit Two there will be a deficiency in capability to meet load responsibility plus 16 percent reserves in 1985. This deficiency will be 128 MW and will increase to 548 MW without Independence Unit Two.

Table 1.1-5 presents the MSU system load and generating capability forecast for 1983 without and with Independence Unit One. This table shows the expected owned capability, purchases, and capability under contract, along with the projected load (without AECC and Jonesboro). This table indicates that the MSU system will have 17.8 percent reserves in 1983 with Independence Unit One. Without Independence Unit One the reserve margin will drop to 14.7 percent or 174 MW below desired reserves of 16 percent.

The MSU system load and capability situation in 1985 without and with Independence Unit Two (without AECC and Jonesboro) are also given in Table 1.1-5. The MSU system will have 17.5 percent reserves in 1985 with Independence Unit Two. Without Independence Unit Two reserves will drop to 14.8 percent, or 191 MW below the desired reserves of 16 percent.

The percentage of generation by fuel types for 1970 through October of 1977 are shown on Table 1.1-6. A review of this table shows that in 1970 almost 95 percent of AP&L generation was on natural gas. By 1976, even with Arkansas Nuclear One Unit One on line, almost 44 percent of the generation was on oil. By 1982, AP&L generating capacity will be fueled as follows: 1748 MW nuclear, 840 MW coal, and 1909 MW oil. There is a slight possibility that some natural gas will be available to replace a small amount of oil. It is apparent that 42 percent of AP&L

owned generation will be oil fired. Yet, the availability of oil in the 1980s is quite uncertain due to U. S. policies and those of the exporting nations. Oil costs are also uncertain and are under control of foreign nations. On the other hand, coal is an abundant domestic supply and not subject to foreign embargo or price fixing. It is the U. S. national policy to develop coal generating capacity and reduce oil burning capacity. For these reasons, it is incumbent upon AP&L to reduce its future dependence upon oil as a fuel. With the Independence Steam Electric Station, the percentage of AP&L's owned generation that is fueled by oil will be reduced to 35 percent. It is concluded that in addition to the capability to satisfy future load and energy needs, the two units planned at Independence Steam Electric Station will provide vitally needed fuel diversification in keeping with the Federal energy policies.

1.1.3 Arkansas Electric Cooperative Corporation

1.1.3.1 Purpose of Participation in the Facility

Arkansas Electric Cooperative Corporation (AECC) is owned by its 17 member distribution cooperatives and has as its sole purpose the supply of wholesale power on a non-profit basis to these 17 members.

AECC presently owns 315 MW of gas/oil burning power plants. These plants were built for natural gas but, due to the non-availability of natural gas, these plants are now burning oil. AECC purchases 189 MW of hydro power and associated energy from the SPA. The balance of AECC's needs have been purchased from other utilities in the area. Most of this purchased power has been generated in gas- and oil-burning power plants.

Natural gas has virtually been eliminated as a boiler fuel. The limited availability of oil and the resulting high prices have made it necessary to substitute other more available fuels for the generation of electricity. The only two alternate fuels available in sufficient quantities are coal and nuclear. Because of the long lead times required for a nuclear plant, this option is not available to the cooperative for the 1983-1985 time period. This leaves only one option for AECC - it must use coal for generation in the future.

Large capacity coal burning plants (500 to 700 MW size) are more economical than smaller units. Because AECC needs smaller increments of capacity due to its smaller loads, it is advantageous for the cooperative to participate in part ownership with others. This way it is possible to obtain the economics of larger scale while adding smaller increments of capacity as needed. Because of these conditions, AECC must do the following basic things:

1. It must, in the most economical manner, provide generation capacity to meet the loads of its members.
2. It must slow the rapid increase in electric rates by substituting lower cost coal for oil and gas, which are much higher in cost, and for which the cost is rapidly escalating.
3. It must reduce use and dependence on oil in cooperation with national energy policies.

To meet these objectives, AECC is presently participating as part owner in two power plant projects. It is a 50 percent owner of the Flint Creek 530 MW coal burning plant near Gentry, Arkansas and a 35 percent owner of the two 700 MW White Bluff coal-burning units being built near Redfield, Arkansas. AECC's proposed 35 percent ownership of the Independence Steam Electric Station will also help meet these objectives.

1.1.3.2 Future Need For Power

Arkansas Electric Cooperative Corporation, for purposes of financing of new construction, is required by the Rural Electrification Administration (REA) to prepare a Power Requirements Study. This study is comprehensive and prepared according to exact and detailed guidelines. It includes, first, a preliminary mathematical total projection by AECC. Next, a preliminary mathematical projection is made by AECC for each of the member distribution cooperatives. Each of the member cooperatives then breaks down its total historical load into various categories such as residential, commercial, etc. Projections are then made of both the number of consumers in each category and the KWH per consumer. These projections are then combined into a total projection for each cooperative. Differences between the mathematical projection and the detailed member projection are jointly resolved, and the individual member cooperative projections are then combined to form the AECC projection. This total projection is then approved by REA and must be used in support of any approvals of financing by REA. The total process requires about one year. This REA Power Requirements Study shows a 12.7 percent load growth, which is a continuation of the historical trend.

For its own purposes in making decisions, AECC must have the latest and most up-to-date information. AECC reviews and revises the results of the power requirements study at least once each year and at any other time a major decision must be made. The latest revision was made in July 1977. This revision adjusts for two basic changes: first is an adjustment for the effect of the recent recession in the national and Arkansas economy; and second, the future rate of growth was reduced from 12.7 to 11.0 percent to accommodate several new factors such as conservation effort in new building design, insulation of existing buildings, and load management of various kinds. Also recognized was the national effort to switch from oil and gas to coal and nuclear which must be done through the form of electric energy. The July 1977 revision reduced the 1985 projected demand by 22 percent.

Although these studies clearly showed the need for the Independence Steam Electric Station Units One and Two on or before 1983 and 1985, AECC also participated in an independent forecast. National Economic Research Associates (NERA) was hired to make this independent forecast, utilizing economic methodology and incorporating important elements of the President's energy program. The NERA forecasts result in a load growth rate through 1985 roughly equal to the growth rate during the recent recession. However, even with the very conservative NERA forecast, the Independence Steam Electric Station would still be needed to replace oil-burning capacity.

Table 1.1-7 shows the historical and projected peak load requirements of AECC. Peak load requirements of AECC have grown from a demand of 184 MW in 1965 to a demand of 734 MW in 1977, or an annual growth rate of 12.2 percent. A review of the table shows that the REA Power Requirements Study projects peak loads of 979 MW in 1978 and 2547 MW in 1986, which is a 12.7 percent annual growth rate; the AECC July 1977 revision forecasts peak loads of 849 MW in 1978 and 1961 MW in 1986, which is an 11 percent growth rate; and the NERA study forecasts peak loads of 826 MW in 1978 and 1342 MW in 1986, which is a 6.3 percent annual growth rate. AECC currently bases its planning on the AECC July 1977 revision.

1.1.3.3 Generating Capacity Requirements To Meet Future Needs

In 1977 the owned generating capability of AECC was 315 MW. All of this capability is gas-fired generation which has been converted to oil. New capacity under construction and planned is as follows:

1978 Flint Creek - 50 percent ownership of 530 MW coal unit
1980 White Bluff One - 35 percent ownership of 700 MW coal unit
1982 White Bluff Two - 35 percent ownership of 700 MW coal unit
1983 Independence One - 35 percent ownership of 700 MW coal unit
1985 Independence Two - 35 percent ownership of 700 MW coal unit

AECC capability will be deficient in 1983 by 114 MW with Independence Unit One in service (Table 1.1-8). Without Independence Unit One, AECC generation would be deficient by 359 MW. Table 1.1-8 also shows that AECC capability will be deficient in 1985 by 254 MW with Independence Units One and Two in service. Without Independence Unit Two, AECC generation would be deficient by 439 MW.

Table 1.1-1

City Water & Light Plant of the City of Jonesboro
Historical and Projected Load

Year	Annual Peak Demand (MW)	Total Annual Energy (GWH)
(Actual)		
1950	6	24
1960	18	63
1968	43	161
1969	52	185
1970	54	204
1971	59	225
1972	68	257
1973	69	269
1974	74	267
1975	81	299
1976	88	331
1977	93	-
(Forecast)		
1977	-	365
1978	107	401
1979	117	441
1980	129	485
1981	142	534
1982	156	587
1983	172	646
1984	189	710
1985	208	781
1986	229	859

Table 1.1-2

City Water & Light Plant of the City of Jonesboro
Projected Loads and Capabilities (MW)

	1983		1985	
	Without Independence Unit One	With Independence Unit One	Without Independence Unit Two	With Independence Unit Two
1. Capability with gas curtailment	90[a]	125[b]	125[c]	160[d]
2. Purchases without reserves	0	0	0	0
3. Total capability (1 + 2)	90	125	125	160
4. System maximum load	172	172	208	208
5. Firm sales and reserves	0	0	0	0
6. Firm purchases with reserves	80	80	80	80
7. Load responsibility (4 + 5 - 6)	92	92	128	128
8. Margin in excess of load (3 - 7)	(2)	33	(3)	32
9. Desired reserves (16.0% of 7)	15	15	20	20
10. Percent margin in excess of load (8 ÷ 7)	(2.2)	35.9	(2.3)	25
11. Capability in excess of desired reserves	(17)	18	(23)	12

[a] Includes: White Bluff participation of 70 MW and CWL Steam Turbine @ 19 MW and diesel unit @ 1 MW.

[b] Includes: Sames as above plus Independence Unit One participation of 35 MW.

[c] Includes: White Bluff participation of 70 MW, Independence Unit One participation of 35 MW, and CWL Steam Turbine @ 19 MW and diesel unit @ 1 MW.

[d] Includes: Same as above plus Independence Unit Two participation of 35 MW.

Table 1.1-3

Historical and Forecast Peak Loads
Arkansas Power & Light and Middle South Utilities System[a]
(Without AECC and CWL)

Year	Arkansas Power & Light Load (MW)	Middle South Utilities System Load (MW)
	Historical	
1958	719	
1959	858	
1960	825	
1961	810	
1962	953	
1963	1081	
1964	1283	
1965	1374	
1966	1577	
1967	1611	
1968	1785	5066
1969	2003	5873
1970	2085	6092
1971	2329	6755
1972	2495	7560
1973	2611	7835
1974	2839	8327
1975	2668	8314
1976	2980	9103
1977	3059	9523
	Forecast	
1978	3314	10333
1979	3480	10995
1980	3831	11548
1981	3982	12253
1982	4246	13093
1983	4406	13871
1984	4570	14692
1985	4738	15561
1986	4841	16385

[a] NERA Peak Load Forecast

Table 1.1-4

Arkansas Power & Light Company
Forecast Peak Loads (MW)
(Without AECC and CWL)

	1983		1985	
	Without Independence Unit One	With Independence Unit One	Without Independence Unit Two	With Independence Unit Two
1. Load	4406	4406	4738	4738
2. Firm purchase	220	220	70	70
3. Load responsibility (1 - 2)	4186	4186	4668	4668
4. Owned capability	4566	4986	4842	5262
5. Capability under contract	25	25	25	25
6. Total capability (4 + 5)	4591	5011	4867	5287
7. Capability over (under) load (6 - 3)	405	825	199	619
8. 16% of load responsibility for reserves	670	670	747	747
9. AP&L reserves-excess (deficiency) (7 - 8)	(265)	155	(548)	(128)

Table 1.1-5

Middle South Utilities Load and Capability
Forecast Peak Loads (MW)
(Without AECC and CWL)

	1983		1985	
	Without Independence Unit One	With Independence Unit One	Without Independence Unit Two	With Independence Unit Two
1. Capability with gas curtailment	15088	15508	17205	17625
2. Purchases without reserves	371	371	371	371
3. Total capability (1 + 2)	15459	15879	17676	17996
4. System maximum load	13871	13871	15561	15561
5. Firm sales with reserves	3	3	3	3
6. Firm purchases with reserves	397	397	248	248
7. Load responsibility (4 + 5 - 6)	13477	13477	15316	15316
8. Margin in excess of load (3 - 7)	1982	2402	2260	2680
9. Desired reserve (16.0% of 7)	2156	2156	2451	2451
10. Percent margin in excess of load (8 ÷ 7)	14.7	17.8	14.8	17.5
11. Capacity in excess of desired reserves	(174)	246	(191)	229

Table 1.1-6

Arkansas Power & Light Company
Percent of Generation by Fuel Type

Year	Percent		
	Natural Gas	Oil	Nuclear Fuel
1970	94.9	3.8	
1971	82.8	16.2	
1972	69.5	29.1	
1973	47.1	49.1	
1974	42.6	52.1	2.3[a]
1975	26.6	22.6	49.1
1976	12.8	43.9	42.3
1977 (January to October)	4.3	54.6	40.4

[a]From December 19, 1974 to end of period.

Table 1.1-7

Arkansas Electric Cooperative Corporation
Historical and Forecast Peak Loads
(MW)

Actual		Forecast			
Year	MW	Year	REA Power Requirements Study	AECC Revision July 1977	NERA
1965	184	1978	979	849	826
1966	209	1979	1103	943	890
1967	225	1980	1243	1048	958
1968	269	1981	1401	1162	1019
1969	327	1982	1579	1289	1084
1970	360	1983	1779	1432	1150
1971	413	1984	2005	1590	1220
1972	476	1985	2260	1766	1290
1973	529	1986	2547	1961	1342
1974	617				
1975	625				
1976	685				
1977	734				

Table 1.1-8

Arkansas Electric Cooperative Corporation
Forecast Peak Loads
(MW)

	1983		1985	
	Without Independence Unit One	With Independence Unit One	Without Independence Unit Two	With Independence Unit Two
1. Capability	1070	1315	1315	1560
2. Purchases without reserves	-	-	-	-
3. Total capability (1 + 2)	1070	1315	1315	1560
4. System maximum load	1432	1432	1766	1766
5. Firm sales with reserves	-	-	-	-
6. Firm purchases with reserves	189	189	189	189
7. Load responsibility (4 + 5 - 6)	1243	1243	1577	1577
8. Margin in excess of load responsibility (3 - 7)	(173)	72	(202)	(17)
9. Desired reserve (15% of 7)	186	186	237	237
10. Percent margin in excess of load responsibility (8 ÷ 7)	(14)	6	(13)	(1)
11. Capacity in excess of desired reserves	(359)	(114)	(439)	(254)

AECC July 1977 revised forecast

1.2 SULFUR DIOXIDE STANDARDS COMPLIANCE

The following presents the Flue Gas Desulfurization (FGD) system and the Low Sulfur Coal (LSC) alternatives for meeting SO_2 emission and ambient standards. The comparison between these alternatives and the rational for the selection of the preferred system are presented.

1.2.1 Environmental Impact

The FGD system, assuming a 3.5 percent sulfur coal with FGD, has three adverse environmental impacts not shared with LSC. These impacts include:

- Most of the FGD systems produce a large quantity of sludge which, although added to the ash storage at most plants, significantly increases the volume of the solid waste storage requirements of the plant. The Independence Steam Electric Station would require 30 to 40 thousand acre feet of additional solid waste disposal volume over the life of the plant. Such solid waste is an environmental impact which is not reversible. The sludge can be covered but not removed.
- Most FGD systems require limestone products as agents to react with and stabilize the SO_2 in the effluent gas streams. This limestone must be mined, usually in strip mines or quarries, thereby causing adverse impacts to these regions. The volume of limestone to be provided is 6 to 8 million cubic yards over the plant lifetime.
- The FGD systems cool and moisten the stack gases while performing the SO_2 removal functions. This results in reduced plume rise from the stack and reduced local dispersion of the residual SO_2 not scrubbed, and all the NO_x and remaining particulates. Also, these cooled and moistened flue gases tend to increase stack maintenance costs. Alternatively, the stack gases can be reheated to return the plume rise to its original value. Such reheating requires more energy expenditures per unit of electric generation than stacks without reheat, thereby wasting valuable natural resources.

The direct environmental impacts of LSC are more favorable than those of FGD systems. There is a secondary impact to LSC which may be unfavorable in comparison with FGD systems, however.

Because more LSC is mined in western states, like Wyoming, and because higher sulfur eastern coal is generally higher in Btu content per unit weight of coal, LSC will require more unit train miles than the eastern coal. Eastern trains, however, affect more people per train mile than western trains. The differential secondary impact for LSC western coal over that for higher sulfur eastern coal may be significant for steam electric stations east of the Mississippi River, locations farther from the LSC source and nearer to the higher sulfur eastern coal. It would appear, for the Independence Steam Electric Station, that the western LSC unit train impact is not greatly different from the unit train impact of the eastern coal due to its more westerly location.

It may be concluded that at a fixed level of SO_2 emission per unit of electric generation, the FGD system has a more severe environmental impact than the use of low sulfur coals at the Independence Steam Electric Station. Also, when LSC achieves the same SO_2 emission rate per million Btu as that achieved by FGD, resulting ambient conditions are the same as or better than with FGD systems. It remains to examine the economic differences between the flue gas desulfurization and the low sulfur coal systems.

1.2.2 Flue Gas Desulfurization at Independence Steam Electric Station

The costs of a flue gas desulfurization system are difficult to estimate because the technology of these systems has not been fully stabilized. There are costs of flue gas desulfurization systems which are related to normal capital and operating costs for the equipment. In evaluating these costs it is usually assumed that the operational reliability of the systems has been established. For flue gas desulfurization systems this is not the case, however. There are additional dollar costs due to system unreliability which are difficult to define but are a very real part of the costs of these systems. The reliability of flue gas desulfurization systems in the United States is summarized in the following section.

1.2.2.1 Reliability of Flue Gas Desulfurization Systems

Kansas Power & Light and Union Electric installed the first full-scale flue desulfurization systems (limestone injection into the boiler followed by scrubbing downstream) in the U. S. in 1968. Since then there has been a succession of scrubbers, principally of the lime-limestone type, each different in design, as the engineering companies sought to find answers to the very difficult technical questions encountered. At each step of the way, regulatory agencies have tended to assume that an acceptable level of technology has been developed, notwithstanding the fact that the developers were abandoning accepted technology and were developing others to combat deficiencies.

The fact that vendors have altered their systems indicates unsatisfactory operation of the units already installed. This is borne out by the operating history of these systems. The system reliability in some has been quite low; and where reliability was acceptable, it was at the expense of extensive modifications and maintenance, redundant FGD units, boiler capacity reduction, periodic open-loop operations or other environmentally unacceptable liquid waste stream disposal, or because low boiler load factors allowed the scrubbers to be cleaned and maintained during shutdowns. The experience also has shown that promising results from pilot plants and small units are not the harbingers of successful large, full-scale operation.

Information regarding operating characteristics of U. S. scrubbers is maintained by PEDCo under contract to USEPA. A summary of PEDCo information, limited to coal burning steam electric stations of greater than 150 MW capacity, is shown in Table 1.2-1. This table shows only 12 scrubbers in operation in the U. S., and the experience of these 12 shows that 7 have serious operational problems, 2 are very new and have little operational experience, and 2 have not reported operational data; leaving only 1 operational plant with fully successful operations.
It is concluded that the indirect cost burdens of FGD, because of

unreliable operations and extensive maintenance, are likely to be quite high, if scrubber installation is required. In light of experience in Japan, it is also quite likely that U. S. scrubber technology will make rapid strides in the next 5 to 10 years in terms of reduced maintenance costs and lower down times. These improved operational characteristics are still unknown and cannot be attributed to present installations.

1.2.2.2 Scrubber Direct Cost Burden

Industry experience has demonstrated that, aside from reliability and maintenance problems, FGD scrubbers add measurably to construction and operating costs resulting in a significant increase in the rate payer's bills. Moreover, the costs typically reported for specific installations are lower than actual costs incurred; this discrepancy appears as a result of incomplete accounting of all FGD costs incurred such as those associated with the design and planning, capital and operational costs, construction, waste disposal, etc.

In the NUS Inc. studies of alternative coals (EIS Section 3.1.3.1), the cost per million Btu of western low sulfur coal was compared with the cost of a 1.72 percent sulfur Illinois coal. These costs were compared for all levels of scrubbing and included transportation, mine mouth coal, and scrubber costs. It was shown that low sulfur western coal was a lower cost fuel than Illinois coal at all levels of sulfur dioxide removal.

Mr. A. V. Slack, an expert on desulfurization processes, has examined costs for installation of scrubbers at Independence Steam Electric Station where 90 percent scrubbing of 3.5 percent sulfur fuel is assumed. These costs are in the range of $80.00 - $90.00 per kilowatt rated capacity and 4.42 mills per kilowatt hour operating costs.

1.2.3 Preferred Alternative

The costs in both environmental expense and in monetary amount indicate the advantage of the low sulfur coal system. It is therefore concluded that the use of the low sulfur coal to satisfy emission and ambient SO_2 standards is preferred over flue gas desulfurization systems.

Table 1.2-1

Large "Operational" Scrubbers in the United States

Owner	Rating % Sulfur	Process Startup	Experience 11/76	12/76	1/77	2/77	3/77	4/77	5/77
Columbus & Southern Conesville #5	400 MW 4.5-4.9	Lime 2/77	—	—	—	43***	ND	30***	50***
			Fire damage to one unit. Data reflects 2nd unit only.						
Commonwealth Edison Co. Will Co. #1	167 MW 4.0	Limestone 2/72	42*	48*	49*	44***	70***	49***	20***
			Continuously plagued with problems. Figures are average for two units.						
Duquesne Light Co. Elrama	510 MW 1.0-2.8 (Only 200 MW coupled to scrubber system)	Lime 10/75	Continuous problems since startup, no reliability data given. Reliability is enhanced by running two scrubbers at partial load. Full continuous operation not expected until 1978.						
Duquesne Light Co. Phillips	410 MW 1.0-2.8	Lime 7/73	Many problems, operability index was 28 percent between July 73 to October 76. Peak load operation, full compliance expected December 77.						
Kansas City Power & Light Co. LaCygne #1	820 MW 5.0 (Output reduced to 700 MW because of scrubber)	Limestone 2/73	94**	90**	93**	93**	92**	92**	—
			Consisted of 7 modules, one of which must be cleaned each night on a rotational basis, requiring 30-36 man hours. Plagued with problems since startup; 1977 modifications included 8th module.						
Kansas Power & Light Co. Lawrence #5	400 MW 0.5	Limestone injection & wet scrubbing 11/71	ND	ND	ND	ND	ND	ND	ND
			Numerous and continued problems, switched to low sulfur Wyoming coal. Construction of lime scrubbing system is in progress.						
Montana Power Co. Colstrip #1	360 MW 0.8	Lime/Alkaline fly ash scrubbing 10/75	ND						

Table 1.2-1 (Continued)

Owner	Rating % Sulfur	Process Startup	Experience 11/76	12/76	1/77	2/77	3/77	4/77	5/77
Montana Power Co. Colstrip #2	360 MW 0.8	Lime/Alkaline fly ash scrubbing 7/76	ND						
Northern States Power Co. Sherburne Co. Sta. #2	710 MW 0.8	Limestone 3/76	93**	95**	90**	91**	95**	95**	ND
			Crew of 70 people required to maintain scrubber operations.						
Northern States Power Co. Sherburne Co. St. # 1	680 MW 0.8	Limestone 4/77	——	——	——	——	——	77**	91**
Pennsylvania Power Co. Bruce Mansfield #1	835 MW 4.7	Lime 4/76	100**	100**	ND	ND	ND	ND	ND
			Availability has been in mid 90 percent since startup.						
Springfield City Utilities Southwest #1	200 MW 3.5	Limestone 4/77	Testing started in April 77; many mechanical corrosion problems.						

*Reliability, expressed as a percentage, is the hours the scrubber operated divided by the hours the scrubber was called on to operate.

**Availability, expressed as a percentage, is the hours the scrubber was available for operation (whether operated or not) divided by the hours in the period.

***Operability, expressed as a percentage, is the hours the scrubber operated divided by the hours the boiler operated.

ND = No data provided

Reference: Summary Report - Flue Gas Desulfurization Systems, May-June 1977, PEDCo Environmental Inc.

1.3 REFERENCES

Hollinden, G. A., and others of Tennessee Valley Authority Power Research Staff, 1977, Flue gas desulfurization. Technical paper prepared for presentation at the Air Pollution Control Conference, American Society of Mechanical Engineers.

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PART 2
SURFACE WATER HYDROLOGY

TECHNICAL SUPPORT DOCUMENT

PART 2

SURFACE WATER HYDROLOGY

CONTENTS

TABLES

FIGURES

PART 2

SURFACE WATER HYDROLOGY

2.1 BASELINE CONDITIONS

2.1.1 Local Environment

As discussed in EIS Section 5.2.1.1, the Independence Steam Electric Station is on the floodplain to the north of the White River, between Oil Trough and Newport. Due to the relatively flat land gradients between these two locations, the White River meanders within this region. The site is to the north of a pronounced meander known as Hulsey Bend (EIS Figure 5.2-2). Bear Wallow Slough is a small, low-lying drainage feature approximately 0.75 mile in length which subtends the lower portion of Hulsey Bend. In the past, during periods of high flow, a portion of the White River flow may have traveled across Bear Wallow Slough rather than following the longer path along Hulsey Bend. During periods of severe flooding, however, a considerable amount of inundation within the entire floodplain takes place, and exact flow paths are impossible to determine. Due to the regulation of flood flows provided since the construction of Beaver, Bull Shoals, Table Rock, and Norfork Reservoirs upstream of the site (EIS Figure 5.2-1), it is unlikely that flows of the magnitude which created Bear Wallow Slough will again occur during the 30-year project lifetime. Data provided in EIS Section 5.2.1.2 indicate that floods of record prior to 1945 at Batesville, approximately 23 river miles upstream of the site, frequently exceeded the largest flood which can be reasonably expected under present regulated conditions.

Ongoing processes of scour and sedimentation have, through time, produced changes in the course of the White River. The rate of change of the river course in the plant vicinity may be assessed by the comparison of photographs taken of the river at widely different times. Figure 2.1-1 is such a comparison, showing the river course at Hulsey Bend at four periods from 1853 to 1976. The base map was reproduced from aerial photographs taken in November 1976 and represents conditions as they presently exist. The 1853 and 1961 river courses, which are superimposed on the base map, were reproduced from the Newport, Arkansas 15-minute U.S. Geological Survey (USGS) topographic quadrangle. The 1949 river course also shown was reproduced from aerial photographs obtained from the Little Rock District Corps of Engineers. The composite figure illustrates the changes of the river course during this 123 year time span. The most radical changes have occurred at the farthest upstream portion of the bend, where the river course changes from roughly easterly, counterclockwise through north, to roughly westerly. The movement of the river course at this location has been generally to the northeast. It is significant to note that the river moved approximately 400 feet at this location during the 14 years between 1961 and 1976. Smaller rates of movement at this point occurred, however, prior to 1961. While it is not possible to quantitatively predict the future movement of the Hulsey Bend, future use of the White River will have to consider the possibility of such movement.

2.1.2 Flow Characteristics

The nearest streamflow gaging station to the site on the White River is number 07074500 at Newport, approximately 12 river miles downstream at the U.S. Highway 67 bridge. While its location is relatively close to the site, it is downstream of the confluence of the Black River. Hence, its contributing drainage area of 19,860 square miles is considerably greater than the 11,270 square miles at the site. An average discharge of 23,020 cubic feet per second (cfs) has been recorded at the Newport station over the 42 year period of record beginning in September 1927. The maximum recorded discharge was 343,000 cfs in April 1945, and the minimum was 2870 cfs in September 1954.

Upstream of the plant site, the nearest currently operating streamflow gaging station on the White River is number 07060500 at Calico Rock. This station, at the Arkansas Highway 5 bridge about 90 river miles upstream of the site, has a contributing drainage area of 9973 square miles. While its location is farther from the site than the Newport gaging station, its drainage area is more closely equivalent to the 11,270 square miles at the site. An annual average discharge of 10,160 cfs has been recorded at the Calico Rock station over the 36-year period of record beginning in October 1939. The maximum recorded discharge at the station was 310,000 cfs in April 1945, and the minimum was 305 cfs in September 1954 (USGS, 1976).

In order to permit a quantitative evaluation of the seasonal flow characteristics of the White River in the site vicinity, the average monthly flows at Calico Rock (drainage area of 9978 square miles) and Newport (drainage area of 19,860 square miles) were computed using the ten most recent years of published data (USGS, 1967-75, 1976). These data (Table 2.1-1) indicate that the month having the highest average flow is April and the month having the lowest average flow is October. In order to estimate the corresponding average monthly flow of the White River at the site, flows were derived by interpolation between the two locations based on the site drainage area of 11,270 square miles. Included in Table 2.1-1 are the estimated average monthly flows at the plant site, and the maximum, minimum, and average daily flows which were derived in an analogous manner.

2.1.3 Derived Floods

The Standard Project Flood (SPF) and 100-year flood have been recently determined by the Corps of Engineers at Batesville and Newport in connection with Flood Plain Information Reports prepared for these communities. These flood discharges for the White River at Batesville (drainage area of 11,070 square miles) and at Newport (drainage area of 19,860 square miles) are shown in EIS Table 5.2-2 (U.S. Army Corps of Engineers, 1973, 1974). Estimates of the corresponding flood discharges at the Arkansas Highway 122 bridge near the site are also included in EIS Table 5.2-2, and were derived by interpolation between the two locations based on the site drainage area of 11,270 square miles.

In addition to the SPF and 100-year flood, floods having return periods of 50, 20, and 10 years were determined. These discharge values, shown in EIS Table 5.2-2, were derived during a study of flood flow characteristics of the White River for the new Arkansas Highway 122 bridge near Oil Trough (USGS, 1973). This report also contains a rating curve for the White River at the bridge location (Figure 2.1-1) which permitted the determination of the flood stages up to the 50-year event. To determine the stages for the SPF and the 100-year flood, the rating curve was extrapolated using the historical flood elevations at Oil Trough shown in Table 2.1-2.

The bridge itself will induce local variations in flow which can result in flood stages slightly different from those which appear in EIS Table 5.2-2 for natural (pre-construction) conditions. The predominant effect of bridge construction will be to increase flood stages upstream of the bridge due to backwater. For example, it has been determined that backwater from the Arkansas Highway 122 bridge will increase the stage of the 50-year flood by 0.50 foot at the bridge, and by 0.45 foot upstream of the bridge at Oil Trough (USGS, 1973). A very slight draw-down of natural flood stages will also occur downstream of the bridge, but this effect will be localized and will not significantly affect flood stages at the plant site. Due to the nature of subcritical flow, backwater effects occur only in the direction upstream of the structure (i.e., bridge) which controls the flow. Since the Arkansas Highway 122 bridge is upstream of the plant site, it cannot control flow condition at the plant site. Therefore, the flood stages and discharges which appear in EIS Table 5.2-2 represent baseline conditions in the site vicinity. Information on floods of historical record is given in Table 2.1-2.

Because the plant site is relatively close to the Black River, flood stages at the site may be influenced by backwater from the Black River. The effect of the Black River is incorporated into the values which appear in EIS Table 5.2-2, since the data at Newport (located below the Black River confluence) include flow contributions by both the White River and the Black River. In the event of severe flooding on only the Black River, some backwater effects on the White River in the plant site vicinity would probably occur. Since the White River itself would not be at flood discharge, the backwater-induced state of the White River would be less than if the White River itself had been assumed to flood. Therefore, the data presented in EIS Table 5.2-2 constitute the controlling flooding conditions in the site vicinity, regardless of whether flooding occurs on only the White River, only the Black River, or on both rivers simultaneously.

2.1.4 Derived Low Flows

In order to quantify the water supply potential of streams during drought conditions, statistical frequency analyses are performed to derive low flows having various probabilities of occurrence. Low flows of varying severity are assigned return periods, in a manner analogous to levels of flooding. The 100-year low flow has a return period of 100 years and will occur, on the average, once every 100 years.

In addition to the frequency of occurrence (or return period) of low flows, the duration of the low flow must also be determined. For example, the instantaneous low flow, the 1-day average low flow, and the 7-day average low flow would have different values even for the same return period. The analysis of flow durations associated with various return periods is usually not performed for floods, since the predominant concern with floods is in determining the peak flow. Statistics on historical low flows are presented in Tables 2.1-3 and 2.1-4.

The USGS performs low flow frequency and duration analyses as described above at the locations of their streamflow gaging stations. EIS Table 5.2-3 summarizes the results of their analyses at the Calico Rock and Newport gaging stations for the 10-year frequency, 7-day duration and the 20-year frequency with durations from 1 to 90 days. The periods of streamflow record used in the analyses at Calico Rock and Newport were 1953-76 and 1954-75 respectively. These periods take into account any low flow augmentation provided since the construction of the upstream reservoirs. Also included in EIS Table 5.2-3 are the estimated low flows at the plant site, derived by interpolation based on the site drainage area of 11,270 square miles.

2.1.5 Arkansas Water Quality Standards

The use classifications for surface waters in the State of Arkansas as defined by the Arkansas Department of Pollution Control and Ecology (ADPCE, 1975) are presented in the following sections.

Class AA: Extraordinary recreational and aesthetic value. Suitable for primary contact recreation, propagation of desirable species of fish, wildlife and other aquatic life, raw water source for public water supplies, and other compatible uses.

Class A: Suitable for primary contact recreation, propagation of desirable species of fish, wildlife and other aquatic life, raw water source for public water supplies, and other compatible uses.

Class B: Suitable for desirable species of fish, wildlife, and other aquatic and semi-aquatic life, raw water source for public water supplies, secondary contact recreation and other uses.

The fisheries classifications are defined as follows:

W Warm Water Fishery

S Smallmouth Bass Fishery

T Trout Fishery

The White River is classified in the site vicinity as Use Class B and Fisheries Class W.

The Arkansas Commission on Pollution Control and Ecology has also established specific physical and chemical water quality standards. These standards, as they apply to the White River in the site vicinity, are summarized below (ADPCE, 1975).

(a) Temperature - During any month of the year, heat shall not be added to any stream in excess of the amount that will elevate the temperature of the water more than 5°F, based upon the monthly average of the maximum daily temperatures as measured at mid-depth or 5 feet, whichever is less. The maximum temperatures due to man-made causes shall not exceed 93°F (33.9°C).

The temperature requirements shall not apply to off-stream or privately-owned reservoirs constructed primarily for industrial cooling purposes and financed in whole or in part by the entity or successor entity using the lake for cooling purposes.

(b) Color - True color attributable to municipal, industrial, agricultural or other waste discharges shall not be increased in any waters to the extent that it will interfere with present or projected future uses of these waters.

(c) Turbidity - There shall be no distinctly visible increase in turbidity of receiving waters attributable to municipal, industrial, agricultural, or other waste discharges. Specifically, in no case shall any such waste discharge cause the turbidity to exceed 50 Jackson Turbidity Units (JTU).

(d) Taste and Odor - Taste and odor producing substances attributable to municipal, industrial, agricultural, or other waste discharges shall be limited in receiving waters to concentrations that will not interfere with the production of potable water by reasonable water treatment processes, or impart impalatable flavor to food fish, or result in offensive odors arising from the waters, or otherwise interfere with the reasonable use of the water.

(e) Solids, Floating Material, and Deposits - Receiving waters shall have no distinctly visible solids, scum, or foam of a persistent nature, nor shall there be any formation of slime, bottom deposits or sludge banks, attributable to municipal, industrial, agricultural, or other waste discharges.

(f) Oil and Grease - Oil, grease or petrochemical substances, attributable to municipal, industrial, agricultural or other waste discharges shall not be present in receiving waters to the extent that they produce globules or other residue or any visible color film on the surface, or coat the banks and/or bottoms of the water course or adversely affect any of the associated biota.

(g) pH - The pH of the water must not fluctuate in excess of 1.0 pH unit, within the range of 6.0 to 9.0, over a period of 24 hours. The pH shall not be below 6.0 or above 9.0 due to wastes discharged to the receiving waters.

(h) Dissolved Oxygen - The dissolved oxygen in the waters shall not be less than 5 milligrams per liter (mg/liter), and in streams this shall be the critical deficit point of the dissolved oxygen profile. The only exceptions will be when periodic lower values are of natural origin and therefore beyond control of the water user. The dissolved oxygen shall be determined by the average of concentrations in samples collected at quarter points across the river.

(i) Radioactivity - The "Rules and Regulations for the Control of Sources of Ionizing Radiation of the Division of Radiological Health, Arkansas State Board of Health," limits the maximum permissible levels of radiation that may be present in effluents to surface waters in uncontrolled areas. These limits shall apply for the purposes of these standards, except that in no case shall the levels of dissolved radium-226 and strontium-90 exceed 3 and 10 picocuries/liter, respectively, in the receiving waters after mixing, nor shall the gross beta concentration exceed 1000 picocuries/liter.

(j) Bacteria - The Arkansas State Board of Health has the responsibility of approving or disapproving surface waters for public water supply and of approving or disapproving the suitability of specifically delineated outdoor bathing places for body contact recreation, and it has issued rules and regulations pertaining to such uses. Otherwise, the fecal coliform content shall not exceed a log mean of 1000/100 ml, nor equal or exceed 2000/100 ml in more than 10 percent of the samples taken in any 30-day period. In all streams, for purposes of routine monitoring and evaluation, fewer numbers of samples collected over longer periods may be used.

(k) Toxic Substances - Toxic materials attributable to municipal, industrial, agricultural, or other waste discharges, shall not be present in receiving waters in such quantities as to be toxic to human, animal, plant or aquatic life or to interfere with the normal propagation of aquatic life. For any toxicants, concentrations in the receiving waters after mixing shall not exceed 0.01 of the ninety-six (96) hour Median Tolerance Limit (TLm), unless they can be shown to be nonpersistent and noncumulative, and to exhibit no synergistic interactions with other waste or stream components. In no case shall concentrations exceed 0.05 of the 96-hour TLm.

(l) Mineral Quality - Existing mineral quality shall not be altered by municipal, industrial or other waste discharges so as to interfere with other beneficial uses. The following limits represent concentrations of chloride, sulfate and total dissolved solids (TDS) not to be exceeded in more than one (1) in ten (10) samples:

Chloride: 20 mg/liter

Sulfate: 60 mg/liter

TDS: 430 mg/liter

(m) Nutrients - The naturally occurring nitrogen/phosphorus ratio shall not be significantly altered due to municipal, industrial, agricultural or other waste dishcarges, nor shall total phosphorus exceed 0.10 mg/liter due to any such discharges. In the interim period until October 18, 1978, application of this requirement will be considered on an individual case basis by the Department, according to ranking of wastewater treatment priorities.

2.1.6 Ambient Water Quality

The following comparison is made between the water quality data which appear in Table 2.1-5 and the Arkansas Water Quality Standards.

(1) Temperature - Maximum value of 78.8°F (26.0°C) is less than the maximum allowable of 93°F (33.9°C).

(2) Color - Maximum value of 40 platinum-cobalt units, average of 8.9 platinum-cobalt units.

(3) Turbidity - Maximum value of 55 JTU exceeds the maximum allowable of 50 JTU. The average value of 8.8 JTU is significantly below the maximum allowable limit.

(4) Taste and Odor - not measured.

(5) Solids, Floating Material, and Deposits - not specifically measured.

(6) Oil and Grease - not measured.

(7) pH - Maximum value of 8.33 is less than the maximum allowable of 9.0. Minimum value of 7.51 is greater than the minimum allowable of 6.0.

(8) Dissolved Oxygen - Minimum value of 7.08 mg/liter is greater than the minimum allowable of 5.0 mg/liter.

(9) Radioactivity - not measured.

(10) Bacteria - The maximum fecal coliform content of 1725/100 ml is less than the maximum allowable of 2000/100 ml. The logarithmic mean fecal coliform content of 43/100 ml, as derived from the raw data, is also less than the maximum allowable of 1000/100 ml.

(11) Toxic Substances - The concentration of toxicants is not measured in terms of the TLm, which is a biologic parameter. However, the mean, maximum, and minimum concentrations of various chemical constitutients which may be toxic to aquatic biota are contained in Table 2.1-5.

(12) Mineral Quality - The maximum chloride concentration of 8.0 mg/liter is less than the maximum allowable of 20 mg/liter. The maximum sulfate concentration of 14.0 mg/liter is less than the maximum allowable of 60 mg/liter. The maximum TDS concentration of 196 mg/liter is less than the maximum allowable of 430 mg/liter.

(13) Nutrients - The maximum total phosphorus concentration of 0.12 mg/liter is greater than the maximum allowable of 0.10 mg/liter. However, the average total phosphorus concentration of 0.028 mg/liter is significantly less than the maximum limit.

The water temperature data presented in Table 2.1-5 are based on 30 measurements made at Oil Trough between April 1974 and December 1976. The nearest location to the site at which the White River water temperature is continuously monitored is at Sylamore. The Sylamore temperature recording station, number 07060660, is in Izzard County roughly 70 miles upstream of the site; measurements were begun at this station in October 1966. The maximum recorded temperature at the station was 30.5°C (86.9°F) in July 1971, and the minimum was 1.0°C (33.8°F) in February 1971 (USGS, 1976).

2.1.7 Water Quality and Sediment Field Monitoring Program

Dames & Moore collected baseline water quality data from the White River in the site vicinity in November 1976, May 1977, and July 1977.

Sampling was also conducted in Wall and Round Lakes during the July 1977 period. All water quality sampling was accomplished in conjunction with the aquatic ecological monitoring program (TSD Part 5) conducted by Dames & Moore. Sampling efforts were scheduled with the intent of obtaining data representative of the fall, spring, and summer seasons. Sediment samples were collected only during the summer effort at the White River stations which are located closest to the proposed intake and discharge structures.

Sampling stations on the White River were selected with the purpose of providing data from points upstream, adjacent to, and downstream of the site boundaries so that it would be possible to make meaningful comparisons between pre- and post-operational water quality data at a later date, if necessary. Stations 1 through 4 were designated, in accordance with the above criteria, for intensive sampling during the fall program. This field effort provided a greater familiarity with the site which, coupled with a clearer definition of site boundaries, led to the addition of Stations 1A, 2A, and 5 in the spring and summer. Of these three stations, Station 5 was sampled intensively while the other two were monitored only for parameters which could be measured in the field. Detailed water quality analyses were eliminated at Station 4 during the spring and summer because it was felt that Station 5 would provide comparable data.

In the summer, Stations 6 and 7, located on Wall and Round Lakes, respectively, were added to the field sampling program. These stations were included since both lakes receive drainage from the site area and eventually discharge into the White River.

Sediments were collected only from Stations 2 and 2A during the summer. These sampling locations were chosen on the basis of their proximity to the proposed intake and discharge structures.

All sampling locations are shown on EIS Figure 5.2-2; a description of each is provided in TSD Part 5. Water quality parameters measured at all locations during each sampling period are shown in Tables 2.1-6 and 2.1-7; parameters analyzed from sediment samples are presented in Table 2.1-8.

2.1.7.1 Methods

Dames & Moore selected individual water quality parameters to be monitored during the field sampling efforts on the basis of: 1) the availability of Arkansas water quality criteria for that parameter; 2) the USEPA's definition of a parameter as a pollutant associated with steam electric generating stations (USEPA, 1974a); and 3) the likelihood that a particular substance would be released to the aquatic environment as a result of plant construction and/or operational activities. Particle size and heavy metals were chosen as the parameters of concern for the sediment samples due to their relationship to potential impacts from sediment resuspension during construction activities.

The following water quality parameters were measured in the field with portable equipment: air temperature, water temperature, dissolved oxygen, pH, specific conductivity, and transparency. A Yellow Springs Instrument Company meter (YSI Model 57) was used to measure air and water temperatures as well as dissolved oxygen levels. The pH was measured with a Fisher Accumet 150 meter during the fall and spring programs, but a Taylor slide comparator was utilized during the summer effort. Specific conductivity measurements were made with a Yellow Springs Instrument Company meter, YSI Model 33. A Wildco #59 Secchi disc, approximately 20 cm in diameter and divided into alternating black and white quadrants, was used to determine transparency. All meters were calibrated at least twice daily, once before initiation of each day's field efforts and again approximately mid-way through the day's activities. Field water quality measurements were made by lowering the appropriate meter probes to a depth of approximately 0.2 m, allowing the meter readings to stabilize, and then recording the results. Secchi disc readings were taken by lowering the disc and noting the water depth at which it was no longer visible; this process was duplicated for each transparency reading, and the recorded depths were averaged to give the final measurement.

In addition to the above field measurements, whole water samples were collected at subsurface depths of approximately 0.2 m with an Alpha bottle. Samples were placed in containers with appropriate preservatives and held on ice until laboratory analysis (Table 2.1-7). With the exception of BOD_5 and fecal coliforms, all parameters were analyzed within the recommended time frame (USEPA, 1974b; American Public Health Association and others, 1976). It was not always possible to complete the field efforts and transport the samples to the laboratory within the recommended holding times for BOD_5 and fecal coliform samples, 6 hr and 8 hr, respectively. In those instances in which the recommended time limits could not be met, approximate holding times are noted on Table 2.1-7 along with analysis results. Analyses of all parameters except pesticides were performed in accordance with procedures outlined by the USEPA (1974b) in "Methods for Chemical Analysis of Water and Wastes" or with procedures included in "Standard Methods for the Examination of Water and Wastewater" (American Public Health Association and others, 1971). Pesticides were analyzed in accordance with methods cited in the USEPA (1976) "Manual of Analytical Quality Control for Pesticides in Human and Environmental Media."

Sediment samples were collected with a plastic scoop, placed in a plastic bag, and transported on ice to the laboratory for analysis. Analytical procedures were performed in accordance with guidelines presented by the U.S. Army Corps of Engineers (1976).

2.1.7.2 Results

Results of water quality analyses conducted in the field during each of the sampling programs are shown in Table 2.1-6; data derived from laboratory analyses of water samples collected during these field efforts are presented in Table 2.1-7. The results of particle size and heavy metal analyses of sediments are shown in Table 2.1-8.

2.1.8 Water Discharges

Table 2.1-9 provides a summary of the significant industrial dischargers in the White River basin within Arkansas. A detailed description of surface water discharges within the White River basin is provided in "Arkansas Water Quality Inventory Report, 1975," published by the Arkansas Department of Pollution Control and Ecology (1976).

Arkansas Eastman Company, a new unit of the Eastman Chemicals Division of Eastman Kodak Company, has begun work on a $30,000,000 chemical plant near Batesville. Upon completion, it is estimated that employment will be approximately 200 persons and that the plant will produce several organic chemical intermediates and hydroquinone. The initial annual capacity planned for hydroquinone production is estimated at 10,000,000 pounds. Hydroquinone is an important chemical in photography and other industrial uses.

Arkansas Eastman has submitted complete plans and studies for control of both air and water discharges. These plans have been approved by the ADPCE. The total cost of the wastewater treatment system for Eastman is estimated at $2,200,000. The State water discharge permit requires that Eastman provide monitoring data of their treatment system discharge, as well as downstream water quality. After 6 months of operation and monitoring, Arkansas Eastman and the ADPCE will assess the need for additional monitoring of the effluent stream as well as stream quality. After complete treatment, the final effluent BOD_5 concentration is expected to average 150 mg/liter from the industrial wastes.

Table 2.1-1

Flow Characteristics of White River

Average Monthly Flows (cfs)
(October 1965 - September 1975)

Month	Calico Rock (Mile 359.1)	Plant Site (Approx. Mile 270)	Newport (Mile 257.6)
Jan	13,580	15,934	31,584
Feb	15,230	17,802	34,904
Mar	14,550	17,214	34,926
Apr	16,095	19,399	41,369
May	14,101	17,286	38,463
Jun	8,382	9,798	19,216
Jul	9,248	10,019	15,145
Aug	8,658	9,367	14,082
Sep	7,256	7,992	12,886
Oct	6,930	7,626	12,255
Nov	9,066	10,347	18,861
Dec	12,007	14,000	27,255
Average and Extremes Flows Over Period of Record			
Average	10,160	11,841	23,020
Maximum	310,000	314,315	343,000
Minimum	305	640	2,870
Period of Record	36 years	- -	42 years

Note: cfs = cubic feet per second

Source: USGS, 1967-75, 1976

Table 2.1-2

Major Historical Floods on White River
(Batesville to Newport)

Date	White River at Batesville, datum 237.72, Mile 300.1 Elevation	White River at Oil Trough, datum 200.00, Mile 277.3 Elevation	White River at Newport, datum 194.09, Mile 257.6 Elevation	Discharge at Batesville (cfs)	Discharge at Newport (cfs)
1915	269.3	238.4	228.0	373,000	280,000
1916	269.6	238.0	228.4	382,000	303,000
1927	269.1	237.7	229.7	369,000	387,000
1933	262.6	236[a]	226.2	220,000	199,000
1938	265.1	237.2	227.5	260,000	259,000
1939	259.3	--	224.4	165,000	144,000
1943	265.7	--	228.8	281,000	304,000
1945	267.1	--	230.0	324,000	343,000
1949	263.4	237.4	228.1	236,000	260,000
1950	262.5	236[a]	226.2	216,000	194,000
Apr 4, 1957	257.5	--	--	124,000	--
May 9, 1961	--	--	224.25	--	130,000
Feb 1, 1969	--	--	224.1	--	125,000
Mar 17, 1969	--	222.5	212.2	--	--
Apr 3, 1969	--	222.3	214.8	--	--
Apr 28, 1970	--	230.2	219.8	--	73,100

[a] Estimated

Note: cfs = cubic feet/second

Table 2.1-3

Historical Low Flows
White River at Calico Rock

YEAR[a]	1 DAY	3 DAYS	7 DAYS	14 DAYS	30 DAYS	60 DAYS	90 DAYS
1953	733	1190	1590	1620	1650	1780	1950
1954	2400	2750	2880	3240	3620	4200	4810
1955	310	342	412	469	498	619	883
1956	1720	2630	3700	3710	3810	4100	4150
1957	713	2620	3950	4090	4240	4500	4760
1958	3890	4980	5960	6460	6900	7510	7550
1959	1770	3280	4150	4760	5360	6290	6720
1960	2070	3370	3670	4010	4620	5170	5070
1961	1220	1620	2310	2550	3040	3430	3730
1962	2450	2720	3310	3530	3830	4040	4280
1963	1470	1880	2800	2870	3610	4320	4340
1964	713	1020	1390	1690	1990	2190	2780
1965	920	1090	1480	1660	2110	2320	2820
1966	1340	1400	1600	2130	3090	4000	4440
1967	870	1200	2040	2310	3050	3470	3950
1968	1050	1270	2000	2430	2960	3460	4590
1969	1910	2150	2660	2800	3220	5440	6540
1970	1190	1550	2100	2680	3830	4320	4620
1971	1630	2080	3290	4220	4820	5910	5880
1972	761	906	1150	1490	1880	3630	4260
1973	848	1160	2080	3030	3780	4750	5760
1974	2540	3290	5470	6000	7330	8320	12600
1975	2280	3820	5470	7190	9500	11200	12200
1976	958	1130	1820	2140	2940	4320	4870

Note: Low flows (cfs) corresponding to indicated durations

cfs = cubic feet/second

[a] "Water Year," which begins on October 1 of the previous year and ends on September 30 of the indicated year

Table 2.1-4

Historical Low Flows
White River At Newport

YEAR[a]	1 DAY	3 DAYS	7 DAYS	14 DAYS	30 DAYS	60 DAYS	90 DAYS
1954	5890	5990	6090	6370	6800	7400	7850
1955	2870	2870	2960	3110	3520	3580	3720
1956	4520	5160	6010	6120	6340	6570	6590
1957	3880	4910	5790	5980	6210	6600	6840
1958	11600	12100	12400	12800	15200	19400	20300
1959	6900	7400	8020	8470	9190	11000	12600
1960	6600	7030	7530	7610	8300	8880	9180
1961	5520	5710	6060	6380	6790	7050	7400
1962	5800	6120	6490	6700	6970	7130	7500
1963	5800	6170	7120	7280	7650	8280	8320
1964	4120	4210	4360	4580	5040	5920	6190
1965	4440	4630	4980	5130	5170	6490	6840
1966	5590	5840	7310	8040	8430	8740	9140
1967	5290	5490	6010	6280	7570	8000	8190
1968	4260	4400	5250	6060	6510	7100	8640
1969	5350	5850	6590	6700	8970	11100	12000
1970	5300	5730	6040	6610	7520	8310	8370
1971	7420	7660	8570	9960	11100	12300	12500
1972	3610	3830	4280	4520	5130	6120	6920
1973	4530	4680	5710	6310	8010	9580	9730
1974	11300	12000	13400	14000	15300	16600	20500
1975	8790	9760	10700	12300	14600	17400	18500

Note: Lows flows (cfs) corresponding to indicated durations

cfs = cubic feet/second

[a] "Water Year," which begins on October 1 of the previous year and ends on September 30 of the indicated year.

Table 2.1-5

Ambient Water Quality White River at Oil Trough

PARAMETER MEASURED		UNITS	NUMBER OF MEASUREMENTS	MEAN VALUE	MAXIMUM VALUE	MINIMUM VALUE	BEGINNING DATE	ENDING DATE
WATER	TEMP	CENT	30	15.5333	26.0000	5.00000	74/04/09	76/12/28
TURB	JKSN	JTU	29	8.80344	55.0000	2.20000	74/04/09	76/12/28
COLOR	PT-CO	UNITS	29	8.93103	40.0000	.000000	74/04/09	76/12/28
CNDUCTVY	AT 25C	MICROMHO	30	264.333	315.000	219.000	74/04/09	76/12/28
DO		MG/L	30	9.93498	12.4900	7.08000	74/04/09	76/12/28
DO	SATUR	PERCENT	30	97.8333	114.000	84.0000	74/04/09	76/12/28
BOD	5 DAY	MG/L	30	1.66533	4.20000	.090000	74/04/09	76/12/28
COD	HI LEVEL	MG/L	1	5.50000	5.50000	5.50000	76/07/19	76/07/19
PH		SU	30	8.06899	8.33000	7.51000	74/04/09	76/12/28
HCO3 ION	HCO3	MG/L	11	158.000	177.000	138.000	74/05/06	76/10/18
CO3 ION	CO3	MG/L	9	.000000	.000000	.000000	74/05/06	76/04/21
RESIDUE	TOTAL	MG/L	29	176.690	222.000	147.000	74/04/09	76/12/28
RESIDUE	DISS-105	C MG/L	29	159.103	196.000	127.000	74/04/09	76/12/28
RESIDUE	TOT NFLT	MG/L	30	17.5667	78.0000	3.00000	74/04/09	76/12/28
NO3-N	TOTAL	MG/L	29	.395172	.960000	.100000	74/04/09	76/12/28
PHOS-TOT		MG/L P	30	.028033	.120000	.001000	74/04/09	76/12/28
TOT HARD	CACO3	MG/L	11	137.273	196.000	108.000	74/05/06	76/10/18
CALCIUM	CACO3	MG/L	11	88.5454	124.000	68.0000	74/05/06	76/10/18
CALCIUM	CA,DISS	MG/L	11	35.5454	50.0000	27.0000	74/05/06	76/10/18
MGNSIUM	MG,DISS	MG/L	11	11.9091	17.0000	8.00000	74/05/06	76/10/18
SODIUM	NA,TOT	MG/L	11	2.17272	4.10000	.800000	74/05/06	76/10/18
PTSSIUM	K,TOT	MG/L	11	1.11727	1.50000	.090000	74/05/06	76/10/18
CHLORIDE	CL	MG/L	22	4.93182	8.00000	3.50000	74/05/06	76/12/28
SULFATE	SO4-TOT	MG/L	22	4.72727	14.0000	2.00000	74/05/06	76/12/28
ARSENIC	AS,TOT	UG/L	20	2.71515	3.00000	.003000	74/04/09	76/10/18
CADMIUM	CD,TOT	UG/L	19	1.63158	6.00000	.000000	74/04/09	76/10/18
CHROMIUM	CR,TOT	UG/L	20	.600000	3.00000	.000000	74/04/09	76/10/18
COPPER	CU,TOT	UG/L	20	3.35000	16.0000	.000000	74/04/09	76/10/18
IRON	FE,TOT	UG/L	20	250.350	1598.00	17.0000	74/04/09	76/10/18
LEAD	PB,TOT	UG/L	19	4.94737	32.0000	.000000	74/04/09	76/10/18
MANGNESE	MN	UG/L	19	67.0526	241.000	25.0000	74/04/09	76/10/18
ZINC	ZN,TOT	UG/L	19	2.33158	21.0000	.000000	74/04/09	76/10/18
TOT COLI	MFIMENDO	/100ML	33	613.636	6000.00	10.0000	74/01/07	77/02/22
FEC COLI	MFM-FCBR	/100ML	34	166.912	1725.00	4.00000	74/01/07	77/02/22
FECSTREP	MF M-ENT	/100ML	15	87.6000	480.000	4.00000	74/01/07	76/09/20
ALDRIN	WHL SMPL	UG/L	3	.001000	.001000	.001000	74/05/06	75/11/25
DDD	WHL SMPL	UG/L	2	.002000	.003000	.001000	74/05/06	75/02/04
DDE	WHL SMPL	UG/L	3	.001000	.001000	.001000	74/05/06	75/11/25
DDT	WHL SMPL	UG/L	3	.001667	.003000	.001000	74/05/06	75/11/25
DIELDRIN	WHL SMPL	UG/L	3	.001000	.001000	.001000	74/05/06	75/11/25
ENDOSULN	WHL SMPL	UG/L	2	.001000	.001000	.001000	74/05/06	75/02/04
ENDRIN	WHL SMPL	UG/L	3	.002333	.004000	.001000	74/05/06	75/11/25
TOXPHENE	WHL SMPL	UG/L	3	.085667	.107000	.050000	74/05/06	75/11/25
HCHLR	WHL SMPL	UG/L	2	.001000	.001000	.001000	74/05/06	75/02/04
HCHLR-EP	WHL SMPL	UG/L	2	.001000	.001000	.001000	74/05/06	75/02/04
MTHXYCLR	WHL SMPL	UG/L	2	.007500	.011000	.004000	74/05/06	75/02/04
MPARATHN	WHL SMPL	UG/L	3	.004333	.007000	.001000	74/05/06	75/11/25
LINDANE	WHL SMPL	UG/L	3	.001000	.001000	.001000	74/05/06	75/11/25
MERCURY	HG,TOTAL	UG/L	1	.500000	.500000	.500000	76/10/18	76/10/18

Source: U. S. Environmental Protection Agency, 1977

Table 2.1-6

Results of Water Quality

Analyses from the Independence Site Area[a]

Station	1								1A		
Date	11/02	11/03	11/04	5/18	5/19	7/26	7/28	7/29	5/17	5/18	7/26
Time	1200	1020	1310	1515	1200	1615	1050	1130	1720	1620	1710
Air Temperature (°C)	13.5	10.0	6.0	23.9	25.5	23.5	24.9	30.0	26.5	25.9	23.0
Water Temperature (°C)	12.2	11.8	13.0	18.0	18.0	24.5	23.2	24.5	19.6	18.2	24.8
Dissolved Oxygen (mg/l)	10.2	9.7	10.2	11.4	10.2	8.1	7.9	8.7	11.2	11.1	8.4
pH (units)	8.0	8.1	7.6	MI[b]	MI	7.6	7.6	7.5	7.6	MI	7.6
Specific Conductivity (umho/cm)	185	200	210	230	210	300	275	275	225	235	300
Transparency (m)	ND[c]	1.4	ND	ND	1.2	1.3	>1.2	>1.2	ND	ND	>0.3

Station	2								2A	
Date	11/02	11/03	11/04	5/18	5/19	7/26	7/28	7/29	5/18	7/29
Time	1430	1205	1220	1400	1250	1510	1400	1150	1250	1225
Air Temperature (°C)	14.5	14.0	7.0	26.2	24.5	24.8	32.0	32.5	28.0	34.0
Water Temperature (°C)	13.5	12.5	13.0	18.5	17.1	24.8	24.5	25.0	19.5	26.0
Dissolved Oxygen (mg/l)	10.7	10.2	10.8	11.3	10.1	8.1	7.5	7.1	9.1	6.1
pH (units)	7.6	7.9	7.7	MI	MI	7.6	7.5	7.6	MI	7.6
Specific Conductivity (umho/cm)	215	210	200	230	215	300	278	278	230	285
Transparency (m)	>1.5	ND	ND	ND	ND	1.1	ND	ND	0.4	ND

Table 2.1-6 (Continued)

Station Number	3								4			
Date	11/03	11/04	5/17	5/18	5/19	7/26	7/28	7/29	11/03	11/04	5/16	7/28
Time	1450	1030	1305	1040	1315	1325	1455	1240	1600	1100	1630	1615
Air Temperature (°C)	12.0	8.0	28.0	26.0	25.9	22.0	27.5	35.5	14.0	8.0	26.2	29.2
Water Temperature (°C)	13.0	13.0	19.5	18.0	17.5	4.5	25.0	25.0	13.2	13.0	23.2	24.5
Dissolved Oxygen (mg/l)	10.1	11.0	10.[illegible]	6	9.9	7.0	7.9	5.3	9.7	10.4	8.1	7.9
pH (units)	7.8	7.2		MI	MI	7.6	7.6	7.5	8.0	7.7	8.2	7.6
Specific Conductivity (μmho/cm)	210	200		225	215	300	270	285	210	205	235	285
Transparency (m)	ND	ND	[illegible]	ND	ND	0.9	1.5	1.2	1.5	ND	>0.2	>0.3

Station Number	5							6		7	
Date	5/16	5/17	5/18	5/19	7/26	7/28	7/29	7/27	7/29	7/27	7/29
Time	1515	1015	1850	1350	1115	1730	1320	1430	1610	1615	1550
Air Temperature (°C)	27.0	26.0	22.5	25.0	22.5	30.0	34.0	23.0	39.0	21.5	38.0
Water Temperature (°C)	19.5	20.0	18.4	17.5	25.4	24.8	26.5	24.2	37.5	24.0	37.5
Dissolved Oxygen (mg/l)	8.1	10.4	10.7	9.5	7.7	7.7	6.8	6.5	8.7	6.0	9.1
pH (units)	7.9	7.6	MI	MI	7.5	7.4	7.5	T[d]	T	7.6	7.6
Specific Conductivity (μmho/cm)	230	225	230	215	300	285	290	252	320	255	355
Transparency (m)	0.7	1.1	0.8	1.0	ND	1.2	1.1	<0.03	<0.03	0.08	0.08

Mean daily White River flow (cfs) at Batesville dam:

11/02 : 6400	5/16 : 6000	7/26 : 2800
11/03 : 13600	5/17 : 5500	7/27 : 2200
11/04 : 8500	5/18 : 10,000	7/28 : 1500
	5/19 : 6500	7/29 : 1200

Source: Hines, Marion (USGS) and Bob Rentschler (Corps of Engineers), 1977, Personal communications; From U.S. Army Corps of Engineers' data.

[a] Water quality measurements made about 0.2m below the water surface. Stations are shown on EIS Figure 5.2-2.

[b] MI - meter inoperable

[c] ND - no data collected; water flow too swift for Secchi disc reading

[d] Too turbid for pH measurement with color comparator

Table 2.1-7

Results of Laboratory Analyses of Water from the Independence Site Area[a]

Station Number	1			2			3			4	5		6	7
Date	11/4	5/19	7/29	11/4	5/19	7/29	11/4	5/19	7/29	11/4	5/19	7/29	7/29	7/29
Turbidity[c]	<0.4	<1	2.0	<0.4	<1	1.9	<0.4	<1	5.5	<0.4	<1	1.6	500	13
pH (pH units)	7.7	8.1	7.6	7.7	7.9	7.9	7.7	7.9	7.8	7.7	8.0	8.0	7.4	8.2
Color (color units)[d]	5	5	5	5	-	5	5	5	5	5	5	5	50	30
Total Hardness (as $CaCo_3$)	106	119	119	104	123	122	102	120	119	102	212	123	118	105
Carbonate Alkalinity (as $CaCo_3$)	0	7.4	0	0	9.6	0	0	8.6	0	0	8.2	0	0	0
Total Alkalinity (as $CaCo_3$)	134	127	141	130	129	143	130	124	139	130	128	144	120	134
Ammonia[e]	<0.1	<0.05	0.10	<0.1	<0.05	0.09	<0.1	<0.05	0.08	<0.1	<0.05	0.06	0.17	<0.05
Nitrite - N	<0.01	<0.01	<0.01	<0.01	-	0.10	<0.01	-	0.11	<0.01	<0.01	0.11	<0.01	0.09
Nitrate - N[f]	0.4	0.11	0.16	0.4	0.09	0.14	0.5	0.10	0.14	0.3	<0.1	0.15	<0.1	<0.1
Organix Nitrogen	0.3	<0.05	1.2	0.4	<0.05	0.7	0.5	<0.05	0.8	0.5	<0.05	0.7	8.6	1.9
Orthophosphate (as P)	0.02	0.01	0.02	0.01	0.02	<0.01	0.01	0.01	<0.01	0.01	<0.01	0.02	0.09	0.05
Total Phosphorus (as P)[f]	0.02	0.025	0.050	0.03	0.025	0.018	0.03	0.025	0.029	0.03	0.012	0.023	0.108	0.109
Chloride	7.7	6.6	6.3	7.5	6.6	6.0	9.8	6.8	6.4	12	6.8	6.8	30.5	22.8
Sulfate	3	10.1	7.4	3	11.4	6.2	3	11.4	5.0	3	11.6	5.7	8.9	5.8
Silica	2.8	2.0	<2	3.7	-	<2	3.1	-	<2	2.7	2.0	<2	7.0	4.0

Station Number	1			2			3			4	5		6	7
Date	11/4[b]	5/19	7/29	11/4	5/19	7/29	11/4	5/19	7/29	11/4	5/19	7/29	7/29	7/29
Total Dissolved Solids	139	188	400	132	187	290	130	252	420	124	200	339	150	299
Total Suspended Solids	1.8	11.6	<0.1	3.5	13.2	<0.1	5.0	8.4	<0.1	2.0	10.0	1.0	900	21
BOD_5[g]	<1	214	0.7	<1	-	1.0	<1	-	0.8	<1	0.7	0.5	96.0	5.5
COD[h]	<3	<20	<15	<3	-	<15	<3	-	<15	<3	<20	<15	146	<15
Oil and Grease	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2.5	1
Detergents	<0.025	0.080	0.026	<0.025	-	<0.025	<0.025	-	<0.025	<0.025	0.073	<0.025	<0.025	<0.025
Phenols	<0.005	<0.005	<0.005	<0.005	-	<0.005	<0.005[i]	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Calcium	26	28.3	23.2	25	30.1	23.9	25	28.6	23.3	25	29.2	24.1	26.2	24.0
Chromium[j]	<0.05	<0.1	<0.02	<0.05	<0.1	<0.02	<0.05	<0.1	<0.02	<0.05	<0.1	<0.02	<0.02	<0.02
Copper[j]	0.03	<0.05	<0.01	0.03	<0.05	0.02	0.01	<0.05	<0.01	0.02	<0.05	<0.01	<0.01	<0.01
Iron[f]	0.12	<0.1	0.05	0.17	<0.1	0.05	0.10	<0.1	0.05	0.22	<0.1	0.05	4.95	0.82
Lead	-	-	<0.05	-	-	<0.05	-	-	<0.05	-	-	<0.05	<0.05	<0.05
Magnesium	10.2	11.7	14.9	10	11.6	15.0	9.5	11.7	14.8	9.5	11.7	15.2	10.5	10.7
Mercury (μg/l)	-	-	<0.2	-	-	<0.2	-	-	<0.2	-	-	<0.2	<0.2	<0.2
Zinc[f]	0.01	0.06	<0.005	0.02	0.67	<0.005	<0.01	0.03	<0.005	0.03	0.04	<0.005	<0.005	<0.005
Fecal Coliforms[k]	4	46	8	8	49	7	0	46	48	5	49	54	76	<2
Pesticides														
Atrizine	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01
Treflan	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	-	<0.01	<0.01	<0.01	<0.01

[a]Units expressed as milligrams per liter (mg/l) unless otherwise indicated.

[b]Values shown in this column represent averages of results obtained for 2 water samples collected consecutively at the station.

[c]Fall (11/4) and summer (7/29) values presented in nephelometric units; spring (5/19) values are presented as Jackson units.

[d]Measured at pH given above.

[e]Change in analysis sensitivity due to elimination of "background" ammonia levels present in laboratory. Analysis methodology similar for all sampling periods.

[f]Change in sensitivity due to use of more sensitive equipment. Sample preparation for analysis same for each sampling period.

[g]Sensitivity for most BOD_5 was higher in spring and summer than in fall analyses due to substitution of more sensitive method of dissolved oxygen measurement. Sample holding times were longer than the recommended 6-hour limit. Maximum holding times for individual samples were approximately as follows: Fall - St. 1, 10 hr.; St. 2 - 11.5 hr.; St. 3, 13.5 hr.; St. 4, 12 hr. Spring - St. 1, 9 hr.; St. 2, 8 hr.; St. 3, 7.5 hr.; St. 5, 7 hr. Summer - St. 1, 11.5 hr.; St. 2, 11 hr.; St. 3, 10.5 hr.; St. 5, 9 hr.; St. 6, 6 hr.; St. 7, 7 hr.

[h]Sensitivity decreased in spring and summer due to laboratory determination that the procedure for detection of higher COD levels was more reliable than that for low COD levels.

[i]Preservative not completely mixed in the sample.

[j]Sensitivity changes due to normal variability in sensitivity of atomic absorption unit.

[k]Change in apparent sensitivity of summer analyses due to utilization of a different analysis method which yields results comparable to the method used for previous analyses. Results expressed as colonies /100 ml in fall and spring and MPN/100 ml in summer. In some instances the recommended sample holding time of 8-hours was exceeded. See footnote "g" for holding times.

Note: A dash (-) indicates that samples were not collected for this parameter during the particular sampling period.

Table 2.1-8

Results of Analyses on Sediments Collected from the White River in the Site Area
(Summer 1977 Sampling Effort)

Particle Size Distribution
(Percent retained)

Station Number	U.S. Standard Sieve Number/Opening Size (mm)				
	12/1.68	20/0.840	40/0.420	80/0.177	PAN/<0.177
2	16	1.5	3.2	73	7
2A	0	0	0	33	67

Metal Analyses
(ppm)

Station Number	Parameter					
	Cr	Cu	Fe	Pb	Hg	Zn
2	1.70	0.40	649	2.03	0.08	4.4
2A	6.01	1.87	2870	7.45	0.12	14.9

Table 2.1-9

Significant Industrial Dischargers in the White River Basin

Basin Rank	State Rank	Industry
1	20	Helena Chemical Company, West Helena
2	27	Arkansas Technical Industries Batesville
3	28	Tharp Brothers Egg Plant, Hickory Flat
4	32	General Electric Company, Jonesboro
5	33	Baxter Laboratories, Mountain Home
6	37	Revere Copper & Brass, Newport
7	39	Victor Metals Company, Newport
8	49	Quality Metal Finishers, Batesville
9	50	Aerojet Ordnance & Manufacturing, Batesville
10	66	Silica Products Corp., Guion
11	68	Marine Protein Corporation, Mammoth Spring
12	77	Metal Art Frame Company, Inc., Hardy

Note: Ranks, by magnitude of discharge, are those assigned by ADPCE (1976).

LEGEND: -----1853 ———1961
—·—·-1949 (BASE) 1976

2000 1000 0 2000
SCALE IN FEET

Figure 2.1-1. Historical movement of White River at Hulsey Bend.

2.2 CONSTRUCTION IMPACTS

2.2.1 Chemical and Biological Pollutants

Pollution from petroleum products generally occurs from improper disposal of waste material such as crankcase oil and various cleaning solvents, leakage of fuels and oil from storage facilities, and damaged or improperly maintained vehicles; fuel spills during equipment refueling operations; and the use of oils for dust control on roadways.

Herbicides and/or pesticides are used on some construction sites to control undesirable vegetations, insects, and rodents. The primary causes of pollution from the use of these chemicals are in the improper use, handling, and disposal of waste materials.

Fertilizers are extensively utilized in the revegetation of areas affected by grading operations. Like herbicides and pesticides, the primary causes of damaging pollution are improper use, i.e., applying too much fertilizer or improper preparation of the ground surface prior to applications.

The biological pollutants which generally enter receiving streams and other water bodies as an indirect result of construction activities are primarily bacteria, fungi, worms, and viruses. Biological pollution is primarily a result of poor sanitary conditions at a construction site; generally improper disposal of human wastes, garbage, and other organic material. The disturbance, exposure, and subsequent erosion of surface soils that contain bacteria and other organisms are also contributing factors. Regardless of their origin, biological pollutants of major concern are the pathogenic organisms associated with human wastes.

The mitigation and/or prevention of this type of chemical and biological pollution will be obtained through proper application, handling, and disposal of these materials. Also, programs to educate the onsite personnel to the need for preventive measures to control this pollution should aid in this process. Some impact during construction is unavoidable but it is not expected to be significant.

2.2.2 Sewage Treatment Plant Effluent

The permanent package sewage treatment plant for the station is designed to provide 90 percent BOD removal and a total chlorine residual of 1.0 mg/liter after 20 minutes contact time. The BOD of the effluent stream from the treatment plant operating at its design capacity of 12,250 gal/day (0.019 cfs) is computed using the following equation:

$$C_1 = \left(\frac{100 - P}{100}\right)(B/Q_1)$$

Where, C_1 = BOD concentration of sewage effluent

P = percent BOD removal (90 percent)

B = BOD content of sewage (35 lb/day)

Q_1 = flow of sewage effluent (12,250 gal/day)

Therefore, $C_1 = 2.86 \times 10^{-4}$ lb/gal

$= 34.2$ mg/liter

Consistent with the requirements of the Arkansas Water Quality Standards, the effects of wastes on the receiving stream must be determined after the wastes have been thoroughly mixed with the stream water, providing that the mixing zone does not exceed 25 percent of the stream cross sectional area and/or volume of streamflow. To be conservative, the potential impact on water quality resulting from the blowdown discharge was computed during conditions of the 7-day average low flow having a return period of 10 years. This flow condition, is identified in EIS Section 5.2.1.3 as the minimum flow below which the Arkansas water quality standards do not apply, is approximately 1506 cfs in the site vicinity. Applying the 25 percent mixing zone criterion discussed above, a minimum flow of approximately 376.5 cfs is available in the White River for dilution of the sewage treatment plant effluent.

2.2.2.1 BOD

The increase in BOD in the White River due to sewage effluent discharge is computed using the following equation:

$$C_3 = (Q_1C_1 + Q_2C_2)/(Q_1 + Q_2)$$

Where, C_3 = fully mixed BOD concentration of White River mixing zone

Q_2 = flow of mixing zone under 10-year, 7-day low flow conditions

= 376.5 cfs, as determined above

C_2 = ambient BOD concentration of White River at Oil Trough from Table 2.1-5 (4.2 mg/liter, maximum)

Q_1, C_1 = defined in previous formula

Therefore, C_3 = 4.202 mg/liter

The computed increase in BOD concentration in the White River mixing zone, 0.002 mg/liter or less than 0.05 percent of the ambient, is both beyond the accuracy of determination and insignificant. Therefore, no detectable reduction in dissolved oxygen levels or other impacts associated with increased BOD are anticipated.

2.2.2.2 Chlorine

The increase in chlorine concentration in the White River attributable to sewage effluent discharge is computed using the following equation:

$$C_6 = (Q_2C_4 + Q_1C_5)/(Q_1 + Q_2)$$

Where, C_6 = fully mixed chlorine concentration in White River mixing zone

C_4 = ambient chlorine concentration in White River

= assumed to be zero

C_5 = chlorine concentration in sewage effluent

= 1.0 mg/liter, as determined above

Q_1, Q_2 = as defined previously

Therefore, $C_6 = 5.05 \times 10^{-5}$ mg/liter

A concentration of 5×10^{-5} mg/liter total chlorine residual represents such a small quantity that it is probably not detectable or is impossible to measure accurately. At that concentration, it would disappear because the river water contains dissolved inorganic and some organic compounds which would consume the residual chlorine. Therefore, no impacts associated with the sewage effluent chlorine residual are anticipated.

2.3 OPERATION IMPACTS

2.3.1 Temperature

The increase in temperature in the White River due to blowdown discharge is computed using the following equation:

$$T_3 = (Q_1T_1 + Q_2T_2)/(Q_1 + Q_2)$$

Where:

T_3 = temperature of White River mixing zone

Q_1 = flow of mixing zone under 10-year, 7-day low flow conditions [365 cfs: Note, for operational low flow considerations, the maximum withdrawal makeup water of 45.5 cfs is removed from the 10-year, 7-day low flow condition prior to determining the 25 percent mixing zone criterion (EIS Section 6.2.1.2).]

T_1 = ambient temperature of White River at Oil Trough (Table 2.1-5)

Q_2 = flow of blowdown discharge (11.2 cfs)

T_2 = temperature of blowdown discharged (95° F maximum)

Therefore, $T_3 = (365T_1 + 1064)/376.2$

The maximum recorded water temperature from Table 2.1-5 is 26.0°C (78.8°F). Under these conditions:

$$T_3 = 79.3°F$$

$$\Delta T = T_3 - T_1 = 79.3 - 78.8 = 0.5°F$$

The minimum recorded water temperature from Table 2.1-5 is 5.0°C (41.0°F). Under these conditions:

$$T_3 = 42.6°F$$

$$\Delta T = T_3 - T_1 = 42.6 - 41.0 = 1.6°F$$

2.3.2 Blowdown Reconcentration

The chemicals constituents in the plant blowdown will contain a number of elements native to the White River, as shown in Table 2.1-5, but concentrated approximately 4 to 6 times above the naturally occurring levels. The increase in concentration of these constituents after mixing with the White River is computed as follows:

$$C_3 = (Q_1C_1 + Q_2C_2)/(Q_1 + Q_2)$$

Where:

C_3 = concentration in White River mixing zone

Q_1 = flow of mixing zone under 10-year, 7-day low flow conditions (365 cfs)

C_1 = ambient concentration of White River at Oil Trough (Table 2.1-5)

Q_2 = flow of blowdown discharged (11.2 cfs)

C_2 = concentration of blowdown ($4C_1$)

Therefore, $C_3 = 1.09\ C_1$

Thus, the concentrations of the chemical constituents in the White River after mixing will be 109 percent of the ambient concentrations shown in Table 2.1-5 due to blowdown reconcentration. This increase does not pertain, however, to those constituents discussed in the sections entitled "Chemicals Present in Drainage" and "Chemical Additives" which follow.

2.3.3 Chemicals Present in Drainage

The surge pond drainage water may contain chemical constituents, present in the water of the surge pond, which may not be completely removed by chemical treatment prior to entering the plant makeup. A discussion of the surge pond drainage treatment and chemical constituency of the treated effluent stream is provided in EIS Section 6.2.1.2. Because these chemicals are present in the plant makeup, the resulting increase in concentrations in the White River will be greater than if determined using the procedures in the preceeding section, "Blowdown Reconcentration."

2.3.3.1 Combined Makeup

The steady state concentrations in the combined makeup are computed as follows:

$$C_3 = (Q_1C_1 + Q_2C_2)/(Q_1 + Q_2)$$

Where:

C_3 = concentration in combined makeup

Q_1 = flow of treated discharge from surge pond (4.9 cfs average)

C_1 = concentration in flow Q_1 (Column 2 of Table 2.3-1)

Q_2 = flow of makeup contribution from White River (40.6 cfs average, at peak load)

C_2 = concentration in flow Q_2 (Column 3 of Table 2.3-1)

Therefore, $C_3 = (4.9\ C_1 + 40.6\ C_2)/45.5$

The computed values of C_3 appear in Column 4 of Table 2.3-1.

2.3.3.2 Blowdown

The steady state concentrations in the blowdown are computed as follows:

$$C_4 = 4\ C_3$$

Where:

C_4 = concentration in blowdown, due to operation at 4 cycles of concentration

C_3 = as defined previously

The computed values of C_4 appear in Column 5 of Table 2.3-1.

2.3.3.3 White River

The steady state concentrations after mixing with the White River are computed as follows:

$$C_5 = (Q_2'C_2 + Q_4C_4)/(Q_2' + Q_4)$$

Where:

C_5 = concentration in White River mixing zone

Q_2' = flow of mixing zone under 10-year, 7-day low flow conditions (365 cfs)

Q_4 = flow of blowdown discharged (11.2 cfs)

C_2, C_4 = as defined previously

Therefore, $C_5 = (365\ C_2 + 11.2\ C_4)/376.2$

The computed values of C_5 appear in Column 6 of Table 2.3-1.

Due to the application of sulfuric acid to the cooling water, the sulfate concentration in the White River mixing zone is not given. The increase in sulfate concentration and other chemical constituents resulting from chemical additives is discussed in the section which follows.

2.3.4 Chemical Additives

2.3.4.1 Chlorine

Under worst-case conditions, a maximum chlorine concentration of 0.5 mg/l could theoretically occur in the plant blowdown. The increase in concentration of chlorine under these conditions is computed as follows:

$$C_3 = (Q_1C_1 + Q_2C_2)/(Q_1 + Q_2)$$

Where:

C_3 = chlorine concentration in White River mixing zone

Q_1 = flow of mixing zone under 10-year 7-day low flow conditions (365 cfs)

C_1 = ambient chlorine concentration in White River (assumed to be zero)

Q_2 = flow of blowdown discharged from one unit being chlorinated (11.2 cfs/2 = 5.6 cfs)

C_2 = chlorine concentration in blowdown (Column 5 of Table 2.3-1)

Therefore: $C_3 = 5.60\ C_2/370.6$

The computed value of C_3 appear in Column 6 of Table 2.3-1.

2.3.4.2 Sulfuric Acid

The application of sulfuric acid to the cooling water will control the blowdown pH and increase the sulfate concentration. The pH of the plant blowdown will be in the range of 6.5 to 7.0.

The effect on the pH of the White River is computed as follows:

$$C_6 = -\log\ [(Q_1\ \log^{-1}(-C_4) + Q_5\ \log^{-1}(-C_5))/(Q_1 + Q_5)]$$

Where:

C_6 = pH of White River mixing zone

C_4 = ambient pH of White River (Column 3 of Table 2.3-1)

Q_5 = flow of blowdown discharged (11.2 cfs)

C_5 = pH of blowdown (Column 5 of Table 2.3-1)

Q_1 = as defined above

Therefore $C_6 = -\log\ [(365\ \log^{-1}(-C_4) + 11.2\ \log^{-1}(-C_5))/(376.2)]$

The computed value of C_6 appears in Column 6 of Table 2.3-1.

In addition to controlling the pH, the application of sulfuric acid will increase the sulfate concentration of the blowdown above the range 61 to 125 mg/liter as computed in the previous section. The amount of increase in the sulfate concentration is controlled by the alkalinity of the makeup water. In the absence of carbonate (CO_3), the alkalinity may be computed from the bicarbonate (HC_3) concentration by the following equation:

Alkalinity = (concentration of HCO_3)/1.22

From Table 2.1-5, the bicarbonate concentration ranges from 138 to 177 mg/liter. Therefore, the alkalinity has a range of 113 to 145 mg/liter.

The maximum alkalinity level maintained in the cooling towers is 60 mg/liter. Therefore, the alkalinity reduction required is computed as follows:

Minimum alkalinity reduction = 4(113) - 60 = 392 mg/liter @ $CaCO_3$
Maximum alkalinity reduction = 4(145) - 60 = 520 mg/liter @ $CaCO_3$

The above alkalinity reductions may be converted to sulfate increases by the ratio of the two molecular weights:

Mol. wt. $CaCO_3$ = 40 + 12 + 3(16) = 100 atomic units
Mol. wt. SO_4 = 32 + 4 (16) = 96 atomic units

(Mol. wt. $CaCO_3$)/(Mol. wt. SO_4) = 100/96 = 1.0417

Minimum sulfate increase = 392/1.0417 = 376 mg/liter @ SO_4
Maximum sulfate increase = 520/1.0417 = 499 mg/liter @ SO_4

Therefore, the total sulfate concentration in the blowdown is computed as follows:

Total sulfate = (sulfate in blowdown prior to acid) + (sulfate increase due to acid)

Therefore:

Minimum sulfate concentration = 61 + 376 = 437 mg/liter
Maximum sulfate concentration = 125 + 499 = 624 mg/liter

These values appear in Column 5 of Table 2.3-1.

The effect of blowdown discharge on the sulfate concentration of the White River is computed as follows:

$$C_9 = (Q_1C_7 + Q_5C_8)/(Q_1 + Q_5)$$

Where:

C_9 = fully mixed sulfate concentration in White River

C_7 = ambient sulfate concentration in White River = Column 3 of Table 2.3-1

C_8 = sulfate concentration of blowdown discharge = Column 5 of Table 2.3-1

Q_1, Q_5 = as defined previously

Therefore: $C_9 = (365\ C_7 + 11.2\ C_8)/376.2$

The computed values of C_9 appear in Column 6 of Table 2.3-1

2.3.5 Overflow of Surge Pond

The inflow volume to the surge pond resulting from drainage from the ash disposal area, coal storage area, and plant yard drainage is computed using the following operation:

$$V_1 = CD\ (A_1 + A_2 + A_3)/12$$

Where:

V_1 = volume of drainage inflow

C = runoff coefficient (assumed to be 1.0)

D = depth of rainfall contributing to overflow (0.8 inch)

A_1 = ash disposal area (approximately 450 acres)

A_2 = coal storage area (approximately 200 acres)

A_3 = plant yard areas (approximately 200 acres)

Therefore, V_1 = 56.7 acre-feet

The inflow volume resulting from rainfall interception on the surface of the surge pond is computed using the following equation:

$$V_2 = DA_4/12$$

Where:

V_2 = volume of rainfall inflow

A_4 = surge pond surface area (approximately 40 acres)
D = as defined previously

Therefore, V_2 = 2.7 acre-feet

The sum of the two volumes of inflow, 59.4 acre-feet, are assumed to overflow from the surge pond. This corresponds to an average overflow rate of approximately 30 cfs. The additional overflow produced by the inflow contribution from the sewage treatment facility, approximately 0.02 cfs, is considered to be insignificant.

The steady state concentrations after mixing with the White River are computed as follows:

$$C_3 = (Q_1C_1 + Q_2C_2)/(Q_1 + Q_2)$$

Where:

C_3 = concentration in White River mixing zone
Q_1 = overflow rate (30 cfs, as determined above)
C_1 concentration in surge pond (EIS Table 6.2-3)
Q_2 = flow of mixing zone under 10-year, 7-day low flow conditions (365 cfs)
C_2 = ambient concentrations in the White River (EIS Table 6.2-3)

Therefore, $C_3 = (30\ C_1 + 365\ C_2)/395$

The computed values of C_3 appear in EIS Table 6.2-3.

The effect of the pH of the White River is computed as follows:

$$C_6 = -\log[(Q_1 \log^{-1}(-C_4) + Q_2 \log^{-1}(-C_5))/(Q_1 + Q_5)]$$

Where:

C_6 = pH of White River mixing zone
C_4 = pH of surge pond (EIS Table 6.2-3)
C_5 = ambient pH of White River (EIS Table 6.2-3)
Q_1, Q_2 = as defined above

Therefore, $C_6 = -\log[(30 \log^{-1}(-C_4) + 365 \log^{-1}(-C_5))/395]$

The computed values of C_6 appear in EIS Table 6.2-3.

Table 2.3-1

Effects of Blowdown Discharge on Chemical Water Quality Parameters

(1) Parameter	(2) Surge Pond Effluent After Treatment Min.	Max.	(3) Makeup from White River (ambient) Min.	Max.	(4) Combined Makeup Min.	Max.	(5) Blowdown Min.	Max.	(6) White River After Mixing Min.	Max.
Chemicals Present In Drainage										
Chloride	10.	50.	3.5	8.0	4.20	12.5	16.8	50.1	3.90	9.3
Calcium	40.	60.	27.	50.	28.4	51.1	114.	204.	29.6	54.6
Sulfate	125.	175.	2.	14.	15.2	31.3	61.0a	125a	b	b
Zinc	0.033	0.033	0.0	0.021	0.004	0.022	0.014	0.089	0.0004	0.021
Cadmium	0.042	0.042	0.0	0.006	0.005	0.010	0.018	0.040	0.0005	0.007
Copper	0.024	0.024	0.0	0.016	0.003	0.017	0.010	0.067	0.0003	0.018
Aluminum	0.15	0.15	*	*	0.016	0.016	0.065	0.065	0.002	0.002
Barium	1.78	1.78	*	*	0.192	0.192	0.767	0.767	0.023	0.023
Chromium	0.024	0.024	0.0	0.003	0.003	0.005	0.010	0.021	0.0003	0.004
Boron	0.29	0.29	*	*	0.031	0.031	0.125	0.125	0.004	0.004
Struntium	2.94	2.94	*	*	0.317	0.317	1.266	1.266	0.038	0.038
Titanium	0.026	0.026	*	*	0.003	0.003	0.011	0.011	0.0003	0.0003
TDS	700.	750.	127.	196.	189.	256.	755.	1023.	146.	221.
TSS	50.	100.	3.	78.	8.1	80.4	32.2	321.	3.9	85.2
Chemical Additives										
Chlorine	N.A.	N.A.	0.0	0.0	N.A.	N.A.	0.0	0.5	0.0	0.008
pH	N.A.	N.A.	7.51	8.33	N.A.	N.A.	6.5	7.0	7.40	8.12
Sulfate	125.	175.	2.	14.	15.2	31.3	437.	624.	15.0	32.2

Note: All concentrations expressed in mg/liter
* = not measured; N.A. = not applicable

[a]Prior to the application of sulfuric acid

[b]Indicated under "Chemical Additives"

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PART 3
GEOLOGY

TECHNICAL SUPPORT DOCUMENT

PART 3

GEOLOGY

CONTENTS

TABLES

FIGURES

PART 3

GEOLOGY

3.1 GEOLOGY/SEISMOLOGY/SOILS

This section presents information regarding the geology, seismology, and soils of northeastern Arkansas with emphasis on Independence and Jackson Counties and the immediate area of the site. The geologic time scale in Table 3.1-1 is presented as a reference for geologic discussions; more detailed information on geologic formations in the area is provided in Table 3.1-2.

3.1.1 Regional Geology

As noted in EIS Section 5.1, the site is in an area of transition between two physiographic provinces (Figure 3.1-1). Most of Jackson County and the White River Valley eastward from Batesville are in the Mississippi Alluvial Plain, while most of Independence County, with the exception of the southeasternmost portion of the county and the White River Valley, is in the Ozark Plateaus.

Topographically the region ranges from flat bottomland along the White River, through a belt of rolling hills, to fairly rugged, hilly country where the Plateaus Province begins. Surface elevations generally range between 500 and 700 feet above sea level in the Springfield Plateau to less than 300 feet in the White River Valley.

The rocks in the region are of two types: hard consolidated rocks of Paleozoic age crop out in the Ozark Plateaus, and unconsolidated deposits of Mesozoic and Cenozoic age occur in the Coastal Plain Province. The rocks found at the surface and in the subsurface in the region are shown in Figure 3.1-2, a generalized geologic map of the area.

The Paleozoic rocks consist basically of chert, limestone, sandstone, and shale deposited during the Ordovician to Pennsylvanian periods. At the embayment edge, Coastal Plain deposits overlap the eroded surfaces of the Paleozoics. Deposits of Cretaceous age rest unconformably on rocks of Paleozoic age. The Cretaceous sediments are primarily of marine origin and consist basically of calcareous sands, clays, chalks, and marls. The Tertiary sediments are mostly unconsolidated and consist mainly of sand, clay, and shale.

Holocene alluvium and terrace deposits cover much of the lowlands and provide the surface materials in the Mississippi Alluvial Valley and along the rivers. The recent alluvium has been deposited by streams and consists of sand, gravel, clay, and silt. The terrace deposits are generally Pleistocene in age, representing former levels below which streams have now cut.

Structurally the Ozark Plateaus Province is a broad, irregular flattened dome whose core is exposed in the Precambrian granite of the St. Francis Mountains in southeastern Missouri (Caplan, 1954). In general, the dips are of low order; however, locally the regional dip is obscured by occurrence of minor folds. Normal faulting predominates, with the downthrown sides south in most cases. South and east of Batesville the strata slope to the east and south, and the prominent escarpment gives way to low hills and ridges with the Coastal Plain sediments overlapping the Paleozoics.

The Mississippi Alluvial Plain is a comparatively level south- to southeast-sloping plain. The Cretaceous and Tertiary rocks dip gently toward the southeast in the direction of the embayment axis, which generally follows the present course of the Mississippi River.

No evidence of faulting has been recorded in rocks exposed within the immediate area of the site.

3.1.2 Seismology

The region (which includes portions of Kentucky, Missouri, Tennessee, and Arkansas) has been divided into five seismotectonic regions by Stearns and Wilson (1972). These are defined principally by structural geology and have different relative earthquake expectancies (Figure 3.1-3). In order of decreasing earthquake expectancy these are: 1) the New Madrid (Reelfoot) Seismotectonic Region; 2) the West Embayment Seismotectonic Region; 3) the East Embayment Seismotectonic Region; 4) the Western Kentucky Faulted Belt; and 5) the Nashville Dome.

The site lies along the westernmost extent of the West Embayment Region which is the evenly sloping western segment of the Mississippi Embayment. It is a seismotectonic region of low to medium activity, with a maximum associated event of Modified Mercalli (MM) VI. Within the State of Arkansas the eastern region is more apt to experience damage than the western portion due to the proximity to the Reelfoot Structure (Stearns and Wilson, 1972). Historical observations have shown the majority of earthquake activity has been in the Mississippi Embayment area east of Crowleys Ridge in this northeastern section of the State. Only five earthquakes, intensity V or greater on the Modified Mercalli scale (MM V), have occurred outside the northeast section of the State.

The historical seismic activity within a 40-mile radius of the site has consisted of three events with MM intensities of V or greater. They are the 1883 MM V event near Morriston, the 1918 MM V event at Portia, and the 1919 MM IV-V event near Fender. The strongest ground motion to have affected the site in historic time resulted from the 1811-1812 New Madrid, Missouri events (MM XII) which produced an intensity of VIII-XI at the site (Nuttli, 1973).

A record of earthquakes in the region with MM intensity of VI or greater (strong enough to cause structural damage) is presented in Table 3.1-3.

There are no mapped faults in the unconsolidated Gulf Coastal Plain deposits in the area of the site. However, there are mapped faults in the Mesozoic and Paleozoic rocks of the Ozark Plateaus Province; all of them are at least Cretaceous in age, or more than 135 million years old (Croneis, 1930).

3.1.3 Soils

There are two soil associations present on the immediate site: 1) Egam-Staser-Hontas association; and 2) Amagon-Dundee-Sharkey association.

The Egam-Staser-Hontas is the major association and is present except in the extreme northeastern portion of the site (Figure 3.1-4).

This association is characterized as moderately well drained and well drained, level, deep, loamy soils on floodplains. Egam soils have very dark grayish brown silty clay loam surface soils over mottled brown and gray silty clay subsoils. Staser soils have dark brown silt loam surface soil over dark brown loam subsoil, and Hontas soils have brown silt loam surface soil over dark yellowish brown or yellowish brown, mottled silty clay loam subsoil (USDA, 1977).

The Amagon-Dundee-Sharkey association which is very minor in areal extent is classified as poorly drained and somewhat poorly drained level and gently undulating deep, loamy and clayey soils on low natural levees. Amagon soils have light brownish gray silt loam surface soil over gray or dark gray mottled silt loam or silty clay loam subsoil. Dundee soils have brown silt loam surface soils over light brownish gray mottled silt loam, silty clay loam or loam subsoil. Sharkey soils have dark grayish brown and dark gray silty clay loam surface soil over dark gray and gray mottled clay subsoil (USDA, 1977).

Table 3.1-1

The Geologic Time Scale

ERA	PERIOD	EPOCH	APPROXIMATE AGE (in yrs) BEFORE PRESENT
CENOZOIC	QUATERNARY	Holocene	10,000
		Pleistocene	1,000,000
	TERTIARY	Pliocene	13,000,000
		Miocene	25,000,000
		Oligocene	36,000,000
		Eocene	58,000,000
		Paleocene	63,000,000
MESOZOIC	CRETACEOUS		135,000,000
	JURASSIC		180,000,000
	TRIASSIC		230,000,000
PALEOZOIC	PERMIAN		280,000,000
	PENNSYLVANIAN		310,000,000
	MISSISSIPPIAN		345,000,000
	DEVONIAN		405,000,000
	SILURIAN		425,000,000
	ORDOVICIAN		500,000,000
	CAMBRIAN		600,000,000
PRECAMBRIAN			4,500,000,000

Table 3.1-2

Generalized Geologic Column

ERA	SYSTEM	SERIES	GEOLOGIC UNIT	DESCRIPTION
CENOZOIC	QUATERNARY	Holocene	Alluvium and terrace deposits	Sand, fine to very coarse, and gravel; abundant silt and clay near surface. 0-155 feet.
		Pleistocene	Loess	Silt, light-tan to reddish-brown. 0-12 feet.
	TERTIARY(?)	Pliocene(?)	Undifferentiated deposits	Sand and gravel to boulder size; contains some sandy clay. 0-25 ft.
	TERTIARY	Eocene	Wilcox Group	Sand, silt, and clay, gray and greenish-to dark-brown. Does not appear at surface. 0-350 feet.
		Paleocene	Midway Group	Clay, silty in part, black with some dark-gray and green; and limestone, sandy, fossiliferous. 0-350 feet.
MESOZOIC	CRECTACEOUS	Upper	Arkadelphia Marl	Clay, silty and sandy in part, interbedded, lignitic in part contains shell fragments. Does not appear at surface. 0-30 feet.
			Nacatoch Sand	Sand, medium to coarse, clayey in part, glauconitic, phosphatic. 0-300 feet.
			Saratoga Chalk(?)	Clay, sand and clay, chalk interbedded. Does not appear at surface. 0-117 feet.
PALEOZOIC	PENNSYL-VANIAN	Atoka	Atoka Formation	Sandstone, medium-grained, light brown; locally interbedded with black shale; contains basal conglomerate in southern Indepdendence County. 200-250 feet.
		Morrow	Morrow Group	Shale, fissile, brown or dark gray to black; limestone and sandstone; gray to brownish-grey. 120-250 feet.
	MISSISSIP-PIAN	Upper	Pitkin Limestone	Limestone, finely crystalline compact, fossiliferous, bluish-gray to black; lenses of brown to black shale. 240 feet.
			Fayetteville Shale	Shale, platy to fissile, dark-gray to black; and limestone, fine to coarse-grained, brownish-gray to dark-gray fossiliferous. 330-355 feet.
			Batesville Sandstone	Sandstone, medium-grained, calcareous, brown or buff to gray; lenses of limestone and dark-gray shale. 70 feet.
			Ruddell Shale	Shale, fissile, calcareous in part, dark-gray and green. 120-272ft.
			Moorefield Formation	Shale, platy, calcareous, dark-gray to black, and dark siliceous limestone. 25-199 feet.
		Lower	Boone Formation and St. Joe Limestone Member	Chert, dense, brown and brownish-gray to black, and gray to white finely crystalline or cherty limestone. 132-295 feet.
	DEVONIAN	Upper	Chattanooga Shale and Sylamore Sandstone Member	Shale, fissile, bituminous, black to brownish-black; sandstone, brown to white phosphatic fine to coarse grained. 25 feet
		Lower or Middle	Penters Chert	Chert, light-gray to black with interbedded gray crystalline limestone, and dolomite. 85 feet.
	SILURIAN	Middle	Lafferty Limestone	Limestone, earthy, thin-bedded, red to gray. 85 feet.
			St. Clair Limestone	Limestone, pinkish-gray, finely crystalline, fossil fragments. 100 feet.
	ORDOVICIAN	Upper	Cason Shale	Shale, platy to fissile, calcareous in part, black and gray to bluish green; some phosphatic sandstone and limestone. 20 feet.
			Fernvale Limestone	Limestone, coarsely crystalline, massive crossbedded, white to pinkish gray. 125 feet.
		Middle	Kimmswick Limestone	Limestone, saccharoidal to finely crystalline, fossiliferous, white to light gray. 60 feet.
			Plattin Limestone	Limestone, dense, sublithographic, light-gray to bluish-gray. 250 feet.
			Joachim Dolomite	Dolomite, finely crystalline, slightly saccharoidal, silty in part gray to brown; some calcareous sandstone. 150 feet.
			St. Peter Sandstone	Sandstone, fine to coarse grained, white to buff; contains some shale, clayey sand, and dolomite. 100-175 feet.
			Everton Formation	Dolomite, very finely crystalline, dense, slightly sandy, gray to brown, and dolomitic limestone; beds of fine to coarse grained sandstone.
		Lower	Black Rock Formation	Limestone, dolomitic, slightly sandy, fossiliferous, dark-gray, cherty. 55-425 feet.

Adapted from Albin and others (1967)

Table 3.1-3

Chronological List of Epicenter Locations Within Region[a]
(Modified Mercalli Intensity of VI or Greater)

YEAR	DATE	LOCALITY	INTENSITY (MM)
1811	Dec. 16	New Madrid, Mo.	XII
1812	Jan. 23	New Madrid, Mo.	XII
1812	Feb. 7	New Madrid, Mo.	XII
1838	Jun. 9	St. Louis, Mo.	VI
1843	Jan. 4	Western Tennessee	VIII
1857	Oct. 8	St. Louis, Mo.	VI
1865	Aug. 17	Southeastern Missouri	VII
1878	Nov. 18	Southeastern Missouri	VI
1882	Oct. 22	Arkansas	VI-VII
1883	Jan. 11	Cairo, Ill.	VI
1883	Apr. 12	Cairo, Ill.	VI-VII
1889	Jul. 19	Memphis, Tenn.	VI
1895	Oct. 31	Charleston, Mo.	VIII
1903	Feb. 8	St. Louis, Mo.	VI
1903	Nov. 4	St. Louis, Mo.	VI-VII
1905	Aug. 21	Mississippi Valley	VI
1915	Dec. 7	Near mouth of Ohio River	V-VI
1916	Dec. 18	Hickman, Ky.	VI-VII
1917	Apr. 9	Eastern Missouri	VI
1923	Oct. 28	Marked Tree, Ark.	VII
1927	May 7	Mississippi Valley	VII
1931	Dec. 16	Northern Mississippi	VI-VII
1933	Dec. 9	Manila, Ark.	VI
1934	Aug. 19	Rodney, Mo.	VII
1941	Nov. 16	Covington, Tenn.	V-VI
1947	Jun. 29	Near St. Louis, Mo.	VI
1952	Jul. 16	Dyersburg, Tenn.	VI
1954	Feb. 2	Missouri-Arkansas border	VI
1955	Jan. 25	Tennessee-Missouri-Arkansas border	VI

YEAR	DATE	LOCALITY	INTENSITY (MM)
1955	Mar. 29	Finley, Tenn.	VI
1955	Apr. 9	West of Sparta, Ill.	VI
1956	Jan. 28	Tennessee-Arkansas border	VI
1956	Oct. 30	Northeastern, Okla.	VIII
1956	Nov. 25	Wayne County, Mo.	VI
1962	Feb. 2	New Madrid, Mo.	VI
1962	Jul. 23	Southern Missouri	VI
1963	Mar. 3	Southeastern Missouri	VI
1965	Aug. 14	Southwestern Ill.	VII
1965	Oct. 20	Eastern Missouri	VI
1967	Jun. 4	Near Greenville, Miss.	VI
1967	Jul. 21	Missouri	VI
1968	Oct. 14	Durant, Okla.	VI
1970	Nov. 16	Northeastern Arkansas	VI
1971	Oct. 1	Northeastern Arkansas	V-VI
1972	Feb. 1	Northeastern Arkansas	V-VI

[a]Location: Area bounded by approximately 89°W to 96°W and 32°N to 38.5°N.

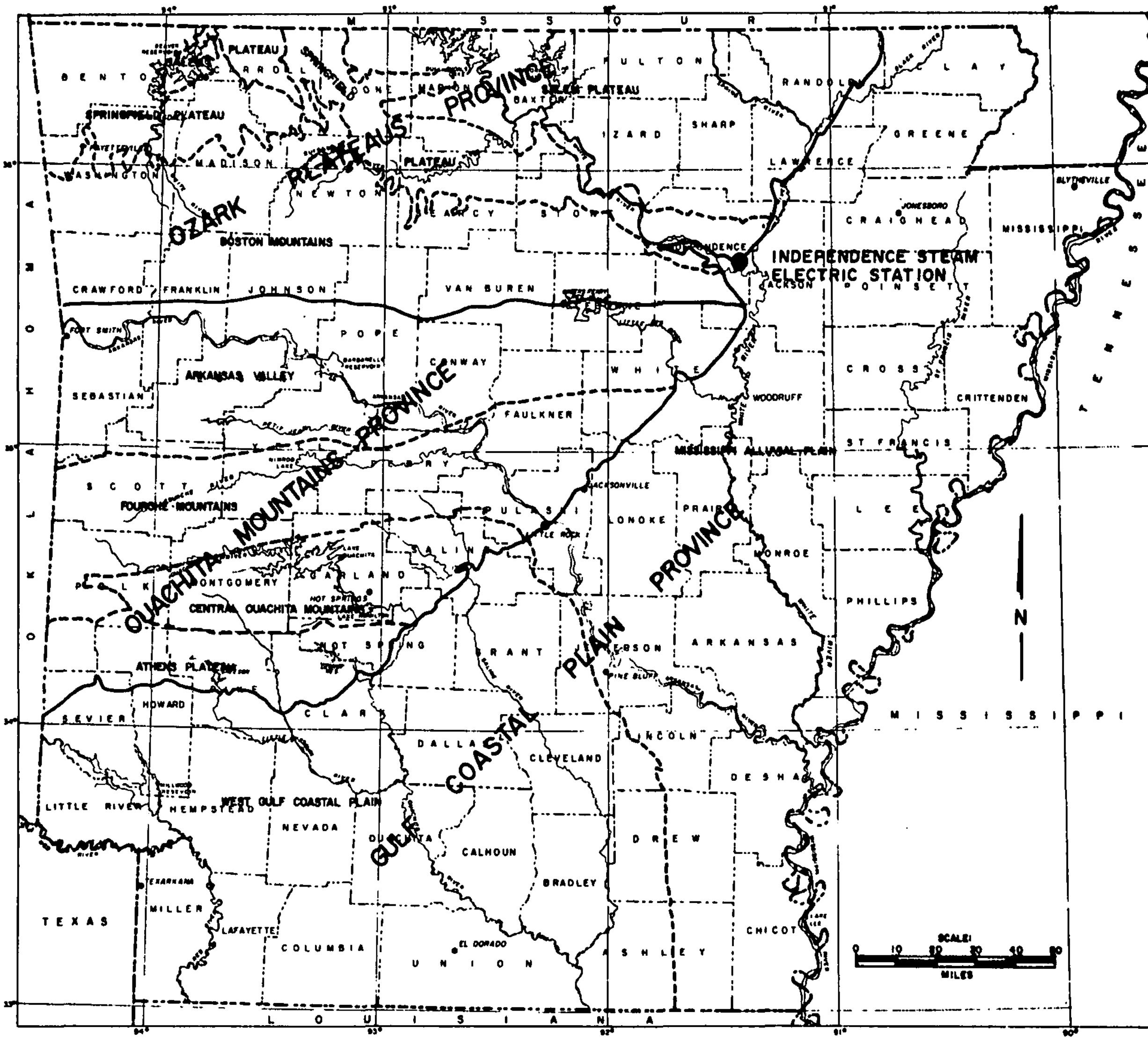


Figure 3.1-1. Physiographic regions.

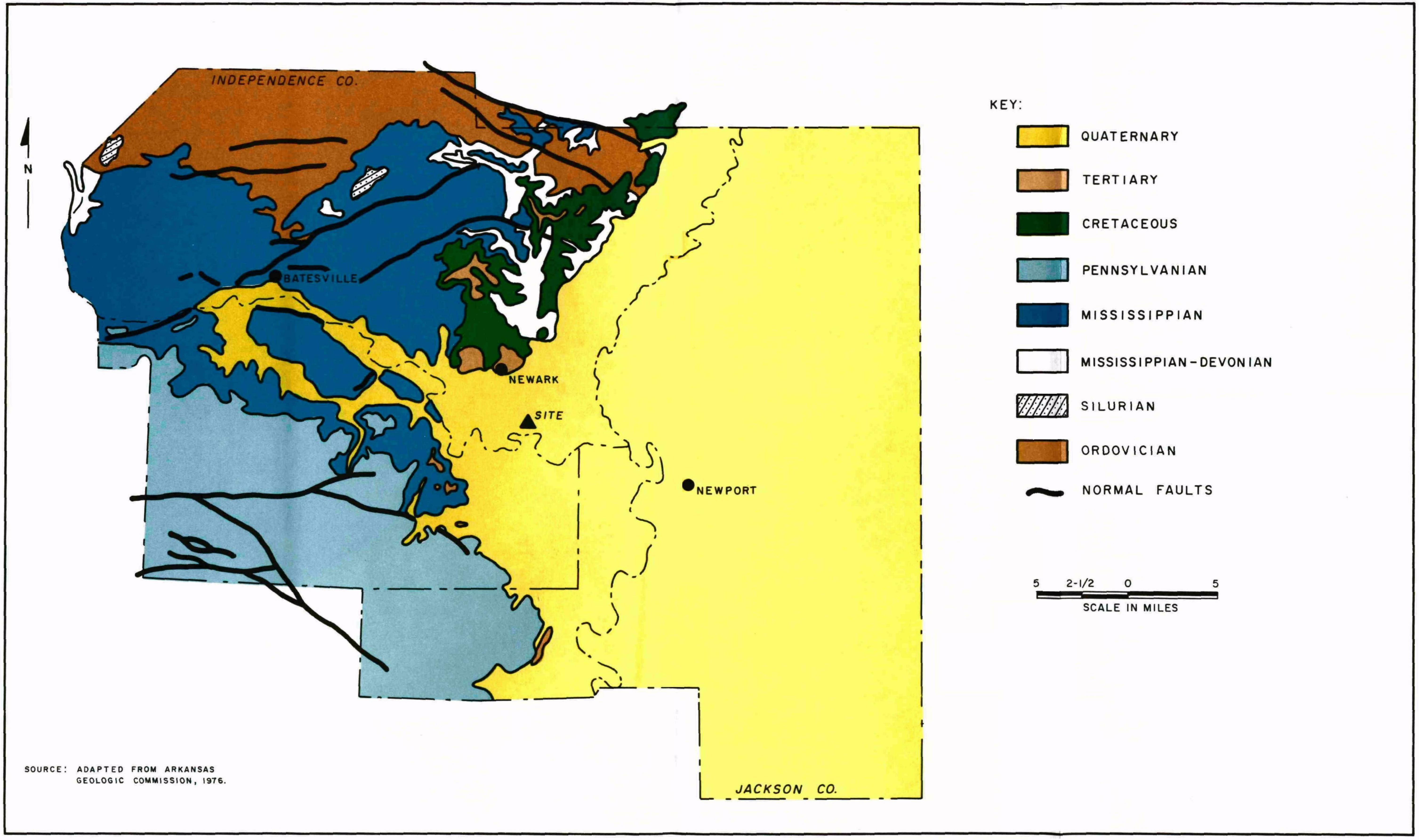
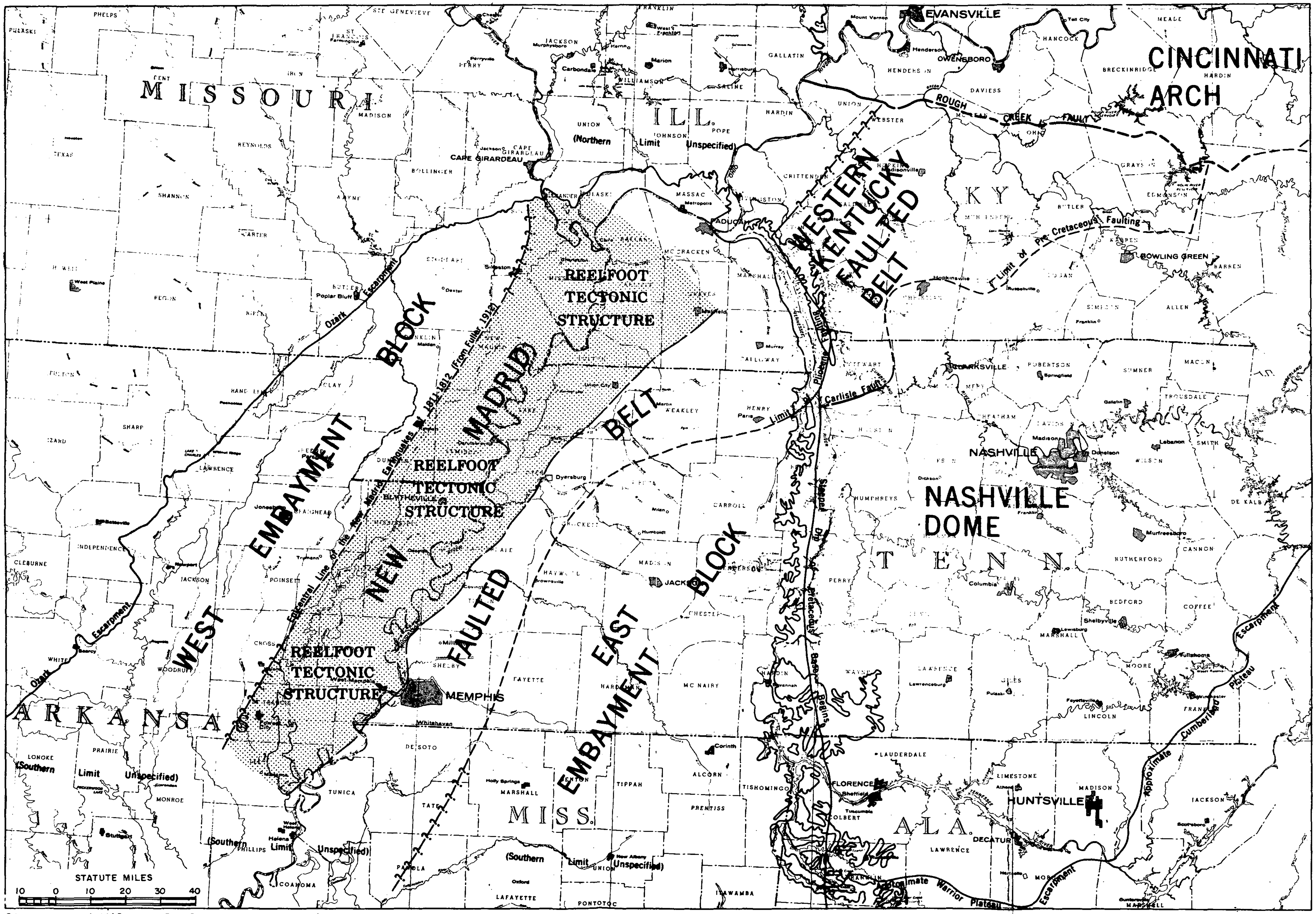


Figure 3.1-2. Generalized geologic map.



Stearns and Wilson, 1972

Figure 3.1-3. Seismotectonic regions.

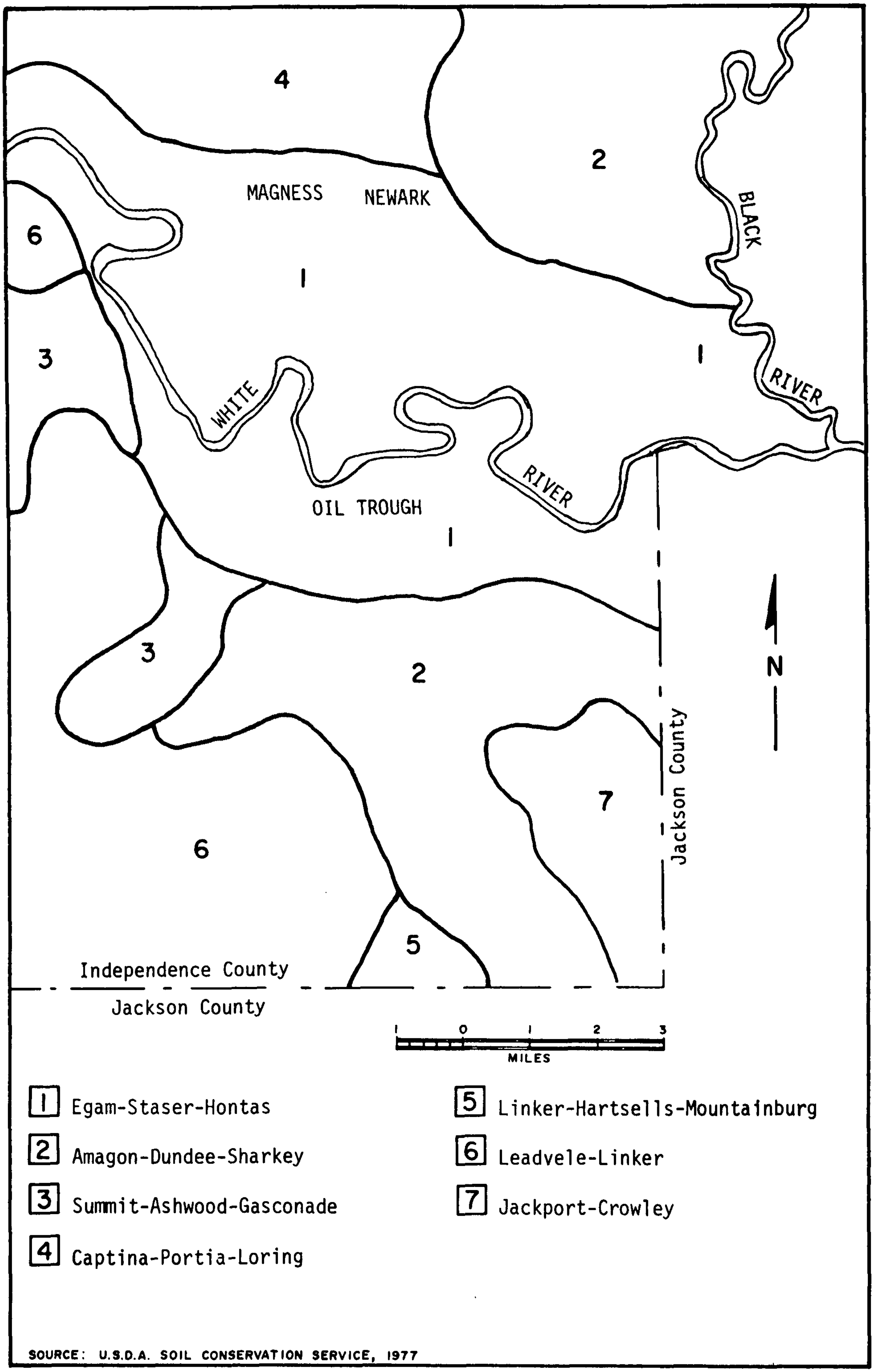


Figure 3.1-4. Soil association and site vicinity map.

3.2 SITE GEOLOGY

The subsurface conditions at the site were explored by drilling 39 borings at locations shown on Figure 3.2-1. Borings B-1, B-3, and B-4 were drilled in conjunction with preliminary foundation evaluation studies while the remaining 36 A-Series borings were drilled as part of the environmental studies. Logs of the borings are presented on Figures 3.2-2 through 3.2-22, and a key to symbols used on the logs is given in Figure 3.2-23.

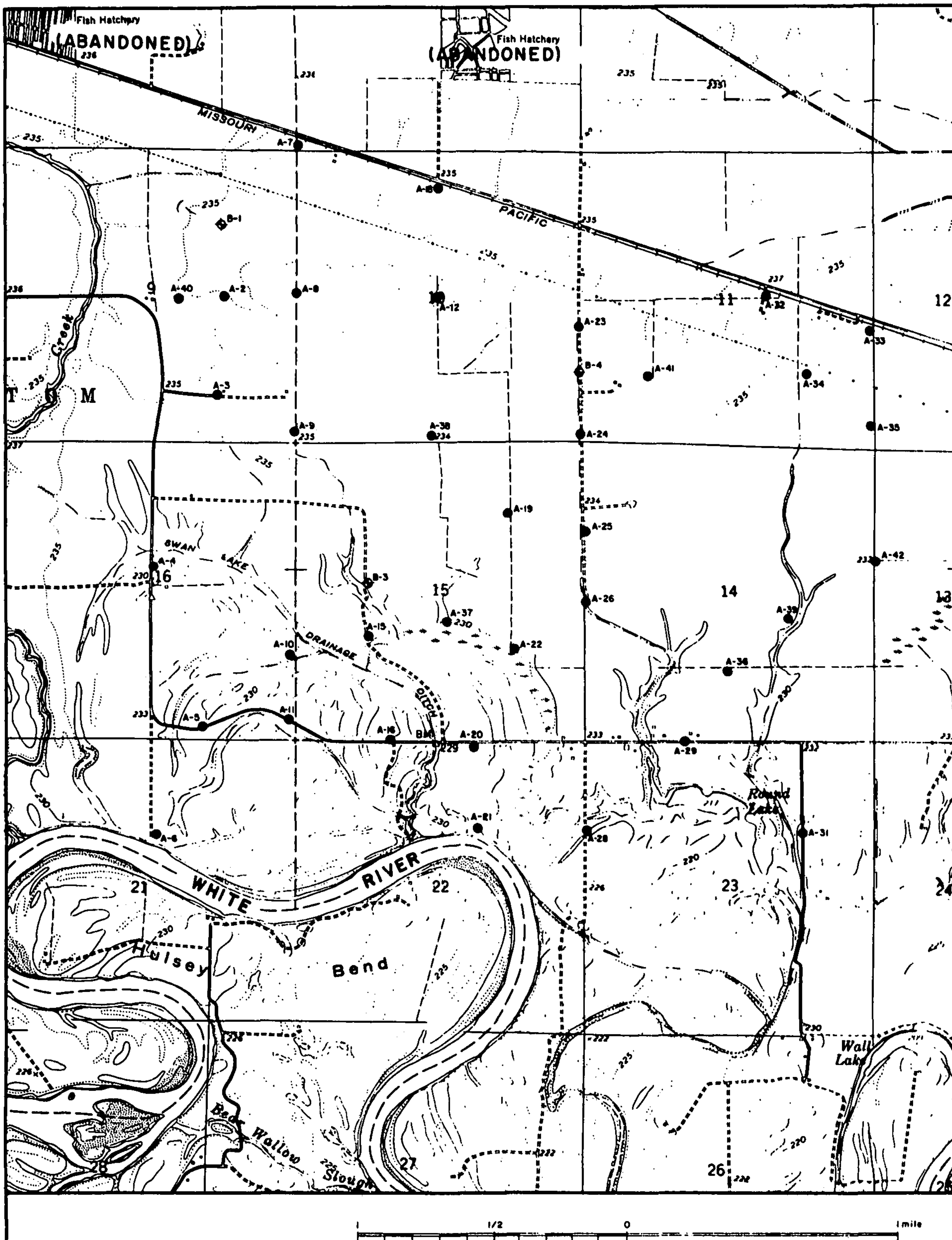
The results of the borings indicate that subsurface conditions are fairly uniform. The site is blanketed by a surficial zone of fine-grained alluvial soils which vary in thickness from approximately 15 feet to 33 feet (Table 3.2-1). Generally, the surficial soils are clays and silts grading from stiff to very stiff in the upper portion to medium stiff in the lower portion (Figure 3.2-23). Immediately underlying the surficial soils is a relatively thick (25 to 45 feet) fine to medium-grained sandy subrounded to subangular chert gravel with varying amounts of silt and clay. The gravels vary from loose to very dense, but generally are medium dense to dense. The gravel is underlain by sands, silts, clays, and clayey gravels which in turn overlie an interbedded shale and limestone bedrock.

During the field explorations, the ground water was generally observed to be approximately 24 feet below the ground surface. The measured water level at each boring is presented on Table 3.2-1 and at the bottom of the log of borings.

Table 3.2-1

Summary of Borings

Boring Number	Ground Elev. (MSL)	Depth to Water (Ft.) 8/22/77	Depth to top of Gravel (Ft.)
A-2	235.1	25.7	23.0
A-3	236.0	14.2	20.0
A-4	226.5	7.7	25.1
A-5	231.7	20.5	23.5
A-6	232.7	---	34.8
A-7	235.7	25.9	28.7
A-8	235.6	26.4	23.6
A-9	233.9	25.5	26.5
A-10	219.6	6.1	28.0
A-11	232.7	---	15.0
A-12	235.0	27.4	20.4
A-15	226.8	7.6	32.5
A-16	227.4	22.5	26.5
A-18	233.9	25.4	23.0
A-19	≈ 233.7	18.1	28.5
A-20	230.5	24.7	23.7
A-21	229.8	22.5	33.5
A-22	230.2	24.2	33.0
A-23	235.0	26.5	28.0
A-24	235.3	---	23.0
A-25	234.2	26.0	23.5
A-26	233.8	25.6	33.0
A-28	222.2	18.4	21.7
A-29	229.6	25.1	26.5
A-31	229.3	---	29.0
A-32	235.9	27.7	27.5
A-33	233.4	25.4	32.0
A-34	232.7	24.2	27.0
A-35	235.3	24.5	36.5
A-36	230.7	24.7	23.5
A-37	227.9	17.9	27.0
A-38	234.1	26.7	30.0
A-39	230.1	23.2	27.5
A-40	≈ 235.2	---	23.0
A-41	235.2	---	23.5
A-42	233.4	23.4	33.0
B-1	234.9	25.2	19.0
B-3	230.3	24.4	23.0
B-4	235.3	22.3	32.0



Legend:

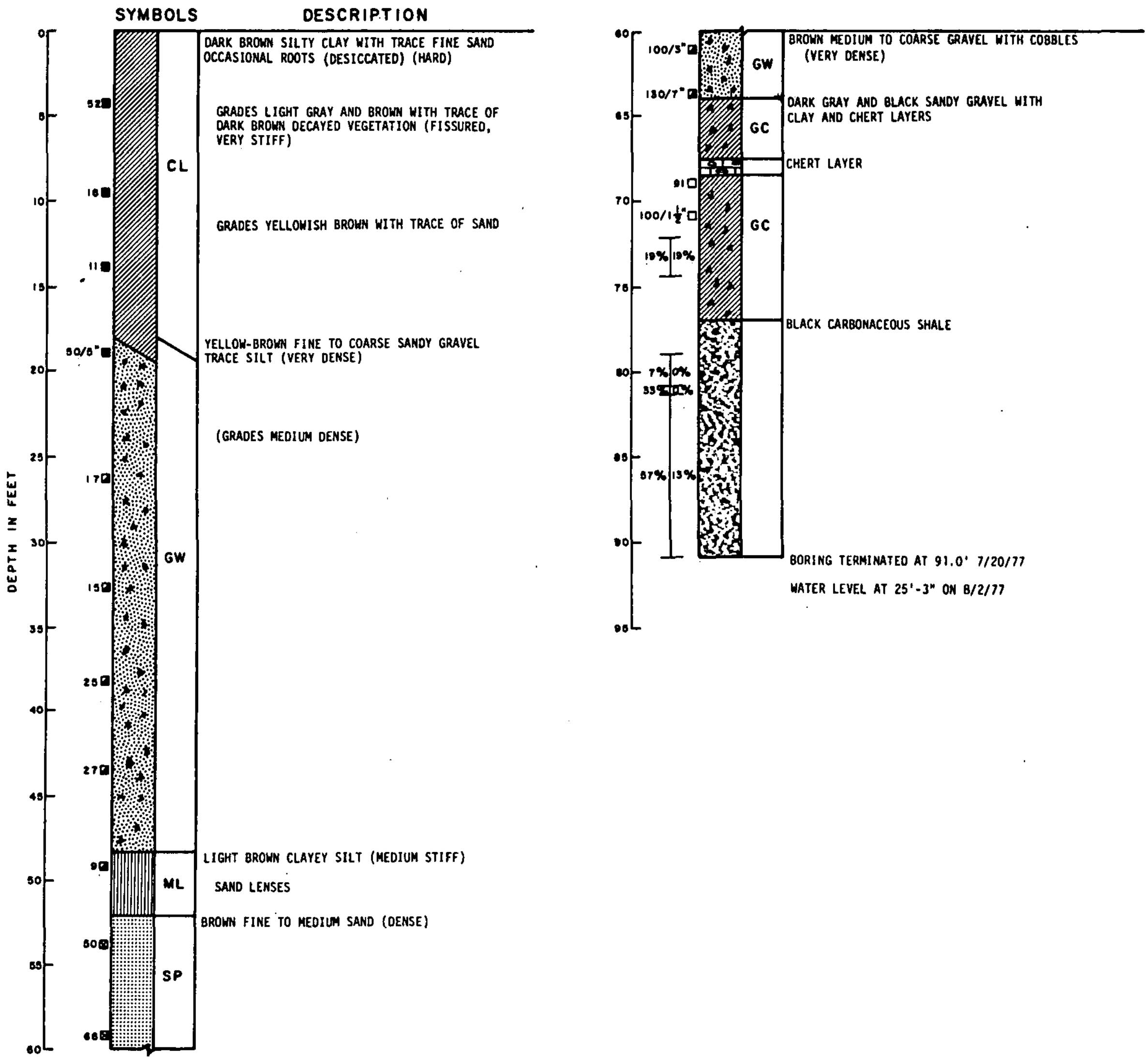
◆ B - Borings drilled for use in site evaluations

● A - Borings drilled for environmental studies

Figure 3.2-1. Plot plan - boring locations.

BORING B-1

ELEVATION: 234.9'



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ◩ SPT SAMPLER (NO RECOVERY)

NOTE:

1. THE 3.25 " O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
2. BLOWCOUNT WITH DAMES & MOORE SAMPLER IS APPROXIMATELY TWO TIMES THE STANDARD PENETRATION TEST I.E. $\frac{D\&M}{2} = SPT$

Figure 3.2-2. Log of boring.

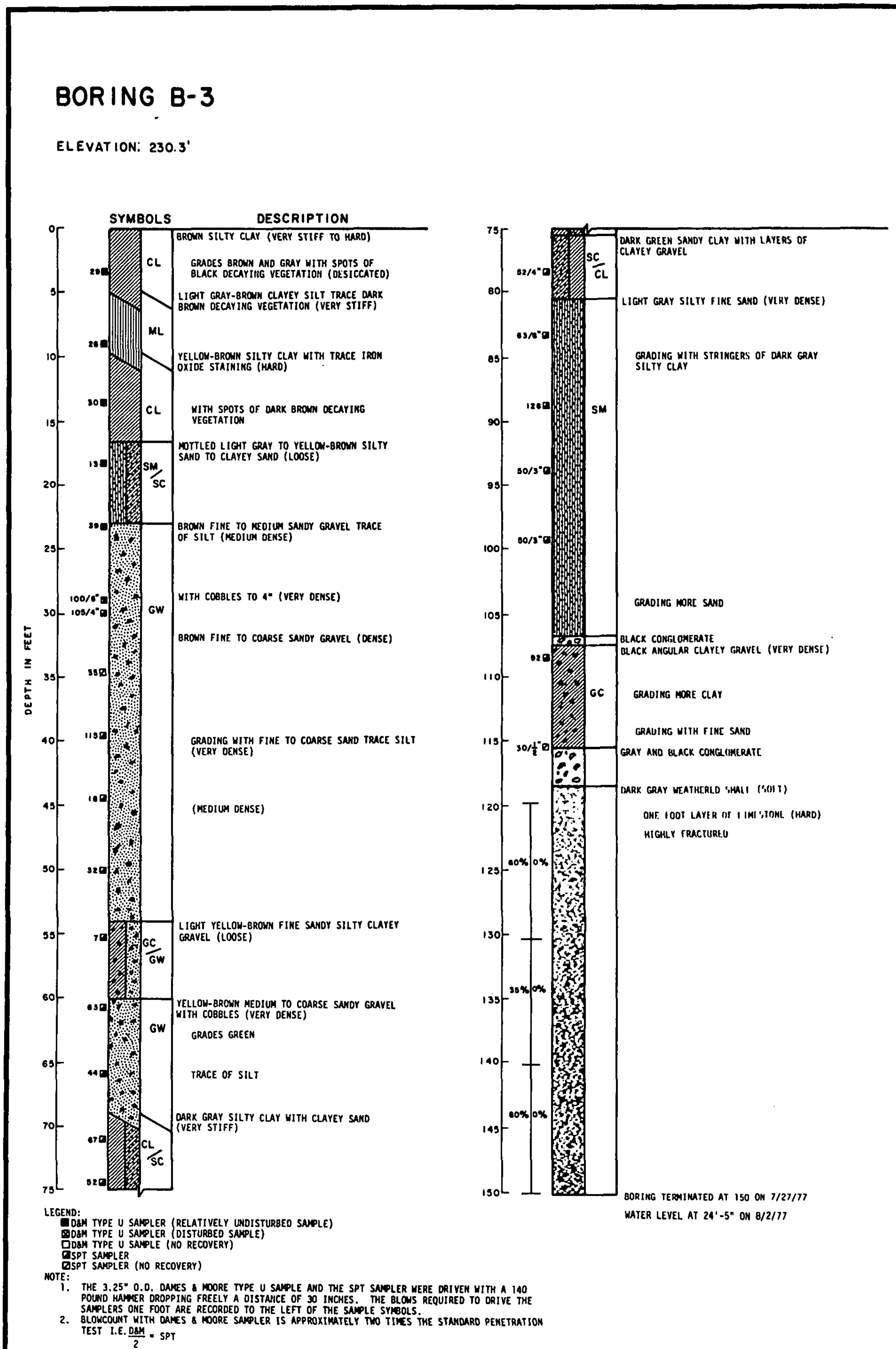
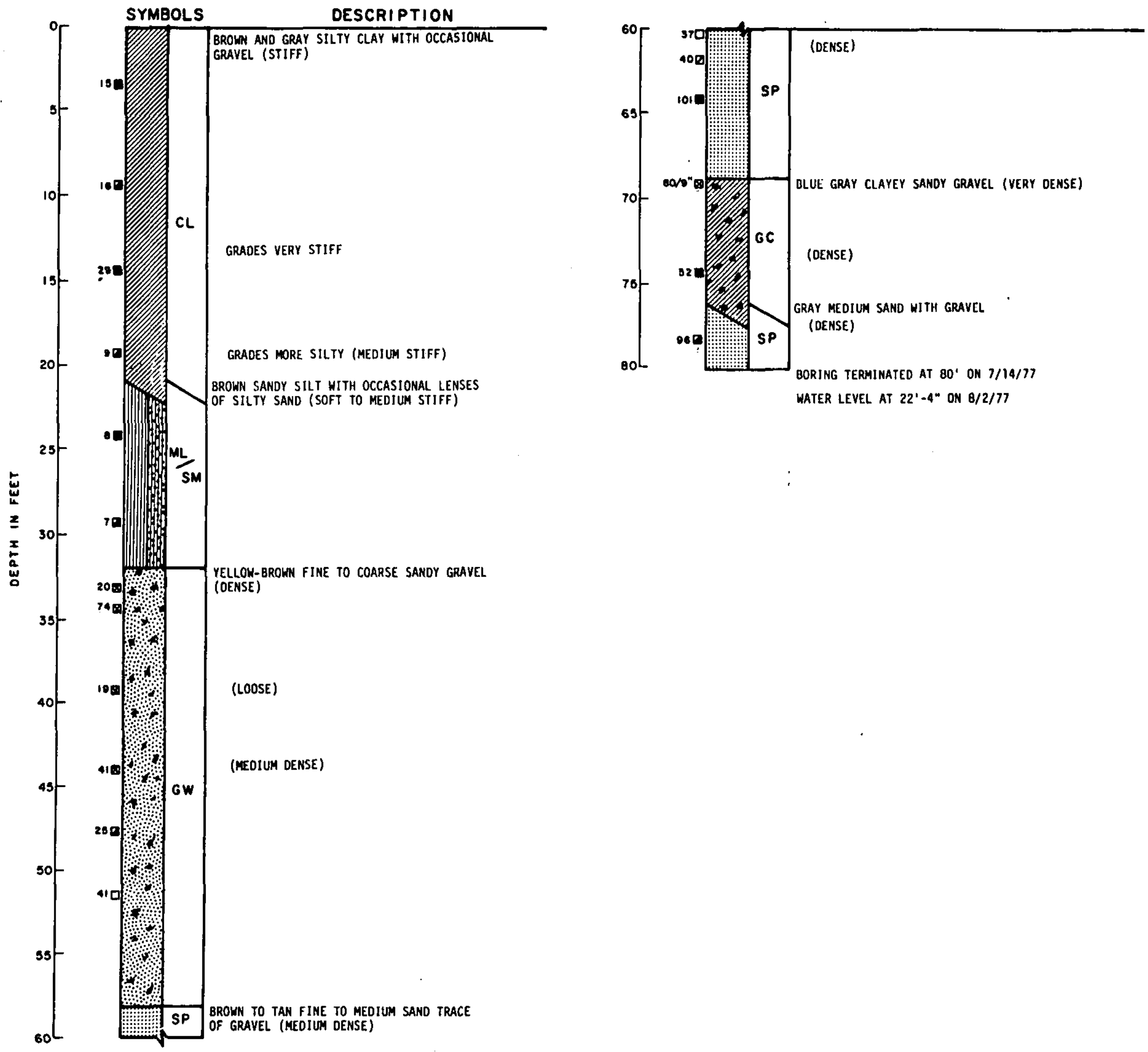


Figure 3.2-3. Log of boring.

BORING B-4

ELEVATION: 235.3'



LEGEND:
- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ◩ SPT SAMPLER (NO RECOVERY)

NOTE:
1. THE 3.25 " O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
2. BLOWCOUNT WITH DAMES & MOORE SAMPLER IS APPROXIMATELY TWO TIMES THE STANDARD PENETRATION TEST I.E. $\frac{D\&M}{2}$ = SPT

Figure 3.2-4. Log of boring.

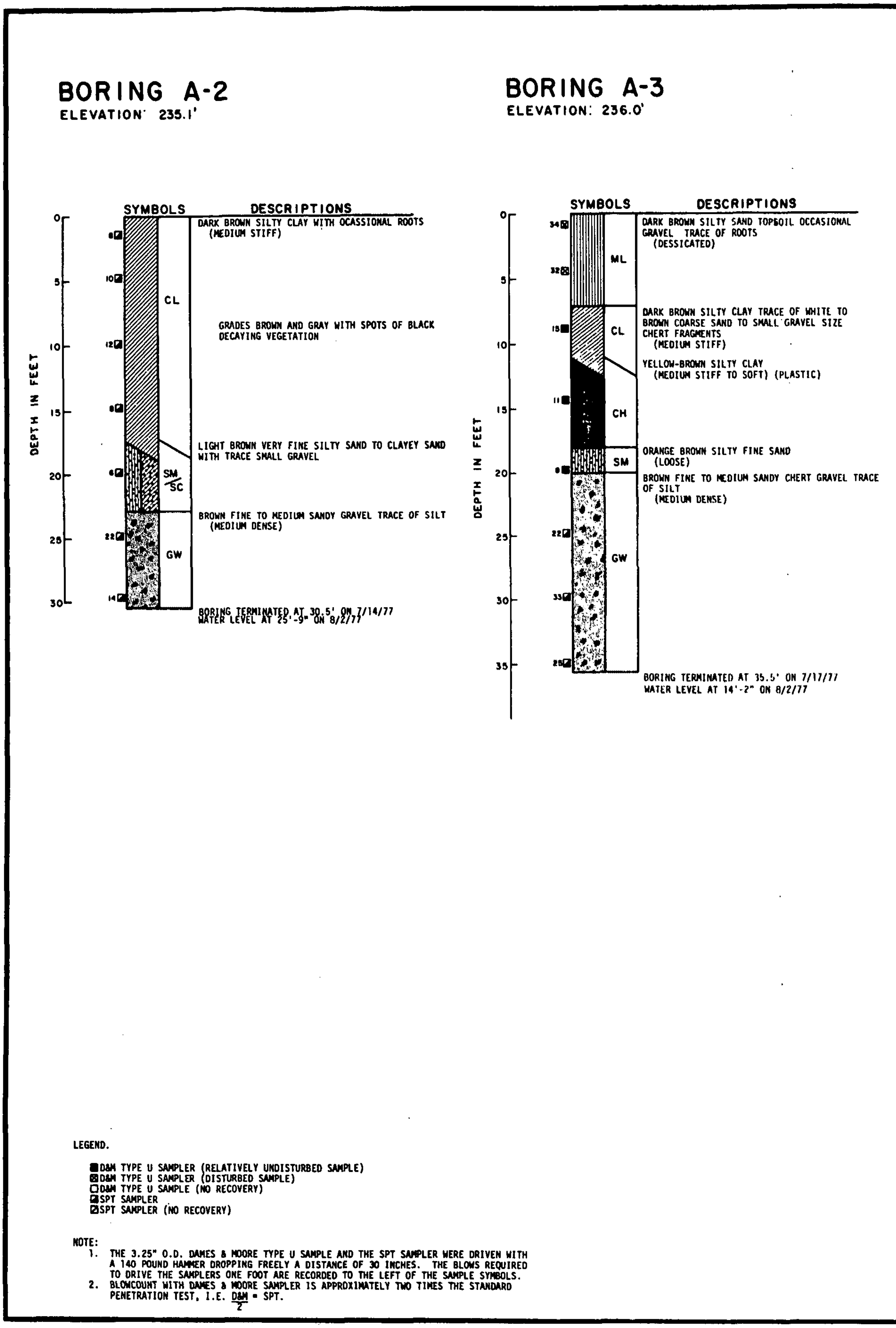
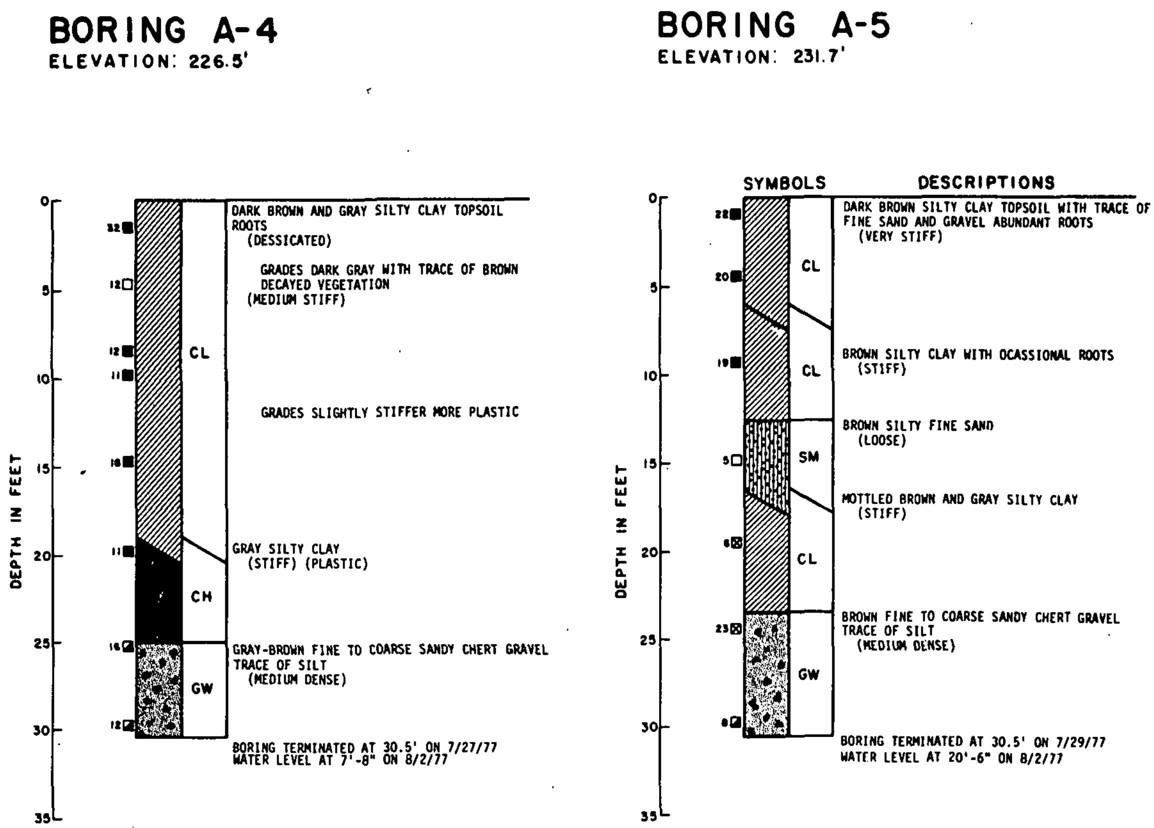


Figure 3.2-5. Log of borings.

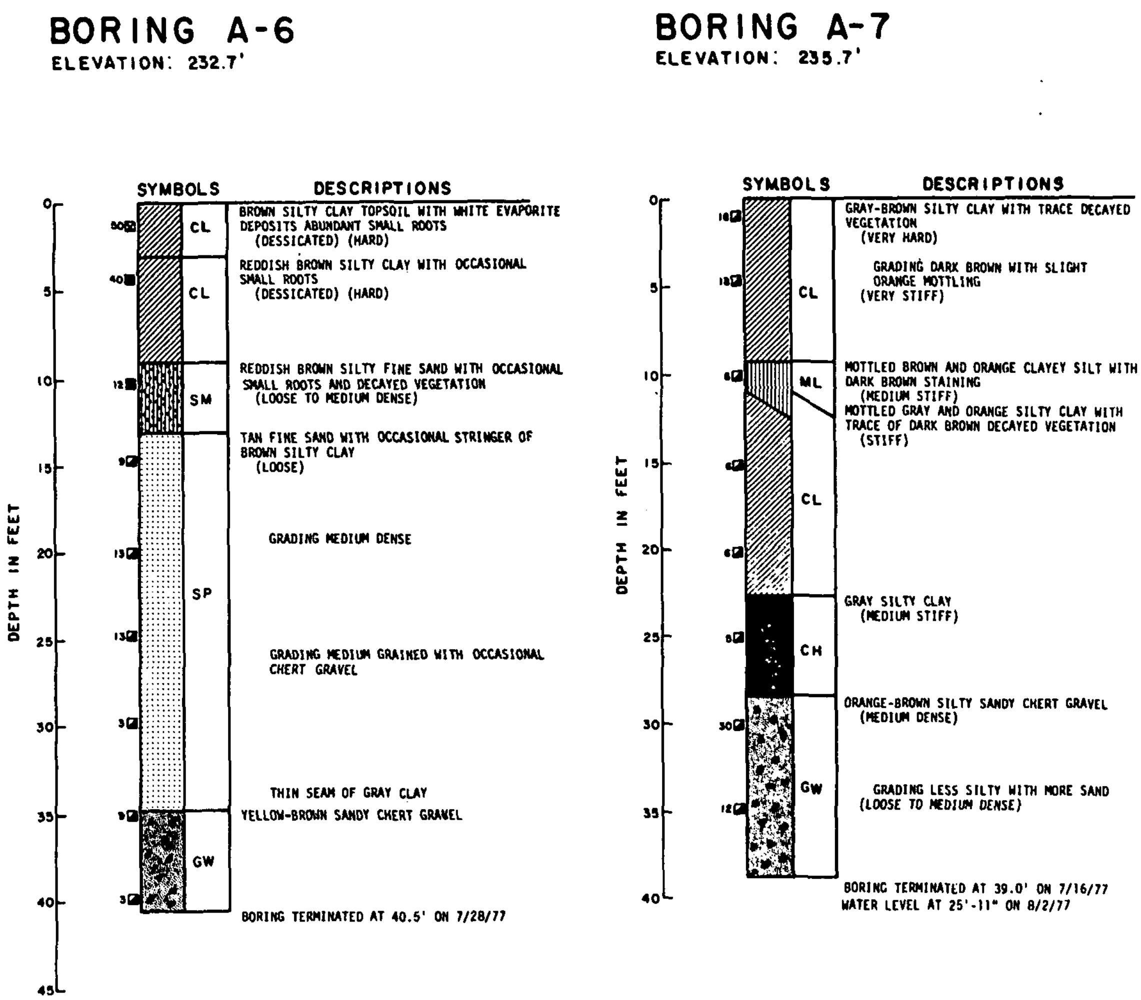


LEGEND

D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
D&M TYPE U SAMPLER (DISTURBED SAMPLE)
D&M TYPE U SAMPLE (NO RECOVERY)
SPT SAMPLER
SPT SAMPLER (NO RECOVERY)

NOTE:
1. THE 3.25" O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
2. BLOWCOUNT WITH DAMES & MOORE SAMPLER IS APPROXIMATELY TWO TIMES THE STANDARD PENETRATION TEST, I.E. $\frac{D\&M}{2}$ = SPT.

Figure 3.2-6. Log of borings.



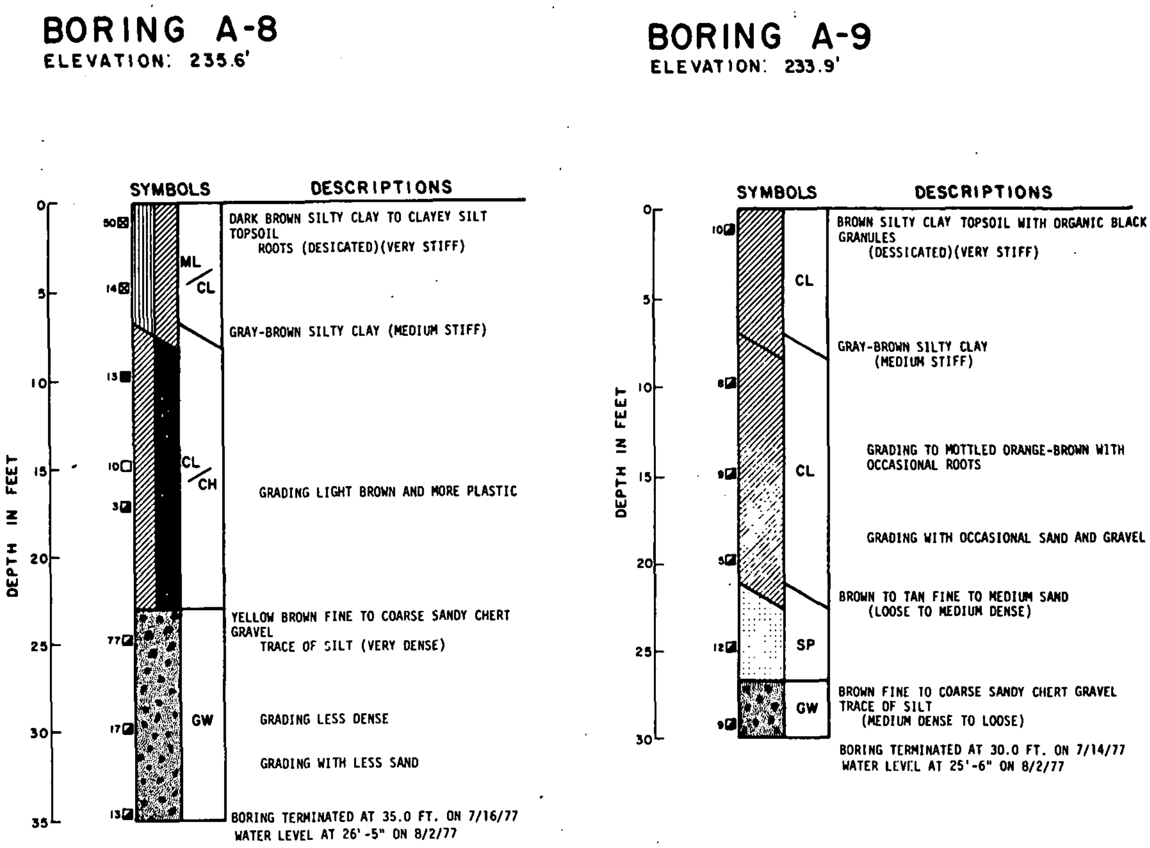
LEGEND:

- D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- D&M TYPE U SAMPLE (NO RECOVERY)
- SPT SAMPLER
- SPT SAMPLER (NO RECOVERY)

NOTE:

1. THE 3.25" O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
2. BLOWCOUNT WITH DAMES & MOORE SAMPLER IS APPROXIMATELY TWO TIMES THE STANDARD PENETRATION TEST, I.E. $\frac{D\&M}{2}$ = SPT.

Figure 3.2-7. Log of borings.



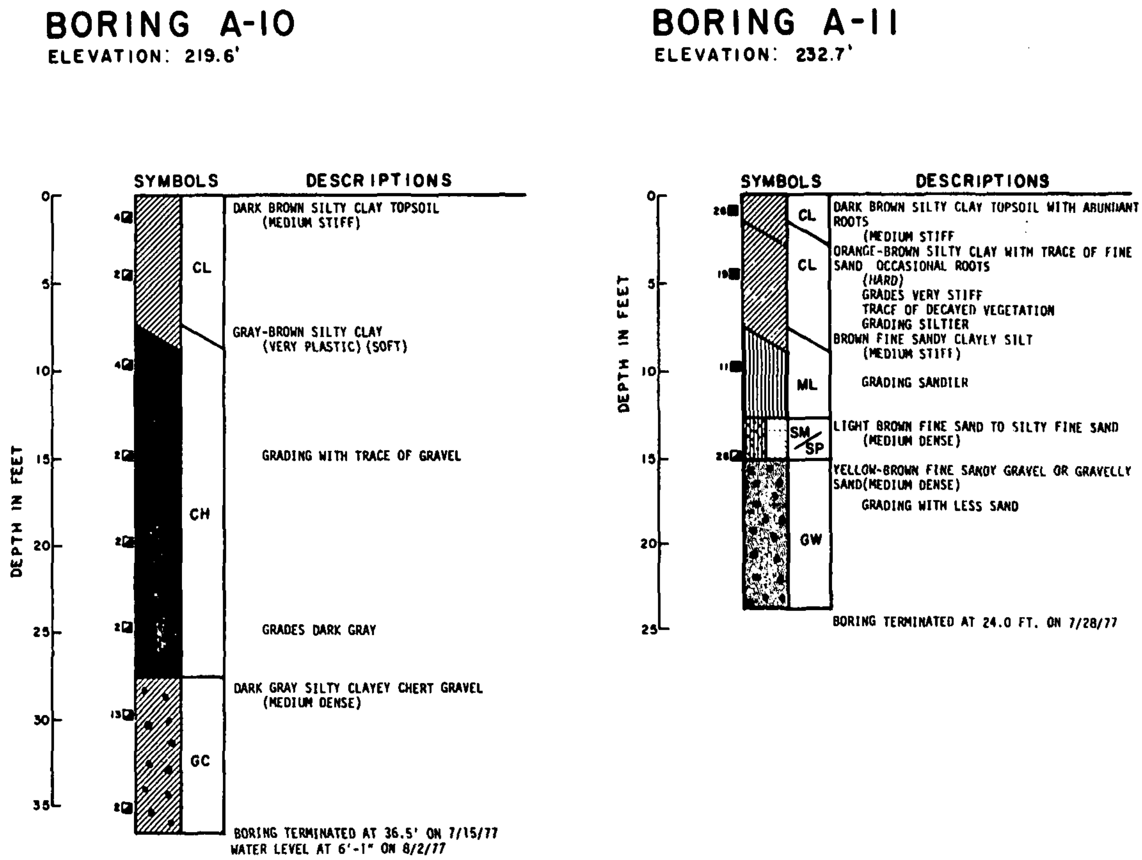
LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ◩ SPT SAMPLER (NO RECOVERY)

NOTE:

1. THE 3.25" O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
2. BLOWCOUNT WITH DAMES & MOORE SAMPLER IS APPROXIMATELY TWO TIMES THE STANDARD PENETRATION TEST, I.E. $\frac{D\&M}{2}$ = SPT.

Figure 3.2-8. Log of borings.



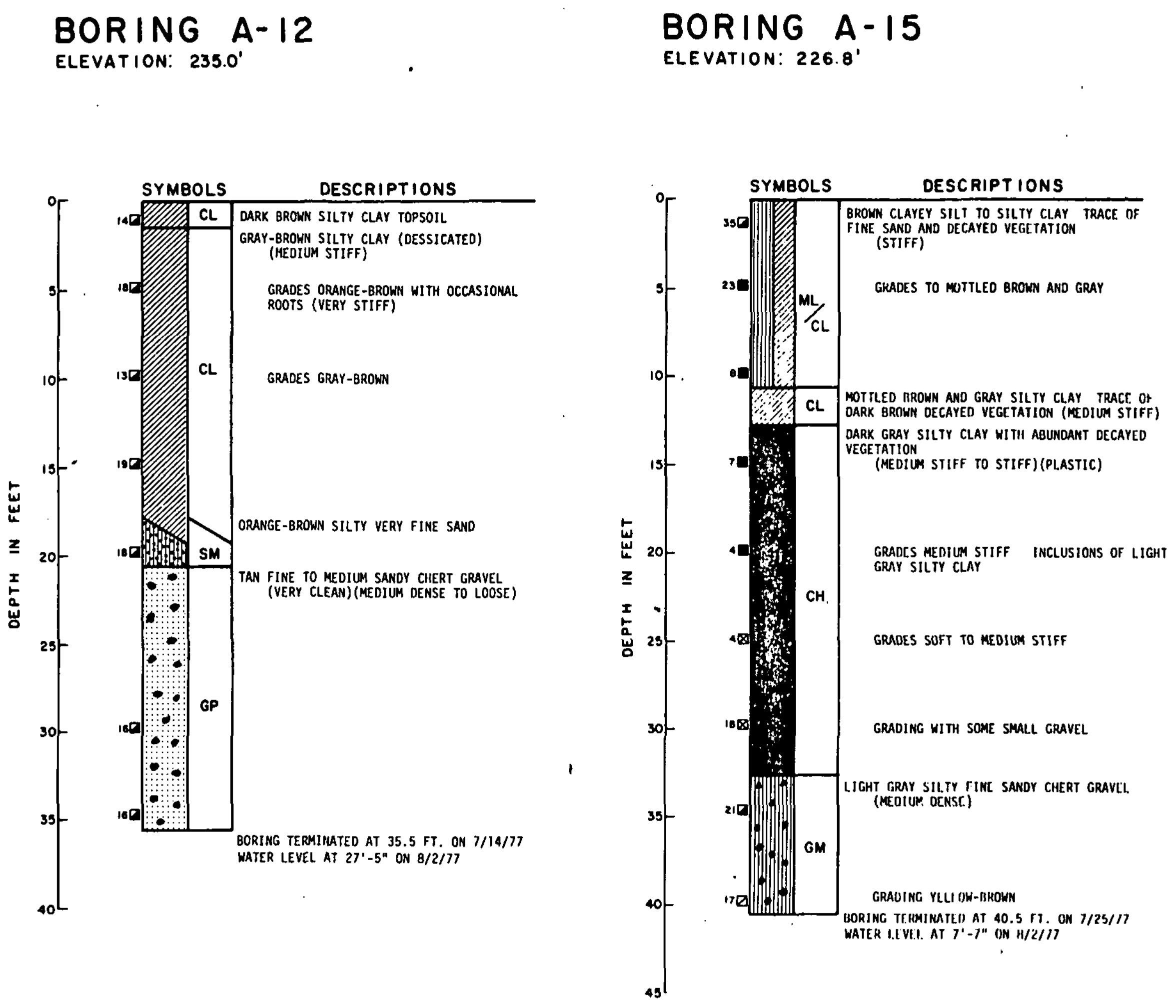
LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◩ SPT SAMPLER
- ◪ SPT SAMPLER (NO RECOVERY)

NOTE:

1. THE 3.25" O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
2. BLOWCOUNT WITH DAMES & MOORE SAMPLER IS APPROXIMATELY TWO TIMES THE STANDARD PENETRATION TEST, I.E. $\frac{D\&M}{2} = SPT$.

Figure 3.2-9. Log of borings.



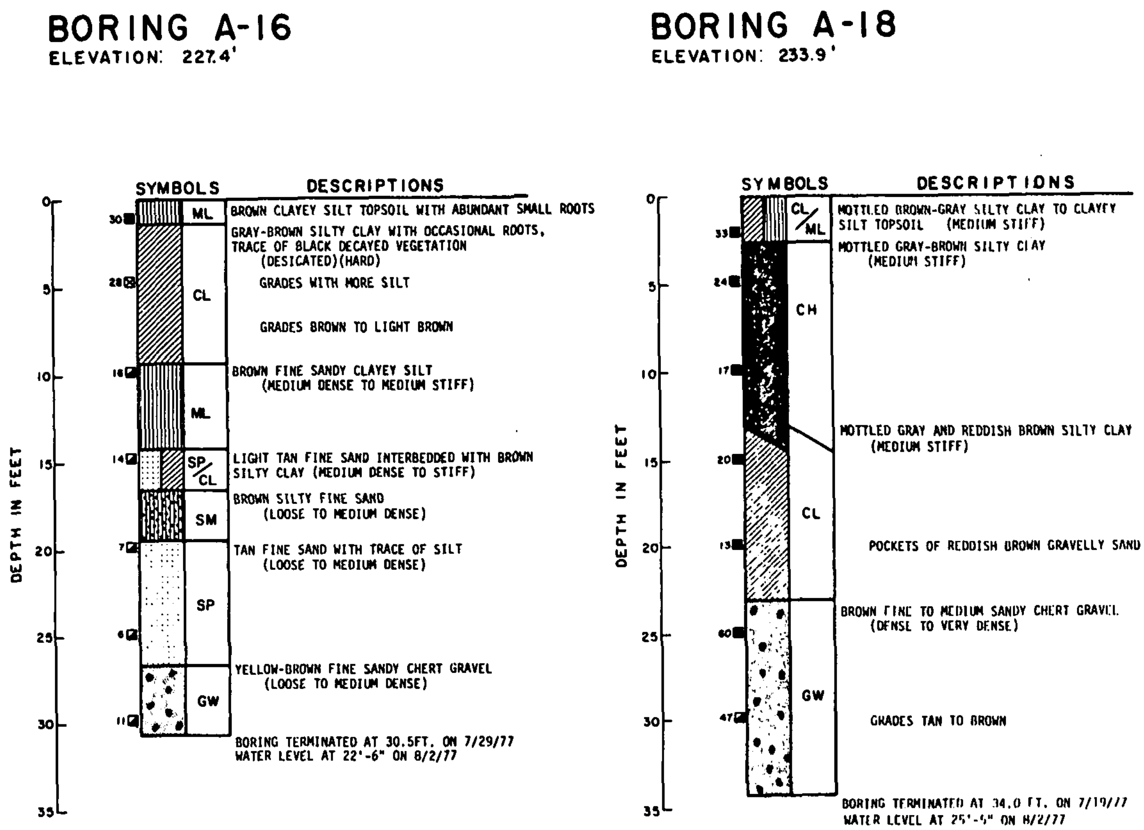
LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ⧄ SPT SAMPLER (NO RECOVERY)

NOTE:

1. THE 3.25" O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
2. BLOWCOUNT WITH DAMES & MOORE SAMPLER IS APPROXIMATELY TWO TIMES THE STANDARD PENETRATION TEST, I.E. $\frac{D\&M}{2}$ = SPT.

Figure 3.2-10. Log of borings.



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ◩ SPT SAMPLER (NO RECOVERY)

NOTE:

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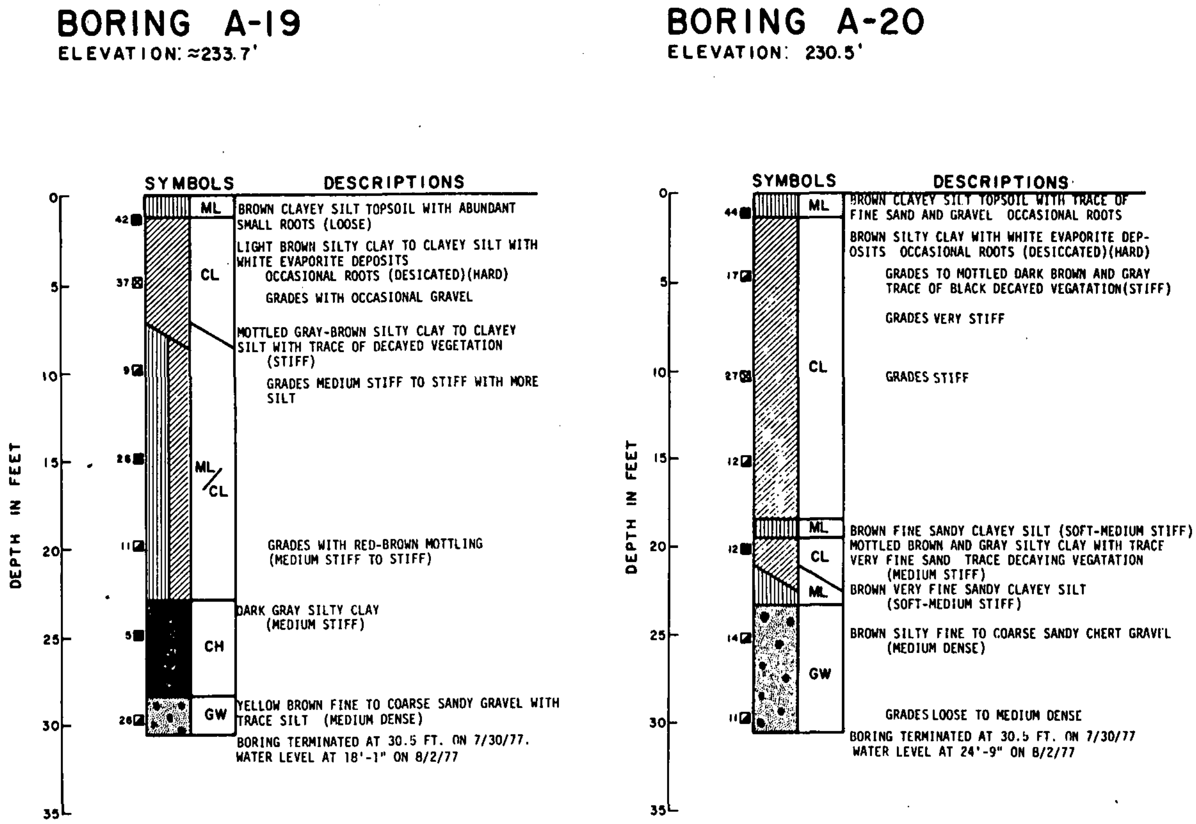
Figure 3.2-11. Log of borings.



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ◩ SPT SAMPLER (NO RECOVERY)

NOTE:
1. THE 3.25" O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
2. BLOWCOUNT WITH DAMES & MOORE SAMPLER IS APPROXIMATELY TWO TIMES THE STANDARD PENETRATION TEST, I.E. $\frac{D\&M}{2}$ = SPT.

Figure 3.2-12. Log of borings.

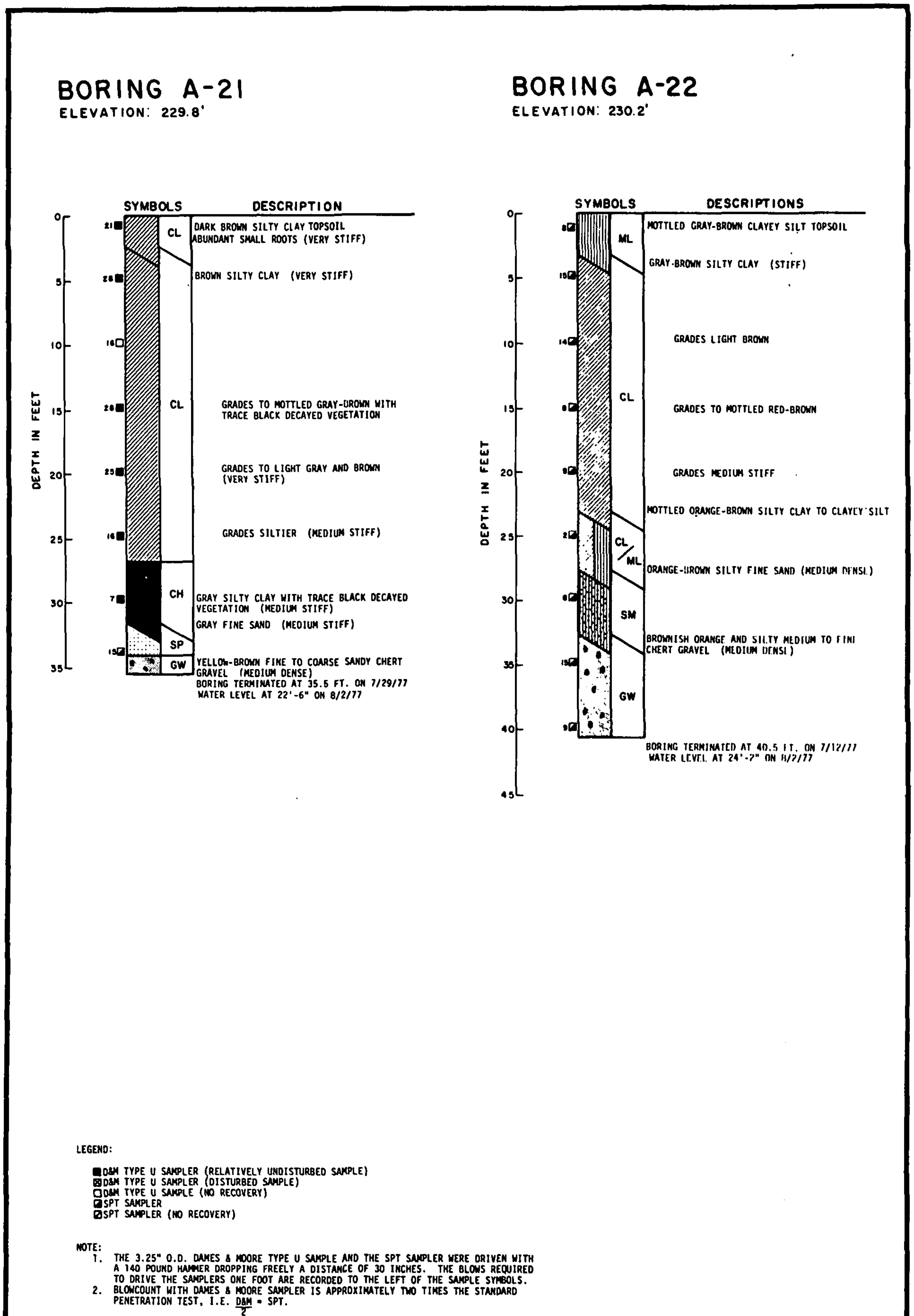
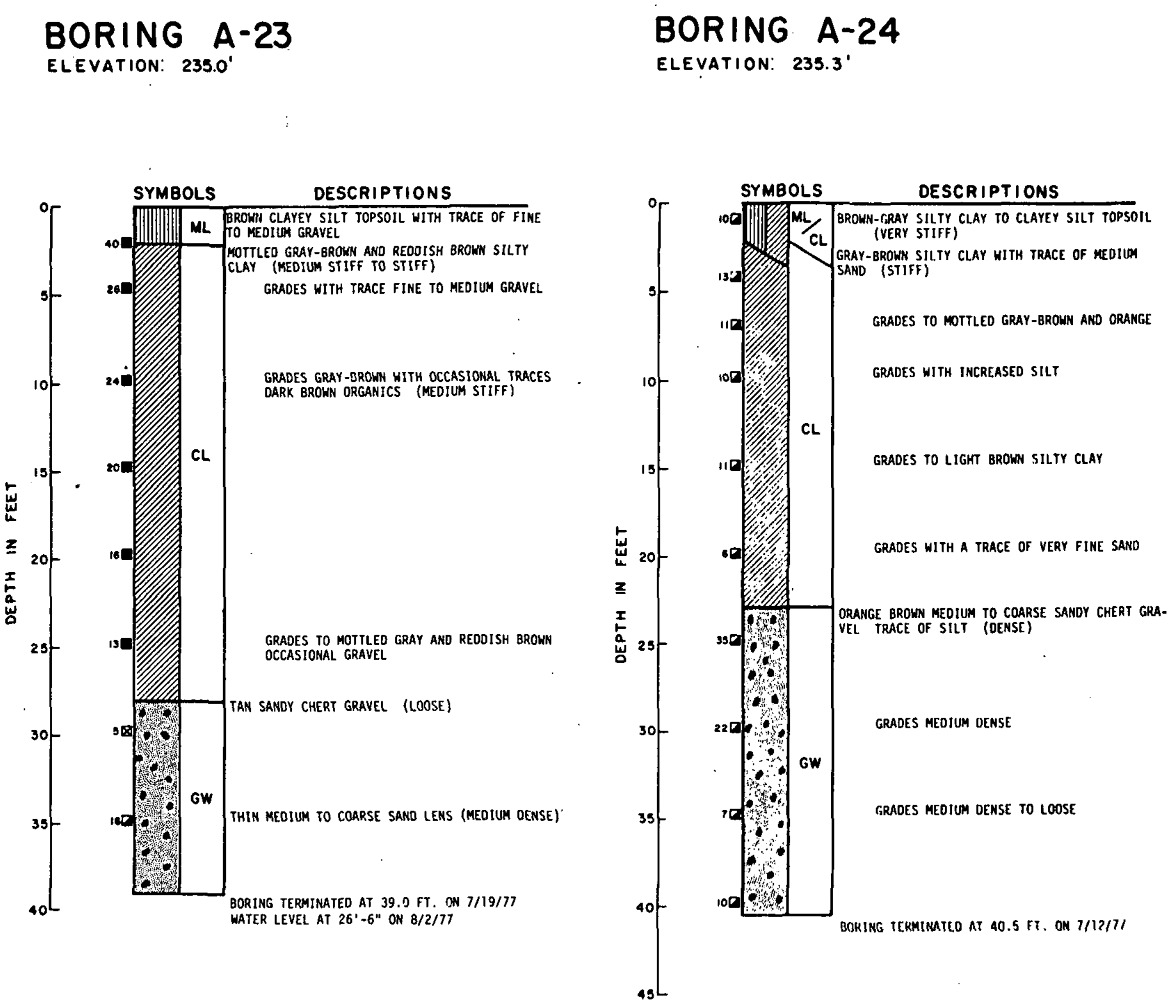


Figure 3.2-13. Log of borings.



LEGEND:

■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
□ D&M TYPE U SAMPLE (NO RECOVERY)
◪ SPT SAMPLER
◩ SPT SAMPLER (NO RECOVERY)

NOTE:
1. THE 3.25" O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
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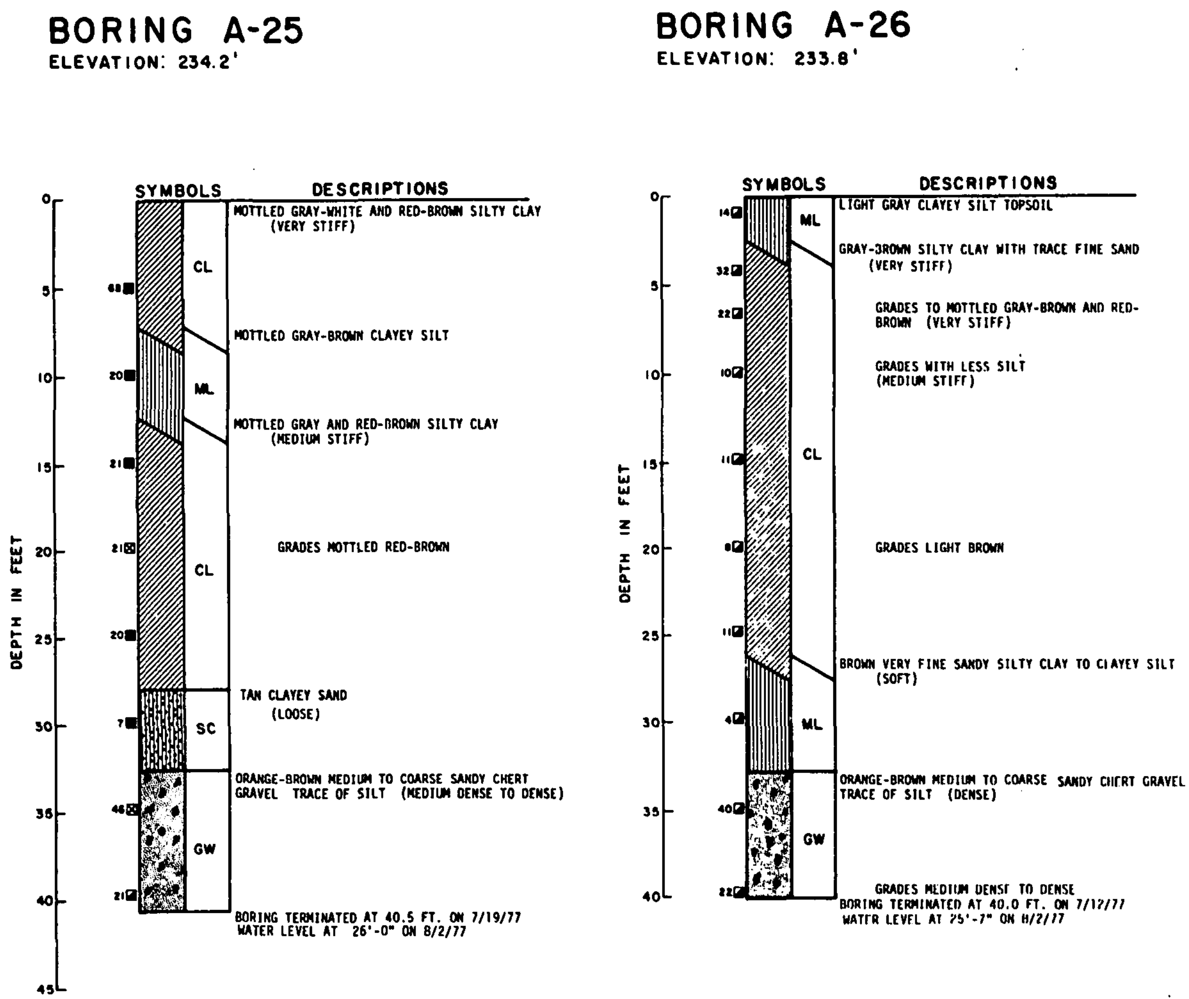
Figure 3.2-14. Log of borings.



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ⧄ SPT SAMPLER (NO RECOVERY)

NOTE:

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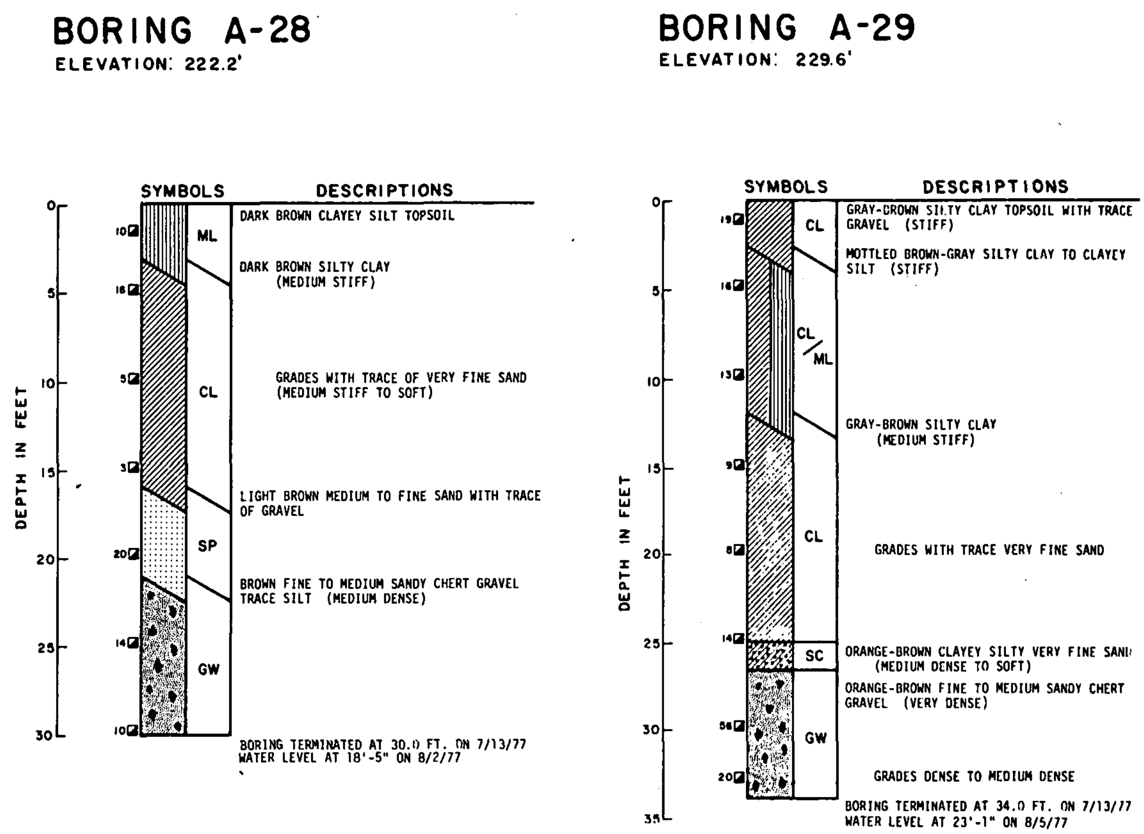
Figure 3.2-15. Log of borings.



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
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- ◩ SPT SAMPLER (NO RECOVERY)

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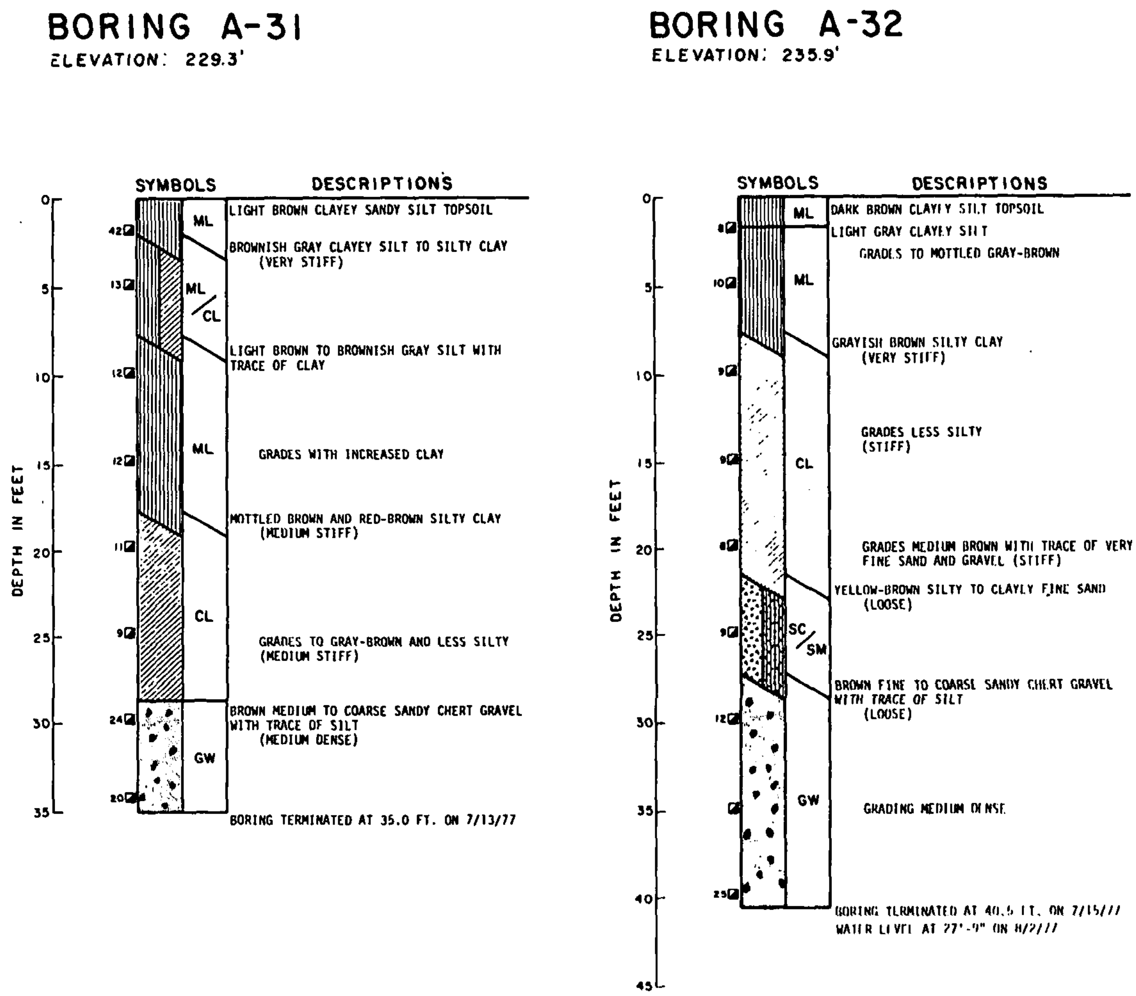
Figure 3.2-16. Log of borings.



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ◩ SPT SAMPLER (NO RECOVERY)

NOTE:
1. THE 3.25" O.D. DAMES & MOORE TYPE U SAMPLE AND THE SPT SAMPLER WERE DRIVEN WITH A 140 POUND HAMMER DROPPING FREELY A DISTANCE OF 30 INCHES. THE BLOWS REQUIRED TO DRIVE THE SAMPLERS ONE FOOT ARE RECORDED TO THE LEFT OF THE SAMPLE SYMBOLS.
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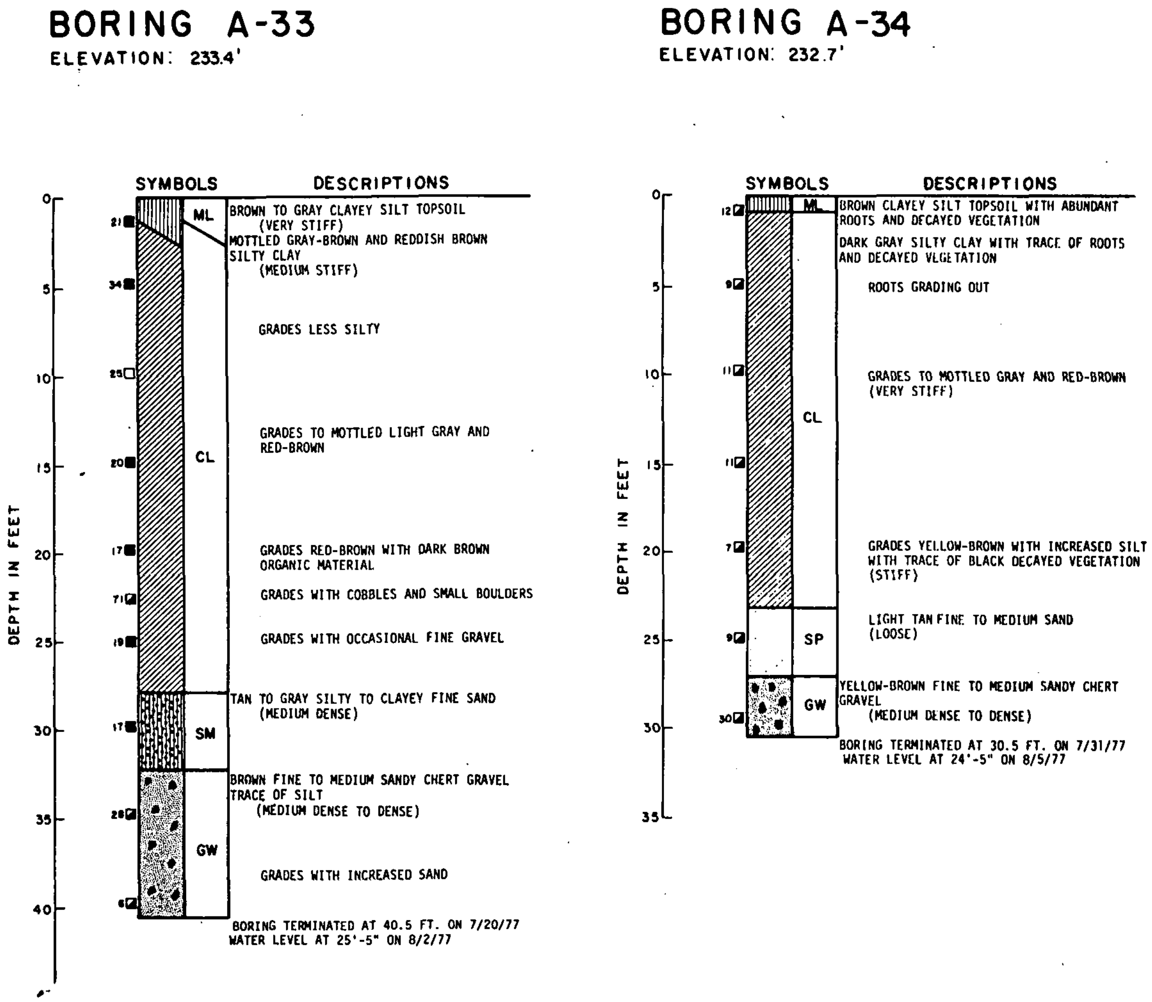
Figure 3.2-17. Log of borings.



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ◩ SPT SAMPLER (NO RECOVERY)

NOTE:

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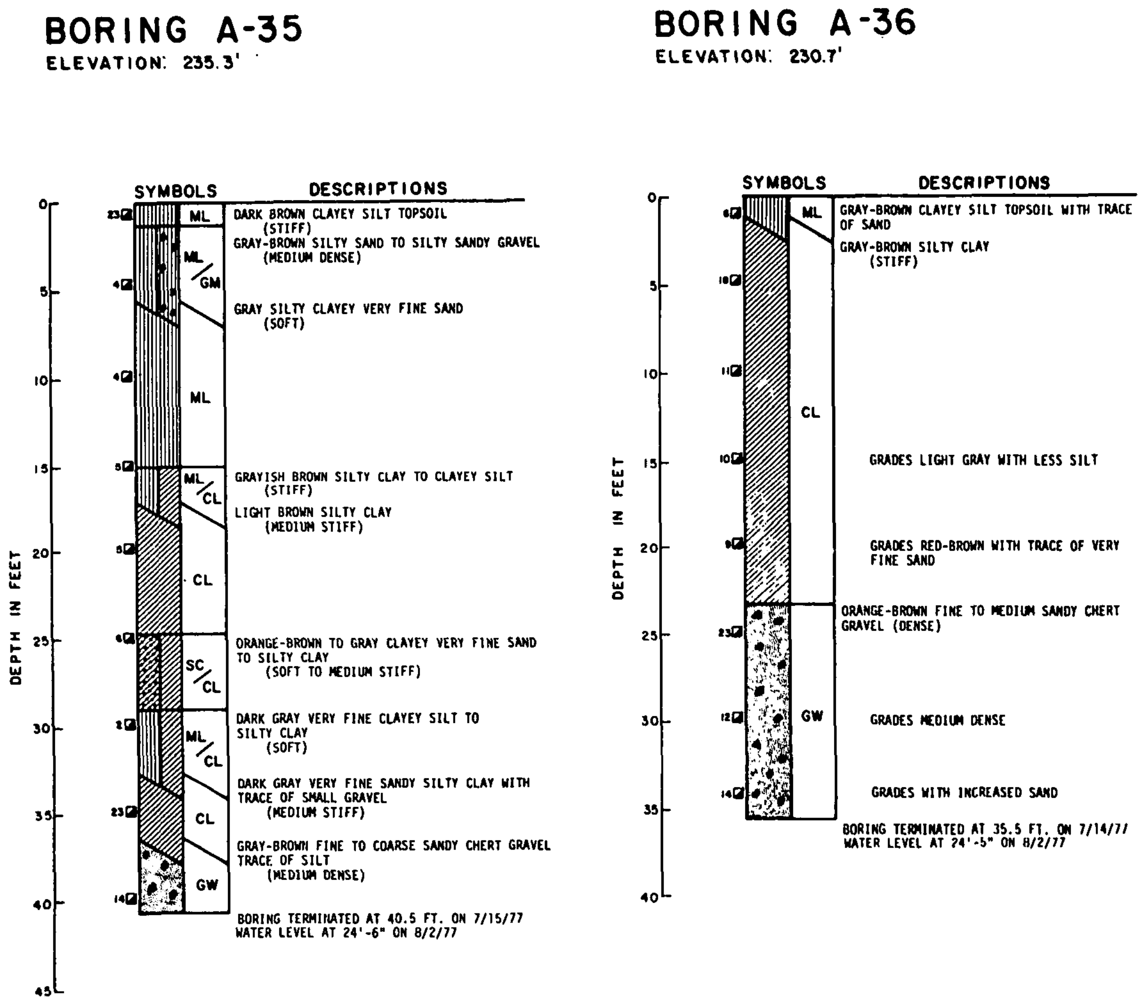
2. BLOWCOUNT WITH DAMES & MOORE SAMPLER IS APPROXIMATELY TWO TIMES THE STANDARD PENETRATION TEST, I.E. $\frac{D\&M}{2}$ = SPT.

Figure 3.2-18. Log of borings.



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ▣ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◩ SPT SAMPLER
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NOTE:

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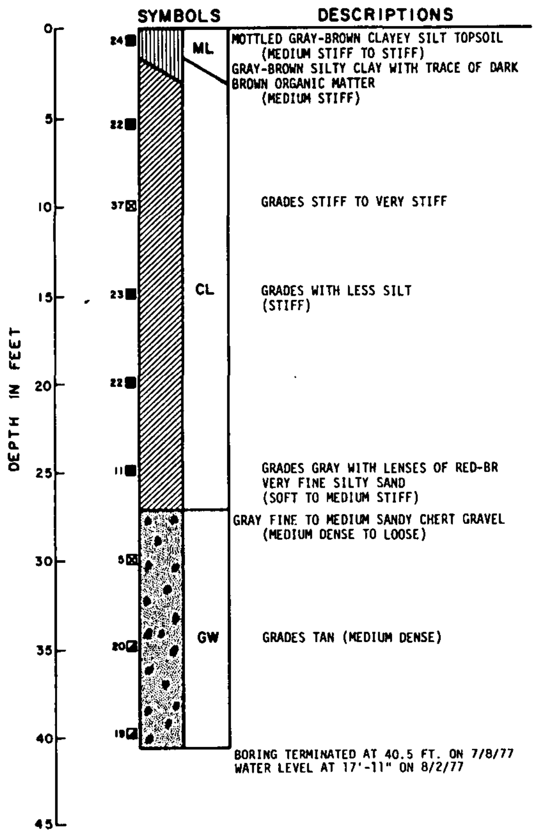
Figure 3.2-19. Log of borings.

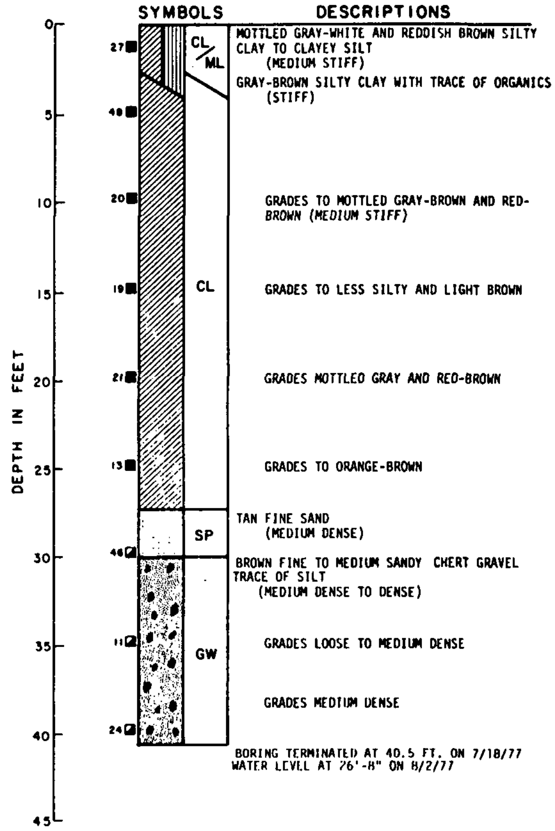
BORING A-37

ELEVATION: 227.9'



BORING A-38

ELEVATION: 234.1'



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
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Figure 3.2-20. Log of borings.

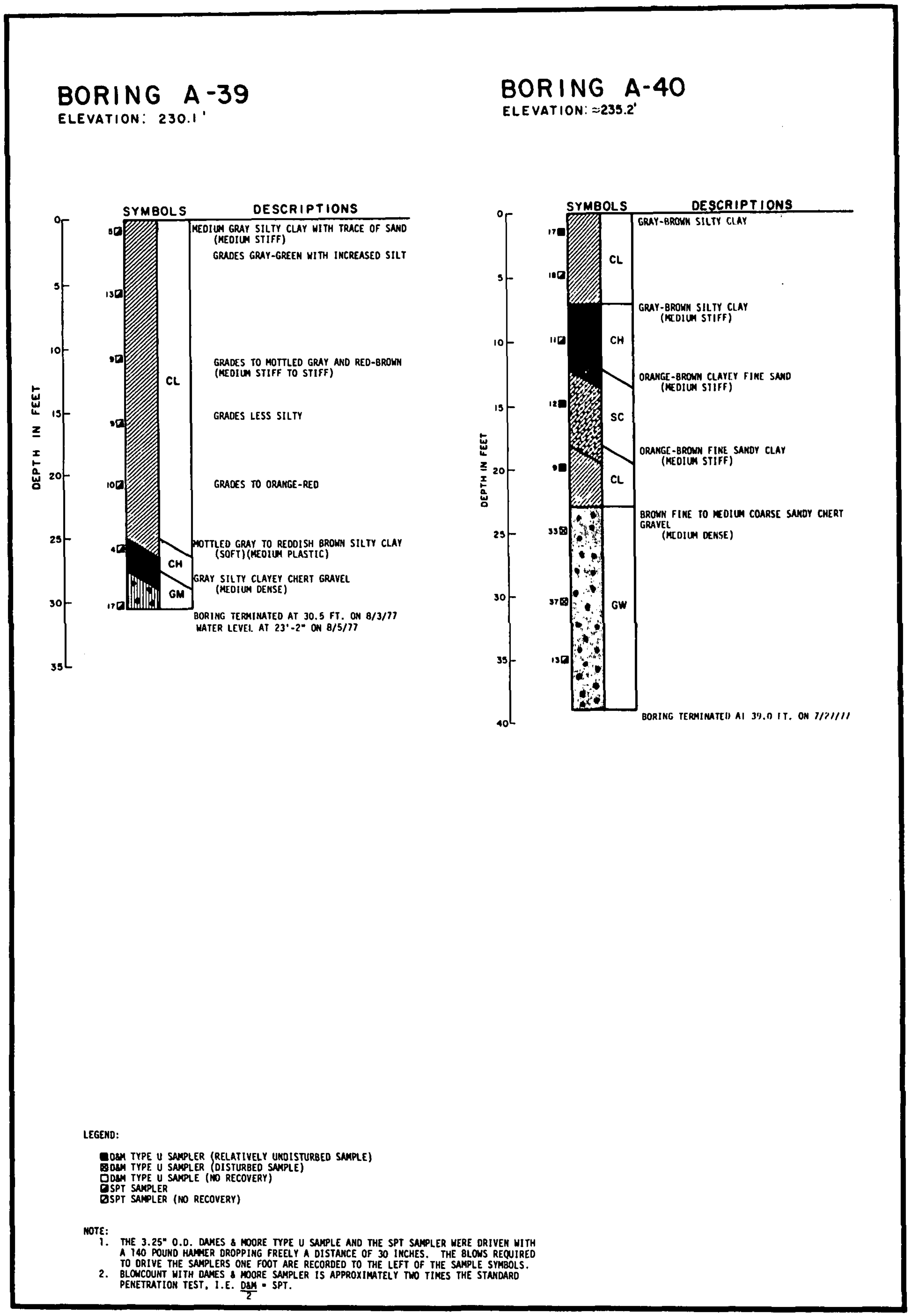
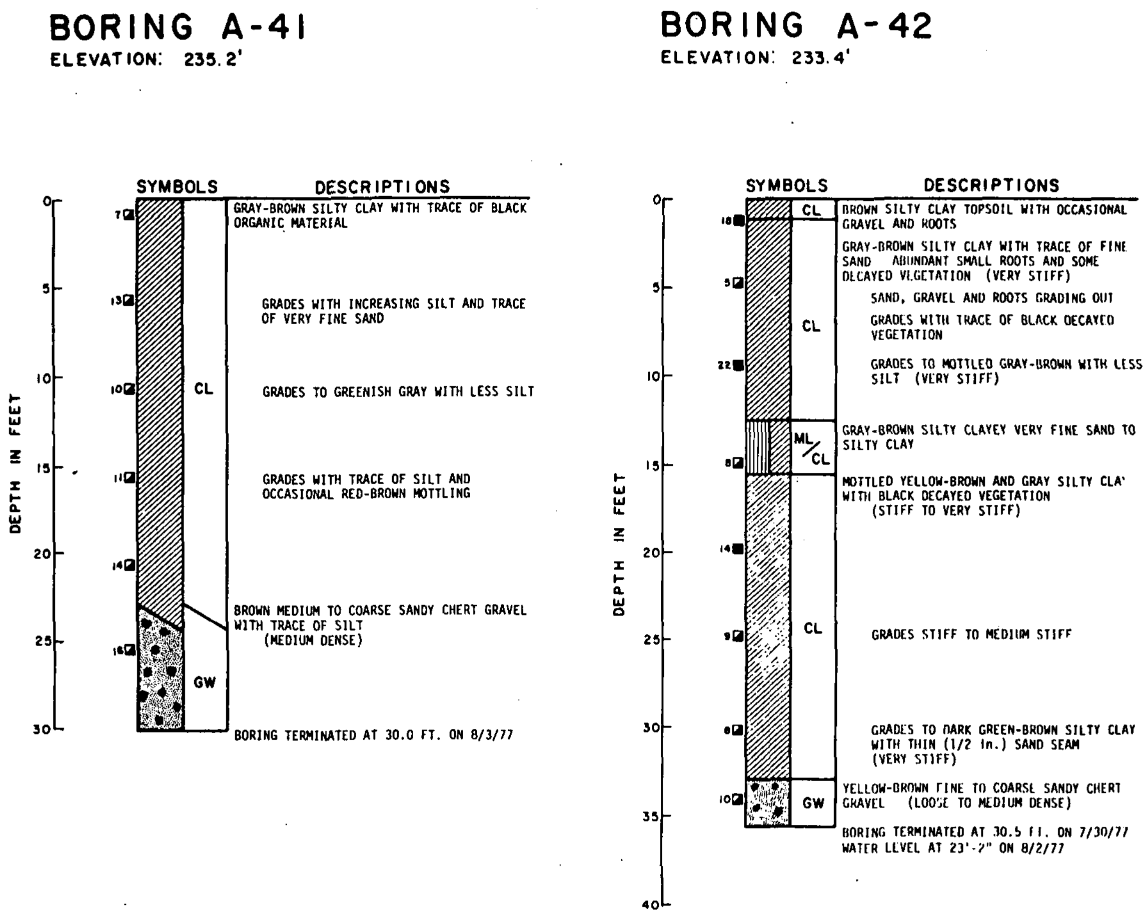


Figure 3.2-21. Log of borings.



LEGEND:

- ■ D&M TYPE U SAMPLER (RELATIVELY UNDISTURBED SAMPLE)
- ⊠ D&M TYPE U SAMPLER (DISTURBED SAMPLE)
- □ D&M TYPE U SAMPLE (NO RECOVERY)
- ◪ SPT SAMPLER
- ⧄ SPT SAMPLER (NO RECOVERY)

NOTE:
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Figure 3.2-22. Log of borings.

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50 % OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50 % OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50 % OF MATERIAL IS SMALLER THAN NO 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICTY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

Figure 3.2-23. Unified soil classification system.

3.3 REFERENCES

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PART 4
AIR QUALITY/METEOROLOGY

TECHNICAL SUPPORT DOCUMENT

PART 4

METEOROLOGY/AIR QUALITY

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

TABLES

TABLES (Continued)

FIGURES

PART 4

METEOROLOGY/AIR QUALITY

4.1 REGIONAL CLIMATOLOGY

This section describes baseline climactic features which are considered to be representative of conditions at the proposed site. Long-term climatological records from the National Weather Service (NWS) station at Little Rock, supplemented by data from locations near the site were used in this study. Because of the homogeneous climactic conditions over the eastern part of Arkansas, these data are considered to be generally representative of climatic conditions at the site.

4.1.1 Surface Winds

An annual wind rose for the period from 1955 to 1964 at Little Rock is shown in Figure 4.1-1. These data indicate that winds from south through west-southwest are most common, although the distribution is fairly uniform over all directions. The annual average wind speed is 7.3 kt (8.4 mph), and the frequency of calms is 5.2 percent (USDC, 1973a). This compares favorably with a 32-year mean wind speed at Little Rock of 7.1 kt (8.2 mph) (USDC, 1974).

The "fastest mile" of record at Little Rock during the period from 1942 to 1974 was 65 mph (USDC, 1974). The fastest mile is defined as the highest wind speed lasting for any time interval during which a length of air one mile long passes a wind instrument.

4.1.2 Temperature

Monthly and annual values of daily mean temperatures, and average daily maximum and minimum temperatures for Little Rock (USDC, 1974) are shown in Table 4.1-1. Based on these data, the annual mean temperature is 61°F. The highest average daily maximum temperature, near 93°F, occurs during the months of July and August, while the lowest average daily minimum temperature, 29°F, occurs in January. Data published for stations nearer the site (Batesville and Newport) are in close agreement with the above averages (USDC, 1965). Data for Batesville and Newport indicate annual averages of 59.9°F and 61.7°F, respectively. The highest average daily maximum value of temperatures, 92-93°F, occurs during July and August. The lowest average daily minimum occurs in January, with 27°F at Batesville and 30°F at Newport (USDC, 1965).

Summer weather is consistently quite warm, with maximum temperatures equal to or greater than 90°F approximately 75 days each year. The temperature can be expected to drop to freezing or below about 60 days each year (USDC, 1968a). The extreme highest temperature recorded at Little Rock (about 100 years of record) was 110°F, while the extreme lowest was -13°F (USDC, 1974). However, long-term records at Batesville yield an extreme high of 115°F and an extreme low of -18°F (USDC, 1965). Extremes at Newport based on data records from 1891 through 1960 were 114°F and -14°F.

4.1.3 Relative Humidity

Relative humidity is generally high in the site area. Based on Little Rock data from 1961 to 1974 (USDC, 1974), the annual average relative humidity is approximately 70 percent, while monthly averages range from near 65 percent in March to over 75 percent in September. Diurnally, the relative humidity averages 79 percent at midnight, 84 percent at 6:00 a.m., 57 percent at noon, and 61 percent at 6:00 p.m.

4.1.4 Precipitation

Monthly and annual precipitation means and extremes at both Little Rock and Batesville are set forth in Table 4.1-2. Although the periods of record are different, the annual mean at both stations was 49.5 in. These data indicate that rainfall is rather evenly distributed throughout the year, with a peak in spring and a minimum in late summer and early fall. Maximum monthly totals of approximately 18 in. at Little Rock and 14 in. at Batesville occurred in January at both stations. The maximum rainfalls (inches) at Little Rock from 1900 to 1961 (USDC, 1963) for various time periods to 24 hours are as follows:

Period (min.)	5	10	15	30	60
Rainfall (in.)	0.63	1.01	1.35	2.07	3.00

Period (hrs.)	2	3	6	12	24
Rainfall (in.)	4.60	6.82	7.68	8.19	9.58

Data presented for Batesville from 1951 to 1960 (USDC, 1965) indicate that daily rainfall rates of 0.5 in. or more can be expected about 2 or 3 days each month, or approximately 30 days per year. Measurable precipitation (0.01 in. or greater) occurs on an average of 104 days each year (USDC, 1974).

The annual average snowfall is approximately 5 in. at Little Rock (USDC, 1974) and almost 7 in. at Batesville (USDC, 1965). Extremes of snowfall (inches) for both Little Rock and the State of Arkansas are set forth below (Ludlam, 1970):

Period	Little Rock (1885-1970)	State of Arkansas
24 hr.	13.0	25.0 (Corning, 76-year period)
Single storm	13.0	25.0 (Corning, 76-year period)
Calendar month	19.4	48.0 (Calico Rock, 66-year period)
Season	26.6	61.0 (Hardy, 64-year period)

Precipitation in the form of freezing rain (glaze and ice storms), although infrequent, is at times severe. Moderate to heavy ice storms are estimated to occur about once every 4 years and can be very damaging to utility lines and trees, as well as being a serious traffic hazard.

Hail is another form of frozen precipitation and is usually associated with moderate to severe thunderstorms. Hard hail (which does not shatter on impact) of 1 in. diameter and larger will cause heavy damage to roofs, pit thin steel surfaces such as automobiles, and may break windows. For the period 1955-1967, there was an average of about one report per year of hail 0.75 in. or greater in diameter within the one-degree latitude-longitude square containing the proposed site (Pautz, 1969). Almost half of these occurrences were in April.

4.1.5 Fog

Heavy fog is defined as that fog which reduces visibility to 0.25 mile or less. The average number of days each year with heavy fog is 16, based on Little Rock data from 1943 to 1974 (USDC, 1974). The average number of days each month with heavy fog reaches a peak of 3 in January, and a minimum of less than 0.5 in June.

4.1.6 Thunderstorms

Thunderstorms can be expected on 55 to 60 days each year (USDC, 1974). Thunderstorm occurrences reach a peak in July with an average of 9 days, and average about 6 days a month during both spring and summer. Thunderstorms generally occur on about two days each month during the rest of the year.

4.1.7 Tornadoes

During the period from 1955 through 1967, a total of 27 tornadoes were recorded in the one-degree latitude-longitude square containing the proposed site (Pautz, 1969). According to Thom (1963), the probability and return period of a tornado occurrence at a specific point in this area would be 0.00151 and 663 years, respectively. For comparison, the maximum probability in the United States, based on the 1955 to 1967 data set, is 0.00588 (return period of 170 years). This maximum occurs near Oklahoma City.

4.1.8 Windstorms

Strong, gusty surface winds, 50 kt or greater, usually occur in association with severe thunderstorm activity. On occasion, winds of such magnitude may occur in association with intense extra-tropical cyclones (low pressure areas), and strong winds also may accompany well-developed cold fronts. From 1955 through 1967, 18 windstorms with winds equal to or greater than 50 kt were reported in the one-degree latitude-longitude square containing the proposed site (Pautz, 1969).

4.1.9 Tropical Cyclones

Tropical cyclones, including hurricanes, lose strength rapidly as they move inland. Their greatest potential impact in the site area comes from flooding due to heavy rainfall; high winds are seldom associated with them. Wind and precipitation extremes presented in previous sections include hurricane effects. An average of one tropical cyclone per year, none with hurricane-force winds, affected Arkansas during the period from 1931 to 1960 (Cry, 1967).

4.1.10 Atmospheric Stability

Atmospheric stability in conjunction with the general ventilation (winds) indicates the ability of the atmosphere to disperse airborne effluents. Analyses of dispersion, based on these variables, are presented in subsequent sections. The mean annual frequency distribution of Pasquill stability classes for the 10-year period from 1955 to 1964 at Little Rock (USDC, 1973a) is presented below:

Pasquill Stability Class	Description	Percent Occurrence
A	Extremely Unstable	0.6
B	Unstable	6.0
C	Slightly Unstable	13.3
D	Neutral	43.6
E	Slightly Stable	14.9
F	Stable	14.9
G	Extremely Stable	6.7

Stability determinations are based on the well-known Turner (1964) or STAR method which assigns a stability class on the basis of surface wind speed, cloud cover, and solar angle. Joint annual frequency distributions of wind speed, wind direction, and stability class at Little Rock for the period 1955 to 1964 are shown in Tables 4.1-3 through 4.1-10.

4.1.11 Air Pollution Potential

Meteorological conditions conducive to high air pollution potential on a regional basis are light winds accompanied by a shallow mixing height. Mixing height is defined as the vertical extent of the surface layer in which relatively vigorous vertical mixing takes place. Holzworth (1972) has compiled isopleths of seasonal and annual mean mixing heights for both morning and afternoon cases. The Little Rock mean mixing heights and associated average wind speeds through the mixing layer (period 1960 to 1964) are as follows:

Season	Morning Mixing Height (Meters)	Morning Wind Speed (m/s)	Afternoon Mixing Height (Meters)	Afternoon Wind Speed (m/s)
Winter	541	5.2	1101	6.6
Spring	544	5.7	1612	7.0
Summer	375	3.7	1851	4.9
Autumn	342	3.8	1401	5.2
Annual	450	4.6	1491	5.9

The above data show that, on the average, the greatest air pollution potential occurs on summer and autumn mornings because of the more shallow mixing depths and lower wind speeds.

The persistence of high meteorological potential for air pollution is indicated by what Holzworth calls episodes and episode days. An episode occurs if a mixing height of 2000 meters or less, combined with a wind speed of 6 meters per second or less, persists without precipitation for at least 2 days. Holzworth determined the frequency of 2-day and 5-day episodes for several combinations of wind speeds and mixing heights. Episode days are the total number of days included in the episodes. The number of episodes in 5 years (1960 to 1964) at Little Rock, lasting 2 or more days and 5 or more days, are:

Mixing Height (meters)	Two or More Days Wind Speed (m/s)			Five or More Days Wind Speed (m/s)	
	≤2	≤4	≤6	≤4	≤6
≤500	0	1	2	0	0
≤1000	0	9	30	0	2
≤1500	0	23	68	0	5
≤2000	0	39	126	1	16

These data show that there were only 16 episodes in 5 years lasting 5 or more days; of these only 2 had a mixing depth of 1000 meters or less.

Based on a 40-year period of record (1936-1975), Korshover (1976) tabulated the number of times stagnating anticyclones persisted for 4 or more and 7 or more days. Occurrences of stagnation were determined primarily on the basis of a surface pressure-gradient analysis. In the general site area, there were 20 stagnation cases which persisted for at least 4 days during the 40-year period, involving a total number of 92 stagnation days. Of the 20 cases, 12 occurred during the fall and 8 during the summer season. There was only one case which persisted for 7 or more days during this period.

The above indicates that conditions condusive to high air pollution in the region are infrequent. This is due to frequent air mass changes resulting from frontal passages in this region.

4.1.12 Average Wind Speed in the Mixing Layer

Depending on the type of model and plume rise calculation technique used, the results of a modeling analysis sometimes show that low wind speeds are associated with higher ground level concentrations for elevated, buoyant emission releases. To determine the frequency with which such winds occur, an evaluation of average wind speeds representative of the Independence site within the entire mixing layer was conducted. This evaluation is based on twice-daily (morning and afternoon) rawinsonde soundings made at Little Rock during the 5-year period 1960 to 1964.

Wind speed averaged over the entire mixing layer is a more meaningful statistic than surface wind speed, since a plume released from a 1000-ft stack will be affected by winds throughout the vertical extent from ground level to the top of the mixing layer and not just by surface winds. Furthermore, the mixing layer must be of sufficient height, or a buoyant plume released from a tall stack will ascend above the mixing height and not contribute significantly to ground level concentrations. Computations performed using Briggs' plume rise equations (Briggs, 1971; Briggs, 1972) indicate that the plume from the Independence Steam Electric Station when both generating units are operating will be above 500 m during very low wind speed conditions. Therefore, only those non-precipitation cases were considered when the mixing height, determined by the Holzworth (1972) technique, was 500 m or greater.

The resulting frequency of occurrence of mixing layer average wind speeds has been tabulated by the National Climatic Center (USDC, 1968b) and is presented in Table 4.1-11 for both morning and afternoon soundings. Average wind speeds of 2 m/s or less are very infrequent, occurring only 5 percent of the time during the 429 morning cases when the mixing height was 500 m or greater, and only 3 percent of the time during the 1377 afternoon cases when the mixing height was at least 500 m.

4.1.13 Average Wind Speed and Direction at Stack Height

As a means of estimating prevailing transport conditions for a plume released from the Independence site at a height of 1000 ft (305 m), average annual percent frequency of winds at the 300 m level are presented in Table 4.1-12. These data are based on twice-daily Little Rock rawinsonde measurements over the period 1960 to 1964 (USDC, 1973b). Although wind direction is resolved only to the four primary compass directions, it appears that westerly wind flow between 5 and 10 m/s is the most common morning condition, and southerly wind flow between 5 and 10 m/s the most common afternoon condition.

4.1.14 Temperature Inversion Frequency

A temperature inversion exists in the atmosphere when temperature increases with height rather than decreases as is usually the case. An estimate of morning and afternoon temperature inversion frequency at the Independence site is provided in Table 4.1-13 and is based on twice-daily rawinsonde observations taken at Little Rock over the 5-year period 1960 to 1964 (USDC, 1973b). This table includes both surface-based inversion frequency and frequency of inversions with bases above the surface. Surface-based inversions are more frequent in the early morning and are due primarily to radiational cooling effects. Elevated inversions are more common during the late afternoon and are presumably largely attributable to subsidence heating when high pressure systems are present.

Information is presented in Table 4.1-14 regarding the seasonal frequency with which a plume emitted from the Independence Steam Electric Station's 1000-ft stack might actually be embedded within an inversion layer. This table shows the precentage frequency of occurrence of inversions which are based below 250 m, i.e., below the top of the stack, and are at least 500 m thick so that they extend well above the top of the stack. Such inversions are most common in the early morning, particularly during the winter months when they occur about 26 percent of the time.

Table 4.1-1

Values of Mean and Average

Daily Maximum and Minimum Temperatures (°F)

at Little Rock (1941-1970)

Month	Mean	Average Daily Maximum	Average Daily Minimum
January	39.5	50.1	28.9
February	42.9	53.8	31.9
March	50.3	61.8	38.7
April	61.7	73.5	49.9
May	69.8	81.4	58.1
June	78.1	89.3	66.8
July	81.4	92.6	70.1
August	80.6	92.6	68.6
September	73.3	85.8	60.8
October	62.4	76.0	48.7
November	50.3	62.4	38.1
December	41.6	52.1	31.1
Annual	61.0	72.6	49.3

Source: USDC, 1956, 1965, 1974.

Table 4.1-2
Monthly and Annual Precipitation
Little Rock and Batesville, Arkansas
(Inches)

	Little Rock		Batesville	
	Mean (1941-1970)	Maximum (1935-1974)	Mean (1931-1960)	Maximum (1931-1960)
January	4.24	18.04	4.40	13.85
February	4.42	11.02	4.17	10.53
March	4.93	9.49	4.68	10.48
April	5.25	14.20	4.34	10.63
May	5.30	12.74	4.94	12.07
June	3.50	7.82	4.17	10.81
July	3.38	7.60	3.81	7.88
August	3.01	14.46	3.43	7.99
September	3.55	9.09	3.23	9.56
October	2.99	9.68	3.27	11.34
November	3.86	9.54	4.27	11.32
December	4.09	8.33	3.87	9.96
Annual	48.52	74.39	48.58	65.25

Source: USDC, 1956, 1965, 1974.

Table 4.1-3

Class A Wind Frequency Distribution

ANNUAL RELATIVE FREQUENCY DISTRIBUTION STATION =13963 LITTLE ROCK,AK 24OBS

1955-64

	SPEED(KTS)						
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.000016	0.000183	0.000000	0.000000	0.000000	0.000000	0.000199
NNE	0.000072	0.000251	0.000000	0.000000	0.000000	0.000000	0.000323
NE	0.000071	0.000388	0.000000	0.000000	0.000000	0.000000	0.000460
ENE	0.000083	0.000377	0.000000	0.000000	0.000000	0.000000	0.000460
E	0.000123	0.000548	0.000000	0.000000	0.000000	0.000000	0.000671
ESE	0.000180	0.000491	0.000000	0.000000	0.000000	0.000000	0.000671
SE	0.000159	0.000400	0.000000	0.000000	0.000000	0.000000	0.000559
SSE	0.000125	0.000297	0.000000	0.000000	0.000000	0.000000	0.000422
S	0.000101	0.000297	0.000000	0.000000	0.000000	0.000000	0.000398
SSW	0.000053	0.000320	0.000000	0.000000	0.000000	0.000000	0.000373
SW	0.000091	0.000331	0.000000	0.000000	0.000000	0.000000	0.000422
WSW	0.000123	0.000274	0.000000	0.000000	0.000000	0.000000	0.000398
W	0.000060	0.000114	0.000000	0.000000	0.000000	0.000000	0.000174
WNW	0.000066	0.000183	0.000000	0.000000	0.000000	0.000000	0.000248
NW	0.000087	0.000137	0.000000	0.000000	0.000000	0.000000	0.000224
NNW	0.000006	0.000069	0.000000	0.000000	0.000000	0.000000	0.000075
TOTAL	0.001416	0.004659	0.000000	0.000000	0.000000	0.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF A STABILITY = 0.006075

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH A STABILITY = 0.000491

Table 4.1-4

Class B Wind Frequency Distribution

ANNUAL			RELATIVE FREQUENCY DISTRIBUTION			STATION =13963 LITTLE ROCK,AK 24OBS	
							1955-64
			SPEED(KTS)				
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.000542	0.001176	0.000617	0.000000	0.000000	0.000000	0.002334
NNE	0.000707	0.001507	0.001028	0.000000	0.000000	0.000000	0.003241
NE	0.000796	0.001998	0.001450	0.000000	0.000000	0.000000	0.004245
ENE	0.000837	0.002284	0.002147	0.000000	0.000000	0.000000	0.005268
E	0.000905	0.002204	0.002090	0.000000	0.000000	0.000000	0.005199
ESE	0.000926	0.002581	0.001987	0.000000	0.000000	0.000000	0.005495
SE	0.000864	0.002729	0.001850	0.000000	0.000000	0.000000	0.005443
SSE	0.000762	0.002032	0.001279	0.000000	0.000000	0.000000	0.004073
S	0.000739	0.001644	0.001667	0.000000	0.000000	0.000000	0.004050
SSW	0.000517	0.001576	0.001861	0.000000	0.000000	0.000000	0.003954
SW	0.000698	0.001770	0.002227	0.000000	0.000000	0.000000	0.004694
WSW	0.000867	0.001964	0.001621	0.000000	0.000000	0.000000	0.004452
W	0.000452	0.000891	0.000559	0.000000	0.000000	0.000000	0.001902
WNW	0.000412	0.001028	0.000674	0.000000	0.000000	0.000000	0.002113
NW	0.000411	0.001005	0.000765	0.000000	0.000000	0.000000	0.002180
NNW	0.000263	0.000959	0.000582	0.000000	0.000000	0.000000	0.001804
TOTAL	0.010699	0.027347	0.022403	0.000000	0.000000	0.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF B STABILITY = 0.060448

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH B STABILITY = 0.002135

Table 4.1-5

Class C Wind Frequency Distribution

ANNUAL			RELATIVE FREQUENCY DISTRIBUTION		STATION #13963 LITTLE ROCK,AK 240BS	
					1955-64	
			SPEED(KTS)			
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.000281	0.001599	0.002843	0.000251	0.000000	0.000000	0.004973
NNE	0.000249	0.001678	0.004362	0.000662	0.000000	0.000000	0.006951
NE	0.000327	0.001816	0.004967	0.000754	0.000000	0.000000	0.007863
ENE	0.000414	0.002626	0.006908	0.000948	0.000011	0.000000	0.010907
E	0.000444	0.002501	0.006075	0.000731	0.000000	0.000000	0.009750
ESE	0.000438	0.002877	0.006132	0.000400	0.000011	0.000000	0.009858
SE	0.000492	0.002512	0.004624	0.000411	0.000000	0.000000	0.008040
SSE	0.000359	0.001975	0.004191	0.000697	0.000000	0.000000	0.007221
S	0.000432	0.001998	0.006291	0.001108	0.000080	0.000000	0.009909
SSW	0.000342	0.002124	0.007194	0.002238	0.000126	0.000011	0.012034
SW	0.000484	0.002592	0.007993	0.002044	0.000080	0.000000	0.013193
WSW	0.000467	0.002740	0.006817	0.001233	0.000046	0.000011	0.011315
W	0.000243	0.001325	0.002421	0.000320	0.000023	0.000000	0.004331
WNW	0.000196	0.001587	0.003037	0.000525	0.000080	0.000034	0.005460
NW	0.000240	0.001507	0.004133	0.000605	0.000034	0.000000	0.006520
NNW	0.000188	0.001165	0.003026	0.000148	0.000000	0.000000	0.004527
TOTAL	0.005595	0.032622	0.081012	0.013074	0.000491	0.000057	

RELATIVE FREQUENCY OF OCCURRENCE OF C STABILITY = 0.132852

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH C STABILITY = 0.001758

Table 4.1-6

Class D Wind Frequency Distribution

ANNUAL			RELATIVE FREQUENCY DISTRIBUTION			STATION #13963 LITTLE ROCK,AK 24OBS 1955-64	
			SPEED(KTS)				
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.000860	0.004305	0.013188	0.009728	0.001119	0.000069	0.029269
NNE	0.000960	0.005184	0.015072	0.009945	0.000365	0.000023	0.031550
NE	0.001256	0.005675	0.016648	0.008792	0.000320	0.000000	0.032690
ENE	0.001405	0.006771	0.018121	0.008415	0.000251	0.000011	0.034975
E	0.001576	0.005778	0.011110	0.004796	0.000137	0.000023	0.023419
ESE	0.001227	0.006212	0.009728	0.004739	0.000308	0.000034	0.022248
SE	0.001645	0.005709	0.009591	0.004442	0.000285	0.000023	0.021695
SSE	0.000851	0.004978	0.011669	0.005721	0.000388	0.000046	0.023654
S	0.000999	0.005024	0.017070	0.015266	0.001553	0.000091	0.040004
SSW	0.000817	0.003996	0.014981	0.017527	0.002352	0.000240	0.039914
SW	0.000997	0.004579	0.012423	0.011315	0.001176	0.000091	0.030582
WSW	0.000639	0.003631	0.008689	0.007742	0.000776	0.000251	0.021728
W	0.000432	0.002386	0.004624	0.004704	0.001016	0.000183	0.013346
WNW	0.000450	0.002489	0.007102	0.012389	0.002843	0.000343	0.025616
NW	0.000499	0.002912	0.008404	0.009751	0.001507	0.000126	0.023199
NNW	0.000425	0.003083	0.009431	0.008587	0.000719	0.000069	0.022313
TOTAL	0.015038	0.072711	0.187853	0.143058	0.015118	0.001621	

RELATIVE FREQUENCY OF OCCURRENCE OF D STABILITY = 0.436200

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH D STABILITY = 0.004910

Table 4.1-7

Class E Wind Frequency Distribution

ANNUAL			RELATIVE FREQUENCY DISTRIBUTION			STATION =13963 LITTLE ROCK,AK 24OBS	
						1955-64	
			SPEED(KTS)				
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.000000	0.003209	0.007331	0.000000	0.000000	0.000000	0.010539
NNE	0.000000	0.003266	0.006257	0.000000	0.000000	0.000000	0.009523
NE	0.000000	0.004031	0.004019	0.000000	0.000000	0.000000	0.008050
ENE	0.000000	0.004293	0.003631	0.000000	0.000000	0.000000	0.007924
E	0.000000	0.003700	0.002352	0.000000	0.000000	0.000000	0.006052
ESE	0.000000	0.004362	0.002272	0.000000	0.000000	0.000000	0.006634
SE	0.000000	0.004328	0.002603	0.000000	0.000000	0.000000	0.006931
SSE	0.000000	0.005412	0.004659	0.000000	0.000000	0.000000	0.010071
S	0.000000	0.005195	0.008529	0.000000	0.000000	0.000000	0.013725
SSW	0.000000	0.004213	0.007034	0.000000	0.000000	0.000000	0.011247
SW	0.000000	0.005218	0.009569	0.000000	0.000000	0.000000	0.014787
WSW	0.000000	0.005355	0.009409	0.000000	0.000000	0.000000	0.014764
W	0.000000	0.002169	0.003974	0.000000	0.000000	0.000000	0.006143
WNW	0.000000	0.001610	0.005184	0.000000	0.000000	0.000000	0.006794
NW	0.000000	0.002078	0.005287	0.000000	0.000000	0.000000	0.007365
NNW	0.000000	0.002386	0.005743	0.000000	0.000000	0.000000	0.008130
TOTAL	0.000000	0.060825	0.087852	0.000000	0.000000	0.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF E STABILITY = 0.148677

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH E STABILITY = 0.000000

Table 4.1-8

Class F Wind Frequency Distribution

ANNUAL RELATIVE FREQUENCY DISTRIBUTION STATION =13963 LITTLE ROCK, AK 24OBS

1955-64

	SPEED(KTS)						
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.001298	0.006040	0.000000	0.000000	0.000000	0.000000	0.007339
NNE	0.001486	0.006189	0.000000	0.000000	0.000000	0.000000	0.007675
NE	0.001666	0.005424	0.000000	0.000000	0.000000	0.000000	0.007090
ENE	0.001686	0.005367	0.000000	0.000000	0.000000	0.000000	0.007053
E	0.002045	0.004647	0.000000	0.000000	0.000000	0.000000	0.006692
ESE	0.002013	0.005412	0.000000	0.000000	0.000000	0.000000	0.007426
SE	0.002312	0.006668	0.000000	0.000000	0.000000	0.000000	0.008981
SSE	0.002100	0.008472	0.000000	0.000000	0.000000	0.000000	0.010573
S	0.002064	0.008061	0.000000	0.000000	0.000000	0.000000	0.010125
SSW	0.001639	0.007616	0.000000	0.000000	0.000000	0.000000	0.009254
SW	0.002714	0.013805	0.000000	0.000000	0.000000	0.000000	0.016518
WSW	0.002999	0.022848	0.000000	0.000000	0.000000	0.000000	0.025847
W	0.001423	0.006737	0.000000	0.000000	0.000000	0.000000	0.008160
WNW	0.000787	0.003517	0.000000	0.000000	0.000000	0.000000	0.004304
NW	0.000927	0.004670	0.000000	0.000000	0.000000	0.000000	0.005597
NNW	0.001193	0.005138	0.000000	0.000000	0.000000	0.000000	0.006331
TOTAL	0.028352	0.120611	0.000000	0.000000	0.000000	0.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF F STABILITY = 0.148963

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH F STABILITY = 0.012218

Table 4.1-9

Class G Wind Frequency Distribution

ANNUAL			RELATIVE FREQUENCY DISTRIBUTION			STATION =13963 LITTLE ROCK,AK 24OBS 1955-64	
			SPEED(KTS)				
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.002235	0.000000	0.000000	0.000000	0.000000	0.000000	0.002235
NNE	0.001984	0.000000	0.000000	0.000000	0.000000	0.000000	0.001984
NE	0.003843	0.000000	0.000000	0.000000	0.000000	0.000000	0.003843
ENE	0.003926	0.000000	0.000000	0.000000	0.000000	0.000000	0.003926
E	0.004532	0.000000	0.000000	0.000000	0.000000	0.000000	0.004532
ESE	0.004302	0.000000	0.000000	0.000000	0.000000	0.000000	0.004302
SE	0.005221	0.000000	0.000000	0.000000	0.000000	0.000000	0.005221
SSE	0.004887	0.000000	0.000000	0.000000	0.000000	0.000000	0.004887
S	0.004386	0.000000	0.000000	0.000000	0.000000	0.000000	0.004386
SSW	0.004448	0.000000	0.000000	0.000000	0.000000	0.000000	0.004448
SW	0.007831	0.000000	0.000000	0.000000	0.000000	0.000000	0.007831
WSW	0.009857	0.000000	0.000000	0.000000	0.000000	0.000000	0.009857
W	0.003780	0.000000	0.000000	0.000000	0.000000	0.000000	0.003780
WNW	0.002151	0.000000	0.000000	0.000000	0.000000	0.000000	0.002151
NW	0.002088	0.000000	0.000000	0.000000	0.000000	0.000000	0.002088
NNW	0.001316	0.000000	0.000000	0.000000	0.000000	0.000000	0.001316
TOTAL	0.066785	0.000000	0.000000	0.000000	0.000000	0.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF G STABILITY = 0.066785

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH G STABILITY = 0.030270

Table 4.1-10

Wind Frequency Distribution for all Stabilities

ANNUAL RELATIVE FREQUENCY DISTRIBUTION STATION =13963 LITTLE ROCK,AK 24HRS

1955-64

SPEED(KTS)

DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.005704	0.016511	0.023978	0.009980	0.001119	0.000069	0.057360
NNE	0.006155	0.018075	0.026719	0.010608	0.000365	0.000023	0.061944
NE	0.008140	0.019331	0.027084	0.009546	0.000320	0.000000	0.064421
ENE	0.008712	0.021718	0.030806	0.009363	0.000263	0.000011	0.070873
E	0.009606	0.019377	0.021626	0.005526	0.000137	0.000023	0.056295
ESE	0.009334	0.021934	0.020119	0.005138	0.000320	0.000034	0.056380
SE	0.010615	0.022346	0.018669	0.004853	0.000285	0.000023	0.056790
SSE	0.009121	0.023168	0.021797	0.006417	0.000388	0.000046	0.060937
S	0.008894	0.022220	0.033558	0.016374	0.001633	0.000091	0.082770
SSW	0.007704	0.019845	0.031069	0.019765	0.002478	0.000251	0.081112
SW	0.011951	0.028294	0.032211	0.013359	0.001256	0.000091	0.087162
WSW	0.013636	0.036812	0.026536	0.008975	0.000822	0.000263	0.087044
W	0.005958	0.013622	0.011578	0.005024	0.001039	0.000183	0.037404
WNW	0.004065	0.010413	0.015997	0.012914	0.002923	0.000377	0.046689
NW	0.004417	0.012309	0.018589	0.010356	0.001541	0.000126	0.047338
NNW	0.003874	0.012800	0.018783	0.008735	0.000719	0.000069	0.044980
TOTAL	0.127884	0.318775	0.379120	0.156932	0.015609	0.001678	

TOTAL RELATIVE FREQUENCY OF OBSERVATIONS = 1.000001

TOTAL RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE = 0.051782

Table 4.1-11

Frequency of Occurrence of Average Wind Speeds Through the Mixing Layer for Non-Precipitation Cases When the Mixing Height is 500 m or Greater

Month	Number of Occurrences					
	Morning Average (0600 CST) Wind Speed (m/s)			Afternoon Average (1800 CST) Wind Speed (m/s)		
	0-2.0	2.1-6.0	>6.0	0-2.0	2.1-6.0	>6.0
January	0	17	22	4	55	38
February	1	15	27	1	49	41
March	1	18	30	0	42	69
April	1	6	40	0	43	65
May	2	16	20	5	66	66
June	3	18	11	6	82	34
July	5	5	11	4	90	39
August	3	13	6	4	107	21
September	0	13	10	3	94	26
October	2	6	17	9	89	35
November	0	10	24	5	68	31
December	2	18	26	3	49	44
Total	20	165	244	44	834	499
Total Percent Frequency	5%	38%	57%	3%	61%	36%

Source: USDC, 1968b

Table 4.1-12

Annual Joint Distribution (Percent Occurrence) of Wind Speed and Direction at 300-Meter Level (Based on Little Rock Rawinsonde) Observations, 1960-1964)

Wind Speed (m/s)	Percent Occurrence: Morning (0600 CST) Direction N	E	S	W	Afternoon (1800 CST) Direction N	E	S	W
0.1-2.5	1.7	1.8	1.8	2.5	1.7	3.6	3.7	1.8
2.6-5.0	6.0	7.5	6.9	5.9	6.5	12.9	12.0	5.3
5.1-10.0	10.8	9.5	12.1	14.0	7.3	8.0	18.9	9.5
>10.0	3.3	0.9	7.8	7.5	1.5	0.6	3.9	3.1

Source: USDC, 1973b

Table 4.1-13

Seasonal and Diurnal Distribution of Inversion Frequency (Based on Little Rock Rawinsonde Observations, 1960-1964)

	Percent Occurrence			
	Morning (0600 CST)		Afternoon (1800 CST)	
Season	Surface-Based	Elevated	Surface-Based	Elevated
Dec-Jan-Feb	49.6	47.9	20.0	69.6
Mar-Apr-May	57.0	36.2	2.8	66.2
Jun-Jul-Aug	75.9	14.7	3.9	33.4
Sep-Oct-Nov	73.4	20.7	20.5	49.3
Annual	64.0	29.8	11.8	54.5

Source: USDC, 1973b

Table 4.1-14

Seasonal and Diurnal Frequency Distribution
of Inversions Based Below 250 Meters
and At Least 500 Meters Thick
(Based on Little Rock Rawinsonde Observations,
1960-1964)

	Percent Occurrence	
Season	Morning (0600 CST)	Afternoon (1800)
Dec-Jan-Feb	26.1	5.3
Mar-Apr-May	13.4	0.2
June-Jul-Aug	10.2	0.6
Sep-Oct-Nov	19.2	0.6
Annual	17.4	2.2

Source: USDC, 1973b

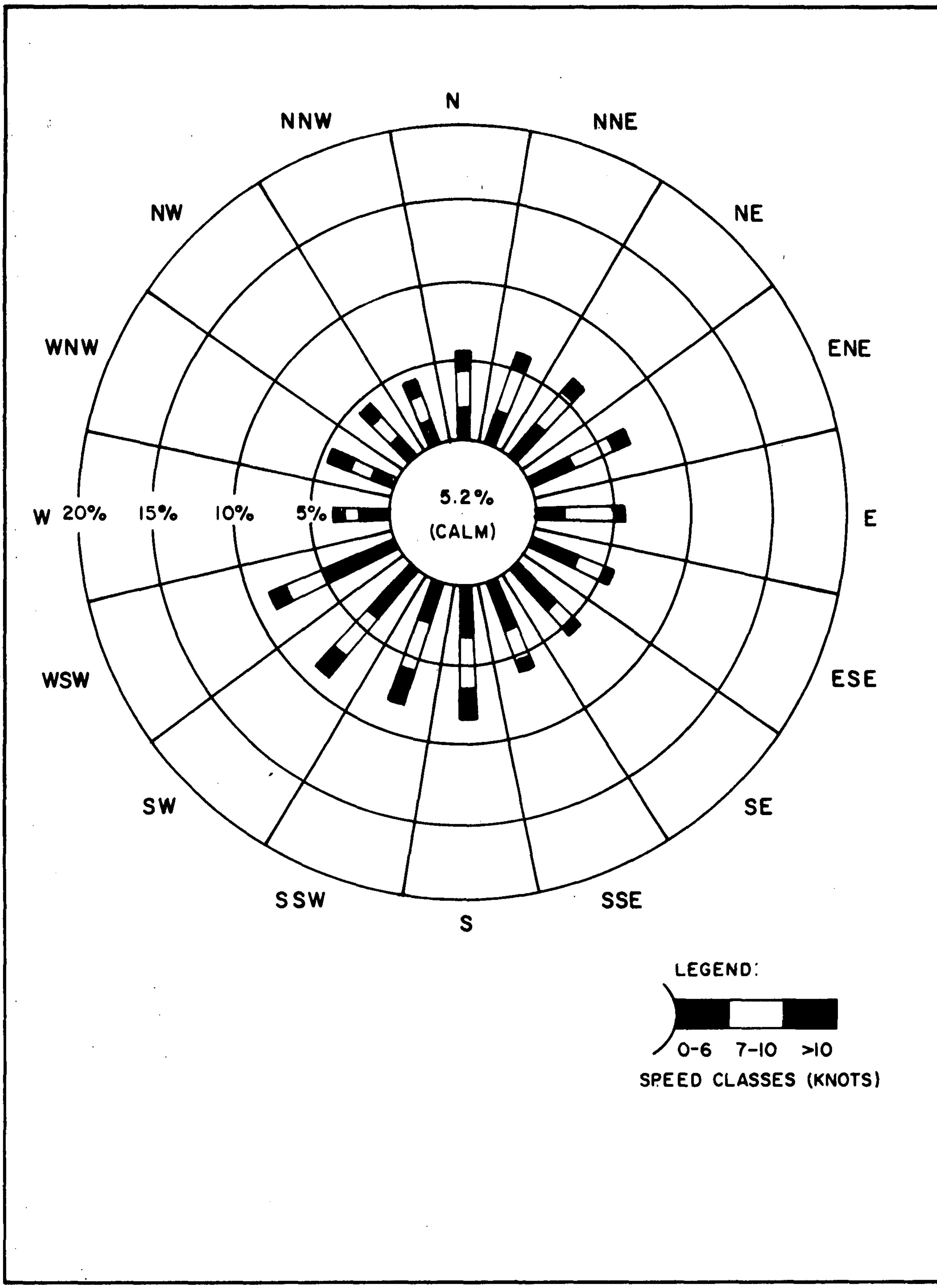


Figure 4.1-1. Annual wind frequency distribution - Little Rock (1955-1964).

4.2 EMISSION CONTROL TECHNOLOGY

4.2.1 Sulfur Dioxide Control

Control of sulfur dioxide emissions at the Independence Steam Electric Station will be achieved through the use of low-sulfur coal obtained from mines in eastern Wyoming. This coal, contracted to meet the fuel requirements of both units, will have a typical sulfur content of 0.28 percent by weight (as received).

Additional reductions in sulfur emissions can be expected when using Wyoming coal. Investigations of sulfur balances at subbituminous- and lignite-fired power plants indicate that over 50 percent of sulfur in the coal may be retained in the fly ash. The variables which affect the quantity of sulfur retained are: coal mineral matter, boiler temperature, load, and combustion gas residence time.

The three forms of sulfur which are present in coal are organic, pyritic, and sulfate. Organic sulfur generally predominates in low sulfur coal. Pyritic sulfur (FeS_2) is easily oxidized to sulfate. Sulfate sulfur in fresh coals is usually less than 0.05 percent, and its presence in more than this amount indicates the coal has weathered. Sulfate sulfur usually occurs as $CaSO_4$ and $FeSO_4$.

During combustion, organic sulfur and pyritic sulfur are oxidized to SO_2 and $FeSO_4$ respectively. $FeSO_4$ decomposes at 330°F to form Fe_2O_3 and sulfur oxides. Calcium sulfate decomposes to CaO and sulfur oxides at temperatures above 1900°F. Since furnace temperatures will range from 2100 to 2200°F, all three forms of sulfur can result in sulfur oxides emissions.

The more alkaline coals such as low sulfur Wyoming coal have a greater tendency to retain sulfur in collected ash. An example of this sulfur retention factor is provided in a study of a 350 MW coal-fired generating unit performed for USEPA by Radian Corporation (USEPA, 1977). The fuel used udring this study was sub-bitumious, low sulfur Wyoming coal very similar to that which will be used by the Independence Steam Electric Station. Sulfur balance data obtained over a 7-day sampling period during which the boiler was operating, essentially at full load, demonstrated that the percentage of sulfur retention was between 14 and 16 percent.

Operating conditions also have an effect on sulfur retention. At a reduced load or with a low heat release, the gas temperature is lowered, and the residence time is longer. This results in greater sulfur retention in the ash. Sulfur balances conducted at Neil Simpson Power Station and Black Hills Power indicate that sulfur retention in ash increased from approximately 30 percent at rated capacity to approximately 65 percent at half load. Studies conducted on plants burning German brown coals have also shown that the sulfur retained in the ash is greatly influenced by boiler load and gas residence time.

Tests have shown a wide variation in the amount of sulfur retained in the various ash fractions. These fractions depend upon the amount of alkali and the temperature of the ash. The ash fraction highest in sulfur is the fine fly ash. Less sulfur is retained in the dust collection fly ash and least sulfur is found in slag. Thus, ash collected by electrostatic precipitators is considerably enriched in sulfur compared to the slag.

Analysis of the coal to be used for the Independence Steam Electric Station indicates that sulfur retention should be greater than 10 percent. However, a 10 percent value has been used for all mathematical modeling. At the time Unit One becomes operational, tests will be conducted measuring sulfur content in the coal and quantity of sulfur dioxide leaving the stack. The results of these tests will provide an accurate prediction of what the actual retention rates will be. Such information will be used to determine operating procedures.

More detailed information is presented in EIS Tables 6.3-4 and 6.3-5 on specific coal analysis. Emissions for various operating levels are listed in Section 4.3. The coal will be tested to insure compliance with the Federal New Source Performance Standard for coal-fired steam generators (1.2 lb $SO_2/10^6$ Btu). Typical coal used is expected to produce an emission rate approximately half of the allowable.

4.2.2 Nitrogen Oxides Control

Control of nitrogen oxides is accomplished through control of the combustion process. At present there are no feasible flue gas cleaning systems for nitrogen oxides. The use of tangentially fired boilers has been found to be the most effective means of reducing nitrogen dioxide emissions. Both units at Independence Steam Electric Station will use boilers of this design.

Tangential firing is a technique of locating burners in the corners of the box-like furnace area and distributing the fuel and combustion air tangentially about the center of the furnace, resulting in a fire-ball-type flame.

Through a USEPA sponsored program, Combustion Engineering (the boiler manufacturer for the Independence Steam Electric Station) joined with ESSO Research and Engineering Company for extensive testing of one 500 MW, twin furnace, tangentially coal-fired unit. As a result, many quantitative and qualitative observations were made regarding the effect of change in operation or design variables on nitrogen oxides emission for tangentially fired units. The burners designed by Combustion Engineering for use at the Independence Steam Electric Station incorporate control technology gained from studies such as these. Table 4.2-1 is a listing of expected nitrogen oxides emissions vs boiler load. Based on this information supplied by the manufacturer, the greatest NO_x emission rate anticipated is 0.6 lb/10^6 Btu, less than the allowable Federal New Source Performance Standard for coal-fired steam generators of 0.7 lb/10^6 Btu.

4.2.3 Particulates Control

4.2.3.1 Combustion

Experience at other coal-fired generating plants has shown that approximately 20 percent of the total ash produced by the burning of the coal will be collected in hoppers at the furnace bottom and in the economizer section of the furnace. The remaining 80 percent of the total ash can be expected to be entrained in the flue gas stream which leaves the furnace. Downstream of each steam generator will be an electrostatic precipitator for removal of the fly ash from flue gases. These precipitators will be located on the upstream side of the air preheater. Temperatures in this area are in the range of 750-800°F and experience throughout the power industry has shown that higher collection efficiencies are more readily attainable with these "hot" precipitators in conjunction with Western coals than with "cold end" precipitators. The precipitators at Independence will be guaranteed at a collection efficiency of 99.5 percent. As an extra margin to insure that this efficiency is reached, AP&L will require that the precipitators be designed to handle 100 percent of the ash produced, whereas only 80 percent is expected to leave the steam generators. Also, each precipitator will be required to have 110 percent of the collector plate area actually needed, as determined by design calculations, to reach the rated efficiency.

4.2.3.2 Coal and Ash Handling

Other potential sources of particulate air contamination include dust blown from coal during transportation; dust produced during coal unloading; dust produced by the coal handling equipment; particulates becoming airborne during the transfer of fly ash from ash silos to trucks for hauling to the ash disposal area; dust resulting from unloading of these trucks; and particulates blown by wind from the surface of the stacked ash in the disposal area and from the coal storage area.

Fly ash which is collected from the electrostatic precipitator will be conveyed within piping by air pressure to fly ash silos. The fly ash will then be loaded on trucks and hauled to the ash storage area. The dry ash silos are fitted with water injection systems combined with dustless rotary truck loading devices to prevent escape of particulates. Therefore, fugitive dust emission should not be a problem during the transport of ash to the ash disposal area.

The bottom ash will be sluiced from the boiler area to dewatering bins. The dewatering bins separate excess water from the ash, and a 75 percent solid and 25 percent liquid mixture will be trucked to the ash disposal area. The excess water from the dewatering bins will be returned to the recycle water pond for reuse in the ash sluice system. Bottom ash will thus be transported to the onsite waste disposal area in a semi-dry state, thereby minimizing dusting conditions.

Measures of controlling dust from coal unloading and transfer operations include dust suppression and removal systems. In addition, all conveyors from the crusher house to the silos at the boilers will be of covered design to minimize any dusting due to high winds. Coal will be delivered to the plant site in approximately 110-car unit trains. Cars will be open-type, each containing 100 tons of coal. Discussion between AP&L and coal suppliers who operate similar unit trains has established that dusting along the railroad right of way should not be a problem. The coal delivered in the cars will be of a relatively large size (2 inches nominal diameter), and the smaller pieces that are loaded will have a tendency to settle to the bottom of the car preventing their being blown out onto the right-of-way. Also, the coal is of a high moisture content (28 percent typical) with entrained surface moisture amounting to 5 percent. These high moisture levels will resist dust formation and further reduce the problem of dust blowing during coal delivery.

There is no practical method of modeling these fugitive dust sources due to the many variables involved. It is expected, however, that the effects of such random and unpredictable emissions will, in light of the control measures to be used, be indistinguishable from normal background at points outside the plant boundary. This assertion will be confirmed by the use of post-operational particulate monitoring near site boundaries.

4.2.4 Other Facility Emissions

While most emissions will come from the boiler stack and cooling towers, there will also be a number of minor, mostly intermittent sources of air contaminants.

Fugitive dust can be produced from many operations at the proposed facility. These include the various phases of coal manipulation, transfer of fly ash, vehicle movement on the property, and particle entrainment when winds blow across the coal storage pile and the ash disposal area. Control of these sources has been discussed in the section on particulates control. The level of total suspended solids beyond the site boundary is not expected to be noticeably affected by these fugitive dust sources.

The auxiliary boiler will emit nitrogen oxides, particulates, and sulfur dioxide. This boiler will burn a No. 2 light fuel oil with a very low sulfur content, typically on the order of 0.18 percent by weight. The fuel consumption rate is expected to be 12,696 lb/hr at an operating level 100 percent of rated capacity. Based on this consumption rate, a sulfur content of 0.18 percent, and an oil density of 7.24 lb/gal, expected emissions are as follows:

SO_2	46 lb/hr
NO_x (as NO_2)	39 lb/hr
Particulates	4 lb/hr

NO_x and particulate emission rates are derived from USEPA emission factors (USEPA, 1976).

The No. 2 fuel oil to be used by the auxiliary boiler will be stored in an 80,000 barrel storage tank. Some hydrocarbon vapors will escape as a result of tank loading and storage losses.

Other minor emissions include the emergency diesel generators. Due to the fact that their use is for emergencies only, emissions will very seldom occur. Exhaust from vehicle traffic on the site constitutes another minor source of emissions.

Table 4.2-1

Nitrogen Oxides Emissions vs. Boiler Operating Level

Operating Level (Percent)	Nitrogen Oxides Emissions ($lb/10^6$ Btu)
30	0.20
50	0.30
70	0.40
100	0.55
110	0.60

Note: Federal New Source Performance Standard = 0.70 $lb/10^6$ Btu

4.3 DIFFUSION MODELS

4.3.1 Introduction

Recent publications issued under the auspices of the U.S. Environmental Protection Agency (1977a, 1977b) contain the conclusion that Gaussian diffusion modeling is generally considered a state-of-the-art method for both single and multiple emission source evaluations in areas which are not dominated by peculiarities in terrain or other factors which might produce atypical dispersion patterns. The word Gaussian refers to the statistical distribution of pollutant concentrations about a plume centerline; a distribution with a well-defined analytical expression which can be applied readily to the calculation of pollutant concentrations so long as values for each variable in the expression are available. All models applied in evaluating the air quality impact of the Independence Steam Electric Station are basically Gaussian models.

In Gaussian models, pollutant concentration is a function of transport by the mean wind speed and diffusion in both the crosswind (horizontal) and vertical directions. Diffusion refers to the spread of a plume from a region of high concentration at the plume centerline to regions of lower concentration farther away from the centerline. In the programs employed for this study, the variation in concentration from the plume centerline outward is defined by the Gaussian statistical distribution. The basic equation which specifies the concentration at ground level resulting from the emissions of an elevated point source is:

$$\chi = \frac{10^6 Q}{\pi \sigma_y \sigma_z u} \exp\left[-1/2 \left(\frac{y}{\sigma_y}\right)^2\right] \exp\left(-1/2 \left[\left(\frac{H}{\sigma_z}\right)^2\right]\right)$$

where,

χ = ground level concentration, $\mu g/m^3$

Q = pollutant emission rate, g/s

y = crosswind (horizontal) distance from the plume centerline, m

H = effective stack height (physical stack height + plume rise), m

u = mean wind speed, m/s

σ_y = standard deviation of plume concentration distribution in the crosswind (horizontal) direction, as a function of atmospheric stability and downwind distance, m

σ_z = standard deviation of plume concentration distribution in the vertical direction as a function of atmospheric stability and downwind distance, m

π = 3.14159

This formulation stems from several important assumptions:

- There is total reflection of the plume at the earth's surface, and none of the material emitted is lost by chemical transformation, deposition at the ground, or any other removal mechanism. In other words, the amount of material passing through a vertical plane of infinite size oriented perpendicular to the wind direction is always the same regardless of downwind distance.

- The concentration, χ, represents an average value which is appropriate for the sampling time used to derive estimates of σ_y, and σ_z; χ usually represents a 3- to 15-minute average concentration.

- The emission rate, Q, is assumed to be continuous over time so that diffusion in the direction of transport can be neglected.

- The material emitted is assumed to be a stable gas or a small aerosol (less than about 20 microns in diameter) which behaves as a stable gas and remains suspended in the air for a long period of time. (This is similar to the assumption of perfect reflection and no deposition.)

- Pollutant concentrations are distributed "normally" (in the Gaussian sense) in both the crosswind and vertical directions; the standard deviation of plume spread is assumed to be a function of atmospheric stability and downwind distance only.

4.3.2 Model for Annual Concentrations

The primary program used to calculate annual average concentrations is the Air Quality Display Model (AQDM), a model which was originally developed for regional air quality evaluations and one which has been widely used (U.S. Public Health Service, 1969a). The basic product of this model is an estimate of annual arithmetic average ground level concentrations at specified receptor points resulting from the emissions of one or more pollutant sources.

4.3.2.1 Calculation Concepts

Calculations are based on Gaussian diffusion concepts with horizontal plume spread assumed to be uniform across sectors 22.5 degrees in width, corresponding to 16 compass directions (N, NNE, NE, E, etc.). This assumption is based on the reasonable expectation that over an annual period discrete wind directions within any given sector will occur with equal frequency. In actual practice, this assumption would result in discontinuities in calculated concentrations at sector boundaries; therefore, a modification is inserted which provides for linear interpolation of concentrations between sector centerline values. The concentration at a given receptor is thus composed of contributions from both the sector containing the receptor and the nearest adjacent sector.

Under this linear crosswind distribution modification, the form of the standard Gaussian equation for ground level concentrations resulting from an elevated source becomes:

$$\chi = \frac{2 \cdot 10^6 \, Q \, (c-y)/c}{u\sigma_z \sqrt{2\pi} \, (2 \, X/16)} \quad \exp\left[-1/2 \left(\frac{H}{\sigma_z}\right)^2\right]$$

where,

χ = annual average ground level concentration, $\mu g/m^3$

Q = pollutant emission rate, g/s

c = width of a sector (centered at the emission source) at the receptor location, m

y = crosswind distance between the receptor and the sector centerline, m

u = wind speed, m/s

σ_z = standard deviation of plume concentration in the vertical direction as a function of stability and downwind distance, m

X = downwind distance, m

H = effective stack height, m.

This equation is referred to as the univariate form of the Guassian distribution, since plume spread in the Gaussian sense (the familiar bell shape) is permitted only in the vertical dimension and not in both the vertical and horizontal (crosswind) dimensions.

A further modification is made to account for the presence at some elevation above ground of a stable layer which acts as a cap to prevent any further dispersion in the vertical direction. A plume having reached this cap will be reflected downward so that at some distance from the emission source the plume will be uniformly mixed from the ground to the top of the mixing layer. The equation for ground level concentrations after uniform mixing occurs can be simplified to the following form:

$$\chi = \frac{10^6 \; Q \; (c-y)/c}{Lu \; (2\pi \; X/16)}$$

where L is the mixing layer height (m) and all other variables are as previously defined. Concentrations are calculated using the univariate Gaussian equation out to a distance X_L at which σ_z = 0.47 L. (At this distance, pollutant concentration at the top of the mixing layer will be one-tenth that of the plume centerline concentration.) At distances beyond 2 X_L, the limited mixing equation is used. At intermediate distances, concentrations are calculated by linear interpolation between the concentration at X_L and the concentration at 2 X_L. If the effective stack height is above the top of the mixing layer, the plume is assumed to remain above the ground and no ground level concentration is calculated.

The meteorological input required for operation of AQDM consists of a normalized annual joint frequency distribution of wind speed, wind direction, and atmospheric stability. Average annual mixing values are also required. For a particular source-receptor combination, the average annual concentration is computed by summing all individual concentrations computed for each wind speed, wind direction, and stability class combination where each individual concentration is weighted by the frequency of occurrence of each combination. The general computational formula is therefore:

$$\chi \quad \sum_{\theta}\sum_{u}\sum_{s} F(\theta,u,s) \cdot \chi(\theta,u,s)$$

where,

$F(\theta,u,s)$ = annual frequency for joint combination of wind direction sector θ, wind speed class u, and stability class s.

The total concentration at a specific receptor is obtained by summing the results obtained by the procedure above for all emission sources.

4.3.2.2 Mixing Height

A modification of the original AQDM program was made in the treatment of mixing height in recognition of the higher than average height at which emissions will be released. In the original program, a mixing height of 100 meters is assumed for all Class E occurrences. With a stack height of over 300 meters, this would mean no ground level concentrations calculated for stable (E) cases. The program was modified to allow specification of any desired mixing height value to be associated with Class E rather than a fixed value of 100 meters. Other than this modification, mixing height is treated the same as in the original program. An annual average afternoon mixing height, typically taken from Holzworth (1972), is used for Class B and C calculations. This afternoon value is multiplied by a factor of 1.5 for Class A calculations. A separately assigned mixing height, which can be equivalent to Holzworth's annual average morning mixing height or any other value lower than the afternoon mixing height, is used for Class E. For D stability, 60 percent of the occurrences of this class are associated with the afternoon mixing height value, and the other 40 percent with a mixing height which is intermediate between the afternoon value and the lower Class E value. This 40 percent represents the transition between daytime neutral (Class D) conditions and nighttime stable (Class E) conditions.

4.3.2.3 Plume Rise

Another modification introduced in the current application of AQDM is substitution of Briggs' (1971, 1972) plume rise equations for the original Holland equation. Using the Briggs method, plume rise is calculated as follows:

For unstable or neutral conditions, the plume rise, Δh, is calculated as:

when $X < 3.5\, X^*$ (where $3.5\, X^*$ is the distance to the point of final plume rise),

$$\Delta h = \frac{1.6\, F^{1/3}\, X^{2/3}}{u} ;$$

when $X \geq 3.5\, X^*$,

$$\Delta h = \frac{1.6\, F^{1/3}\, (3.5\, X^*)^{2/3}}{u} .$$

For stable conditions, plume rise is calculated as:

for normal wind speeds and $X > X_f$,

$$\Delta h = 2.4 \left(\frac{F}{us} \right)^{1/3} ;$$

for very light wind speeds and $X > X_f$,

$$\Delta h = \frac{5\, F^{1/4}}{s^{3/8}} ;$$

for $X \leq X_f$,

$$\Delta h = \frac{1.6\, F^{1/3}\, X^{2/3}}{u} ,$$

if this value of Δh is less than the value computed when $X > X_f$; otherwise, Δh is set equal to the value computed when $X > X_f$.

The symbols used in these expressions have the following definitions:

F = buoyancy flux = $\frac{g\, V_f}{\pi} \frac{(T_s - T)}{T_s}$, m^4/s^3

s = stability parameter = $\frac{g}{T}\, d\theta/dz$, sec^{-2}

X^* = distance at which turbulence begins to dominate, m

= $14\, F^{5/8}$ for $F < 55$

= $34\, F^{2/5}$ for $F \geq 55$

X_f = distance to final plume rise for stable conditions, m

= $\frac{\pi u}{s^{1/2}}$,

and

g = acceleration due to gravity, 9.8061 m/s^2

T = ambient temperature, °K

T_s = stack gas temperature, °K

u = wind speed, m/s

V_f = stack gas volumetric flow rate, m^3/s

X = downwind distance from source, m

$d\theta/dz$ = potential temperature lapse rate, °K/m

= 0.02 for Class E

= 0.035 for Class F

π = 3.14159

Briefly summarizing, at some point downwind of an emission source it can be assumed for practical purposes that the centerline of the plume levels off and remains at a constant height above the ground (over level terrain). This final plume rise is calculated by one formula for unstable and neutral conditions and by another formula for stable conditions. At distances prior to the point at which final plum occurs, plume rise is calcuated by the same formula for all stabilities; however, calculation of the distance to the point of final plume rise is dependent on stability. The value of plume rise calculated at distances less than the distance of final plume rise is compared with the final plume rise value, and the lower of these two values is used for further computations.

4.3.2.4 Meteorological Input

Primary meteorological information needed for the AQDM model consists of a joint frequency distribution of wind direction, wind speed, and stability class. Wind direction is specified as one of 16 sectors 22.5 degrees in width. Wind speed is divided into six categories with the following upper and lower limits: 0-3, 4-6, 7-10, 11-16, 17-21, >21 knots. A representative speed within each category is used for computation purposes, namely, the metric equivalent of 1.3, 4.8, 8.7, 13.5, 18.7, and 23.3 knots. Stability class can be one of five values corresponding to the Pasquill classes A (extremely unstable), B (unstable), C (slightly unstable), D (neutral), and E (stable).

As previously stated, the required joint frequency distribution was derived from Little Rock surface observations made over a 10-year period from 1955 to 1964. The well-known STAR method, based on techniques proposed by Turner (1964), was used to develop distribution tables. These tables are reproduced as Tables 4.1-3 through 4.1-10. The tables supplied by the National Climatic Center have stable cases split into three classes (E, F, and G). For computation purposes, all stable cases are lumped into one class (E). The resulting stability class distribution for the 10-year Little Rock data set is as follows:

Class	Percent Frequency
A	0.6
B	6.0
C	13.3
D	43.6
E	36.5

The relative infrequency of extremely unstable occurrences (Class A) is a characteristic result of the STAR method but is certainly not inappropriate for tall-stack, elevated plume modeling. The existence of an extremely unstable condition is basically a near-surface phenomenon, and its occurrence at the effective height of a buoyant plume emitted from a 1000-ft stack would be a rare event. In fact there is some question if such conditions would ever persist at this elevation for a long enough time (more than a few minutes) to be accurately modeled.

4.3.3 *Models for 24-Hour and 3-Hour Concentrations*

Ambient concentrations for 24-hour and 3-hour averaging periods were estimated primarily through use of the CRSTER program developed for USEPA and recommended for application to single-source modeling evaluations (USEPA, 1977a). This model incorporates Gaussian diffusion concepts similar to those discussed above and calculates ground level concentrations using hourly values of meteorological variables. The Briggs equations previously discussed are used to compute plume rise.

The equations for calculating concentrations under limited mixing conditions differ somewhat from those discussed in connection with the AQDM model. The top of the mixing layer is treated as a reflecting boundary so that multiple reflections of the plume occur between the ground and the mixing layer boundary until at some distance downwind of the source uniform vertical concentration within the mixing layer is achieved. The equations used to calculate ground level concentrations under this approach are as follows:

if $\sigma_z \leq 1.6L$,

$$\chi = \frac{10^6 Q}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)\sum_{n=-\infty}^{+\infty} \exp\left[-\frac{1}{2}\left(\frac{h+2nL}{\sigma_z}\right)^2\right]\right.$$

if $\sigma_z > 1.6L$,

$$\chi = \frac{10^6 Q}{\sqrt{2\pi}\ \sigma_z L u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

where all variables are as previously defined. The summation term is continued until the contribution from the next two terms is less than 0.01 s/m^3, or to a maximum of 45 iterations.

Concentrations for 24-hour averaging times are determined by considering successive midnight-to-midnight periods. The concentration at each receptor is simply the average concentration obtained by summing up the concentration obtained from each hourly observation and dividing by the total number of hours. Three-hour concentrations are obtained in a similar manner. Concentrations are calculated for each successive 3-hour block within the basic midnight-to-midnight time period. In this way eight 3-hour concentrations are obtained for each complete day of data.

The latest version of the CRSTER program is described in a recent publication (USEPA, 1977c). The version used for analyzing projected emissions from the Independence site differs slightly from this published description, primarily in terms of the available output options, but the calculation principles are essentially identical.

4.3.3.1 Meteorological Input

The hourly meteorological input data required for the CRSTER model must be created from two separate data base files through application of a preprocessor program. One data base consists of hourly surface observations of wind speed, wind direction (to the nearest ten degrees), temperature, and cloud cover specifications. Based on these data, the preprocessor program reformats the wind and temperature and determines a stability class for each hour based on the STAR method developed by Turner (1964). In addition, reported wind direction to the nearest 10 degrees is randomized to the nearest degree by addition of a random integer between -4° and +5°. By removing the directional bias created by a forced reporting to the nearest 10 degrees, the wind direction randomization procedure provides a means of simulating natural fluctuations in direction which serves to adjust the instaneous (3- to 10-minute) concentrations calculated by CRSTER to values more representative of hourly concentrations.

The second primary data base required to execute the preprocessor program consists of a morning and an afternoon mixing height for each day considered. These heights are determined from twice-daily upper air soundings using the Holzworth method (Holzworth, 1972).

From these morning and afternoon mixing heights, a mixing height for each hour is assigned based on an interpolation technique. Actually two techniques are used, one for urban sites and one for rural sites. Only rural mixing heights were considered in the Independence site analysis. The following narrative taken from the CRSTER User's Manual (USEPA, 1977c) describes the method used to calculate both rural and urban mixing heights.

> "The method by which hourly mixing heights are determined is depicted schematically in [Figure 4.3-1]. The procedure uses values for the maximum mixing height (MAX) from the previous day (i-1), the computation day (i) and the following day (i+1) and for the minimum mixing height (MIN) for days (i) and (i+1). For urban sites between midnight and sunrise under neutral stability (i.e., Class D), the interpolation is between MAX_{i-1} at sunset and MAX_i at 1400 LST. Under stable conditions (i.e., Class E or F), the value for MIN_i is used. During the hours between sunrise and 1400 LST, if the stability was classified as neutral in the hour before sunrise, the earlier interpolation between MAX_{i-1} and MAX_i is continued; if the hour before sunrise was classified as stable, the interpolation is between MIN_i and MAX_i. For the period 1400 LST to sunset, the value for MAX_i is used. During the hours between sunset and midnight under neutral stability the interpolation is between MAX_i at sunset and MAX_{i+1} at 1400 LST the next day; if the stability is stable, the interpolation is between MAX_i at sunset and MIN_{i+1} at midnight.
>
> For rural sites between midnight and sunrise, the interpolation is between MAX_{i-1} at sunset and MAX_i at 1400 LST. During the hours between sunrise and 1400 LST, if stability was classified as neutral in the hour before sunrise, the earlier interpolation between MAX_{i-1} and MAX_1 is continued; if the hour before sunrise was classified as stable, the interpolation is between 0 and MAX_i. For the period 1400 LST to sunset, the value for MAX_i is used. During sunset to midnight, the interpolation is between MAX_i at sunset and MAX_{i+1} at 1400 LST the next day."

In the actual operation of the CRSTER program, the effective stack height (stack height plus plume rise) for any given hour is compared with the mixing height. If the effective stack height exceeds the mixing height, no concentration computation is made.

It is possible for the preprocessor program, in its utilization of the Turner (STAR) stability determination method, to compute a stability class 7 corresponding to what might be called a Pasquill Class G - a highly stable, ground-based nocturnal temperature inversion situation with erratic wind flow conditions. The CRSTER program makes no attempt to calculate a concentration for this stability condition because of the uncertain meandering of wind direction which would be expected to occur when this condition exists.

As many days of meteorological data as desired can be used in running CRSTER. A typical practice is to use hourly data for the year 1964. The significance of this year is that it is the first year in which wind direction was stored on readily available National Climatic Center tapes to the nearest 10 degrees rather than to the nearest 22.5 degrees, and the last year in which each hourly observation was stored, rather than observations every 3 hours. No doubt some bias is created when any specific year is selected in preference to others, but the large number of hourly values in any given year guarantees that a wide range of conditions is examined regardless of the year selected.

For the Independence site study, hourly surface observations from Little Rock for the year 1964 were used. Mixing heights for the year 1964 were taken from observations made at the Little Rock upper air sounding station. Little Rock is the closest major surface observation station to the Independence site (only major stations observe and record the type of data required for the CRSTER main program and preprocessor), and is also considered to be the most representative from a standpoint of geographical and climatological similarities. Furthermore, Little Rock is the only station within 200 miles or more of the Independence site where both surface and mixing height data are available for the same location.

4.3.3.2 Plume Rise

The CRSTER program version used in this study contains the same form of the Briggs plume rise equations as previously described.

4.3.3.3 Wind Speed

The raw wind speed data input to the CRSTER program are representative of conditions a few meters above ground level (usually about 7 m). The program adjusts these speeds to obtain values more representative of conditions at the top of the stack where emissions first enter the atmosphere. This is accomplished by a power law relationship of the form

$$u = u_o \,(h/7)^p$$

where

u = wind speed at stack height (m/s)
u_o = wind speed near 7 m above the ground (m/s)
h = stack height (m)
p = wind profile exponent

The value of p is specified as 0.10, 0.15, 0.20, 0.25, 0.30, and 0.30 for Pasquill Classes A, B, C, D, E, and F, respectively. No adjustment of wind direction is made.

4.3.3.4 Terrain

CRSTER allows for a simple consideration of terrain variation. For all stabilities, plume centerline height is reduced by the difference between receptor elevation and stack base elevation. However, when the receptor height is above the top of the stack, making plume impaction a possibility, this terrain correction method is not considered valid, and no concentration calculation is attempted.

No terrain adjustment is applied to mixing height values. As the terrain height increases, the distance between the ground and the top of the mixing layer is assumed to remain constant.

4.3.3.5 Receptor Orientation

The receptor grid used in CRSTER is a concentric grid centered on the emission source with receptors spaced along each 10-degree azimuth. Through multiple program runs, as many distances can be specified along each azimuth as are required to pinpoint maximum concentrations.

4.3.3.6 Emission Data

The CRSTER program version used for the Independence site analysis permits consideration of monthly variations in pollutant emission rate but does not provide for simultaneous consideration of changes in exit velocity and temperature which would accompany changes in emission rate. A discussion of emission input variations used in the actual modeling analysis appears in a later section where modeling results are presented.

4.3.3.7 Program Output

Output available from the program version used in the Independence site analysis consists of the highest and second highest 24-hour concentration at each receptor and the highest and second highest 3-hour concentration. The annual average concentration at each receptor is also given. In addition, the day for which each 24-hour concentration was calculated and the day and hours for each 3-hour concentration are included as part of final output so that it is possible to go into the meteorological input file and identify the meteorological data resulting in highest concentrations.

Only the highest 3-hour and 24-hour concentrations are summarized in the presentation of results below even though national ambient air quality standards for 3-hour and 24-hour periods are stated in terms of second highest values (values not to be exceeded more than once a year). This in part compensates for analysis of only one year of meteorological data.

4.3.3.8 Interpretative Remarks

The following remarks are based in part on a discussion of model limitations contained in the CRSTER User's Manual (USEPA, 1977c).

The CRSTER program, in common with typical Gaussian models, assumes steady-state emission and meteorological conditions. Included in these steady-state assumptions is the assumption of a homogeneous horizontal wind field. This assumption has less validity the greater the distance from the emission source and the more irregular the terrain. Within 15 km of the Independence site where highest concentrations are calculated to occur, the terrain is relatively flat, and the assumption of uniform wind conditions is probably a fairly good one.

Also assumed is an absence of changes in wind direction with height. This assumption is less valid the greater the effective stack height. The implication of this assumption for a 1000-ft stack with a large plume rise is uncertain, but it is probable that if wind shear were considered there would be greater plume spread and lower calculated ground level concentrations.

The values of the dispersion coefficients σ_y and σ_z, simulated in CRSTER by analytical expressions segmented on the basis of downwind distance, are the Pasquill-Gifford estimates based on measurements taken in open, generally level terrain at points fairly near the ground. These dispersion coefficients are less representative of conditions affecting emissions from stacks above 100 m in height; in other words, they are probably not independent of source height. They are also probably less accurate at distances beyond a few kilometers from the emission source. Furthermore, expression of discrete dispersion coefficient values for a finite number of stability categories is only an approximation of the continuum of conditions present in the atmosphere.

The CRSTER model makes no provision for chemical transformations, deposition, or other depletion mechanisms. It is therefore not well suited to the modeling of pollutants which quickly enter into complex reactions when emitted into the atmosphere. It should provide an adequate depiction of SO_2 behavior so long as the distances to receptors considered do not involve excessive travel times. Suspended particulate matter consisting primarily of particles less than about 20 microns in diameter also fits the non-depletion assumption fairly well.

The construction of hourly mixing height values from measurements which are taken only twice daily leads of course to values which are only approximations of actual conditions. This constitutes an additional limitation for the model. However, sensitivity tests which have been conducted to check the effect of changes in model input parameters (both source terms and meteorological terms) on predicted concentrations indicate that the model is relatively insensitive to variations in mixing height, particularly with regard to 24-hour averages (Tikvart and Mears, 1976; Freas and Lee, 1976).

The CRSTER model also allows computations to be made for extremely unstable, Class A, conditions. This is not an unreasonable procedure when modeling the effect of emissions released from short and medium height stacks, but the likelihood of Class A stability extending far enough above the surface to affect a buoyant plume from a 1000-ft stack is very remote. One of the concerns raised at the recent specialists' conference on proposed modeling guidelines (USEPA, 1977b) was that there is evidence indicating the σ_z curve for A stability may result in serious overestimates of short-term maximum concentrations resulting from tall-stack emissions. However, to maintain consistency with the form of the model recommended and previously applied in other power plant studies, calculation of concentrations under Pasquill Class A conditions was allowed in the evaluation of the Independence Steam Electric Station.

4.3.3.9 Validation Studies

Validation studies of the CRSTER model have been performed at one power plant in Massachusetts and three power plants in Ohio (Tikvart and Mears, 1976; Lee, Mills, and Stern, 1975). Unfortunately these plants are not directly representative of the Independence Steam Electric Station because of differences in terrain setting and source parameters (particularly volumetric flow and stack height). However, the results obtained at least provide an estimate of the accuracy limitations of the model.

Without going into great detail concerning the conduct of these studies, the basic approach was to obtain measurements at a number of fixed sampling sites and then compare these observations with predicted concentrations obtained from the CRSTER model. A basic conclusion drawn from these studies is that the model is generally accurate within a factor of two (in line with the widely accepted accuracy limitations of point-source Gaussian models), but demonstrates a tendency to underestimate highest and second highest 24-hour and 3-hour concentrations.

4.3.4 Models To Evaluate Compliance With Arkansas 30-Minute Standards

4.3.4.1 Introduction

Experience accumulated by other utility systems, particularly within the Tennessee Valley Authority (TVA) system, indicates that maximum short-term ground level concentrations tend to be associated with two types of atmospheric conditions: limited layer mixing (hereafter referred to as limited mixing) and inversion breakup. These conditions are illustrated schematically in Figure 4.3-2.

Limited mixing (also referred to as trapping) is basically a mid-morning to mid-afternoon phenomenon associated with fair skies and large high pressure systems. Under such conditions there can often be a stable layer aloft which traps emissions and restricts upward diffusion, causing confinement of an elevated plume within a limited layer and thereby leading to high ground level concentrations as the plume mixes to the surface. Provided there is rapid enough mixing within the confining layer - that is, the atmosphere below the stable air aloft has suitable stability characteristics to promote rapid mixing - high ground level concentrations can occur at fairly close distances to the emission source. TVA's experience, for example, has demonstrated highest concentrations at distances of 3 to 10 km from tall power plant stacks (Montgomery and others, 1973a; Carpenter and others, 1971).

Inversion breakup (also referred to as fumigation) is basically a mid-morning occurrence, again associated primarily with fair weather patterns. Within large air masses dominated by high pressure, a very stable layer originating at the ground and extending several hundred feet upward typically develops during nighttime hours. This condition arises as a result of rapid cooling of the ground and the adjacent atmospheric boundary layer, causing a temperature inversion - an increase of temperature with height. A plume emitted into this very stable layer can remain essentially intact with very little spread, particularly in the vertical dimension. (A plume pattern of this type is often referred to as a fanning plume.) As the sun rises and the ground surface warms, a neutral or unstable layer will eventually build upward from the ground until reaching the embedded plume. At this point the plume can be brought rapidly to the ground producing high concentrations for a short period of time generally no more than an hour in duration. This event can occur at distances well removed from the emission source depending upon the length of time required for the nocturnal inversion to be eroded by daytime heating.

Estimation of 30-minute SO_2 and particulate concentrations associated with limited mixing and inversion breakup has been performed based on concepts developed by TVA and the National Oceanic and Atmospheric Administration (NOAA).

4.3.4.2 TVA Modeling Approach

The general TVA modeling methodology has been previously described in reports submitted in applications for permits for AP&L's White Bluff project (AP&L, 1974a; AP&L, 1974b). TVA's experience in the field of air quality modeling and analysis covers a period of many years and has included the assessment of many types of power generation facilities in a variety of geographic settings. Two aspects of TVA's experience especially significant for evaluation of the Independence Steam Electric Station are the extensive field testing programs and analytical studies which have been directed towards evaluation of large, tall-stack facilities analogous to those planned for the Independence site.

Development of modeling methodologies by TVA's air quality management staff has of course not remained static over the years, so that it is not correct to speak of the TVA model when summarizing the extensive experience of this organization. A number of modeling concepts and modeling components have been considered and used for one purpose or another. For example, at the present time, assessment of USEPA models, particularly the CRSTER model, is being conducted (TVA, 1977). This is in line with encouragement of greater standardization in modeling techniques, in part to foster more common ground for comparisons between projects of a similar nature. Also, because of the standards applicable in states where its plants are located, TVA's major concern when evaluating planned new projects is in evaluation of pollutant concentrations over averaging periods of 3 hours or more, another reason for interest in the USEPA models which are oriented toward such periods. Another area of active development by TVA is refinement of time-dependent models which can utilize frequently updated measurements from TVA's meteorological monitoring network on a day-by-day basis to predict concentrations which can be used as part of the sulfur dioxide emission limitation (SDEL) program which has been implemented at some of TVA's existing plants.

The TVA limited mixing and inversion breakup modeling approach which has been used in evaluating the impact of the Independence Steam Electric Station had its conceptual and empirical origins in the late 1960s and has been utilized with refinements in a variety of applications since that time. At present, these concepts are being used by TVA's environmental planning staff in initial evaluations of new and modified generating stations (TVA, 1977).

The basic modeling package used is presented in Table 4.3-2, in the form of an equation with explanatory notes. Terms used are defined in Table 4.3-1. For brevity, this package will be referred to below as the TVA model. The term model refers not only to the basic plume rise and dispersion equations, but also to dispersion coefficients, atmospheric stability class designations, peak-to-mean ratios, and the method of applying calculation expressions. The basic equations have been presented in a number of TVA publications (Carpenter and others, 1970, 1971; TVA, 1970, 1974; Montgomery and others, 1973a;). TVA peak-to-mean ratios, used to adjust the nearly instantaneous concentration values produced by direct application of dispersion equations to longer averaging periods, are from Montgomery and Coleman (1975). In addition, discussions with TVA staff members have been held to further clarify various technical points. It should be noted that the equation used to calculate horizontal dispersion coefficients under inversion breakup conditions (Equation 8 in Table 4.3-2) is also being increasingly used by TVA to calculate coefficients for limited mixing cases in place of Equation 6 in

Table 4.3-2. Use of this alternative equation would have resulted in lower maximum concentrations, for example, a 23 percent decrease in the highest limited mixing concentration shown in Table 4.4-5. However, in the interest of conservatism, only those limited mixing concentrations obtained from use of Equation 6 are reported in this discussion.

Emission Source Characteristics

Realistic estimates of the air quality impact of the proposed facility require not only appropriate specification of meteorological parameters, but also definition of the most probable source characteristics occurring simultaneously with the meteorological conditions of interest. To this end, an assessment of plant operating levels as a function of month and time of day was performed.

For the fifteenth of each month, the times of sunrise and sunset were determined for the Independence site. From these times, the release periods of emissions most likely to participate in limited mixing and inversion breakup episodes were obtained. The limited mixing episodes were regarded to range in average length from 2.5 hours in winter to 4 hours in summer, and the time of their termination was treated as some two hours before sunset. For a minimum limited mixing distance of 3 to 10 km, with wind speeds in the range of 2 to 4 m/s (worst cases), the travel time for limited mixing emissions is about 1 hour. Therefore, the termination time of emissions affected by limited mixing was regarded to be some 3 hours before sunset, and the onset as the termination time minus the mean duration of limited mixing (see Figures 4.3-3 and 4.3-4).

The maximum concentration from inversion breakup results from emissions occurring when the inversion has been dissipated to stack height but the plume is still emitted into a stable layer (Turner, 1970). The time required for insolation to produce this condition is variable depending on season and cloud cover. The emissions for each month resulting in maximum inversion breakup concentrations were obtained by centering a 1 1/2 hour period upon the time 2 hours after sunrise (see Figures 4.3-3 and 4.3-4).

Load factor curves used for these analyses were the monthly system peak days for August and December 1973 and January and February 1974. These are projected to be representative of summer and winter maximum load profiles. The January 1974 curve exhibited the highest mean load of the three winter maxima, and therefore was used for subsequent calculations.

The summer maximum profile was used to represent daily variations for the months April through September, and the winter maximum profile was used for the months October through March.

Load factors applicable to limited mixing and inversion breakup diurnal emission periods were obtained from the diurnal load profiles in conjunction with mean monthly load factors shown in Table 4.3-3. The procedure used can be illustrated by considering the month of January. An average system load value was obtained from the January diurnal curve (Figure 4.3-3) by arithmetic averaging of each hourly load level. This results in an average of 1710 MW which is assumed to correspond with the mean monthly load factor of 0.59 (equivalent to an operating level of 59 percent). Next, an average system load of 1900 MW during the inversion breakup emissions period and an average load of 1950 MW during the limited mixing emissions period were determined using an equal areas graphical method. The ratio of 1900:1710 multiplied by the mean monthly load factor of 0.59 gives an inversion breakup load factor of 0.66. The ratio 1950:1710 similarly applied gives a limited mixing load factor of 0.68. Load factors for each month were determined in this manner.

This method of treating site emissions as a function of month and time of day provides a means of matching probable emission characteristics with variations in meteorological conditions, which is more realistic than assuming that peak emissions are always in effect. However, for comparison purposes, calculations based on peak emission characteristics have also been made as reported in a later section.

Variations in stack exit characteristics were available only for selected operating levels within the range 30 to 110 percent. From these values, exit characteristics for each 10 percent increment were created by interpolation (Table 4.3-4). For each inversion breakup and limited mixing load factor lying intermediate between 10 percent levels, a probabilistic treatment was used to obtain appropriate stack characteristics. For example, the load factor relevant to the limited mixing phenomenon in the month of August was determined to be 1.09. This was treated as 90 percent of the time at the load factor 1.10 and 10 percent of the time at load factor 1.00. The 4-hour period of limited mixing emissions in August was assumed to have this distribution. Because each monthly value is intermediate, each month had to be treated in this manner for both inversion breakup and limited mixing.

Meteorological Input Data and Selection Criteria

One of the basic objectives in selecting meteorological data was to duplicate as near as possible the range and frequency of conditions to which a plume emitted at the Independence site from a 1000-ft stack would actually be exposed. It is of interest to consider hypothetical worst-case meteorology as well, but the greater concern is to simulate conditions which are known to have occurred based on historical data and therefore have a reasonable probability of recurring. Allied with this objective is the objective of matching the monthly and, if possible, diurnal variations in plume characteristics with most probable concurrent meteorological conditions. For example, if peak emissions occur most often during a particular season at a particular time of day, it is reasonable to evaluate the impact of these emissions using meteorological data charateristic of the applicable season and diurnal period. In applying the TVA (and NOAA) models to assessment of maximum 30-minute concentrations, the time periods of concern are those associated with inversion breakup and limited mixing conditions. Assignment of emission characteristics for these periods is discussed above. Specification of meteorological factors is the subject of the following paragraphs.

To obtain the upper air meteorological data needed for computer modeling, each of the twice daily rawinsonde balloon soundings made at Little Rock (Adams Field) during the period 1966 to 1970 was analyzed. Sounding data are available in tape form, and an automated method has been developed to process these data without the need for laborious manual examination of each sounding as plotted on a thermodynamic diagram. This data reduction method is described more fully in Section 4.3.4.4.

Limited Mixing Case

For the purpose of investigating conditions resulting in limited mixing, afternoon soundings were examined. Afternoon balloon ascents are taken at a nominal time of 0000 Greenwich Mean Time (GMT), or 1800 Central Standard Time (CST). However, the actual balloon release time is about 1715 CST because the entire rawinsonde run requires about 1 1/2 hours. As a result, the lowest 10,000 feet of the atmosphere are traversed by about 1730 CST. This is particularly advantageous for the investigation of limited mixing conditions. In the summer, this probably represents a time less than 1 hour after termination of limited mixing. In the winter, it is less than 2 1/2 hours after limited mixing has occurred. For such short time lags, no drastic changes aloft would be expected on the stationary weather pattern days associated with worst limited mixing cases.

The first condition sought on each 0000 GMT sounding was the presence of an inversion or isothermal layer between the top of the stack and 700 mb, a pressure level which is usually found at about 10,000 feet above the surface. A further check is made to see if the layer below the lid has stability characteristics suitable to produce vigorous mixing. (This is further discussed below.) If a mixing lid is not found or there is no indication of sufficient mixing below the lid, no further data are obtained and the next sounding is examined. For those cases meeting the selection criteria, the following items are extracted or calculated for further processing:

1) Date
2) Change of potential temperature ($d\theta/dz$) from stack height level to the top of the mixing layer (°K/100m)
3) $d\theta/dz$ from the top of the mixing layer to 30 mb above the top of the mixing layer

4) Mean wind speed within the mixing layer

5) Resultant wind direction within the mixing layer.

Before making concentration calculations utilizing the TVA equations presented in Table 4.3-2, the following criteria and adjustments were applied:

1. Stability within the mixing layer - The concept of limited mixing entails thorough mixing of a plume beneath a capping layer. For this to happen within the relatively close distances of 3 to 10 km where highest concentrations have been observed to occur, this mixing must be fairly rapid, implying that the stability of the atmosphere from the top of the stack to the top of the mixing layer should be no more stable than a neutral condition. As an initial approach, therefore, a $d\theta/dz$ value of 0.135 °K/100 m, intermediate between the TVA neutral and slightly stable mid-point values (see Table 4.3-5), was used as a cutoff point. For potential temperature lapse rate greater than this value, rapid mixing would not be expected. However, as a more conservative check for comparison purposes, an upper cutoff of 0.455 °K/100 m (intermediate between TVA slightly stable and stable classes) was also considered.

2. Stability within the mixing lid - Because limited mixing requires capping by a stable layer to prevent vertical (upward) diffusion and to limit the vertical growth of the mixing layer, a minimum stability ($d\theta/dz$) in the mixing lid was specified. For each sounding, a search was first made for a layer at least 30 mb thick (approximately 1000 ft) with a $d\theta/dz$ value of 1.0 °K/100 m or greater, corresponding to the TVA isothermal stability class. If no such layer was found below 700 mb, a layer with a $d\theta/dz$ value of at least 0.64 °K/100 m (TVA stable class) was considered to satisfy the necessary capping lid stability requirement.

3. Minimum wind speed - At very low wind speeds, the fluctuation of wind direction is so great that high ground level

concentrations would not be expected. When the mean wind speed in the mixing layer was less than 2 m/s, no calculation was made.

4. Plume penetration - As a conservative initial approach in evaluating SO_2 associated with mean monthly, rather than peak, operating levels, a plume was considered to participate in a limited mixing episode if the level defined by stack height plus 70 percent of final plume rise was at or below the top of the mixing layer. In other words, a sizable portion of the plume (all of that above the plume centerline and also that from the centerline downward to a height 30 percent of plume rise below centerline) could penetrate through the top of the mixing layer and all of the plume would still be considered as contributing to limited mixing concentrations. Furthermore, no minimum mixing height was specified even though TVA's experience indicates that limited mixing cases typically occur with mixing heights at least 760 m above ground level (Carpenter and others, 1971; Montgomery and others, 1973a). When evaluating highest SO_2 emissions, those associated with peak operating levels, an approach more in line with TVA recommendations for evaluating maximum limited mixing concentrations was used (TVA, 1977). TVA evaluates worst case concentrations by establishing mixing heights below which the entire plume is located. Actually a more conservative approach than this was taken in evaluating highest SO_2 emissions from the Independence Steam Electric Station by allowing limited mixing calculations to be made whenever the final plume <u>centerline</u> height was at or below the mixing height. This still permits a significant portion of the plume to penetrate through the mixing layer and yet be considered for calculation purposes. Also, because the model was set up to make calculations for the nearest 10 percent operating level increments below and <u>above</u> the monthly mean, peak operating level limited mixing calculations were actually made for the summer months (when

the mean operating level is above 100 percent) with the 70 percent plume penetration assumption in effect. This conservative procedure has an important bearing on the maximum concentration predicted by the TVA model.

In addition to these criteria applied to the upper air data, others were applied to surface observations in order to ascertain whether limited mixing could have occurred. Limited mixing generally occurs under anticyclonic flow with subsidence aloft. Such conditions produce relatively cloud-free skies, strong insolation, and a lid to vertical mixing (Carpenter and others, 1971). If the sky conditions are such that surface insolation is strongly inhibited, vigorous mixing in the vertical will not be generated. Even though rawinsonde data may exhibit conditions satisfying the upper air criteria, limited mixing may be impossible. One example of such an instance would be a day on which thunderstorms and rainshowers were occurring for most of the day, thereby creating a conditionally unstable sounding, but otherwise eliminating limited mixing conditions.

The period of interest for determining whether limited mixing could have occurred on the basis of surface data was defined to be the 6-hour period ending one hour prior to the end of the occurrence of limited mixing (as a function of month). The exclusion criteria adopted for limited mixing are as follows:

1. Cloud conditions - If either (a) an overcast deck below 12,000 feet, or (b) a broken deck below 12,000 feet with a rate of change of surface temperature with time less than 1.5°F per hour persisted for 5 hours of the period, limited mixing was excluded (Montgomery and others, 1973b).

2. Precipitation - If precipitation was occurring for at least two hours during the period, limited mixing was excluded.

3. Frontal passage - If a frontal passage occurred during the period, limited mixing was excluded.

4. Diurnal surface temperature variation - If the difference between the minimum and maximum temperatures for the day was less than 11°F, limited mixing was excluded (Montgomery and others, 1973b).

5. Maximum temperature - If the maximum temperature for the day exceeded 92°F, limited mixing was excluded (Montgomery and others, 1973b).

Inversion Breakup Case

Morning rawinsonde soundings, made at a nominal time of 1200 GMT (0600 CST), were used as the basis of assessing the effects of inversion breakup. The 0515 CST release is advantageous for the investigation of inversion breakup because the ultimate stabilization of the atmosphere due to ground radiation in the layer of interest should be present by this time during each season. From each 1200 GMT sounding the following data were extracted for further processing:

1. Date
2. Surface pressure (mb)
3. $d\theta/dz$ from stack height level to 40 mb above stack height
4. Mean wind speed within the surface to 40 mb above the stack
5. Wind direction at first level below 40 m above stack height.

Calculations were made using the equations set forth in Table 4.3-2. The $d\theta/dz$ used in the plume rise and dispersion equations was defined over the layer from stack top to 2000 feet above ground level. The same $d\theta/dz$ was used in the calculation of the minimum inversion breakup distance. Only two restrictions were applied. First, the minimum permitted mean wind speed in the layer of interest was 1.5 m/s. At lower wind speeds, the meander of wind direction renders inversion breakup at any one point extremely transient. Second, if $d\theta/dz$ was less than 1.0 °K/100 m, no calculations were made. This requires that there be at least an isothermal layer present if not an actual inversion layer.

In addition to the criteria which were applied to the upper air data, surface data conditions were also considered in order to determine whether inversion breakup could have occurred. An inversion breakup fumigation occurs when a plume which is initially expelled into a stable atmosphere is dispersed to the ground as a result of thermally induced mixing, with light to moderate wind speeds (TVA, 1970). The plume rise is inhibited because of the stability of the atmosphere, as are the vertical and horizontal diffusion of the plume, thereby resulting in high contaminant concentrations when the plume is brought to the surface. If strong insolation at the surface is prevented or substantially delayed by cloud cover, fumigation cannot take place.

The period of interest for determining whether inversion breakup could have occurred on the basis of the surface data was defined to be the 5-hour period following sunrise. The exclusion criteria adopted are as follows:

1. Cloud conditions - If either (a) an overcast deck below 12,000 feet, or (b) a broken deck below 12,000 feet with a rate of change of temperature with time less than 1.5°F per hour, persisted for 4 hours of the period, inversion breakup was excluded (TVA, 1974).

2. Precipitation - If precipitation was occurring for at least 2 hours during the period, inversion breakup was excluded.

3. Frontal passage - If a frontal passage occurred during the period, inversion breakup was excluded.

Additional Calculations

The 5 year Little Rock upper air data base constitutes a representative portrayal of atmospheric conditions likely to affect the Independence site during periods of limited mixing and inversion breakup. For comparison purposes, however, some assumed meteorological data were also considered based on those suggested by TVA (Montgomery and others, 1973a; TVA, 1977). Conditions assumed for limited mixing are as follows: $d\theta/dz$ (used to calculate plume rise) = 1.15 °K/100m; wind speed = 3 m/s; mixing height = 762 m or the top of the plume, whichever is greater; downwind distance = 3 km. For inversion breakup, the same values of $d\theta/dz$ and wind speed are used as for limited mixing.

Plume Rise

The plume rise equation used, with symbols as defined in Table 4.3-1, is as follows:

$$\Delta h = (114)\ (CC)\ F^{1/3} u^{-1}$$

This is the form of the plume rise equation as presented in Carpenter and others (1971) and Montgomery and others (1973a). The importance of the equation in this form is not just in the way plume rise is calculated but in how this method of calculation fits together with other components of the modeling approach. There are, of course, many other ways of predicting plume rise, including other expressions which have been developed by TVA (e.g., Montgomery and others, 1972). The objective in using the equation shown above is to remain consistent in major respects with the overall modeling approach which has been selected as representing a TVA-developed evaluation of maximum concentrations under limited mixing and inversion breakup conditions.

In order to provide an alternative approach to calculation of 30-minute concentrations, Briggs' plume rise equations have also been applied, as part of the NOAA model to be described later. In comparing results obtained from use of the TVA and Briggs plume rise equations, it can be shown that the TVA equation predicts much higher plume rise with very light winds (<3 m/s) and stable conditions, comparable plume rise with moderate winds and stable conditions, and lower plume rise with high winds and stable conditions and with neutral and slightly stable conditions at all wind speeds. Again, however, the TVA plume rise equation should be considered for this evaluation as part of a total modeling approach rather than as an isolated segment.

Another point to bear in mind, with regard to limited mixing, is that plume rise does not appear explicitly in the calculation equation. Instead, mixing height is used. Plume rise serves only as a check to determine if a sufficient portion of the plume is beneath the top of the mixing layer.

Stability Classifications and Dispersion Coefficients

The field work which has been conducted by TVA on tall stacks indicates that atmospheric stability at these heights varies from neutral conditions to the extremely stable conditions associated with intense inversions. For descriptive and computational purposes, the continuum of stability over this range has been separated into six discrete categories, analagous to the way in which stability has been stratified for many modeling studies on the basis of Pasquill classes. TVA stability classes are defined on the basis of the change in potential temperature with height ($d\theta/dz$). The average $d\theta/dz$ value for each class is tabulated in Table 4.3-5. For example, a $d\theta/dz$ value of 1.0 °K/100 m defines the class labeled as isothermal, and a value of 1.36 °K/100 m defines the moderate inversion class.

For each stability class, curves have been developed on the basis of empirical studies giving the value of horizontal standard deviation of plume distribution (σ_y) and vertical standard deviation of plume distribution (σ_z) as a function of downwind distance from an emission source. These curves are reproduced in Figure 4.3-5. Not surprisingly, comparison of these curves with the familar Pasquill-Gifford (P-G) curves (which were developed for fairly low emission sources) displays several differences when looking at stability classes which can be considered as basically similar. Of particular significance, the TVA σ_y and σ_z values for isothermal and moderate inversion classes are lower than those for Pasquill Class E at distances beyond 2 km.

The significance of this difference relates to the TVA model's assumption that plume spread under limited mixing conditions is governed by a stability between the isothermal and moderate inversion classes equivalent to a potential temperature gradient of 1.15 °K/100 m. Therefore, even though the limited mixing concept entails vigorous mixing of a plume within a layer no more than slightly stable, the coefficients used to model this mixing are restricted to those of a much more stable atmosphere, thereby introducing a conservative element into the computation of limited mixing concentrations.

Peak-to-Mean Concentrations Ratios

The concentrations produced by direct application of the basic TVA equations are peak concentrations valid for an averaging period of about 3 to 5 minutes. To convert to longer time periods, a peak-to-mean ratio factor is needed. TVA has developed such factors based on field measurements made at the Paradise Steam Plant (Montgomery and Coleman, 1975; Montgomery, Carpenter, and Lindley, 1971.) The procedure followed was to take 5-minute average measurements at various sampling points and compute 1-hour, 3-hour, and longer period concentrations from the 5-minute samples. Ratios between the computed average concentrations and the peak measured concentrations were then determined. Results are expressed in terms of percentile values, i.e., the peak-to-mean ratio which exceeds 99 percent of the computed values, 95 percent of the computed values, etc. TVA recommends using the 95th percentile ratio for modeling purposes (TVA, 1977). In evaluating the Independence Steam Electric Station, a peak-to-mean ratio of 1.2 was used to convert to 30-minute concentrations and a ratio of 1.8 to convert to 3-hour concentrations. (3-hour averages relate to limited mixing conditions only.)

Although the Paradise Plant monitoring program was not set up to identify separate peak-to-mean ratios for limited mixing, coning, and inversion breakup occurrences, the clustering of monitoring instruments at distances less than 10 km suggests that the results are less likely to apply to inversion breakup cases. Use of a 1.2 factor for conversion of inversion breakup calculations to 30-minute concentrations is probably an overly conservative adjustment, particularly for emissions from a 1000-ft stack where the resulting ratio of 30-minute to shorter term concentrations is less likely to be near unity than is the case for the lower stack emission sources around which most measurement programs have been conducted.

4.3.4.3 NOAA Modeling Approach

The equations making up what is here called the NOAA model are presented in Table 4.3-6 with terms used defined in Table 4.3-1. The source of dispersion equations, diffusion coefficients and peak-to-mean ratios is Turner (1970). The plume rise equations are those of Briggs (previously referenced in the discussion of annual average modeling). The auxiliary equations needed to calculate the distance at which maximum inversion breakup concentrations occur are from Pooler (1965). The method of calculating minimum limited mixing distances is that used in the Southwest Energy Study (NOAA, 1972), which is more conservative than that found in Turner. Stability classes were determined using the Nuclear Regulatory Commission dT/dz criteria (USNRC, 1972) shown in Table 4.3-5. The upper air and surface exclusion criteria used with the TVA model were also used with the NOAA model, the only change being that a dT/dz value of -0.5 °K/100 m (equivalent to a dθ/dz of 0.48) was used as a cutoff point in deciding if inversion breakup conditions were present.

Differences between the TVA and NOAA models as used in this study include the form of the equations applied and the way in which some of the equation variables are developed. Two major differences are as follows:

1. The NOAA model computes a distance at which maximum limited mixing concentrations occur, whereas with the TVA model distances are specified as input data.

2. For limited mixing episodes, the TVA model calculates σ_y and σ_z using a dθ/dz value of 1.15 °K/100 m (equivalent to a very stable condition). The NOAA model takes the change in temperature with height as determined from rawinsonde soundings and uses this temperature gradient to compute σ_y and σ_z values. Therefore, because of the selection criteria imposed to determine if sufficient mixing is present in the mixing layer, the stability conditions from which NOAA σ_y and σ_z values are produced are less stable than that used in the TVA model.

The emission source characteristics used in both the TVA and NOAA models are the same. Plume penetration for limited mixing cases was handled in the same way, and the same meteorological data set and data reduction methods were used.

4.3.4.4 Rawinsonde Data Reduction and Utilization

Data Input

Upper air soundings are taken twice daily at a number of rawinsonde stations throughout the country. Nominal observation times are 1200 GMT and 0000 GMT. Data transmitted from the balloon-borne instrument package and recorded by ground tracking facilities are transcribed to data tapes maintained in the archives of the National Climatic Center and available for purchase by the general public.

Recorded data are stored in what is called TDF 56 Format. This format provides for documenting information at up to 79 different height levels beginning with the surface. At some stations, including Little Rock, data are available for both standard and significant levels, where "significant" refers to significant changes in temperature or humidity. For each standard level, measurements of height (geopotential meters), temperature (°C), relative humidity (%), wind direction (degrees), and wind speed (m/s) are recorded. The standard levels through 700 mb are: surface, 1000 mb, 950 mb, 900 mb, 850 mb, 800 mb, 750 mb, 700 mb. For significant levels, temperature and relative humidity are recorded, and in some cases wind direction and wind speed.

Data Processing and Output

Limited Mixing

For limited mixing, the 0000 GMT sounding is used. A typical limited mixing case, as plotted on a temperature-pressure diagram, is shown in Figure 4.3-6. The processor program which extracts required data from the upper air tape first requests a stack height value in meters. This height is then converted to a pressure in millibars. The following steps are then taken:

1. Check to see if the stability in the immediate layer from the top of the stack to 15 mb above the top of the stack is too

stable to allow a plume penetrating this layer to return to the ground. If this layer is too stable, no further processing of that sounding is completed.

2. Check to find a suitably stable layer to serve as the mixing layer cap. Initially a search is made for a layer at least 30 mb thick in which $d\theta/dz$ is 1.0 °K/100 m (TVA isothermal class) or greater. Temperatures and heights for 30 mb intervals are obtained from successive measurement levels by log-linear interpolation. If no layer meeting this criterion is found, another search is made to see if a 30 mb layer with a $d\theta/dz$ of 0.64 °K/100 m exists. If so, this less stable layer is used as a mixing cap.

3. Check to see if the stability between the cap and the stack top is sufficient to promote mixing. This is done by comparing the actual $d\theta/dz$ in this layer with a selected value. In evaluating the Independence Steam Electric Station, values of 0.135 and 0.455 °K/100 m were used as selection criteria. If the actual value is greater (more stable) than the selected value, limited mixing is assumed not to occur and no further processing is completed.

4. If all previous tests have been satisfied, mean wind speed and resultant wind direction from the surface to the top of the mixing layer are computed.

For days on which limited mixing is judged to occur, the output of the meteorological data processor program is the mixing height (level at which the top of the mixing layer is found), $d\theta/dz$ within the capping layer, $d\theta/dz$ from stack top to the top of the mixing layer, mean wind speed and resultant wind direction within the mixing layer. The TVA model uses these output data directly for all calculations. The NOAA model converts $d\theta/dz$ in the mixing layer to dT/dz prior to calculating plume rise and diffusion coefficients.

Inversion Breakup

For inversion breakup, the 1200 GMT sounding is used. A typical inversion case, as plotted on a temperature-pressure diagram, is shown in Figure 4.3-7. Very few operations are performed on the sounding data for further use in making inversion breakup calculations. A log-linear relationship between pressure and temperature is used to calculate temperature at the top of the stack and at 40 mb (approximately 1000 feet) above the top of the stack. These temperatures are then converted to a $d\theta/dz$ value for the 40 mb layer. The wind direction at the first recorded level below 40 mb above the stack and the mean wind speed between the surface and 40 mb above the stack are also determined.

The TVA model takes these data and computes an inversion breakup concentration whenever d /dz is greater than or equal to 1.0 °K/100 m and mean wind speed in the layer of interest is greater than or equal to 1.5 m/s. With the NOAA model, $d\theta/dz$ is converted to dT/dz and a check is made to see that dT/dz is greater than -0.5 °K/100 m. If dT/dz is lower than this value, this is considered a demonstration that an inversion breakup situation will not occur and no calculation is made. (In the stability typing scheme used with the NOAA model, a change in temperature with height of less than -0.5 °K/100 m indicates unstable or neutral conditions.) The 1.5 m/s wind speed criterion is also applied to the NOAA model.

Examples

As an example of actual input used in calculations, data taken directly from the upper air data tape are listed in Table 4.3-7 for soundings resulting in highest limited mixing and inversion breakup concentrations using the TVA model, and highest inversion breakup concentration using the NOAA model.

Nomenclature for Terms Used in TVA and NOAA Equations

Note: Dimensions of each term are given in brackets:

CC	=	Atmospheric stability coefficient for buoyant plume rise [dimensionless]
C_p	=	Specific heat at constant pressure [cal/g-°K]
$d\theta/dz$	=	Vertical potential temperature gradient [°K/m]
F	=	Momentum flux, $gvr^2 \frac{(Ts-T)}{T}$ $[m^4/s^3]$
g	=	Gravitational acceleration $[m/s^2]$
h	=	Stack height [m]
H	=	Effective stack height = $h + \Delta h$ [m]
H_F	=	Height of plume top prior to inversion breakup
	=	$1.1\ (H + 2.15\ \sigma_z)$ [m]
L	=	Mixing height [m]
Q	=	Contaminant emission rate [g/s]
r	=	Stack inside radius [m]
R	=	Net rate of sensible heating of an air column by solar radiation $[cal/m^2\text{-}s]$
R_I	=	TVA inversion breakup 5- to 30-minute peak-to-mean ratio [dimensionless]
R_{L30m}	=	TVA limited mixing 5- to 30-minute peak-to-mean ratio [dimensionless]
R_{L3H}	=	TVA limited mixing 5-minute to 3-hour peak-to-mean ratio [dimensionless]
RR_I	=	NOAA inversion breakup 10-to 30-minute peak-to-mean ratio [dimensionless]
RR_{L30m}	=	NOAA limited mixing 10- to 30-minute peak-to-mean ratio [dimensionless]
RR_{L3H}	=	NOAA limited mixing 10-minute to 3-hour peak-to-mean ratio [dimensionless]

s	=	(g/T) dθ/dz = Restoring acceleration per unit vertical displacement for adiabatic motion [s^{-2}]
t_m	=	Time required to heat stable column of air between stack top and plume top [s]
T	=	Ambient air temperature [°K]
T_s	=	Stack effluent exit temperature [°K]
u	=	Wind speed [m/s]
v	=	Stack effluent exit velocity [m/s]
X	=	Downwind distance [m]
X*	=	Distance at which turbulence begins to dominate; Briggs plume rise, unstable and neutral cases [m]
X_f	=	Distance to final plume rise; Briggs plume rise, stable cases [m]
Δh	=	Plume rise [m]
θ	=	Potential temperature [°K]
κ	=	Eddy conductivity of the atmosphere [cal/m-°K-s]
ρ	=	Ambient air density [g/m^3]
σ_y	=	Horizontal diffusion coefficient [m]
σ_{yf}	=	Horizontal diffusion coefficient for inversion breakup, TVA Model [m]
σ_{yt}	=	Horizontal diffusion coefficient for limited mixing, TVA Model [m]
σ_z	=	Vertical diffusion coefficient [m]
χ	=	Ground level concentration [$\mu g/m^3$]

TVA Model Equations

DISPERSION COEFFICIENTS

1. $\sigma_z = a X^b$

2. $\sigma_y = c X^d$

where,

TVA Stability Class	Coefficients a	b	c	d
1	0.388	0.749	0.377	0.760
2	1.340	0.509	0.562	0.692
3	3.126	0.3336	0.729	0.642
4	5.795	0.227	1.128	0.576
5	8.345	0.167	1.456	0.5256
6	9.525	0.141	1.839	0.486
(4.5)	6.729	0.201	1.318	0.545

with stability class defined by TVA $d\theta/dz$ criteria (see Table 4.3-5).

PLUME RISE

3. (All stability classes)

$\Delta h = (114) \; (CC) \; F^{1/3} \; u^{-1}$

where

4. $CC = 1.58 - (41.4) \; (d\theta/dz)$

LIMITED MIXING

5. Ground level concentration (5-minute)

$$\chi = \frac{10^6 \, Q}{\sqrt{2\pi} \, \sigma_{yt} \, uL}$$ at any selected distance X

and

6. $\sigma_{yt} = \sigma_y + .47 \; (L/1.1 - 2.15 \; \sigma_z)$

where

σ_y and σ_z are specified by the selected distance X and TVA stability class 4.5 ($d\theta/dz$ = 1.15°K/100 m).

INVERSION BREAKUP

7. Ground level concentration

$$\chi = \frac{10^6\, Q}{\sqrt{2\pi}\, \sigma_{yf}\, u H_F}$$

where

8. $\sigma_{yf} = \sigma_y + .47H$

and

9. $H_F = 1.1\,(H + 2.15\,\sigma_z)$

at the distance X iteratively determined where

10. $X = u\rho C_p\,(H_F^2 - h^2)\,/4\kappa$

and

11. $\kappa = 24259.3\, e^{-(d\theta/dz)(0.983595)}$

PEAK-TO-MEAN RATIOS

12. $R_I = 1.2$

13. $R_{L30m} = 1.2$

14. $R_{L3H} = 1.8$

REFERENCE SOURCES FOR EQUATIONS

Equation Number	Source
1.	Developed from curves in TVA, 1970
2.	Developed from curves in TVA, 1970
3.	Montgomery and others, 1973a; Carpenter and others, 1971
4.	Montgomery and others, 1973a; Carpenter and others, 1971
5.	Montgomery and others, 1973a; Carpenter and others, 1971
6.	Montgomery and others, 1973a; Carpenter and others, 1971
7.	Montgomery and others, 1973a; Carpenter and others, 1971
8.	Montgomery and others, 1973a; Carpenter and others, 1971
9.	Montgomery and others, 1973a: Carpenter and others, 1971
10.	TVA, 1970
11.	Carpenter and others, 1970
12.	Montgomery and Coleman, 1975
13.	Montgomery and Coleman, 1975
14.	Montgomery and Coleman, 1975

Table 4.3-3

Mean Monthly Load Factors

MONTH	SUNRISE (CST)	SUNSET (CST)	HOURS OF LIMITED MIXING	HOURS OF INVERSION BREAKUP	MEAN MONTHLY LOAD FACTOR	MEAN LIMITED MIXING LOAD FACTOR	MEAN INVERSION BREAKUP LOAD FACTOR
January	0658	1702	2.5	.5	.59	.68	.66
February	0631	1728	2.5	.5	.59	.68	.66
March	0602	1728	3.0	.5	.58	.67	.65
April	0528	1832	3.0	.5	.59	.72	.44
May	0500	1900	3.5	.5	.67	.82	.49
June	0445	1915	4.0	.5	.85	1.03	.62
July	0451	1909	4.0	.5	.88	1.07	.65
August	0515	1844	4.0	.5	.89	1.09	.65
September	0547	1812	3.5	.5	.79	.97	.58
October	0620	1740	3.0	.5	.69	.79	.77
November	0649	1710	3.0	.5	.64	.73	.71
December	0705	1654	2.5	.5	.64	.73	.71

Note: Load factors are fractional equivalents of percent operating levels.

Table 4.3-4

Stack Exit Characteristics for Ten Percent Operating Level Increments

OPERATING LEVEL (Percent of Rated Capacity)	VELOCITY (ft/s)	TEMPERATURE (°F)	SO_2 EMISSION RATE, TYPICAL COAL (lb/hr)	SO_2 EMISSION RATE, HIGH SULFUR COAL (lb/hr)
30	31.84	219	2722	4265
40	36.80	225	3629	5687
50	44.42	230	4536	7109
60	51.30	236	5442	8528
70	59.45	241	6348	9948
80	66.10	247	7255	11369
90	74.30	253	8162	12790
100	81.99	258	9069	14212
110	89.74	264	9907	15524

Table 4.3-5

Stability Categorizations

TVA CRITERIA

Description	Class	Mid-Point $d\theta/dz$[a] (°K/100 m)	Range of $d\theta/dz$[b] (°K/100 m)
Neutral	1	0.00	<0.135
Slightly Stable	2	0.27	0.135 to 0.455
Stable	3	0.64	0.455 to 0.820
Isothermal	4	1.00	0.820 to 1.180
Moderate Inversion	5	1.36	1.180 to 1.5455
Strong Inversion	6	1.73	>1.5455
(Applied to L.M.)	(4.5)	(1.15)	(N/A)

NRC CRITERIA (FOR NOAA MODEL) [c]

Description	Pasquill Class	Range of dT/dz (°K/100 m)
Extremely unstable	A	<-1.9
Moderately unstable	B	-1.9 to -1.7
Slightly unstable	C	-1.7 to -1.5
Neutral	D	-1.5 to -0.5
Slightly stable	E	-0.5 to 1.5
Stable	F	>1.5

[a] Source: TVA, 1970

[b] Range limits are halfway between successive mid-point values.

[c] Source: USNRC, 1972

NOAA Model Equations

DISPERSION COEFFICIENTS

1. $\sigma_z = 1000\ a\ X^b$

2. $\sigma_y = 1000\ c\ X^d$

where

Pasquill Stability Class	Coefficients a	b	c	d
A	0.45	2.1	0.2	0.88
B	0.11	1.1	0.16	0.88
C	0.061	0.92	0.1	0.88
D	0.033	0.6	0.07	0.88
E	0.023	0.51	0.052	0.88
F	0.015	0.45	0.035	0.88

with stability defined by AEC dT/dz criteria (see Table 4.3-5)

PLUME RISE

Neutral and Unstable

3. $\Delta h = 1.6\ F^{1/3}\ (3.5X^*)^{2/3}\ u^{-1}$, if $X \geq 3.5X^*$

4. $\Delta h = 1.6\ F^{1/3}\ (X)^{2/3}\ u^{-1}$, if $X < 3.5X^*$

and

5. $X^* = 14\ F^{5/8}$, if $F < 55$

6. $X^* = 34\ F^{2/5}$, if $F \geq 55$

Stable

7. $\Delta h = 2.4\ (\frac{F}{us})^{1/3}$, if $X \geq X_f$

where

8. $s = \frac{g}{T}\ \frac{d\theta}{dz}$

and

9. $X_f = \pi(\frac{u}{s})^{1/2}$

10. $\Delta h = 1.6\ F^{1/3} X^{2/3} u^{-1}$, if $X < X_f$

LIMITED MIXING

11. Ground Level Concentration (10-Minute)

$$\chi = \frac{10^6\ Q}{\sqrt{2\pi}\ \sigma_y\ u\ L} \quad \text{at distance } X$$

where X is twice the distance at which

12. $\sigma_z = \frac{0.75L}{2.15}$

INVERSION BREAKUP

13. Ground Level Concentration (10-Minute)

$$= \frac{10^6\ Q}{\sqrt{2\pi}\ u\ (\sigma_y + H/8)\ (H + 2\sigma_z)} \quad \text{at distance } X$$

where

14. $X = ut_m$

and

15. $t_m = \frac{\rho C_p\ d\theta/dz}{R} \quad (\Delta h + 2\sigma_z)\ (h + \Delta h/2 + \sigma_z)$

where

16. $R = 66.7\ cal/m^2/sec$

PEAK-TO-MEAN RATIOS

17. $RR_I = 1.245$

18. $RR_{L30m} = 1.245$

19. $RR_{L3H} = 1.8$

REFERENCE SOURCES FOR EQUATIONS

Equation number	Source
1.	Developed from curves in Turner, 1970
2.	Developed from curves in Turner, 1970
3.	Briggs, 1971; Briggs, 1972
4.	Briggs, 1971; Briggs, 1972
5.	Briggs, 1971; Briggs, 1972
6.	Briggs, 1971; Briggs, 1972
7.	Briggs, 1971; Briggs, 1972
8.	Briggs, 1971; Briggs, 1972
9.	Briggs, 1971; Briggs, 1972
10.	Briggs, 1971; Briggs, 1972
11.	Turner, 1970
12.	NOAA, 1972
13.	Turner, 1970
14.	Pooler, 1965
15.	Pooler, 1965
16.	Pooler, 1965
17.	Turner, 1970
18.	Turner, 1970
19.	Turner, 1970

Table 4.3-7

Examples of Actual Upper Air Data

Date/Time	Pressure (mb)	MSL Height (m)	Temperature (°C)	Wind Direction (°)	Wind Speed (m/s)
6/10/66	1007	79	25.0	40	7
1800 CST	1000	142	23.4	43	4
	993	200	21.1	*	*
	950	600	18.5	42	3
	914	920	15.4	*	*
	900	1047	17.9	10	4
	850	1535	17.5	340	5
1/22/70	1019	79	-12.8	130	2
0600 CST	1001	210	-10.3	*	*
	1000	220	-10.5	136	2
	976	410	-11.7	*	*
	950	620	- 9.0	224	1
	948	630	- 8.9	*	*
	925	820	- 6.5	*	*
10/28/67	1011	79	1.1	110	3
0600 CST	1000	167	8.2	104	2
	998	190	8.6	*	*
	966	460	11.5	*	*
	950	600	10.6	249	1
	900	1039	7.5	234	2

* Not reported

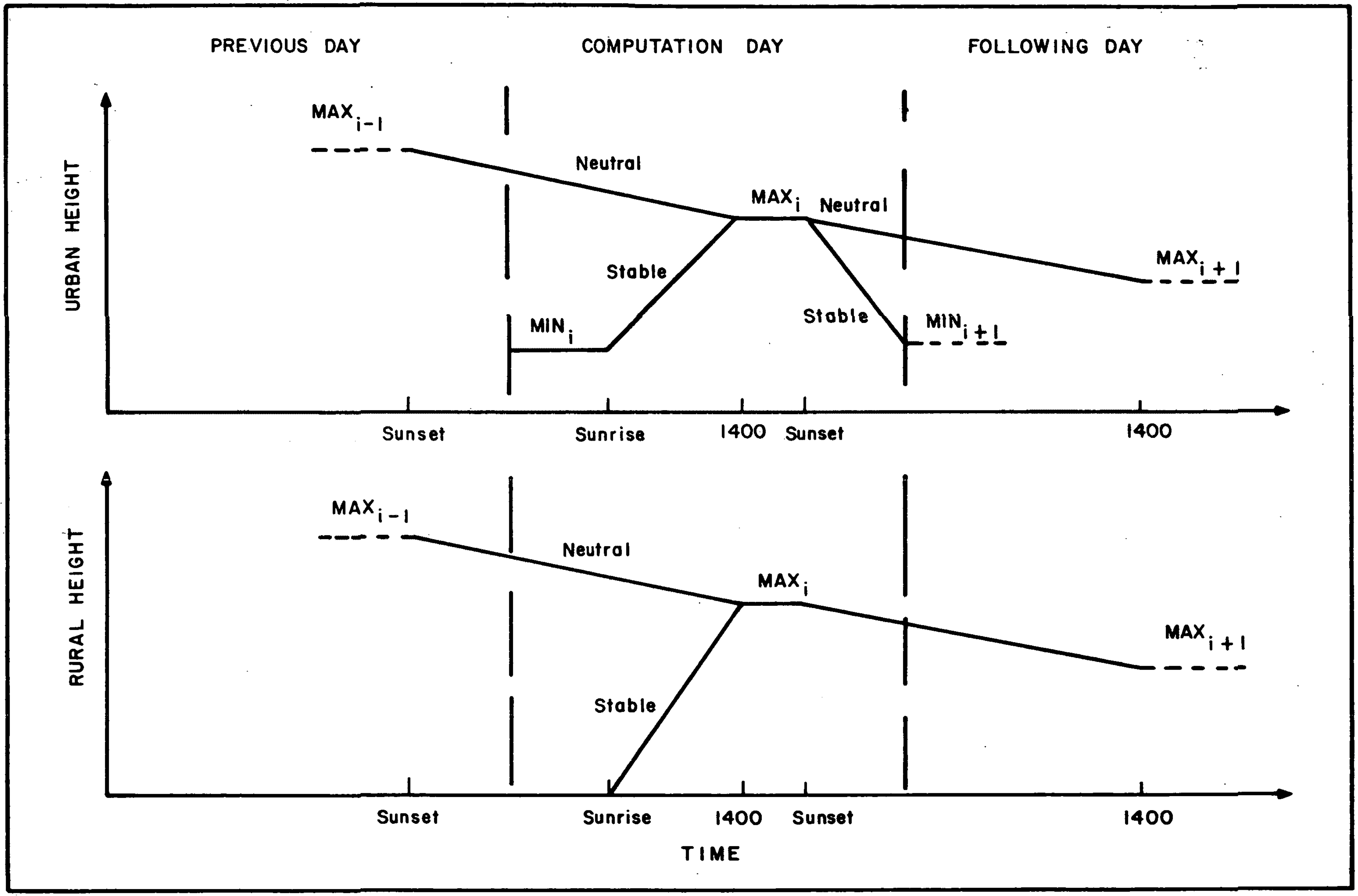
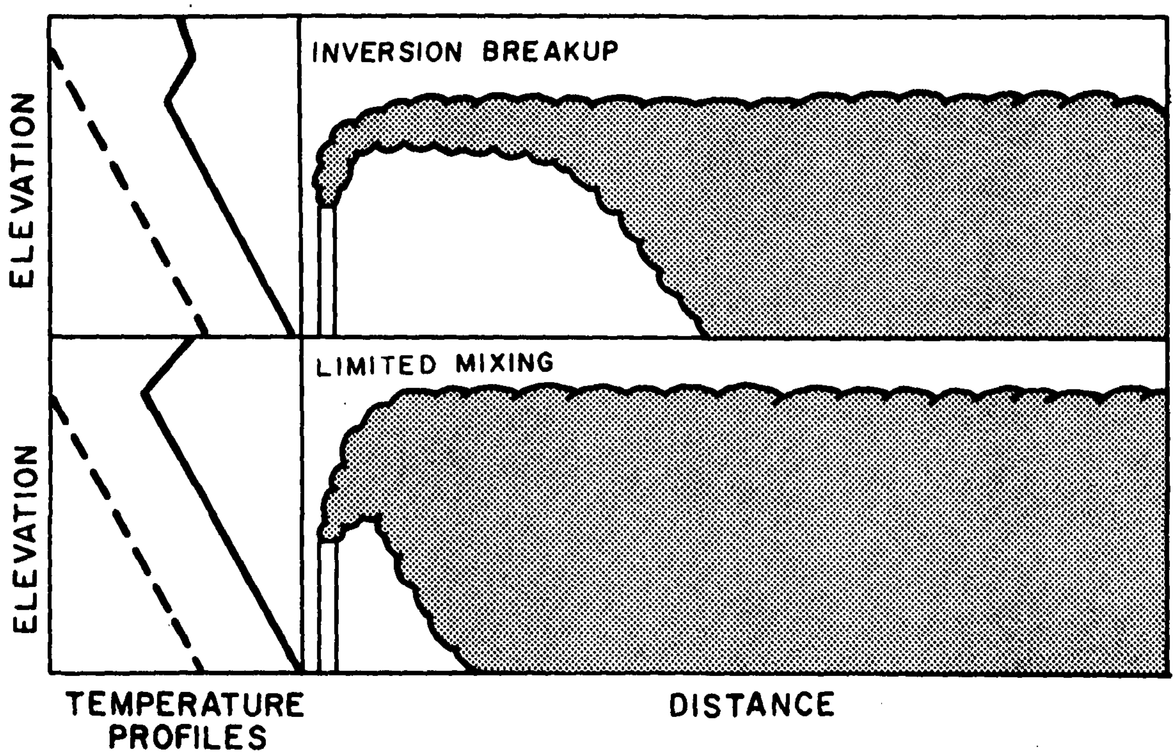


Figure 4.3-1. Determination of hourly mixing heights by the CRSTER model preprocessor program.



Note: Dashed line represents dry adiabatic lapse rate.

Figure 4.3-2. Illustration of limited mixing and inversion breakup conditions.

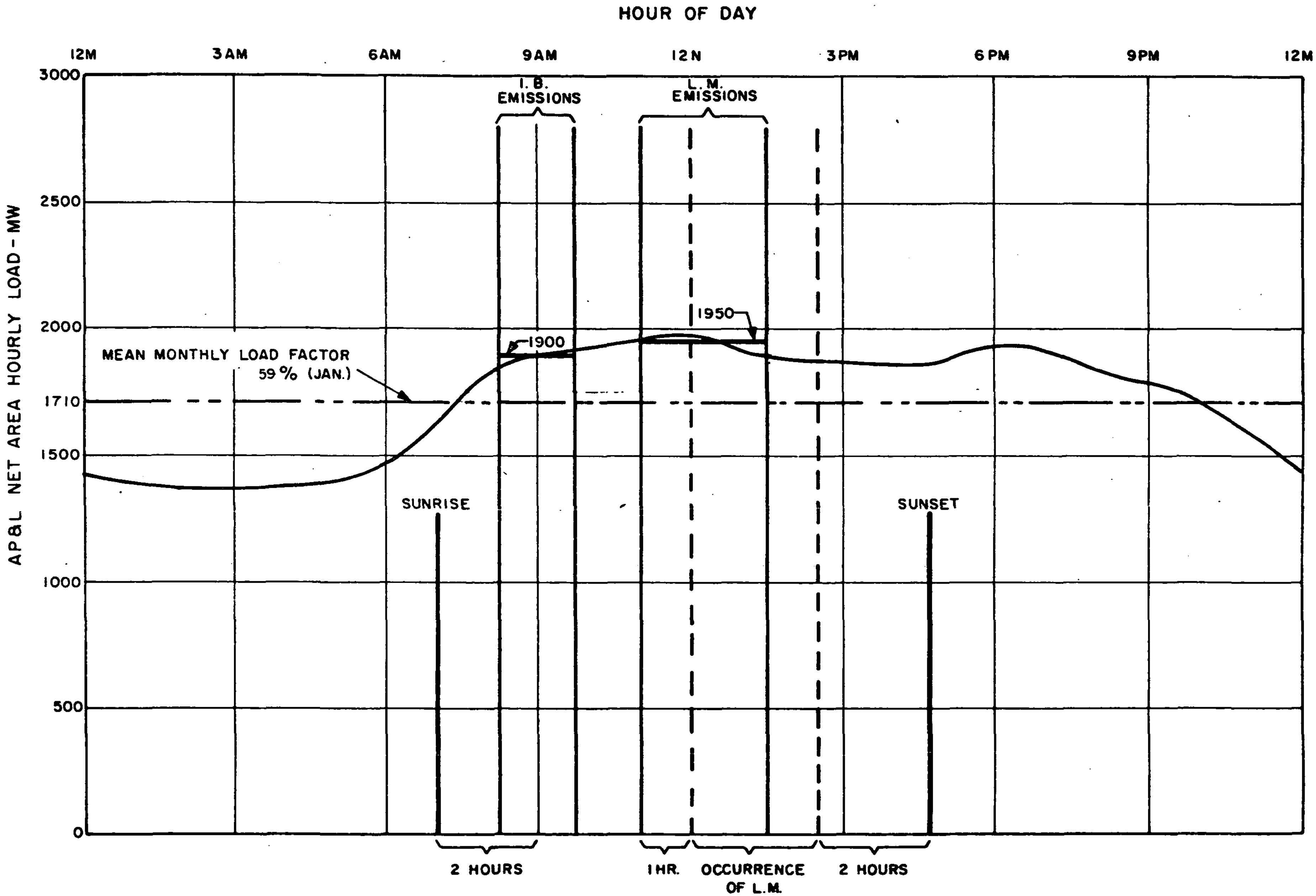


Figure 4.3-3. AP&L system load curve (winter maximum, 1/2/74).

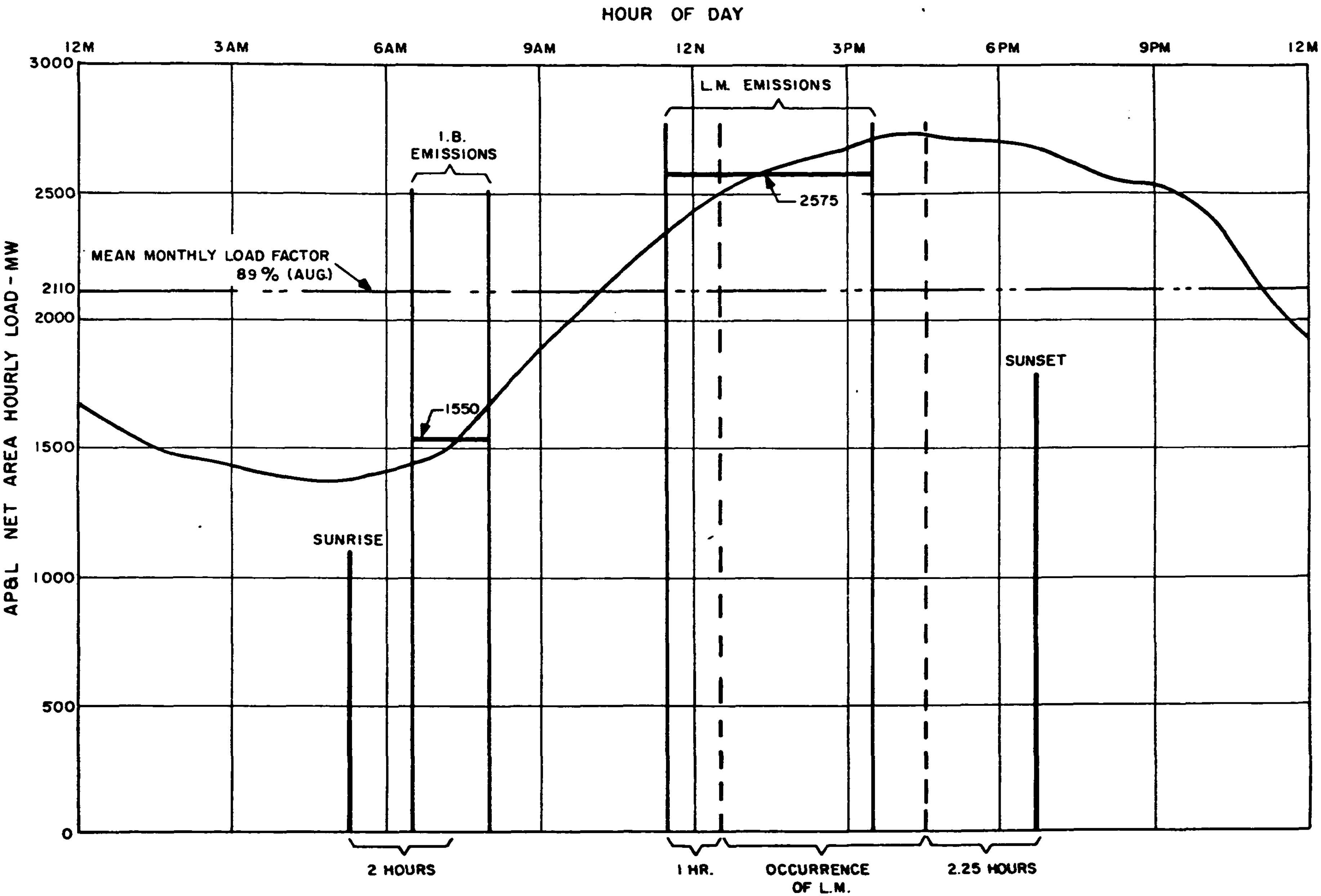
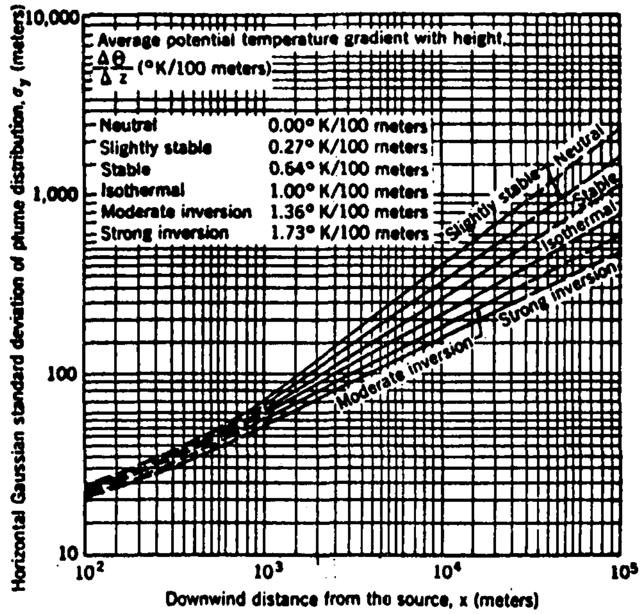
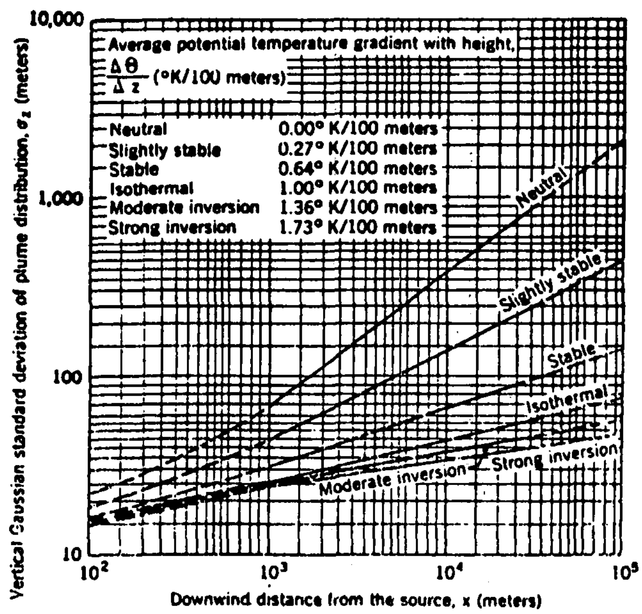


Figure 4.3-4. AP&L system load curve (summer maximum, 8/20/73).



Horizontal Gaussian standard deviation of plume distribution as a function of downwind distance from the source.



Vertical Gaussian standard deviation of plume distribution as a function of downwind distance from the source.

Source: Carpenter and others, 1971

Figure 4.3-5. TVA horizontal and vertical diffusion coefficients, σ_y and σ_z.

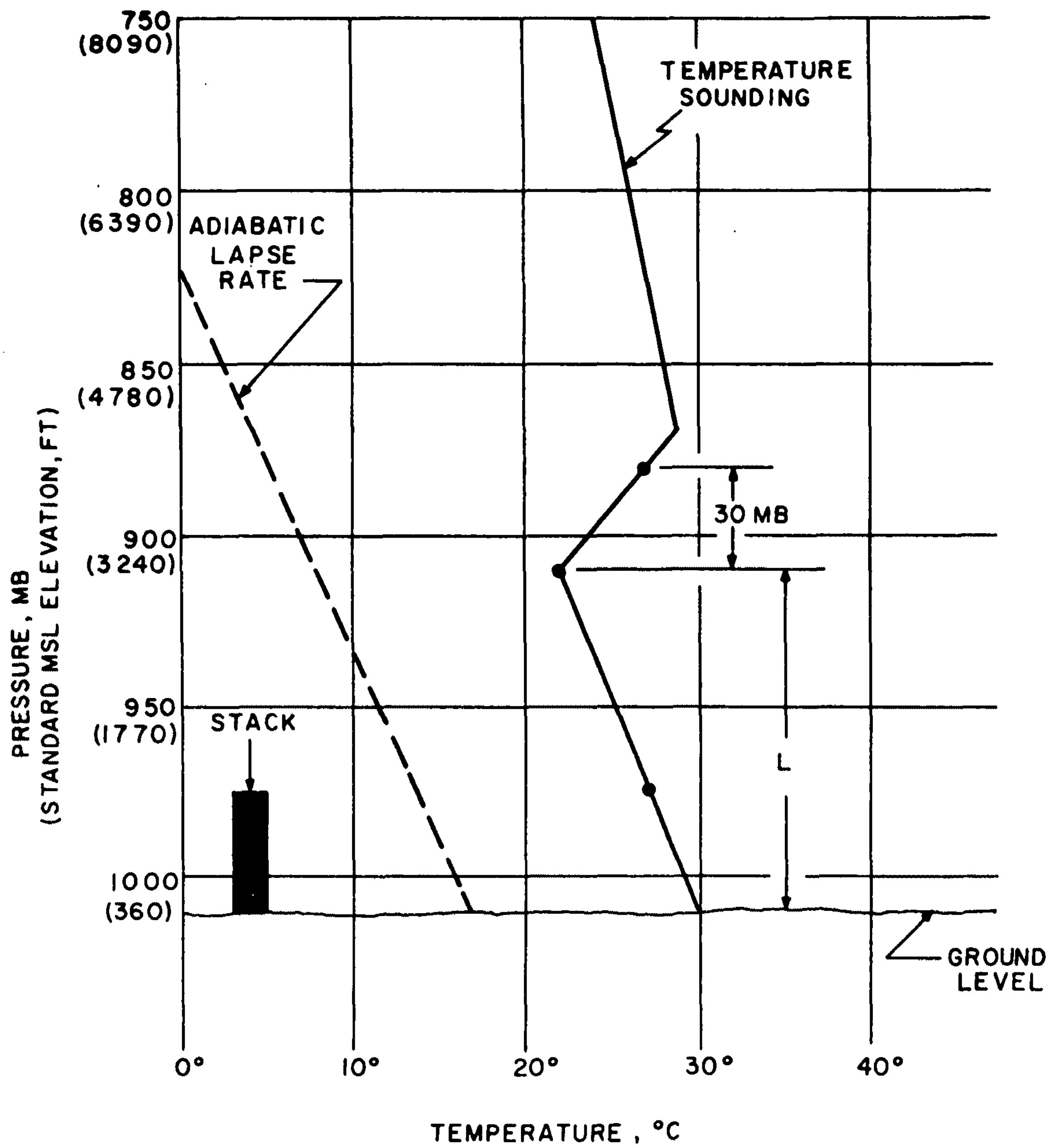


Figure 4.3-6. Typical limited mixing case, 0000 GMT sounding (1715 CST release).

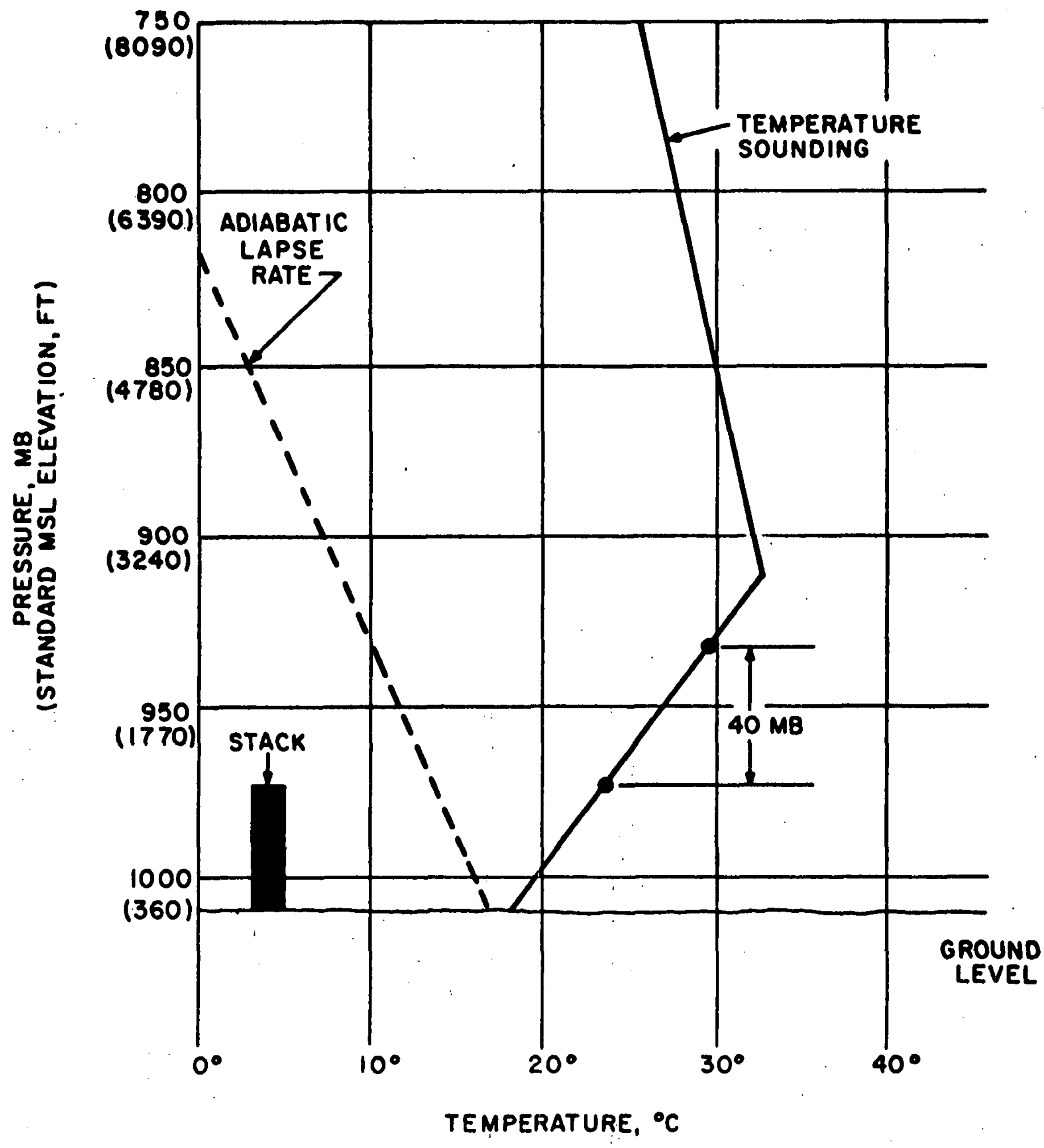


Figure 4.3-7. Typical inversion breakup case, 1200 GMT sounding (0515 CST release).

4.4 MODELING RESULTS

4.4.1 Annual Average Concentrations

In calculating annual average concentrations using the Air Quality Display Model (AQDM), emission source characteristics representative of an average operating level were used. This annual average level is estimated to be 65 percent of rated capacity, which for modeling purposes was rounded to 70 percent. Stack parameters for the 70 percent operating level are shown in Table 4.3-4. Pollutant emission rates on an annual basis are those resulting from use of typical coal, i.e., coal with a sulfur content of 0.28 percent and an ash content of 5.99 percent.

In running AQDM, receptor points are specified by a rectangular grid array which allows up to 225 points per run. To determine maximum annual concentrations, successive runs were made with grid arrays oriented in different directions and distances from the Independence site. A grid spacing (distance between adjacent receptor points) of 2 km was used at distances within approximately 20 km of the site, and a spacing of 4 km at greater distances. Calculations were made to distances beyond 100 km. Basic meteorological input consisted of the Little Rock wind/stability frequency distribution previously discussed, an ambient temperature of 289°K, an ambient pressure of 1000 mb, an afternoon mixing height of 1431 m and a mixing height for Class E calculations of 700 m.

Within 100 km of the Independence site, the highest annual average SO_2 concentration is calculated to be less than 1 $\mu g/m^3$. Since NO_2 emissions (all NO_x assumed to be NO_2) and particulate emissions are less than SO_2 emissions, maximum annual average NO_2 and particulate concentrations are also calculated to be less than 1 $\mu g/m^3$. These results are summarized in Table 4.4-1. Although the concentration distribution pattern is not very meaningful with concentrations this low, the area of highest concentration is indicated to be about 90 km northeast of the site.

The extremely low annual average concentrations predicted by the model are not surprising considering the height of the stack and plume rise from the stack. Other studies have indicated that tall stacks are very protective of annual ambient standards.

4.4.2 24-Hour Concentrations

Concentrations over an averaging period of 24 hours were calculated using the CRSTER model. The version of the model used permits consideration of monthly variations in emission rate but does not provide for introduction of corresponding monthly variations in the exit gas conditions (temperature and velocity) which affect plume rise. Given this restriction and given the objective of computing concentrations for both typical coal and high sulfur/high ash coal, the following emission source configurations were modeled:

	EMISSION RATES		EXIT GAS CHARACTERISTICS		COAL	
CONFIGURATION	Monthly Average	110%	70%	110%	Typical	High Sulfur/ High Ash
1	X		X		X	
2	X		X			X
3		X		X	X	
4		X		X		X

Monthly average emission rates refer to rates obtained by correcting the emission rate for the 70 percent operating level (the average level when generating units are in operation) in accordance with the monthly mean operating levels shown in Table 4.3-3. The "110%" emission rates column refers to peak load emission rates. (An assumption of 24 continuous hours at peak load generation is not very realistic but was included for comparison purposes.) The two columns shown for exit gas conditions refer to velocity and temperature characteristic of a 70 percent operating level and a 110 percent operating level.

In applying the model, only SO_2 concentrations were calculated directly. Particulate concentrations were obtained through multiplication of SO_2 concentrations by the ratio of particulate emissions to SO_2 emissions.

Each model run is capable of including up to five downwind distances along each 10-degree azimuth line. To determine the distance at which the maximum concentration occurs, successive model runs were made until a maximum concentration, using distance spacings of 0.1 km, was apparent.

Table 4.4-2 summarizes highest SO_2 and particulate concentrations for each emission source configuration in comparison with national ambient air quality standards. Also shown in this table are the distance and direction at which the maximum concentration is calculated to occur. Although the second highest concentration at each receptor point is also computed by the model, these concentrations have not been included in the summary of results.

As can be seen in Table 4.4-2, predicted 24-hour concentrations are well below ambient air quality standards. Also, the distances at which maximum concentrations are expected to occur are barely beyond site boundaries. These close distances result from allowing Class A stabilities to be included in modeling computations. The day on which highest concentrations occurs includes two hours of Class A conditions during which the wind is blowing toward the point of maximum concentration. Since existence of Class A stabilities at plume height is an unlikely event, as has been discussed, this adds a degree of conservatism to the modeling results.

4.4.3 3-Hour Concentrations - CRSTER Model

Concentrations over a 3-hour averaging period have been calculated using the CRSTER model and, for comparison, the TVA and NOAA models. TVA and NOAA model results are presented in a later section.

The same emission source configurations considered in computation of 24-hour concentrations were also considered in computing 3-hour concentrations. Results for SO_2 (the only pollutant for which a 3-hour standard exists) are shown in Table 4.4-3. Predicted concentrations are well below applicable standards. Also, as was the case with 24-hour concentrations, maximum 3-hour concentrations occur near the emission source, again the result of including Class A stabilities in computations.

4.4.4 30-Minute and 3-Hour Concentrations - TVA, NOAA Models

4.4.4.1 Emission Source/Modeling Concept Combinations

Several combinations of emission source characteristics and modeling concepts were tested - both those considered most realistic and those conceivable but not likely to occur. Combinations tested by both the TVA and NOAA models are outlined in Table 4.4-4 and further explained in the following paragraphs.

Emission Characteristics - Use of mean monthly limited mixing load factors (as listed in Table 4.3-3) and the emission characteristics associated with these factors is considered the most realistic approach to the modeling of maximum 30-minute concentrations when combined with measured (as opposed to hypothetical) meteorological conditions. There will be brief periods during afternoon hours when both units will operate at peak load (110 percent), however. Therefore, peak load emission characteristics were also used in the calculation of limited mixing concentrations with mixing lid penetration constraints as explained below. In the case of inversion breakup, emissions participating in this condition are released early in the morning when peak load levels are not likely to be in effect. Therefore, mean monthly load factors were used for inversion breakup calculations.

Coal Quality - Emissions from the Independence Steam Electric Station will most commonly result from combustion of coal which has previously been described as "typical" coal. However, since the coal contract which has been obtained specifies a quality range, high sulfur/high ash coal emissions characteristic of coal at the upper end of the contracted range were also modeled.

Mixing Lid Penetration - In application of the TVA model to analysis of monthly mean limited mixing load factors, calculations were made provided the height defined by the stack height plus 70 percent of the plume rise ($0.7\ \Delta h$) was at or below the mixing height and other selection criteria were met. As previously explained, this allows a sizeable portion of the plume to penetrate into the capping lid and still participate in the limited mixing occurrence. This adds an element of conservatism considered reasonable when using monthly mean factors since conditions on any given day may differ from the mean. When assuming emissions are at peak level, however, the factor of deviation from the mean does not exist. The modeling approach in this case was to allow limited mixing calculations whenever the height defined by stack height plus total plume rise (1.0 μh) was at or below the mixing height. As discussed above, since plume rise computations are in reference to plume centerline, the technique used to model peak load emissions still permits that part of the plume above the centerline to penetrate into the capping lid and still contribute to ground level limited mixing concentrations. This technique is also conservative with respect to a typical TVA practice of comparing mixing height with plume top rather than plume centerline (Carpenter and others, 1976; TVA, 1977). In using the NOAA limited mixing model, the 70 percent plume rise approach was used for all calculations since this model is somewhat less conservative than the TVA limited mixing model.

Mixing Layer Stability - To achieve the fairly vigorous thermal mixing required to uniformly mix a plume between the ground and an elevated trapping lid during limited mixing conditions, stability within the mixing layer cannot be excessively stable. As previously discussed, the initial procedure used with the TVA limited mixing model to determine if adequate mixing could occur was to make calculations only if the change of potential temperature with height ($d\theta/dz$) was no greater than 0.135 °K/100m. This value corresponds to an intermediate level half-way between the mid-point values of TVA's neutral and slightly stable classes. Additional calculations were made with a less restrictive value of 0.455 °K/100m, intermediate between TVA's slightly stable and stable classes. Since these limits are tested in the meteorological processing program prior to execution of the TVA and NOAA concentration computation programs, they apply to both modeling concepts.

Hypothetical Conditions - In the absence of actual upper air data, TVA has suggested hypothetical conditions which can be applied as a preliminary estimate of high concentrations during limited mixing and inversion breakup situations (Montgomery and others, 1973a). Although the main objective pursued in evaluating the Independence Steam Electric Station was simulation of most probable concurrent emission and meteorological characteristics, calculations were also made based on TVA's hypothetical conditions and peak load emission characteristics. The conditions suggested for limited mixing are as follows:

1. potential temperature lapse rate = 1.15 °K/100m (for plume rise computations)
2. wind speed = 3 m/s
3. mixing height = 762 m or the top of the plume, whichever is greater (TVA, 1977)
4. distance = 3 km
5. horizontal dispersion coefficient = 108 m
6. vertical dispersion coefficient = 36 m

Suggested conditions for inversion breakup are:

1. potential temperature lapse rate = 1.15 °K/100m
2. wind speed = 3 m/s
3. horizontal dispersion coefficient = $1.32\ (X_{max})^{0.55}$
4. vertical dispersion coefficient = $6.71\ (X_{max})^{0.21}$
5. distance to point of max concentration (X_{max}) determined using ambient air density of 1220 g/m^3, specific heat of air of 0.24 cal/g-°K, and eddy conductivity of 800 cal/m-°K-s.

For the limited mixing case, the top of the Independence Steam Electric Station plume at peak load for the conditions given is 938 m. This was the value used for mixing height since it exceeds 762 m.

Downwind Distance - The downwind distance at which maximum concentrations occur is calculated automatically when using the TVA inversion breakup equations and NOAA inversion breakup and limited mixing equations. To apply the TVA limited mixing calculation program, distances have to be assigned. TVA experience indicates that maximum concentrations occur at distances between 3 and 10 km from the emission source (Carpenter and others, 1971; Montgomery and others, 1973a). Since the tall stack planned for the Independence Steam Electric Station could conceivably project high concentrations to even greater distances, calculations were made over a range of 3 to 15 km at the following specific distances: 3 km, 5 km, 8 km, 10 km, and 15 km.

4.4.4.2 <u>30-Minute Concentration Modeling Results</u>

TVA and NOAA 30-minute concentration modeling results are presented in Table 4.4-5. These are the results obtained after application of the exclusion criteria previously listed. No 30-minute particulate concentrations are higher than 21 $\mu g/m^3$, and are therefore well below the standard of 150 $\mu g/m^3$. The highest 30-minute SO_2 concentration is a limited mixing concentration of 516 $\mu g/m^3$, just slightly below the standard of 533 $\mu g/m^3$. However, it should be noted that this concentration results from use of the most conservative horizontal dispersion coefficient equation, whereas if the other equation had been used the resulting maximum concentration would have been the 481 $\mu g/m^3$ NOAA inversion breakup maximum. Also, this concentration is associated with use of higher sulfur coal and is calculated for a summer day (6/10/66) when the mean limited mixing operating level is above 100 percent, and therefore calculations are actually made for peak operating level emissions even though the 70 percent plume penetration assumption is in effect. In other words, the 516 $\mu g/m^3$ value results from essentially worst case conditions which would not be expected to occur with any degree of regularity. This conclusion regarding frequency of occurrence is based on the concentration frequency distribution tables which are part of the output from the TVA and NOAA modeling programs. Under limited mixing conditions, for Combination TVA-2 (higher sulfur coal and $d\theta/dz$ cutoff of 0.135) only 0.3 percent of all concentrations are greater than 450 $\mu g/m^3$. For Combination TVA-4 (higher sulfur coal and $d\theta/dz$ cutoff of 0.455) only 0.7 percent of all concentrations are above this level. And for inversion breakup Combinations NOAA-2 or NOAA-4, which produce the second highest maximum concentration of 481 $\mu g/m^3$, only 0.1 percent of all concentrations are above 450 $\mu g/m^3$. (These distributions are based on calculations made prior to any exclusions on the basis of surface data conditions.) Also, it should be remembered that the limited mixing concentrations cited here are at a downwind distance of only 3 km, the distance at which highest concentrations are calculated by the

TVA model. At greater distances, concentrations above 450 μg/m^3 would be extremely unlikely based on modeling results.

For better understanding of the results presented in Table 4.4-5, values of key meteorological variables associated with maximum concentrations are shown in Table 4.4-6. These key variables include mixing height, wind speed, dθ/dz from the top of the stack to the top of the mixing layer (for TVA limited mixing) and from the top of the stack to 40 mb above the stack (for TVA inversion breakup), and dT/dz from the top of the stack to 40 mb above the stack (for NOAA inversion breakup). No information is provided for NOAA limited mixing cases since predicted concentrations are so low. It will be noted that dT/dz for the maximum NOAA inversion breakup case (-0.288 °K/100 m) is within the Pasquill Class E category and does not actually represent a true inversion situation. For this case, an emitted plume might not even remain intact enough to be brought rapidly to the ground in high concentrations as typically visualized for inversion breakup occurrences.

4.4.4.3 3-Hour Concentration Modeling Results

Using peak-to-mean ratios, 3-hour SO_2 concentrations have been calculated from maximum TVA 30-minute limited mixing concentrations and are presented in Table 4.4-7. No 3-hour concentrations have been extrapolated for inversion breakup since this phenomenon typically is not of sufficient duration to result in high concentrations over a period of more than an hour. Also, no 3-hour concentrations are shown for the NOAA limited mixing model since the 30-minute concentrations predicted by this model are so low.

Maximum concentrations are higher than those predicted by the CRSTER model but still far below applicable standards. Comments made regarding frequency of occurrence of 30-minute concentrations also apply to 3-hour concentrations, that is, highest concentrations are rarely predicted. Concentrations over 300 μg/m^3, for 3-hour duration, are calculated by the TVA limited mixing model on less than one percent of all days during the 5-year test period.

Table 4.4-1

Maximum Predicted Annual Average Concentrations

Pollutant	Predicted Concentration ($\mu g/m^3$)	National Primary Air Quality Standard ($\mu g/m^3$)	National Secondary Air Quality Standard ($\mu g/m^3$)
SO_2	<1	80	-
NO_2	<1	100	100
Particulate Matter	<1	75	60

Table 4.4-2

Maximum Predicted 24-Hour Concentrations

Emission Source Configuration[a]	Maximum SO_2 Concentration ($\mu g/m^3$)	Maximum Particulate Concentration ($\mu g/m^3$)	Distance/Direction of Maximum Concentration Point
1	15	1	1.5 km / 30°
2	24	1	1.5 km / 30°
3	18	1	1.6 km / 30°
4	28	1	1.6 km / 30°

National SO_2 Primary 24-Hour Standard: 365 $\mu g/m^3$
National Particulate Primary 24-Hour Standard: 260 $\mu g/m^3$
National Particulate Secondary 24-Hour Standard: 150 $\mu g/m^3$
Arkansas Particulate 24-Hour Standard: 75 $\mu g/m^3$
Class II Area SO_2 24-Hour PSD Increment: 91 $\mu g/m^3$
Class II Area Particulate 24-Hour PSD Increment: 37 $\mu g/m^3$

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[a] Legend for emission source configurations (see text for further information):

1 = Monthly average emission rates; 70 percent operating level exit gas characteristics; typical coal

2 = Monthly average emission rates; 70 percent operating level exit gas characteristics; high sulfur/high ash coal

3 = Peak load (110 percent) emission rate and exit gas characteristics; typical coal

4 = Peak load (110 percent) emission rate and exit gas characteristics; high sulfur/high ash coal

Table 4.4-3

Maximum Predicted 3-Hour Concentrations
Based on CRSTER Model

Emission Source Configuration[a]	Maximum SO_2 Concentration ($\mu g/m^3$)	Distance/Direction of Maximum Concentration Point
1	109	1.6 km / 280°
2	171	1.6 km / 280°
3	106	1.5 km / 290°
4	166	1.5 km / 290°

National SO_2 Secondary 3-Hour Standard: 1300 $\mu g/m^3$
Class II Area SO_2 3-Hour PSD Increment: 512 $\mu g/m^3$

[a] Legend for emission source configurations (see text for further information):

1 = Monthly average emission rates; 70 percent operating level exit gas characteristics; typical coal

2 = Monthly average emission rates; 70 percent operating level exit gas characteristics; high sulfur/high ash coal

3 = Peak load (110 percent) emission rate and exit gas characteristics; typical coal

4 = Peak load (110 percent) emission rate and exit gas characteristics; high sulfur/high ash coal

Table 4.4-4

Emission Source/Modeling Concept Combinations

Emission Source/ Modeling Concept Combination	Limited Mixing Emission Characteristics		Coal Quality		Mixing Lid Penetration		Mixing Layer dθ/dz		Hypothetical Conditions
	Mean Monthly	Peak	Typical	High Sulfur/ High Ash	0.7 Δh	11.0 Δh	0.135	0.455	
TVA-1	X		X		X		X		
TVA-2	X			X	X		X		
TVA-3	X		X		X			X	
TVA-4	X			X	X			X	
TVA-5		X	X			X	X		
TVA-6		X		X		X	X		
TVA-7		X	X			X		X	
TVA-8		X		X		X		X	
TVA-9		X	X						X
TVA-10		X		X					X
NOAA-1	X		X		X		X		
NOAA-2	X			X	X		X		
NOAA-3	X		X		X			X	
NOAA-4	X			X	X			X	
NOAA-5		X	X		X		X		
NOAA-6		X		X	X		X		
NOAA-7		X	X		X			X	
NOAA-8		X		X	X			X	

Table 4.4-5

Maximum 30-Minute SO_2 and Particulate Concentrations - TVA, NOAA Models

Emission Source/ Modeling Concept Combination	Limited Mixing			Inversion Breakup		
	SO_2 Concentration ($\mu g/m^3$)	Particulate Concentration ($\mu g/m^3$)	Distance (km)	SO_2 Concentration ($\mu g/m^3$)	Particulate Concentration ($\mu g/m^3$)	Distance (km)
TVA-1	329	16	3	207	10	43.2
TVA-2	516	21	3	324	13	43.2
TVA-3	329	16	3	207	10	43.2
TVA-4	516	21	3	324	13	43.2
TVA-5	267	13	3	-	-	-
TVA-6	419	17	3	-	-	-
TVA-7	290	14	3	-	-	-
TVA-8	455	18	3	-	-	-
TVA-9	312	15	3	94	5	78.2
TVA-10	489	20	3	147	6	78.2
NOAA-1	31	2	39.5	307	15	16.6
NOAA-2	49	2	39.5	481	19	16.6
NOAA-3	30	1	38.5	307	15	16.6
NOAA-4	47	2	38.5	481	19	16.6
NOAA-5	35	2	43.1	-	-	-
NOAA-6	55	2	43.1	-	-	-
NOAA-7	35	2	43.1	-	-	-
NOAA-8	55	2	43.1	-	-	-

Arkansas 30-Minute SO_2 Standard = 533 $\mu g/m^3$

Arkansas 30-Minute Particulate Standard = 150 $\mu g/m^3$

Table 4.4-6

Meteorological Variables Associated With
Maximum 30-Minute Concentrations

Emission Source/ Modeling Concept Combination	Limited Mixing				Inversion Breakup			
	Date	Mixing Height (m)	Wind Speed (m/s)	dθ/dz (°K/100m)	Date	Wind Speed (m/s)	dθ /dz (°K/100m)	dT/dz (°K/100m)
TVA-1,2,3,4,	6/10/66	841	3.5	0.127	1/22/70	1.5	2.105	-
TVA-5,6	4/24/67	701	6.0	0.073	-	-	-	-
TVA-7,8	1/30/66	741	5.0	0.359	-	-	-	-
TVA-9,10	N/A	938	3.0	1.15	N/A	3.0	1.15	-
NOAA-1,2	-	-	-	-	10/28/67	1.5	-	-0.288
NOAA-3,4	-	-	-	-	10/28/67	1.5	-	-0.288
NOAA-5,6,7,8	-	-	-	-	-	-	-	-

Table 4.4-7

Maximum 3-Hour SO_2 Concentrations
TVA Limited Mixing Model

Emission Source/ Modeling Concept Combination	Concentration ($\mu g/m^3$)
TVA-1	219
TVA-2	344
TVA-3	219
TVA-4	344
TVA-5	178
TVA-6	279
TVA-7	193
TVA-8	303
TVA-9	208
TVA-10	326

National SO_2 3-Hour Secondary Standard = 1300 $\mu g/m^3$
National Class II Area SO_2 3-Hour PSD Increment = 512 $\mu g/m^3$

4.5 ATMOSPHERIC EFFECTS OF COOLING TOWERS

4.5.1 Introduction

The heat dissipation system for the Independence Steam Electric Station consists of two natural draft cooling towers, one for each unit of operation. The towers have the design characteristics as presented in Table 4.5-1. These characteristics, it should be noted, are generally peak or maximum values and will vary depending on the plant load condition and the ambient atmospheric temperature and humidity. These towers represent the best compromise between economic cost of construction/operation and anticipated environmental impact.

The areas of atmospheric concern with the operation of cooling towers are the presence of:

- large drift deposition
- long visible plumes
- frequent ground level fog/icing
- plume generated cloud formation
- modified precipitation
- interaction of flue and cooling tower plumes

4.5.2 Drift Deposition

The design maximum drift rate for these towers is 0.01 percent of the circulation flow rate. This means that, at the maximum flow rate of 310,000 gpm, 31 gpm of water may be emitted from the towers in the form of small water droplets. The design of baffles (drift eliminators) for the towers enables the manufacturer to guarantee such low rates of drift. This low rate, especially for natural draft towers, ensures low impact from cooling towers due to the increased dilution that will occur prior to reaching ground level. It should be noted that this maximum drift rate is an order of magnitude greater than that possible from a well-maintained tower (DeVine, 1975) thus indicating the conservative nature of these analyses.

The settling speed of droplets in the plume (cloud droplets) is less than a few centimeters per second and, therefore, these droplets do not contribute significantly to the ground level settling. Drift droplets settle at speeds of almost 1 meter per second and are of concern in the deposition of water and salts on the surface. Much work has been done in modeling this aspect of the cooling tower impact with very little verification. These models have been found to yield large differences in deposition rates (McVehil and Heikes, 1975). Many studies of drift from saltwater natural draft cooling towers are available and will be used to represent the extreme values expected at the Independence site (Edmonds, Roffman and Maxwell, 1975; Roffman and Grimble, 1975; DeVine, 1975). The maximum centerline chloride deposition rate was estimated to be 1.2 to 17.4 lbs/acre-month for natural draft cooling towers (Edmonds, Roffman and Maxwell, 1975). Roffman and Grimble (1975) estimate the maximum deposition from a natural draft cooling tower to occur under slightly unstable conditions and at a distance of 1500 meters. This rate was estimated to be 1.24×10^{-6} kg/m^2-day. (0.33 lbs/acre-month). The characteristics of the cooling tower used in this study are such that these calculations are very conservative in comparison with the characteristics of the cooling towers at the Independence site.

Another indication of the small magnitude of the impact expected from the drift of the cooling towers can be seen through the conservative calculation of drift deposition assuming all the drift material is deposited within 3.0 km of the site and within the sector having the highest frequency of occurrence. This calculation indicates a maximum of 9.278×10^{-7} lbs/ft^2-day (1.2 lbs/acre-month) deposition for each tower; a maximum of 1.856×10^{-6} lbs/ft^2-day (2.4 lbs/acre-month) from both towers. Such concentrations of salts may be injurious to some crops but it should be noted that these values are the maximum calculated and are not expected to occur. This is especially true considering the fact that the rainfall in this region is both large (40-50 inches) and evenly distributed throughout the year. Thus high build-up of salts is not expected in the plants nor in the soil.

The effects of salt sprays on corn and soybeans as well as on other vegetation has been investigated (Mulchi and Armbruster, 1975; Edmonds, Roffman and Maxwell, 1975). These reports indicate that salt spray treatments of 7.28 kg/hectare-week (2.130 x 10^{-5} lbs/ft^2-day) produce leaf damage in both corn and soybeans. This is at least an order of magnitude larger than that expected at Independence Steam Electric Station. No visual damage or difference in growth occurred for treatments of 1.82 and 3.54 kg/hectare-week (5.32 x 10^{-6} and 1.04 x 10^{-5} lbs/ft^2-day) for an 8 week period. Reports also point out that exposure to salts of 100 μg/m^3 (1.77 x 10^{-3} lbs/ft^2-day) for several hours during the growing season causes foliage damage. Exposure to 60 μg/m^3(1.77 x 10^{-4} lbs/ft^2-day) will affect the vigor and distribution of plants (DeVine, 1975). These concentrations, assuming a settle velocity of 1 meter per second, are two orders of magnitude greater than that expected from the Independence site.

In summary, drift from the two natural draft cooling towers at the Independence site is not expected to produce damaging salt concentrations in the surrounding areas. The deposition expected will be at least an order of magnitude smaller than that which causes damage to vegetation. Also, accumulation of salt in the soils is not anticipated due to the abundant rainfall throughout the year.

4.5.3 Visible Plumes

The natural draft cooling towers will produce visible plumes of various lengths depending on plant load characteristics as well as meteorological conditions. DeVine (1975) points out that visible plumes, from 63 large natural draft cooling towers in the United States, extend more than 1000 yards (914 meters) downwind less than 15 percent of the time and do not contribute to area cloudiness. The larger plume lengths occur with larger plant loads and smaller saturation deficits (difference between saturation moisture density and ambient moisture density). The latter condition occurs more frequently during the cooler months of the year. Junod and others (1975) presented the visible plume length from the Leibstadt power plant (144-meter towers and 950 MW power). Fifty percent of the winter plumes were about 450 meters (0.28 mile) long, while the summer months had plumes about 600 meters (0.37 mile) in length 50 percent of the time. The winter months had plumes of 3000 meters (1.86 mile) or longer 10 percent of the time, while the summer months had only about 1400 meter (0.87 mile) plume length for the same percent level.

DeVine (1975) indicates long visible plumes are possible when the saturation deficit is less than or equal to 0.5 g/m^3. The summary of the wet bulb depression for various ambient temperatures is presented in Table 4.5-2. These data were obtained from observations at Little Rock. The colder months have 9.0 percent of the observations with less than a 2 degree wet bulb depression (saturation deficit of less than 0.63 g/m^3). For the warmer months, 10.8 percent of the observations have saturation deficits less than 1.96 g/m^3. Based on DeVine's criteria and on the data presented on Table 4.5-2, it is anticipated that long plumes will be experienced a maximum of about 120 hours during warmer months and about 394 hours during the colder months of the year.

Other studies have shown, from actual observation, that plumes, at times, persist for long distances (Smith and others, 1974). Plumes extending more than 2 miles occurred in 16 cases of 244 observations; some were in excess of 6 miles. The majority of the plumes observed in the Smith study rose quickly to heights of 400 to 7000 feet and dissipated within 0.5 miles (66.8 percent of the 244 observations).

Moore (1975) reports the existence of long visible plumes, mostly during cloudy or overcast days. Persistent plumes (length greater than 900 meters) occur during 50 percent of the observations in the December-February period, but only 10 percent in the May-July period (Barber and others, 1974). DeVine (1975) also reports plumes of more than 1000 yards occur less than 15 percent of the time.

Furthermore, visible plumes greater than 2 miles in length may occur but are expected to be infrequent and confined to the winter months. Normally, plumes of less than 0.5 mile are expected and will affect only the aesthetic conditions near the plant, not the climatological conditions of the area.

4.5.4 Ground Level Fogging/Icing

Plumes from natural draft towers have, on ocassion, been found to reach the ground. This is generally true in areas with terrain features that would promote such circulation and/or tower design that contributes to such occurrences. DeVine (1975) reports on a study of the Forked River cooling tower where tower-caused ground level fog was found to occur less than 2 percent of the time during the year, with no corresponding occurrences of icing. Smith and others (1974) report that their observations indicate no cooling tower induced fogging; in fact the plumes were observed to rise above existing natural fog formation. Consideration of the increase in humidity at ground level was also discussed by Smith and found to be indistinguishable from natural variations. The maximum increase in relative humidity was calculated to be 1 percent. Moore (1975) notes that no significant changes in rainfall, sunshine, or occurrence of fog was detected from the inspection of climatological records for stations between 4 and 112 km from a 2000 MW power plant. This lack of increase in ground level humidity was also reported for the Keystone Station. The Battelle (1974) study, which reviewed the natural draft cooling tower literature to describe and evaluate the potential atmospheric effects of operating towers, reports no observed increases in fogging or icing due to tower plumes. The Paradise and Keystone tower plumes have never reached the ground under normal operating conditions. This is also true of icing. No icing was observed due to the plumes from operational natural draft cooling towers. Barber and others (1974) also indicate that during a year of observations at eight natural draft cooling towers in England, no plumes came in contact with the ground.

DeVine (1975) reports that ground level fog will usually occur when the saturation deficit is less than or equal to 0.1 g/m^3. Table 4.5-2 indicates this level of saturation deficit will be equivalent to the wet bulb depression of near zero degrees, 4.4 percent of the total. Thus, the maximum potential occurrence of ground fog will be about 385 hours per year.

The results of the above studies are general enough to indicate the nature of the anticipated impact of fogging and icing at the Independence site. Neither ground level fogging nor icing is expected to result from operation of the Independence Steam Electric Station cooling towers.

4.5.5 Modification of Precipitation/Cloud Formation

The plumes from natural draft cooling towers have been observed to merge with existing cloud systems and even, rarely, to form a cumulus cloud. It should be noted that persistent plumes generally occur during overcast and cloudy days and, therefore, may interact with existing cloud development. Both of these conditions are occasional occurrences and do not modify the climatological characteristics of the region. Results of a number of investigations confirm this conclusion (DeVine, 1975; Battelle, 1974; Huff, 1972; and Martin, 1974).

Precipitation from natural draft towers has, in the past, been due to drift of droplets from these towers. The problem has been solved through new design configurations of drift eliminators to collect these droplets prior to discharge. Most towers with modern drift eliminators produce smaller droplets that tend to evaporate prior to reaching the ground. This should be considered with the fact that reported occurrences of precipitation from natural draft cooling towers are infrequent and do not exceed the normally occurring variability in precipitation (Martin, 1974).

Precipitation from plumes is likewise a rare occurrence. Moore (1975) reports that persistent plumes occur mainly in conditions of high ambient relative humidity, with natural clouds usually present and precipitation is very slight, and only occurs when natural rain is falling or when rain is possible. Investigation of weather records near a 2000 MW power station (Martin, 1974) showed a slight increase in rainfall after operation, but the normal scatter in annual values prevents concluding that a correlation exists. The range in the values before operation is similar to those experienced after operation.

Huff (1972) points out that the heat and moisture from cooling towers may contribute to the development of clouds through the "trigger" mechanism, but all indications are that precipitation augmentation will be insignificant when considering the normal amounts of natural rain.

Therefore, modification of precipitation due to the two natural draft cooling towers at the Independence site is unlikely and not expected.

4.5.6 Stack and Cooling Tower Plume Interaction

The intermixing of cooling tower plumes with the plume from the stack is possible due to the location of the release points and to the plume rise characteristies of the various plumes. This intermixing has been observed at the Keystone Generating Station in Pennslyvania (Aynsley, 1970). The towers at Keystone are 325 feet in height (4 towers) with the stacks at 800 feet (2 stacks). Acid droplets were detected in the plume, but no data were given on the amount reaching ground level. This observed increase of acid droplets in the plume is attributed to the increased rate of oxidation of atmospheric SO_2 to sulfates due to the increase in humidity. The Central Electricity Generating Board of England believe the change in growth rate of water droplets due to SO_2 is slow enough that these acid drops seldom reach the ground (Hanna and Swisher, 1971). In other words, if tower and stack interaction cause acid droplet development, do the acid droplets reach the ground? This is a topic that has, heretofore, not been the subject of extensive observational research. Moore (1975) presents observations that tend to support the supposition that the interaction of the chimney and tower plumes is not a significant environmental impact problem. These observations have been made where natural rainfall measured under a stack plume showed no significant differences in pH from rainfall measured at stations not under the stack plume. Pell (1975) also questions whether detectable amounts of acid droplets will reach ground level receptors.

The potential for stack and cooling tower plume interaction is dependent on the relative positions of these release points in both the horizontal and vertical planes. The stack is about 800 feet north of the nearest cooling tower and about 1650 feet north northwest of the second tower. The release points are vertically separated by 610 feet. The six wind direction sectors that would most likely permit plume interaction (NNW-NNE and SSE-SSW) occur only 39 percent of the time based on yearly observations at Little Rock, Arkansas. Considering the vertical and horizontal spread of the release points, the frequency of time the wind directions are in the correct sectors and the generally short length of the visible plumes, frequent interactions of cooling tower and stack plumes are not expected. The relationship of these interactions with ground level impacts is not known. Based on the above studies, little impact is expected from the interaction of stack and tower plumes.

Table 4.5-1
Independence Steam Electric Station
Natural Draft Cooling Tower Characteristics

Number of Towers	2
Height	393 feet (119.8 meters)
Diameter at Base	328 feet (100 meters)
Diameter at Mid-height	210 feet (64.1 meters)
Diameter at Top	211 feet (64.3 meters)
Circulatory Flow Rate (peak)	310,000 gpm (19.6 m^3/s)
Maximum Heat Load	41 x 10^8 Btu/hr (2.87 x 10^8 cal/s)
Evaporation (Maximum 2.46 percent)	7,650 gpm (0.48 m^3/s)
Drift (Maximum 0.01 percent)	31 gpm (0.002 m^3/s)

Table 4.5-2

Percent Occurrence and Saturation Deficit
Little Rock AFB, Arkansas; Data Record 1956-1962

Dry Bulb Temperature (°F)	Saturation Moisture Content[a] (g/m^3)	Percent Occurrence/Saturation Deficit (g/m^3)			
		Wet Bulb Depression (°F)			
		0	2	4	6
80-97	33.67	0.0/0.0	0.1/1.96	0.8/3.80	1.7/5.56
60-80	18.87	2.1/0.0	8.6/1.16	8.3/2.25	5.9/3.28
39-60	9.55	2.3/0.0	6.7/0.63	6.4/1.22	5.8/1.78
Total		4.4	15.4	15.5	13.4

[a] Average for dry bulb interval

4.6 SULFATES ANALYSIS

Although no national ambient air quality standards have been adopted for aerosol sulfates, concern has been expressed about this class of atmospheric particulates. Because of this concern and because of the probable association between sulfur compound emissions from power plants and ambient sulfate levels, a discussion of the sulfates question is provided in this section. This question is a particularly complex one, and the studies which have been conducted in relation to it provide no conclusive means of evaluating the effect which the emissions from a single source will have on sulfate levels. This section therefore focuses more on (a) some of the general aspects of the sulfates question and (b) a discussion of sulfate concentrations which have been measured in Arkansas.

4.6.1 General Analysis

4.6.1.1 Introduction

Sulfates are important because of their reported effect on human health, their potential effect on rainfall acidity, and their fairly well established relationship to impairment of visibility. One source of sulfate formation is the oxidation of sulfur dioxide (SO_2) after the latter is released to the atmosphere. The thermodynamics of simple oxidation are such that almost complete conversion of SO_2 to SO_3 would occur at ordinary temperatures if the reactions were not kinetically limited.

In actuality, the conversion of SO_2 to sulfates is a very complicated and incompletely understood phenomenon. It is often assumed that SO_2 reacts according to a first-order chemical process, one of the simplest encountered in chemical kinetics. A first order reaction is an attractive process when performing diffusion calculations because a minimum of mathematical difficulty is involved. More complicated processes in which the reaction rate depends non-linearly on amounts of material present are very difficult to incorporate in diffusion estimates.

An examination of the literature concerning the reactions of SO_2 within the atmosphere reveals widely differing estimates of reaction rates. Several extensive literature surveys have been prepared (Bufalini, 1971; Harrison, Larson and Hobbs, 1975; Urone and Schroeder, 1969; Kellogg and others, 1972; Levy, Drewers and Hales, 1976). Some information is also contained in "Air Quality Criteria for Sulfur Oxides" (U. S. Public Health Service, 1969b). A brief discussion of information presented in these and other references is given below for the purpose of documenting some of the conclusions which have been drawn regarding the reaction rate of SO_2 and the transport, concentration and effect of resulting sulfates.

4.6.1.2 Sulfate Formation

Sulfur dioxide (SO_2) is a gas at ordinary temperatures. It is a product of some natural activities (e.g., volcanic activities) as well as man's activities. Principle sources of SO_2 related to man are the roasting of metal sulfide ores and the combustion of sulfur-bearing fuels. The latter is the most widespread source of SO_2, although the former produces large amounts of SO_2 in isolated locations.

If there were no removal mechanisms for SO_2, it would continue to build up in the atmosphere. However, no such global buildup has been observed. All of the important removal processes result in eventual oxidation of SO_2 to a higher oxide such as SO_3 or SO_4. This review is concerned with the conversion of SO_2 to sulfates within the atmosphere. Sulfates that form as a result of intake by vegetation, washout, dry deposition, gaseous reaction on solid materials, and gaseous absorption by bodies of water are not considered.

Sulfates can form in the atmosphere by oxidation of SO_2 through three basic types of mechanisms: homogeneous gas phase reactions, aqueous phase reactions, and heterogeneous phase reactions. Various mechanisms falling within these categories have been studied in the laboratory. In the atmosphere, the situation is far more complex than in the controlled reaction environment of the laboratory. Emphasis is placed in this review on information obtained from studies in the uncontained, uncontrolled ambient atmosphere where the oxidation of SO_2 is undoubtedly caused by mechanisms falling within all of the above categories.

Thermodynamics

That SO_2 can be oxidized directly to sulfates is evidenced by the study of the equilibrium thermodynamics of the following chemical reactions:

(1) $SO_2(gas) + 1/2\ O_2(gas) = SO_3(gas)$

(2) $SO_3(gas) + H_2O(liquid\ or\ gas) = H_2SO_4(liquid)$

At temperatures commonly obtained in stack gases and ambient atmospheres, the chemical equilibrium of the first reaction strongly favors the formation of SO_3 (Dow Chemical Company, 1960). The rate at which reaction (1) would proceed is not determined by thermodynamics but by complex kinetic mechanisms. In other words, although the thermodynamics of reaction (1) imply almost complete conversion of SO_2, the rate at which the reaction occurs would be dependent on many other factors not implied in the simple chemical equilibrium formula.

The hydration of SO_3 to H_2SO_4 is also thermodynamically favored at ambient atmospheric temperatures. Thus, the thermodynamic potential is high for sulfate formation as a result of oxidation of SO_2. Whether or not the conversion actually occurs (or at what rate) is a matter of chemical kinetics and not thermodynamics.

Photo-Oxidation

The photo-oxidation of SO_2 has been reported for various concentrations of SO_2 and relative humidities. The rates vary from 0.05 percent per hour to 0.68 percent per hour. This corresponds to half-lives of 1380 hours and 101 hours respectively. On a quantum yield basis, the results vary by a factor of 100 (Bufalini, 1971).

Reaction In a Plume

Experiments on power plant plumes and smelter plumes yield widely varying results. Experiments performed on plumes from TVA plants, for example, show oxidation rates varying from 0 percent per hour to 110 percent per hour (Gartrell, Thomas, and Carpenter, 1963). The TVA experiments indicate a strong influence of ambient relative humidity on reaction rate.

Experiments performed at the Four Corners Generating Station in the San Juan Valley of northwestern New Mexico (University of Utah Research Institute, 1975) gave much lower conversion rates than the TVA study. The Four Corners study consistently showed conversion rates less than one percent per hour.

The wide variability of oxidation rates can be explained in part by variations in meteorological conditions. Relative himidity is clearly an important variable to be considered as is the degree of dilution due to turbulent mixing. From reported data, it would appear that SO_2 conversion occurs most rapidly in atmospheres with a relative humidity greater than 70 percent. That is, with other meteorological factors remaining approximately the same, atmospheres with relative humidity greater than 70 percent show a significantly greater rate of sulfate formation than atmospheres with relative humidity less than 70 percent.

There are also indications that heterogeneous reactions of SO_2 with airborne particulates can be much more rapid than homogeneous gaseous reactions of SO_2 in air (Foster, 1969; Matteson, Stober and Luther, 1969; Freiberg, 1974). It has been observed that oxides of aluminum, calcium, iron, lead, chromium, and vanadium are very efficient in reacting with SO_2 even in the absence of ultraviolet light. Such oxides are often prevalent in atmospheric particulates resulting both from nature and from a variety of man's activities. For example, one important source of many of the above oxides is from the combustion of fossil fuels that contain mineral matter.

The variability in reaction rate of SO_2 within plumes noted above is not unexpected. It is reasonable to recognize the possibility that power plants burning coal of different composition provide different environments for SO_2 reaction, and such environments would be significantly different from those environments provided by, say, ore smelters and refineries. Reactions within large urban environments are also significantly different because of the types of nucleating species which arise from such sources as automobiles (Bufalini, 1971).

4.6.1.3 Concentrations and Transport of SO_2 and Sulfates

Concentration Patterns

The trends in ambient concentration of SO_2 and sulfate throughout the United States have recently been analyzed (Altschuller, 1976; Electric Power Research Institute, 1976). Substantial decreases in ambient SO_2 concentrations have been noted which correlate well with corresponding reductions in SO_2 emissions. Measurements of ambient SO_2 levels at both urban and nonurban stations have indicated a decline in concentrations over the past 10 years.

However, ambient sulfate concentrations have not decreased correspondingly. For example, at sites in New York City, Newark, Baltimore, Indianapolis, Chicago, and St. Louis, SO_2 concentrations decreased by as much as 60 to 75 percent during the period 1963 to 1972. However sulfate concentrations definitely decreased at only 4 of these 6 locations, and the overall average decrease was only 13 percent (Altschuller, 1976).

The apparent lack of correspondence between SO_2 emissions and sulfate concentrations has been further noted by comparison between several midwestern U. S. air quality control regions (Altschuller, 1976). In regions containing such cities as Detroit, Pittsburg, Cleveland, Chicago, and St. Louis, the 1972 annual SO_2 emissions ranged from 700,000 to 1,200,000 tons per year, and annual average sulfate concentrations were 16.7 $\mu g/m^3$. In other midwest air quality control regions containing the cities of Columbus, Dayton, and Indianapolis, annual SO_2 emissions were about 100,000 to 200,000 tons per year, but the average sulfate concentration was 13 $\mu g/m^3$. In other words, regions with 5 to 10 times higher SO_2 emissions had sulfate concentrations only about 28 percent higher. Based on these figures, ambient sulfate concentrations do not appear to be closely correlated with SO_2 emissions originating within the same air quality control region.

The anomalous differences between trends in SO_2 emissions and ambient sulfate concentrations may be related to a shift toward usage of lower sulfur fuel at low-level emission sources combined with larger quantities of SO_2 emissions from plants using tall stacks which emit at higher levels in the atmosphere (National Academy of Sciences, 1974). Thus, the urban monitoring stations measure less SO_2 from local low-level sources, whereas the lack of a similar decline in sulfate concentrations can be attributed to an increasing exposure to sulfates formed in the atmosphere and transported from distant elevated sources, possibly over distances of hundreds of kilometers (Altschuller, 1976; Electric Power Research Institute, 1976).

Transport of SO_2 and Sulfates

The oxidation of SO_2 can be slow enough in many areas to explain sulfate formation over widespread regions possibly hundreds of kilometers downwind from major urban SO_2 sources. Zones of high sulfate concentrations in the northeastern United States have been identified and have been attributed to urban contributions beginning as far away as the midwest (Electric Power Research Institute, 1976).

In situations favoring rapid conversion of SO_2 to sulfates, exposure to sulfates over widespread areas can be assumed to occur on the basis of transport of sulfate particles. The tendency of sulfates to undergo transport depends on particle size and on processes which remove suspended sulfates. Sulfate particle size measurements (Electric Power Research Institute, 1976; Weiss and others, 1977; Hidy and others, 1974) have indicated that over 80 percent of sulfate particles have mass median diameters less than 2 microns. Sub-micron aerosol species have been shown to be dominated in many cases by sulfuric acid, sulfate of ammonia, or both (Weiss and others, 1977; Hidy and others, 1974; Miller and others; 1975). Particles in the sub-micron size range can stay suspended in the atmosphere for long periods of time in the absence of removal processes such as washout and coagulation.

The small size of sulfate particles implies that they could well constitute a regional problem extending over many miles. The implication is that sulfate concentrations in a specific area can be due to SO_2 emissions from sources far removed from the area. Such an implication is based on a great deal of empirical information. However, this does not mean that, under appropriate conditions, sources of SO_2 can not contribute to sulfate concentrations in nearby areas. Time is the most pertinent parameter to consider in the formation and transport of sulfates. If air mass movement is persistent, but the conversion rate is slow, sulfate exposure will reach a maximum at a point distant from the source. Conversely, if the air mass is stagnant, SO_2 may remain in the area long enough for the highest sulfate exposure to occur in the region proximate to the SO_2 source.

4.6.1.4 Visibility Effects of Sulfates

Sulfates are of interest in part because of their effect on the visible (optical) properties of the atmosphere. One of the most effective mechanisms resulting in visibility impairment is that of light scattering by aerosols (particles and droplets suspended in the atmosphere). The effectiveness with which aerosols scatter light depends on the size of the aerosol. Visible light is most effectively scattered by aerosols whose radii are comparable to the wave length of the light. Visible light contains wave lengths from 0.4 to 0.7 micron (10^{-6} meter). It is found that aerosols of diameters between about 0.1 and 1.0 micron are most effective in scattering light.

It has been noted in several investigations of suspended particulate matter that sulfates tend to dominate the sub-micron aerosol species both in urban and rural areas, and that visibility impairment is directly related to sulfate concentration (Weiss and others, 1977; Hidy and others, 1974). Aerosol sulfates, therefore, can contribute to visibility impairment to a greater degree than might be suggested strictly on the basis of mass concentration.

4.6.1.5 Effects of Flue Gas Desulfurization (Scrubber) Systems on Sulfates

Flue gas desulfurization devices, commonly called scrubbers, are a type of pollution control equipment placed at some point in an exhaust gas stream to remove sulfur oxides which formed as the result of fuel combustion or process operations. Ostensibly, any method of SO_2 removal will lead to reduction in ambient sulfate formation, given that a fixed percentage of emitted SO_2 will eventually convert to one sulfate form or another. Ideally, then, scrubbers used to control combustion-related sulfur oxides emissions have the beneficial effect of reducing both ambient SO_2 concentrations and byproduct sulfate concentrations, assuming that the same quality fuel would be used with or without scrubbers, and further assuming that sufficient conditioning of fuel gases (such as reheat) is applied to scrubbed gases so that the plume rise characteristics of scrubbed and non-scrubbed releases are similar.

In reality, of course, other factors must be considered. The incentive to use low-sulfur fuel, for example, is not as great if scrubbers are installed, so that the net effect at any given installation may be little or no decrease in SO_2 emissions. Furthermore, the more humid plume environment of scrubbed emissions may promote more rapid conversion of sulfur oxides to sulfates, possibly resulting in greater impact on local sulfate levels. In addition, there could be carryover of sulfate droplets which escape scrubber demisting equipment, with subsequent fallout of these droplets at distances fairly close to the stack.

Literature concerning the direct effect of scrubber usage on ambient sulfate formation is scant. The general assumption is that any method or reducing SO_2 emissions will also eventually result in lower sulfate concentrations, whether this be accomplished through use of scrubbers, fuel with lower sulfur content, fuel cleaning, or other means. The exact impact on sulfate levels resulting from any particular scrubber application depends on the specific scrubbing technique employed, fuel characteristics, stack characteristics, geographical and average atmospheric conditions, and other interacting factors.

4.6.2 Measured Sulfate Concentrations In Arkansas

4.6.2.1 Introduction

This section summarizes available Arkansas ambient atmospheric sulfate data and examines possible sulfate sources by mapping sulfur oxide emission source strengths on a local and regional scale. A brief review of meteorological conditions occurring simultaneously with episodes of high sulfate concentrations is also provided in an initial attempt to identify meteorological factors important in the formation and transport of sulfates. It should be understood that the results described in this section are not represented to be a comprehensive analysis of sulfate concentrations in Arkansas, but rather an overview of the subject based on a limited scope examination of readily available data.

4.6.2.2 Data Source

The data base used in this analysis was collected and provided by the Arkansas Department of Pollution Control and Ecology. It consists primarily of four years of sulfate concentration measurements (1973-1976), at a total of 76 monitoring stations located throughout the state of Arkansas. High volume samplers were used at the monitoring stations to collect 24-hour midnight to midnight air samples every sixth day during the four year interval. These samples were then analyzed by the turbidimetric barium sulfate technique to determine the 24-hour average sulfate concentration, in $\mu g/m^3$, on the given day for each station. Examination of this data set disclosed no obvious seasonal or area biases in the distribution of the data.

The data were initially examined to determine which days had highest sulfate concentrations. In order to make such a determination, the following criterion was used. A high sulfate concentration day was defined as any day on which 75 percent or more of the stations that sampled on that day reported sulfate concentrations of 10 $\mu g/m^3$ or more. A total of 26 days satisfied this criterion and were thus identified as the high sulfate concentration days. These days are listed in Table 4.6-1 in order of decreasing percentage of reporting stations with concentraions of 10 $\mu g/m^3$ or more. This sample set was then used to determine, first, the seasonal distribution and, second, the area distribution of high sulfate concentrations.

4.6.2.3 Seasonal Distribution

The seasonal distribution of these 26 high concentration days is presented in Figure 4.6-1. This bar graph shows that 65 percent of the days with high sulfate concentrations from 1973-1976 occurred during the four month period June through September.

4.6.2.4 Geographic Distribution

The objectives of the geographical analysis were to determine which monitoring stations reported the highest and lowest mean sulfate concentrations for the 26 high concentration days, and then to determine whether or not there was any pattern in the geographic location of these stations within the state. To achieve these objectives, the geometric mean sulfate concentration from all of the high sulfate concentration days was calculated for each of the 76 monitoring stations.

In order to screen out any stations with unrealistically high or low mean values due to a sporadic sampling record, an initial reduction was made in the number of monitoring stations under consideration. Any station which reported on 50 percent or less of the high concentration days was dropped from analysis. The remaining 42 stations are ranked in Table 4.6-2 in order of decreasing geometric mean sulfate concentrations. The number of high concentration days on which the station actually reported is also listed. This table shows that the six monitoring stations which reported the highest mean concentrations were:

Jonesboro CHFS
Blytheville FS
Jacksonville PO
Mt. Home PO
Eldorado PO/M OIL
West Memphis FS 3

Conversely the six monitoring stations which reported the lowest mean concentrations were:

Harrison FS
Crossett FD/PO
Van Buren FS
Fayet P&C Bldg.
Pine Bluff MC
Hope 2

The geographic locations of these stations are indicated in Figure 4.6-2. An examination of this map reveals that five of the six stations that reported high mean sulfate concentrations are located in the northeast quadrant of the state. Furthermore, the figure also shows that the stations reporting the lowest mean sulfate concentrations are located in either the western or southern portion of the state.

4.6.2.5 Emission Rates and Emission Densities

Total sulfur oxides emissions and emission densities for Arkansas and its neighboring states were estimated and compared. Total emissions are based on 1972 estimates available from the National Emissions Data System (USEPA, 1974). Emission densities were obtained by dividing estimated emission by the surface area of each state. Total emissions and emission densities are shown in Table 4.6-3. When evaluating these numbers, it is important to remember that emission density is an average value for the entire state, even though the majority of the emissions may be concentrated within a small area of that state. It should also be remembered that these figures pertain to the year 1972, prior to the sulfate measurement period analyzed. It is assumed that the ratio of emission densities is applicable to later years.

In Figure 4.6-3, the 1972 sulfur oxides emission density is specified for each particular state. This figure indicates that the states to the north and east of Arkansas have the highest emission densities (Missouri, Illinois, Kentucky, Tennessee and Alabama); whereas, the states to the west have relatively low emission densities (Kansas, Oklahoma and Texas). Arkansas had the lowest sulfur oxides emission density in the entire 11 state region. Relationships between emission densities also pertain to total sulfur oxide emissions. That is, total estimated 1972 emissions were lowest in Arkansas and highest in the states north and east of Arkansas.

4.6.2.6 Arkansas Point Source Emissions

An additional analysis was performed comparing the 1976 total sulfur dioxide point source emissions of different counties within the state of Arkansas. Table 4.6-4 presents the emission estimates for nearly all of the counties for 1976. These emission estimates are also indicated on the county map of Arkansas in Figure 4.6-4. An examination of this figure reveals that the sulfur dioxide point source emission estimates are greatest in the southern half of the state (El Dorado, Saline, Hot Springs and Columbia Counties). The emission estimates are lowest in the northern half of the state, with the exception of Benton County in extreme northwest Arkansas. It is of interest to note that three of the six monitoring stations which reported the highest geometric mean sulfate concentrations (Jonesboro, Blytheville and West Memphis) are located in counties which had low estimated total sulfur dioxide point source emissions. The implication is that these high concentrations are due to non-local sources either outside the state or in a different area of Arkansas.

4.6.2.7 Meteorological Factors

Atmospheric Water Vapor

Previous studies (Electric Power Research Institute, 1976) have indicated that there seems to be a strong positive correlation between high ground level sulfate concentrations and the moisture content of the atmosphere (expressed as dew point temperature). Consequently, an additional analysis was performed to determine whether or not this strong positive correlation was evident on the high concentration days cited in this report. Meteorological data from Little Rock, located approximately in the middle of the state, were used for this purpose.

To perform this analysis, 10-year (1967-1976) mean monthly dew point temperatures were obtained for Little Rock. The observed dew point temperatures were then obtained for Little Rock at 1200 Greenwich Mean Time (GMT) for each of the high sulfate concentration days. A comparison between the observed and mean monthly dew point temperatures was then made for each of these days. The results of these comparisons, as presented in Table 4.6-5, indicate that generally the observed 1200 GMT dew point temperature for a given high concentration day does not have a significant positive deviation when compared to the average dew point temperature for that month. Thus, a strong positive correlation between the high sulfate concentration days and days with unusually high dew point temperatures was not observed.

Atmospheric Dynamics

Atmospheric dynamics present during periods of high sulfate concentrations were studied to gain insight into the conditions and possible sulfur oxide emission source locations associated with high concentrations. The 700 mb (approximately 3000 m MSL) and 850 mb (approximately 1500 m MSL) synoptic weather analysis maps for the high concentration days were reviewed for similarities in dynamic patterns. The usual pattern included a large air mass of negligible horizontal pressure gradient covering a large portion of the southeast with the jet stream located near or above the northern edge of the United States. Figure 4.6-5 is an illustration of a typical 850 mb map on a high sulfate concentration day. Lacking a horizontal pressure gradient, the air is driven by local forces only, and there is no organized regional flow pattern. Under these conditions the upper level wind tends to be weak (less than 5 m/s) and the direction varies rapidly in time and over short distances.

If the air flow patterns over Arkansas could be defined with sufficient precision, the path of a particle arriving at a receptor in Arkansas could be traced backward to its source. This type of study is commonly called a trajectory analysis. The National Weather Service 850 mb and 700 mb wind data are collected once every 12 hours at stations located roughly 300 km apart. Regardless of the trajectory technique used, when the winds are driven by local forces only, the resolution of these data in both time and space is not sufficient to give a meaningful result. Stated differently, any trajectory technique (Petterssen, 1956; EPRI, 1976) using these data assumes that (a) each reading is representative of the winds for 12 hours at a given point, and (b) there is a continuous, relatively small change in the winds over the 300 km distance between stations.

Neither of these assumptions are valid when there is no regional wind driving force. In the 10 examples analyzed, wind directions at the upper air stations nearest to Little Rock varied more than 90° and often some were nearly 180° apart. It was also apparent from analysis of the 850 mb and 700 mb charts that wind direction was strongly a function of height. There was often a complete reversal of direction between the two levels. Thus, air at different elevations above Arkansas flowed from different directions at the time when high sulfate concentrations occurred. Trajectory analysis would require greater spatial and temporal resolution of the data.

4.6.2.8 Summary

On the basis of the information examined, no definitive conclusions can be reached concerning the ultimate sources of emissions which eventually result in measured high sulfate concentrations in Arkansas. High sulfate episodes are most frequent during summer months and occur predominantly when large-scale air mass movement is sluggish, thus providing a mechanism for accumulation of sulfates over a large area. Comparison of sulfur oxide emission densities between Arkansas and adjoining states implies that regional emissions are an important factor in Arkansas sulfate concentrations. Transport of sulfates and sulfate precursors from areas outside the state are further implied by the tendency toward highest sulfate concentrations in the northeast corner of the state where local sulfur oxide emissions are fairly low.

Table 4.6-1

High Sulfate Concentration Days From 1973-1976[a]

Date	Percentage of stations with concentrations ≥10 μg/m³	Date	Percentage of stations with concentrations ≥10 μg/m³
9/13/73	100	8/21/74	89
6/11/76	100	8/20/73	88
8/20/73	88	5/24/75	88
8/10/76	100	5/24/75	88
7/28/74	98	5/30/76	87
6/4/74	97	4/30/76	85
7/29/75	97	1/11/74	84
6/28/74	95	8/22/76	84
6/29/75	93	8/4/76	83
8/26/73	91	2/27/73	79
10/7/73	91	6/5/76	79
4/12/76	91	9/8/74	77
7/5/76	91	2/6/76	75
1/5/74	90	9/20/74	75

[a]Days when 75 percent or more of the reporting stations had sulfate concentrations of 10 μg/m³ or more

Table 4.6-2

Stations Which Reported on Greater Than 50 Percent of the High Sulfate Concentration Days[a]

Rank	Station Name	Number of Reporting Days	Geometric Mean SO_4 Concentration
1	Jonesboro CHFS	26	21.11
2	Blytheville FS	26	20.34
3	Jacksonville PO	26	19.61
4	Mt. Home PO	15	19.31
5	Eldorado PO/M Oil	26	19.25
6	W. Memphis FS 3	25	19.11
7	Sherrill	17	18.57
8	Little Rock WB	26	18.52
9	Helena FS	26	18.40
10	Plum Bayou School	17	17.97
11	Earle FS	25	17.58
12	Magnolia WW	26	16.99
13	Bryant School	25	16.86
14	Stuttgart PAS	24	16.76
15	Conway Mun Bldg	25	16.72
16	Stuttgart HMS	25	16.21
17	Hardy Arkmo PC	17	16.19
18	Russellville WTEL	26	16.16
19	W. Memphis Cent.	24	16.09
20	Forrest City M	25	15.55
21	Hope PO	25	15.41
22	Dumas PO	14	15.25
23	Ft. Smith FS1	17	15.23
24	England CC	19	15.03
25	Rose City PO	24	14.64
26	Paragould MFS	23	14.44
27	Texarkana REHB	25	14.41
28	FS&L Stuttgart	24	14.20
29	Camden FS	24	14.16
30	Hot Springs FS/NE	24	14.13
31	NW Ark RPC	15	14.03
32	Rogers	17	14.01
33	Arkadelphia FS	25	13.75
34	Stuttgart AP	19	13.45
35	Stuttgart KWAK	19	13.34
36	Altheimer TWR	16	13.27
37	Harrison FS	25	13.20
38	Crossett FD/PO	24	12.91
39	Van Buren FS	17	12.76
40	Fayet P&C Bldg	26	12.52
41	Pine Bluff MC	23	11.87
42	Hope 2	16	11.69

[a]Ranked in order of decreasing geometric mean sulfate concentrations

Table 4.6-3

Estimated 1972 Total Sulfur Oxides Emissions and Emission Density for Arkansas and Neighboring States

State	Total Sulfur Oxides Emissions ($kg/yr \times 10^8$)	Area ($km^2 \times 10^5$)	Sulfur Oxides Emission Density ($kg/yr\text{-}km^2$)
Arkansas	.40	1.38	290
Texas	7.52	6.92	1,090
Oklahoma	1.31	1.81	720
Kansas	.87	2.13	410
Missouri	11.51	1.80	6,390
Illinois	20.40	1.46	13,970
Kentucky	12.01	1.05	11,440
Tennessee	11.78	1.09	10,810
Alabama	8.82	1.34	6,580
Mississippi	.51	1.24	410
Louisiana	1.66	1.26	1,330

Note: Emission density was obtained for each state by dividing total emissions by surface area.

Source: USEPA, 1974.

Table 4.6-4

Total Sulfur Dioxide Point Source Emissions for Counties in Arkansas, 1976

County	Total Sulfur Dioxide Point Source Emissions (kg/yr x 10^3)	County	Total Sulfur Dioxide Point Source Emissions (kg/yr x 10^3)
Arkansas	5	Lawrence	0
Ashley	5,805	Lee	0
Benton	17,308	Lincoln	0
Boone	0	Little River	1,434
Bradley	120	Logan	0
Carroll	0	Lonoke	0
Chicot	4	Marion	0
Clark	10	Miller	1,540
Clay	2	Mississippi	19
Cleburne	0	Monroe	1
Columbia	4,903	Montgomery	0
Conway	1,189	Nevada	31
Craighead	101	Ouachita	2,974
Crawford	0	Phillips	7,909
Crittenden	0	Pike	8
Cross	0	Poinsett	1
Dallas	30	Pope	1
Desha	201	Prairie	0
Drew	2	Pulaski	1,202
Faulkner	0	Randolph	0
Franklin	936	St. Francis	1,084
Garland	65	Saline	9,512
Grant	46	Scott	0
Greene	0	Sebastian	5
Hempstead	0	Sevier	0
Hot Springs	6,227	Sharp	0
Howard	62	Union	20,192
Independence	1,501	Van Buren	0
Izard	0	Washington	0
Jackson	141	White	10
Jefferson	11,365	Woodruff	1,268
Johnson	0	Yell	0
Lafayette	398		

Source: ADPCE, 1977

Table 4.6-5

Difference Between Little Rock Dew Point on High Sulfate Concentration Days and Mean Monthly Dew Point

Date	Observed Dew Point at 1200 GMT (°C)[a]	Mean Monthly Dew Point (°C)[b]	Observed - Mean (°C)
2/27/73	0	0	0
8/20/73	18	20	-2
8/26/73	19	20	-1
9/13/73	19	17	+2
10/7/73	19	11	+8
1/5/74	-3	0	-3
1/11/74	-2	0	-2
6/4/74	17	19	-2
6/28/74	15	19	-4
7/28/74	20	21	-1
8/21/74	18	20	-2
9/8/74	16	17	-1
9/20/74	16	17	-1
5/24/75	19	19	0
6/29/75	21	19	+2
7/29/75	22	21	+1
2/6/76	-4	0	-4
4/12/76	6	10	-4
4/30/76	5	10	-5
5/30/76	18	14	+4
6/5/76	*	19	*
6/11/76	*	19	*
6/5/76	*	21	*
8/4/76	12	20	-8
8/10/76	15	20	-5
8/22/76	16	20	-4
5/26/77	16	14	+2
5/27/77	17	14	+3

*Data not available.

Source:

[a] U. S. Department of Commerce, 1973-1977.

[b] U. S. Department of Commerce, 1967-1976.

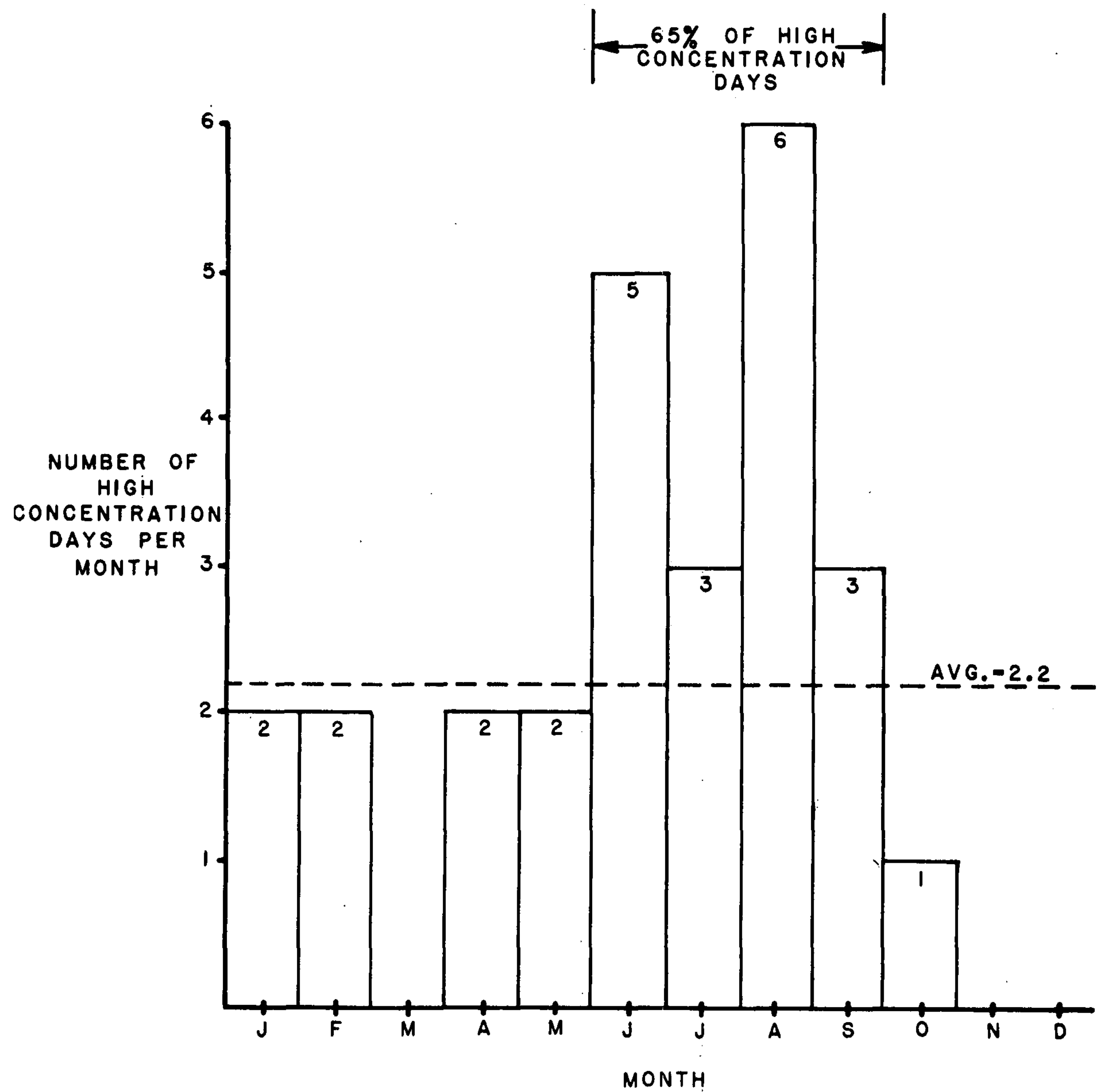
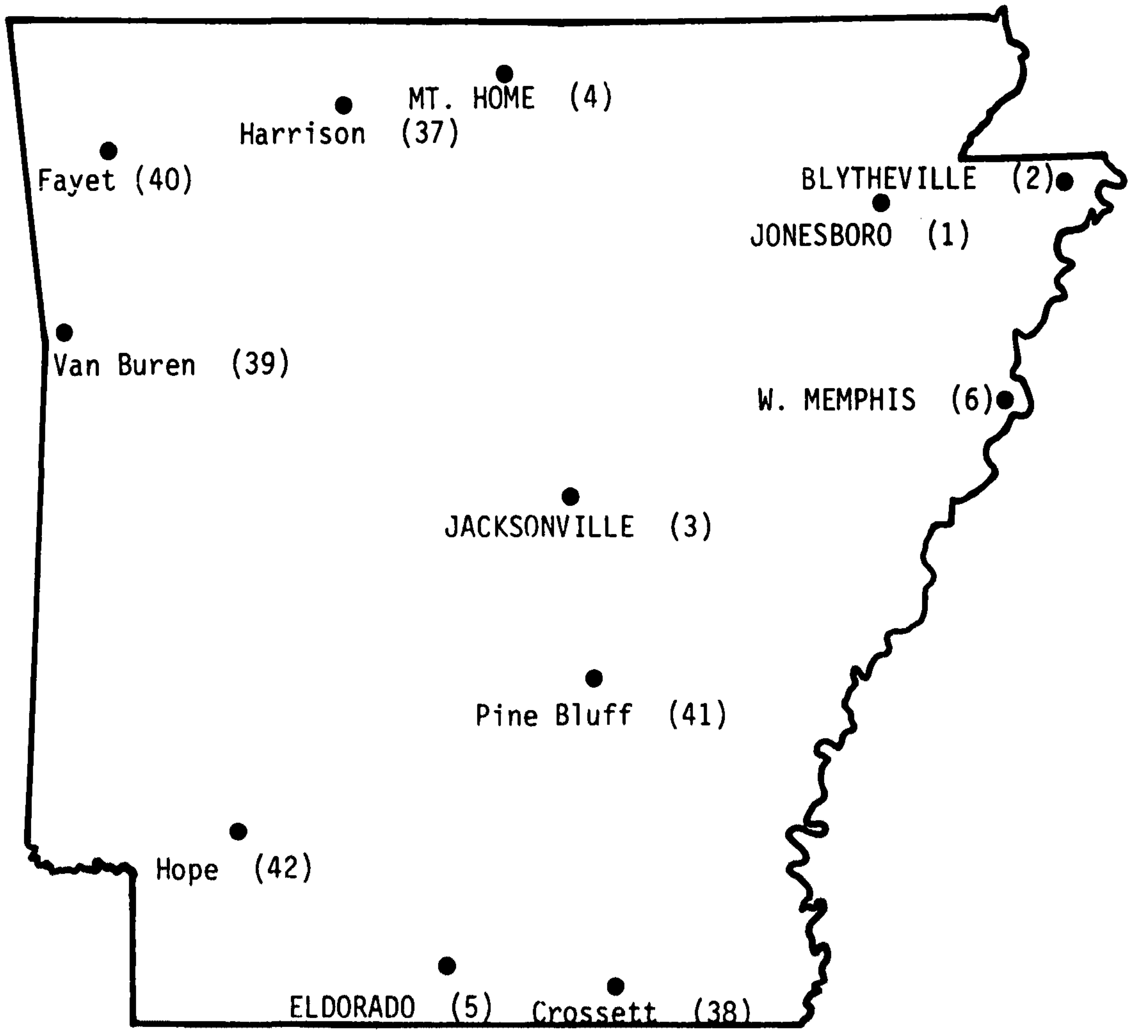


Figure 4.6-1. Number of high sulfate concentration days ($\geq$10 $\mu g/m^3$ at 75% or more of reporting stations) per month.



UPPER CASE indicates stations with highest concentrations days.
Lower Case indicates stations with lowest concentrations days.
Parentheses enclose station rank.

Figure 4.6-2. Location of 6 highest and 6 lowest sulfate concentration stations.

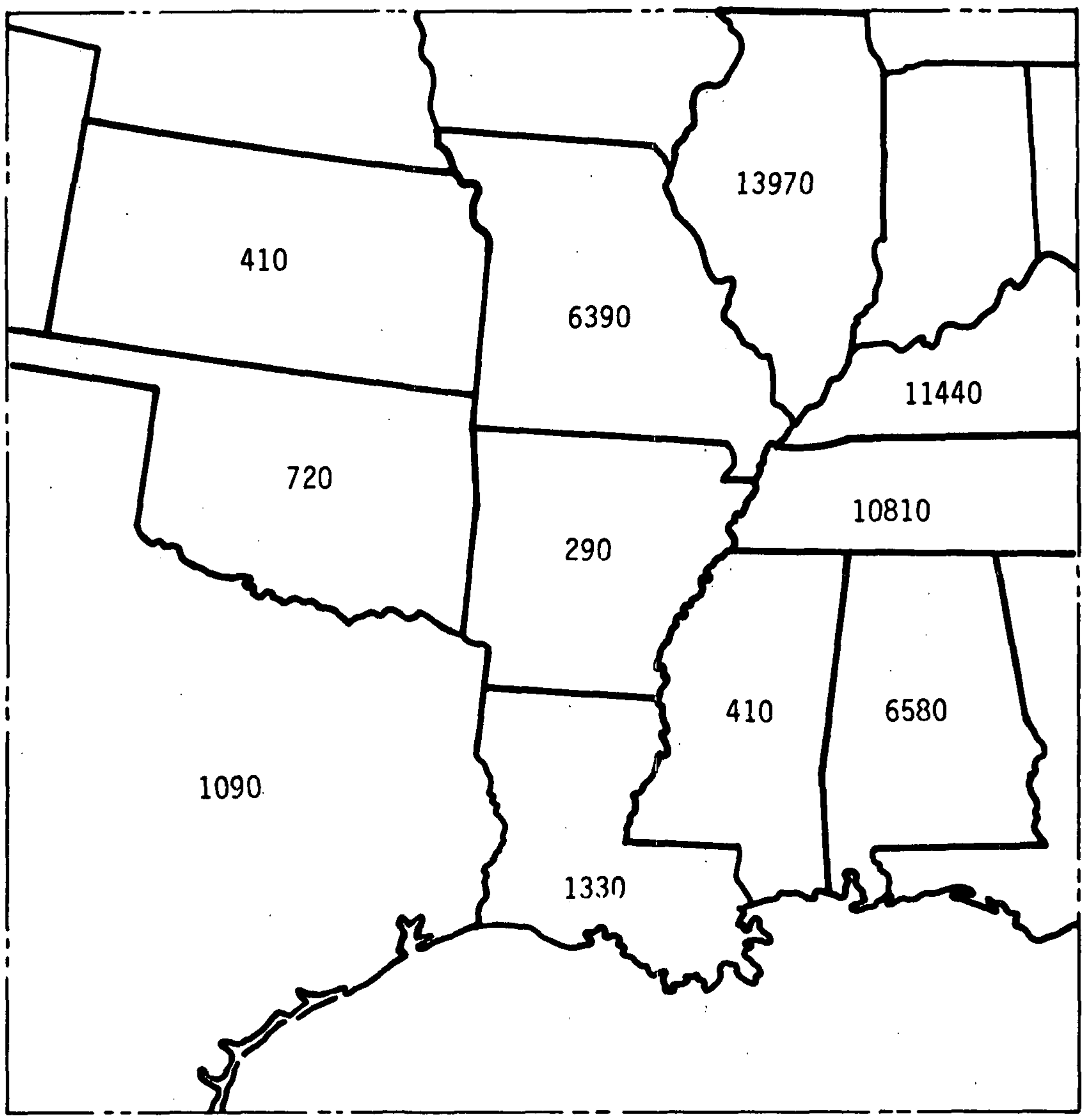
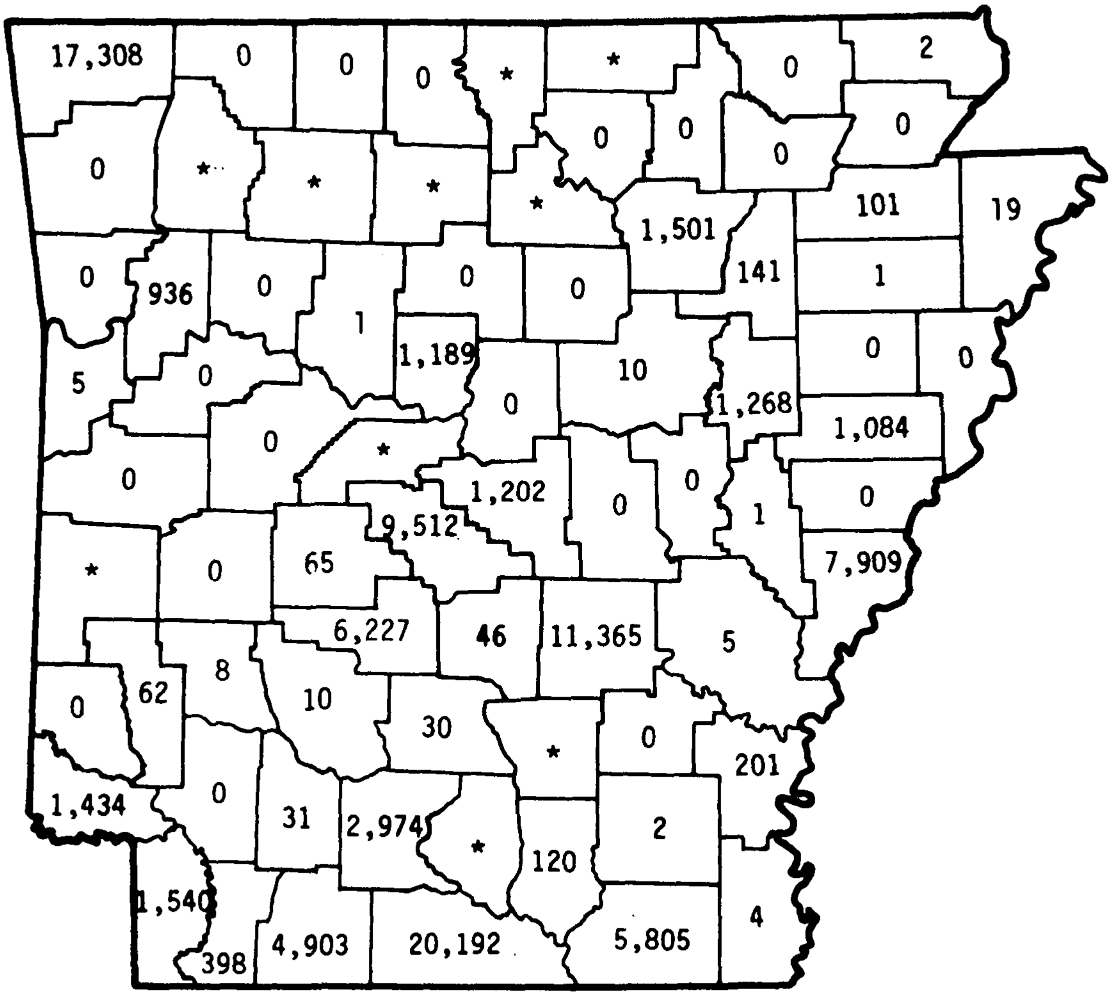


Figure 4.6-3. 1972 sulfur oxides emission densities (kg/yr-km^2).



*No emissions indicated.

Source: ADPCE, 1977.

Figure 4.6-4. Arkansas 1976 sulfur dioxide point source emissions by county (kg/yr x 10^3).

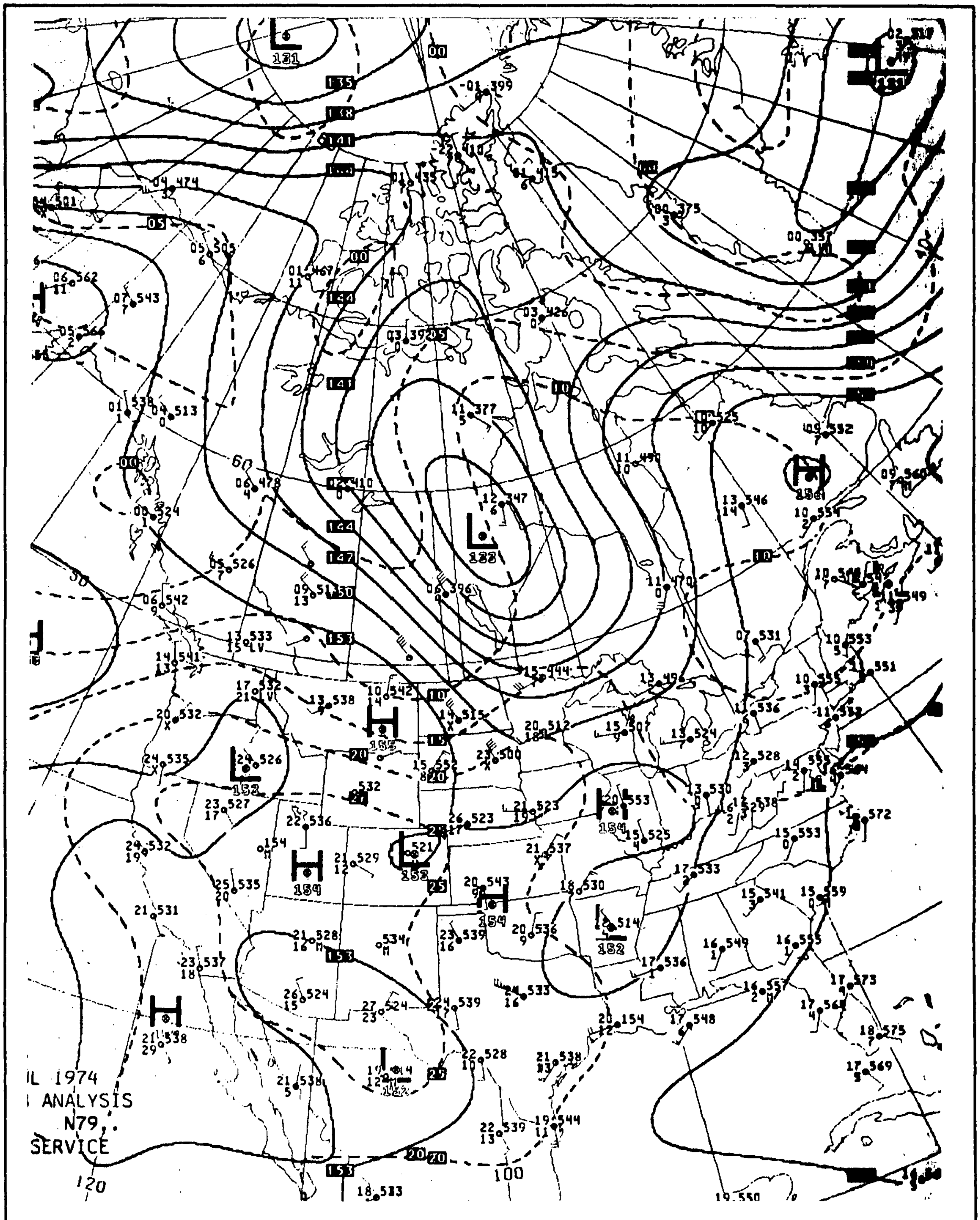


Figure 4.6-5. Typical 850 mb chart for a day of high sulfate concentrations in Arkansas.

4.7 TRACE ELEMENT RELEASES

A listing and quantitative analysis of significant trace elements found in the coal to be used at the Independence Steam Electric Station is shown in Table 4.7-1. It is assumed that, with the exception of mercury, these elements will appear in the ash residue of the combustion process and will be subject to the removal mechanisms applicable to the total ash formed - that is, 20 percent of the total will fall out prior to entering the electrostatic precipitators, and 99.5 percent of the remainder will be removed by the precipitators. Mercury will be predominantly liberated as an elemental mercury vapor, and it can be conservatively assumed that all of the mercury in the coal will be emitted to the atmosphere. Based on the maximum trace element content values in Table 4.7-1 and on fuel consumption rates for coal with Btu content at the lower end of the coal contract range (8200 Btu/lb), maximum trace element emission rates for the peak operating level of 110 percent of rated capacity have been estimated. These rates are reported in Table 4.7-2.

By comparing trace element emission rates with sulfur dioxide emission rates, it is possible to derive estimates of trace element ambient concentrations through proportional reduction of the SO_2, ambient concentrations obtained by computer modeling calculations. The difficulty lies in interpreting the significance of trace element ambient concentrations thus derived.

As of this time, there are no national or State of Arkansas ambient air quality standards for trace elements. Reference can be made, however, to industrial hygiene standards as an approximate basis of comparison. Occupational exposure standards have been adopted by the Occupational Safety and Health Administration (OSHA) for each of the elements listed in Table 4.7-1. These standards are presented in Table 4.7-3 in terms of either an 8-hour average concentration or a short-term ceiling concentration which is not to be exceeded.

At peak load with both generating units in operation, SO_2 emissions are estimated to be roughly between 10,000 and 15,000 pounds an hour. This constitutes an emission rate which is 4 to 6 orders of magnitude higher than maximum trace element emission rates as listed in Table 4.7-2. Consequently, trace element ambient concentrations will be 4 to 6 orders of magnitude lower than SO_2 concentrations and, therefore, considerably below OSHA occupational exposure standards. For example, the lowest OSHA ceiling concentration standard, which is roughly analogous to a 30-minute concentration, is the beryllium standard of 5 $\mu g/m^3$. This value is 2 orders of magnitude less than the Arkansas 30-minute SO_2 standard, but since beryllium emissions are estimated to be about 6 orders of magnitude less than SO_2 emissions, beryllium concentrations will be well below the OSHA standard.

Although OSHA standards were developed for different purposes and for different populations than were ambient air quality standards, the fact that trace element concentrations are estimated to be orders of magnitude below the OSHA standards is a reasonable indication that adverse health effects attributable to trace element emissions will be avoided. It is not possible to judge if continuous trace element emissions will have a cumulative effect on vegetation and soil conditions, but again the extremely low concentrations involved suggest that adverse effects are unlikely.

Table 4.7-1

Coal Trace Element Analysis
(Dry, Whole Coal Basis)

Element	Average Content, Percent by Weight	Content Range (± 2 Std. Dev.), Percent by Weight	
		Minimum	Maximum
Antimony	0.00008	0	0.0002
Arsenic	0.00007	0	0.00015
Beryllium	0.00005	0.00001	0.00009
Boron	0.0142	0.006	0.0224
Cadmium	0.0001	0	0.00015
Chromium	0.0007	0.0003	0.0011
Copper	0.0013	0.0007	0.0019
Fluorine	0.0085	0.0015	0.0155
Lead	0.0012	0	0.0032
Lithium	0.00051	0.00005	0.00097
Manganese	0.0008	0.0004	0.0012
Mercury	0.00001	0.000001	0.00002
Nickel	0.0008	0	0.0018
Silver	0.00004	0.00002	0.00006
Vanadium	0.0018	0.001	0.0026
Zinc	0.0016	0	0.0044

Table 4.7-2

Estimated Maximum Emission Rates of Trace Elements

Element	Emission Rate, lb/hr[a]
Antimony	0.02
Arsenic	0.01
Beryllium	0.01
Boron	1.82
Cadmium	0.01
Chromium	0.09
Copper	0.15
Fluorine	1.26
Lead	0.26
Lithium	0.08
Manganese	0.10
Mercury	0.41
Nickel	0.15
Silver	0.01
Vanadium	0.21
Zinc	0.36

[a]Based on maximum coal trace element content, both generating units operating at peak load, and assuming coal heat content of 8200 Btu/lb; all elements except mercury assumed to be in particulate form and subject to removal by particulate control systems; all mercury in coal assumed to be vaporized and to be emitted into atmosphere.

Table 4.7-3

Occupational Safety and Health Administration (OSHA)
Workplace Exposure Standards

Material	8-Hour Time Weighted Average ($\mu g/m^3$)	Ceiling Concentration ($\mu g/m^3$)
Antimony and compounds	500	-
Arsenic and compounds	500	-
Beryllium and compounds	2	5
Boron (as boron oxide)	15000	-
Cadmium fume	100	600
Chromium, metal and insoluble salts	1000	-
Copper fume	100	-
Fluorine	200	-
Lead and its inorganic compounds	200	-
Lithium (as lithium hydride)	25	-
Manganese	-	500
Mercury	100	-
Nickel, metal and soluble compounds	1000	-
Silver, metal and soluble compounds	10	-
Vanadium (as V_2O_5 fume)	-	100
Zinc (as zinc oxide fume)	5000	-

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PART 5
AQUATIC ECOLOGY

TECHNICAL SUPPORT DOCUMENT

PART 5

AQUATIC ECOLOGY

CONTENTS

TABLES

FIGURES

PART 5

AQUATIC ECOLOGY

5.1 INTRODUCTION

The various plant and animal components of the aquatic community are constantly interacting with one another and with the non-living portions of the environment which surrounds them. Because of this relationship, biological impacts resulting from changes in the aquatic environment can be estimated only if a baseline definition of existing communities is known.

In an effort to supplement baseline data available from the literature, Dames & Moore conducted three comprehensive aquatic field studies in the site area. These surveys were conducted in November 1976, May 1977, and July 1977 in order to collect data indicating seasonal differences in aquatic populations. Sampling involved several stations on the White River during all three programs; Wall and Round Lakes were also included in the summer survey. The scope of the work involved varied among the sampling periods, as indicated by the detail of the results presented for water quality and sediment analyses (TSD Tables 2.1-7 and 2.1-8) and for biological analyses (Tables 5.4-1 through 5.4-7).

In addition to the comprehensive sampling efforts, a field survey was conducted in November 1977 solely to characterize the area's mussel population. The purpose of the program was two-fold: 1) to provide a definition of the size and species composition of the mussel populations and 2) to determine the presence or absence of *Proptera capax*, listed as endangered by the U. S. Fish and Wildlife Service (Section 5.5.1.5), near the site. Due to the sensitive nature of endangered species issues, this program was carried out under an agreement with the Arkansas Game & Fish Commission. Among other requirements, this agreement stipulated that collection of any *P. capax* specimens should not be reasonably anticipated to result in the death or permanent disablement of the organism. A representative of the U. S. Fish and Wildlife Service, Mr. Dennis Jordan (Jackson, Mississippi office), was present during a major portion of the mussel sampling efforts.

5.2 SAMPLING STATIONS

With regard to the comprehensive sampling program, sampling stations on the White River were selected with the intention of providing data from points upstream, adjacent to, and downstream of the intake and discharge areas so that it would be possible to make meaningful comparisons between pre- and post-operational biological data, if necessary. Round and Wall Lake sampling locations were added to the program in order to provide data on two areas that may receive drainage from the site. All station locations are shown on Figure 5.2-1. Sampling was conducted in the vicinity of these stations at points considered to be representative of conditions in the general station area.

Station 1. This station was chosen for its location upstream of the site area and away from any impacts which might occur as a result of plant construction or operation. It is situated approximately at river mile (RM) 273 east of Pleasant Island near a small, unnamed island. The unnamed island supports a stand of trees such as cottonwood, maple, oak, and hickory, some of which overhang the river. The bottom substrate is primarily sand, with some gravel.

Station 1A. This station, located on the opposite side of the island from Station 1, was added to the spring program in order to obtain information on the aquatic populations in an area away from the main stream channel. Stream flow is relatively swift in much of this station area, but some quiet places are present, and a considerable amount of debris (fallen trees and logs) has accumulated in the water. The bottom consists of clay, sand, and organic detritus.

Station 2. Located at the downstream end of a slip-off slope on Hulsey Bend just upstream of RM 270, Station 2 is also upstream of the proposed intake and discharge structures. The substrate is sand and some gravel.

Station 2A. Station 2A is located in the mouth of the Swan Lake Drainage Ditch approximately at RM 269 and near the site of the proposed intake and discharge structures. Numerous hardwoods and shrubs line the shoreline at this station. Muck, clay, and organic detritus comprise the substrate. In the summer, the mouth of the ditch was almost dry due to the low flow conditions of the White River.

Station 3. This station is situated near the mouth of Bear Wallow Slough just upstream of RM 267. The small, quiet area formed by the slough mouth is surrounded by a dense growth of hardwoods, shrubs, and vines. During the fall and spring, water movement in this area appeared to be negligible due to the presence of an underwater sediment deposit at the slough's intersection with the river. In the summer period, the low flow conditions of the river had left the sediment deposit partially exposed, temporarily eliminating the slough mouth's connection with the river.

A large amount of organic debris is present in the area of the slough mouth; the substrate is sand and organic detritus. Across the river from the slough mouth is a slip-off slope which is characterized by a sand, gravel, and cobble bottom. Some sampling activites were conducted at this location.

Station 4. Located approximately at RM 266 near a slip-off slope, Station 4 was selected in the fall as being representative of conditions immediately downstream of the preliminary site boundaries. The site location was more clearly delineated before the spring sampling period, and intensive sampling at this station was eliminated in favor of a location farther downstream. Sand, gravel, and cobble comprised the substrate here.

Station 5. This station was added in the spring to ensure collection of data below the site boundaries. It is located in the vicinity of the Wall Lake drainage entrance into the White River approximately at RM 263.5. The quiet area formed by this entrance is surrounded by hardwoods. During part of the spring effort, a plume of water, appearing much lighter in color than the river water, was observed to originate within this tributary mouth and flow into the river.

In the summer period, the drainage entrance was almost dry. Sampling was conducted in the river channel along the sand bar across from the ditch entrance into the river.

Station 6. This station, sampled during the summer only, is located on Wall Lake. The lake is surrounded by agricultural land, with a narrow strip of trees near the shoreline. The average water depth was less than 0.3 m. Muck, commonly as much as 0.8 to 0.9 m deep, comprised the bottom substrate.

Station 7. This station was also surveyed only during the summer period. It is located on Round Lake, which is tree lined along its border but drains primarily agricultural land. During the summer sampling effort, the average water depth was about 0.9 m. The bottom consisted of muck, ranging in depth from 0.1 to 0.5 m.

The November 1977 mussel sampling effort was conducted between White River miles 261 (near the confluence with the Black River) and 276 (about 1 mile upstream of the old Oil Trough ferry landing). Gravel was the main substrate component in most areas studied. However, a small, unstable sand bar, located upstream of the Oil Trough ferry, and some sand-gravel islands and slip-off slopes were also surveyed, providing some habitat variety.

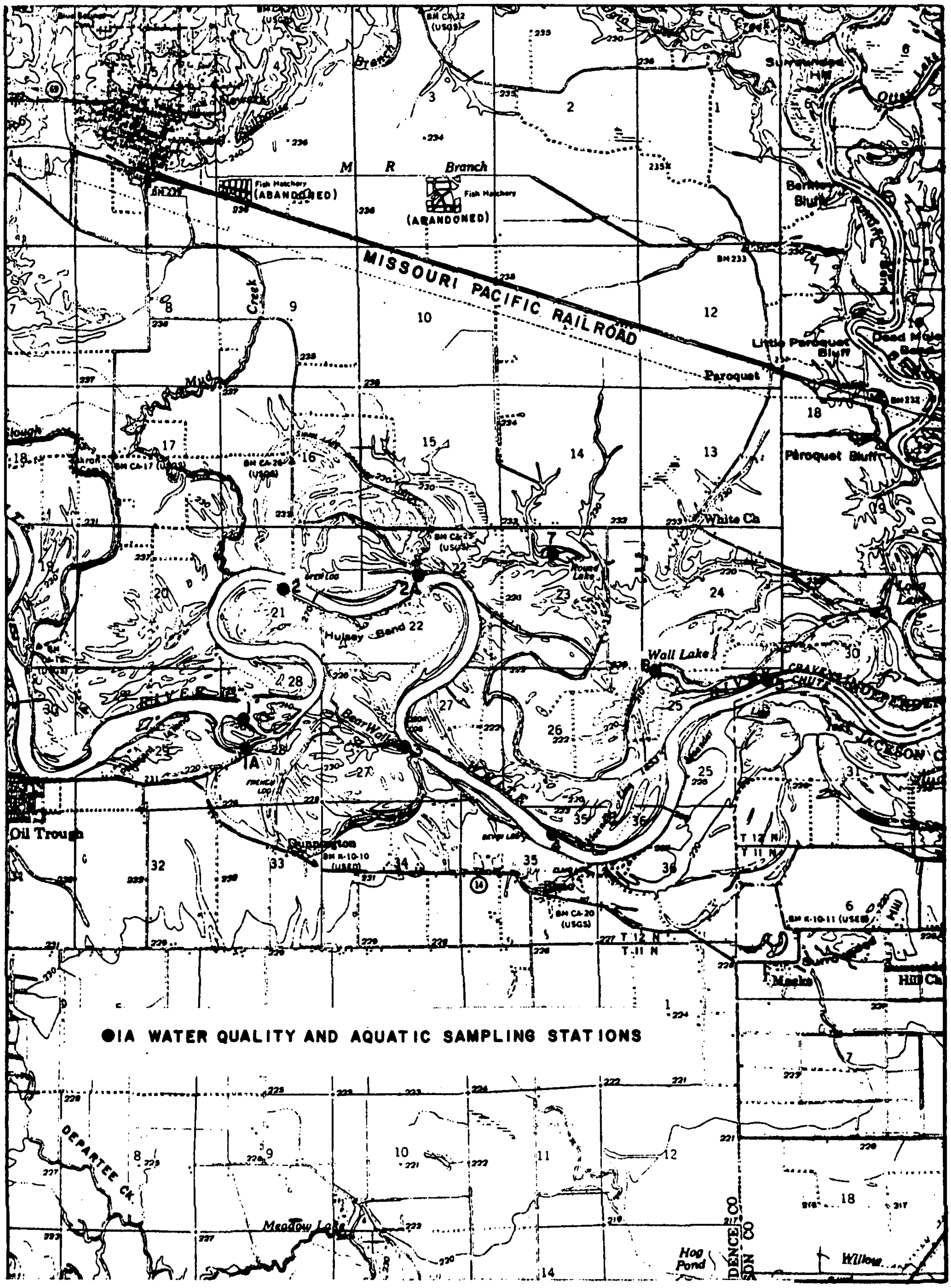

Figure 5.2-1. Location of aquatic sampling stations.

5.3 METHODS

5.3.1 Aquatic Flora

Phytoplankton

Twenty liters of whole water were pumped from a water depth of approximately 0.2 m into a container. Duplicate 1 liter samples were removed from the container and preserved with Lugol's solution and formalin. Organisms were identified and counted in the laboratory. In the fall, laboratory analysis involved the use of a Sedgwick-Rafter (S-R) cell. Spring and summer phytoplankton samples were analyzed by two methods. The S-R cell was used in order to provide data which could be compared with that obtained in the fall; the inverted microscope (IM) technique was also employed as a back-up method to check results of the S-R procedure. Quantitative analyses were performed by counting individual cells except in the case of blue-green filaments. Each of these filaments was counted as an individual cell.

Periphyton

Periphyton were collected at all stations where suitable substrate was accessible. Samples were gathered by scraping material from natural substrates considered to be submerged at all times under normal conditions or by collecting the entire substrate. Specimens were preserved in Lugol's solution and formalin and sent to the laboratory for identification.

Vascular Hydrophytes

The presence of significant rooted and floating vascular plant populations was determined by a general survey of the study area. When possible, observed species were identified in the field. Representative specimens of unknown macrophytes were pressed and sent to the laboratory for indentification.

5.3.2 Aquatic Fauna

Zooplankton

Duplicate 100 liter whole water samples were pumped through a No. 20 plankton net from a depth of about 0.2 m. Plankton were rinsed into a container and preserved with Lugol's solution and formalin. Organisms were identified and counted in the laboratory with a S-R cell.

Benthic Macroinvertebrates

Triplicate benthos samples were collected with a 6-inch Ekman sampler and then filtered through a U.S. Standard No. 30 wire mesh sieve. In addition, some specimens were collected incidentally while seining for fish.

During the summer period, a 4-foot brail was employed for the collection of mussels. The brail was towed in the vicinity of several stations for a combined distance of approximately 1800 feet, and a total area of about 7200 square feet. All stations as well as other areas between stations were also visually searched for live mussels.

In the fall, only organisms observed with the unaided eye were preserved in formalin, stained with rose bengal, and sent to the laboratory for analysis. In the spring and summer, all material retained after sieving was preserved and then analyzed in the laboratory.

During the November 1977 mussel survey, a total distance of 3090 yards, representing an area of about 10,300 square yards was brailed. In addition, several locations were visually searched, and one site upstream of the old Oil Trough ferry was sampled by diving.

Mr. K. C. Ward, a commercial mussel fisherman from Clarendon, Arkansas, and Mr. Raymond Spicer, a mussel shell buyer from Helena, Arkansas, operated the brailing and diving equipment. Both men are familiar with the White River and its mussels. Brailing was conducted with a 10-foot brail consisting of a metal rod to which approximately 250 14-guage crowfeet were attached by nylon cording. The brail was lowered over the side of the boat and dragged for distances ranging from 40 to 150 yards per haul. Areas which were brailed most heavily included: 1) those for which local residents indicated the recent presence of small mussel populations (RM 275-276, RM 272-273 and RM 267-268), and 2) those near the proposed intake/discharge structures (RM 269-270). Water depths were estimated from the length of the brail lead line after initial lowering or just prior to retrieval of the brail.

Several areas were searched for mussels both visually, in particularly shallow waters where the bottom could be seen, and by the use of rakes in somewhat deeper waters where the bottom was not visible. The rakes were used, while wading, to feel along the bottom for mussel shells and as a means of retrieval.

Diving was employed as a sampling method at only one location, just upstream of the old Oil Trough ferry landing. No other areas yielded a sufficient number of specimens as a result of brailing to justify the use of a diver. The diving apparatus consisted of a weighted metal "helmet" fitted with a hose connected to a reserve air tank on the boat. After being fitted with the necessary equipment, the mussel fisherman dived to the river bottom and collected all of the mussels he could find in a 5-minute period. The low temperature of the water precluded the possibility of a more lengthy dive.

Specimens collected by all methods were identified in the field by Mr. Clarence Clark, a former professor at Ohio State University and past Supervisor of Fisheries for the Ohio Game and Fish Commission. Soft parts of all specimens were removed, and the shells were retained for later verification of taxonomy, if necessary.

Fish

Several methods were employed for fish collection. In the fall period, at least three seine hauls were made with a 25-foot, 1/8-inch mesh net at each station. A total of six hauls was made at Station 3, half in the entrance to Bear Wallow Slough and the remainder just across the river near the slip-off slope. Six hauls were also made at Station 1, three on each side of the river. In the fall, two gill nets were set at Station 2 for approximately 21 hours; one gill net was set at Station 3 in the slough mouth for about 19.5 hours. Gill nets were not used at Station 1 or 4 due to the extremely swift river flow and shallow water conditions, respectively. Fyke nets were employed in the fall at Stations 1 and 2 only. Conditions at the other stations were not conducive to their use. The fyke net at Station 1 remained in place for approximately 21.5 hours. However, the net at Station 2 was not retrieved for almost 48 hours; high stream flows made earlier net retrieval at this station impossible.

Spring sampling at Stations 1 and 1A included three seine hauls with a net similar to the one used in the fall; six hauls were made at Station 3 at the same locations seined in the fall. The current at Station 2 was too swift to allow seining. Fish were collected at Station 4 with a dip net. Gill nets were utilized only at Stations 3 and 5 during the spring due to the presence of unsuitable conditions at the other stations. The net at Station 3 remained in place for about 22 hours while the one at Station 5 was set for 19 hours. Fyke nets were used only at Station 1A, where two were set for approximately 23 hours. Conditions at all of the other stations were not conducive to fyke net sampling during the springtime.

During the summer, seining was the only method of fish collection employed since the extremely low water levels made the use of gill or fyke nets impractical. A 25-foot bag seine was used in this effort. Three hauls were made at each station except Station 3 where six hauls were made, as before, and Stations 6 and 7 where seining was not possible because of the mucky bottoms.

During each field survey, large fish were measured and weighed after identification in the field. Smaller specimens were preserved in formalin and sent to the laboratory for identification and permanent preservation in alcohol. In the spring, laboratory analysis of all fish specimens included the designation of life stage. Some fish collected in the summer were also classified by life stage.

5.4 RESULTS

Results of aquatic biological surveys for phytoplankton, periphyton, zooplankton, benthic macroinvertebrates, and fish conducted during the three comprehensive aquatic sampling programs are shown in Tables 5.4-1 through 5.4-6. For comparative purposes, Table 5.4-7 indicates not only the fish species collected during the Dames & Moore monitoring program, but also those collected during other efforts in the site area. The vascular hydrophytes were not abundant in either the White River or Round and Wall Lakes. A few specimens of arrowhead (*Sagittaria* sp.) were observed at Station 1A and duckweed (*Lemna* sp.) was seen floating in the water at Station 7. Table 5.4-8 presents the results of the November 1977 mussel sampling program.

Table 5.4-1

Phytoplankton Collected from the White River in the Site Area[a]

Species	Station/Sampling Period[b] 1 F	1 Sp	1 Su	2 F	2 Sp	2 Su	3 F	3 Sp	3 Su	4 F	5 Sp	5 Su
Chlorophyta												
Chlorophyceae	2400	49050 (11250)[c]	58000 (12950)	13400	21500 (6550)	46000 (67600)	8700	5000 (6450)	35500 (88150)	6700	7000 (12300)	8000 (16100)
Volvocales												
Chlamydomonas spp.			2500 (150)						1000 (1350)			
Dysmorphococcus variabilis		(50)										
Gonium sociale									(200)			
Pandorina morum			8000		(800)							
Tetrasporales												
Gloeocystis planctonica		3500 (500)	500		500 (600)			500 (750)			1500 (650)	(200)
Chlorococcales												
Actinastrum hantzschii			(1200)			2000 (11500)			4000 (1700)		(400)	
Ankistrodesmus convoluta			5000 (850)			6500 (5050)			7500 (12950)			500 (400)
A. falcatus		1000	7500 (600)		1000	7000 (8900)		500 (50)	10000 (10700)		1500 (400)	4500 (4900)
Coelastrum microporum						(1600)						
Coelosphaerium microporum		(1600)			(1200)			(400)				(3200)
Crucigenia irregularis		40000							2000 (13800)		1400	
Dictyosphaerium puchellum						(13800)						
Kirchneriella obesa			2500			3500 (2600)			3000 (5450)			
Pediastrum boryanum			8000						(3200)			

Species	1 F	1 Sp	1 Su	2 F	2 Sp	2 Su	3 F	3 Sp	3 Su	4 F	5 Sp	5 Su
	Station/Sampling Period [b]											
P. duplex			16000		16000						(1600)	
P. tetras			4000									
Planktosphaera gelatinosa						4000						
Scenedesmus arcuatus		2550 (5000)	(2400)		2000 (2950)	8000		4000 (2200)	(16400)		2000 (5200)	
S. bijuga			(300)		(400)	(6800)			(7600)			
S. quadricauda		2000 (4100)	2000 (7250)		2000 (600)	15000 (17000)		(2800)	8000 (14800)		2000 (1800)	3000 (7400)
S. serratus			2000 (200)			(200)		(200)				
Tetraedron minimum						(150)		(50)				
Chaetophorales												
Stigeoclonium sp.											(850)	
Conjugatophyceae		3000 (1100)	3500 (2200)		1500 (500)	1500 (6500)		(600)	4500 (3850)		3500 (450)	500 (350)
Zygnematales												
Mougeotia sp.								(200)				
Desmidiales												
Closterium ehrenbergii			500 (100)			500			500			
Cosmarium undulatum		3000 (1050)	3000 (2100)		1500 (500)	1000 (6500)		(350)	4000 (3850)		3500 (450)	500 (350)
Staurastrum turgescens		(50)						(50)				

Species	Station/Sampling Period[b]										
		1			2			3		4	5	
	F	Sp	Su	F	Sp	Su	F	Sp	Su	F	Sp	Su
Englenophyta												
Euglenophyceae		500	1000 (1150)		(150)	4500 (400)	300	(150)	8000 (3050)		500	1500 (700)
Euglenales												
<u>Euglena acus</u>			500			1000 (50)						(50)
<u>E. tripteris</u>								(100)			500	
<u>E. variabilis</u>		500	(1050)		(150)	3500 (300)			5500 (2000)			1500 (650)
<u>Strombomonas swirenkoi</u>			(100)						(350)			
<u>Trachelomonas cordiformis</u>						(50)						
<u>T. hispida</u>								(50)				
<u>T. volvocina</u>			500						2500 (700)			
Cryptophyta												
Cryptophyceae			36500 (15100)			53000 (30400)			45000 (63750)		(200)	1200 (11900)
Cryptomonodales												
<u>Cryptomonas acuta</u>			6500 (1400)			16000 (10950)			15000 (30200)			3500 (4000)
<u>C. caudata</u>			7000 (5400)			6500 (6000)			5000 (7650)			3500 (2850)
<u>C. erosa</u>											(200)	
<u>C. ovalis</u>			23000 (8300)			30500 (13450)			25000 (25900)			5000 (5050)
Chrysophyta												
Chrysophyceae			2000 (100)			1500 (1400)			1000 (1050)		(50)	500
Chrysomadales												
<u>Dinobryon divergens</u>									(400)			
<u>Mallomonas caudata</u>			500			(50)						

Species	Station/Sampling Period[b] 1 F	1 Sp	1 Su	2 F	2 Sp	2 Su	3 F	3 Sp	3 Su	4 F	5 Sp	5 Su
M. tonsurata			1500 (100)			1500 (1350)			1000 (650)		(50)	500
Bacillariophyceae	195400	145000 (29800)	128000 (39350)	289300	112500 (22300)	121500 (50450)	173500	116500 (53800)	128500 (136050)	153400	139000 (38350)	19500 (40400)
Centrales												
Cyclotella glomerata		(400)	10500 (1600)		(500)	37500 (17600)		(400)	16000 (31000)		(600)	3000 (1500)
C. meneghiniana		2000 (300)			500 (250)			1500 (400)			500 (3350)	
C. stellata		1000			500			1000 (500)			500	
C. stelligera			1000			2000			500			500
Melosira granulata		(250)	18500 (17000)			28000			27500 (51050)			8000 (20400)
M. islandica		13500 (1100)			7500 (850)			(850)			18500 (5850)	
M. italica		(1400)										
M. varians		1500 (11550)			7500 (5850)			30000 (18950)			15590 (4850)	
Microsolenia sp.									2500 (3200)			
Stephanodiscus dubius											(100)	
S. nigrare					500			(200)			500 (250)	
Pennales												
Asterionella formosa								(400)				
Cymatopleura solea		(100)						(150)			(150)	

Species	Station/Sampling Period[b]											
	1			2			3			4	5	
	F	Sp	Su	F	Sp	Su	F	Sp	Su	F	Sp	Su
Cymbella cymbiformis		(250)			(150)						(200)	
C. finis					(50)						(50)	
C. lanceolata			(50)			500			500			
C. tumida		5500 (400)	2000 (2600)		5500 (550)	2500 (2500)		6000 (2450)	1500 (4750)		3000 (3150)	
C. ventricosa											5000	
Diatoma vulgare		20000 (2450)			22500 (4200)			19000 (14500)			12500 (5600)	
Fragilaria capusina		(450)			(800)							
F. crotonensis		18500 (2750)	15500 (550)		7000 (900)	18000 (7000)		11500	19000 (1650)		43500 (1300)	(2150)
Gomphonema sp.			1500 (50)			1000 (550)						
Gyrosigma spenceri								(50)				
Navicula decussis		12500 (2250)	6000 (2500)		12000 (3000)	500		11000 (8400)			10000 (3200)	1000 (2550)
N. pupula		8500 (2700)	500 (1150)		7000 (1550)	2500 (2700)		5000 (750)	4500 (5050)		1500 (1600)	4000 (11150)
N. tripunctata		(800)			(800)			(350)			(350)	
Nitzschia acicularis		50000 (1350)			31000 (1750)			17000 (2300)			17500 (6050)	
N. arcidularis			16000 (11800)			10500 (16250)			34500 (30750)			2000 (1500)
N. denticulata		3000 (250)			5000 (250)			4000 (1550)			5000	
N. dissipata		7000 (1050)	37500 (1050)		5000 (750)	10500 (350)		10500 (1400)	6000		4000	1000 (1150)
N. gracilis											(1350)	

Table 5.4-1 (Continued)

Species	Station/Sampling Period[b]											
	1			2			3			4	5	
	F	Sp	Su	F	Sp	Su	F	Sp	Su	F	Sp	Su
N. kuetzingiana			13500			5000			12000			
Rhoicosphenia curvata					(50)			(50)				
Surirella patella						500		(50)	500			
Synedra ulna		2000	5500 (1000)		1000 (50)	2500 (3500)		(100)	3500 (8600)		1500 (350)	
Cyanophyta												
Cyanophyceae	1500	(50)	7000 (7050)	3700	(550)	4500 (4850)	2000	500 (200)	5500 (10700)	2300	500 (250)	8000 (5350)
Chroococcales												
Aphanocapsa pulchra					(400)						(250)	
Coelosphaerium kuetzingianum			(150)						(150)			(50)
Gomphosphaeria aponina			500			(150)						
Merismopedia glauca			500		(50)				(1050)			500 (1250)
Microcystis flos-aquae			1000			2000 (2250)						(2600)
M. incerta			(250)									
Oscillatoriales												
Anabaena variabilis								(100)				
Aphanizomenon flos-aquae								(50)				
Lyngbya hieronymusii		(50)										
Oscillatoria limosa			4500 (6400)		(100)	3500 (3200)		500 (50)	3500 (6050)		500	5000
Spirulina princeps			500 (250)			1000 (1500)			(1200)			2500 (1450)

Species	Station/Sampling Period[b]										
	1			2			3			4	5	
	F	Sp	Su	F	Sp	Su	F	Sp	Su	F	Sp	Su
Total Density	199300	197550 (42200)	236000 (77900)	306400	135500 (30050)	232500 (161600)	184500	122000 (61200)	228000 (306600)	162400	150500 (51600)	50000 (74800)
Total Number of Species (both methods)		31	45		33	39		36	39		36	25

[a]Densities expressed as average number of organisms per liter from duplicate samples at each station except Station 3, fall period, for which only one sample was analyzed.

[b]F=Fall; Sp=Spring; Su=Summer

[c]Density values without parentheses represent data obtained by analysis with a Sedgwick-Rafter cell; densities reported with parentheses are results from analyses by the inverted microscope technique.

Table 5.4-2

Periphyton Collected from Waterways
in the Site Area

Species	Sampling Station/Sampling Period[a,b]					
	1		2	3	5	7
	Sp	Su	Su	Su	Su	Su
Chlorophyta						
Chlorophyceae						
Chlorococcales						
Ankistrodesmus sp.		M		W		
Oocystis sp.				W		
Pediastrum sp.				W		
Scenedesmus sp.		R	W			
Chaetophorales						
Aphanochaete sp.		R				V
Cladophorales						
Cladophora glomerata	W					
Rhizoclonium sp.		R	W			V
Oedogoniales						
Oedogonium sp.	W	R	W	W,R	R	
Conjugatophyceae						
Zygnematales						
Mougeotia sp.	W					
Spirogyra sp.		M,R	W	W,R		
Zygnema sp.	W					
Desmidiales						
Closterium moniliferum	W					
Closterium sp.		R		W		
Cosmarium undulatum	W					
Cosmarium sp.			W	W		
Hyalotheca dissiliens	W					
Chrysophyta						
Xanthophyceae						
Heterosiphonales						
Vaucheria sp.		R				
Bacillariophyceae						
Centrales						
Cyclotella sp.		P	P	P	P	P
Melosira granulata	P					
M. varians	P					
Melosira sp.		P	P	P	P	P
Stephanodiscus nigrarae	P					

Species	Sampling Station/Sampling Period[a,b]					
	1		2	3	5	7
	Sp	Su	Su	Su	Su	Su
Pennales						
Achnanthes clevei	P					
A. deflexa	P					
A. lanceolata[c]	P					
A. linearis	P					
Achnanthes sp.		P	P	P	P	P
Amphipleura sp.			P			
Amphiprora sp.			P			
Amphora ovalis	P					
Amphora sp.		P				
Asterionella formosa	P					
Caloneis ventricosa	P					
Cocconeis diminuta	P					
C. pediculus	P					
C. placentala	P					
Cocconeis sp.		P	P	P	P	
Cymatopleura solea	P					
Cymbella affinis	P					
C. cymbiformis	P					
C. hustedtii	P					
C. laevis	P					
C. prostrata	P					
C. sinuata	P					
C. tumida	P					
C. ventricosa	P					
Cymbella sp.		P	P	P	P	
Diatoma vulgare[c]	P					
Diatoma sp.		P	P	P	P	P
Eunotia sp.		P		P	P	
Fragilaria capucina	P					
F. crotinensis	P					
F. leptostauron	P					
Fragilaria sp.			P	P	P	P
Frustulia sp.			P	P		
Gomphonema longiceps	P					
G. olivaceum	P					
G. parvulum	P					
G. sphaerophorum	P					
Gomphonema sp.		P	P	P	P	P
Gyrosigma obtusatum	P					
G. spenceri	P					
Gyrosigma sp.		P		P		P
Hantzschia sp.		P				
Meridion circulare[c]	P					
Navicula bacillum	P					
N. cryptocephala[c]	P					

Species	Sampling Station/Sampling Period[a,b] 1		2	3	5	7
	Sp	Su	Su	Su	Su	Su
N. decusis	P					
N. gastrum	P					
N. pseudoreinhordtii	P					
N. radiosa	P					
N. tripunctata	P					
N. tuscula	P					
Navicula sp.		P	P	P	P	P
Neidium dubium	P					
Nitzschia acicularis	P					
N. denticulata	P					
N. dissipata	P					
N. fonticola	P					
N. gracilis	P					
Nitzschia sp.		P	P	P	P	P
Pinnularia mesogongyla	P					
Pinnularia sp.			P			
Rhoicosphenia curvata	P					
Rhopolodia sp.						P
Surirella angustata	P					
S. suecia	P					
Surirella sp.				P	P	P
Synedra vaucheriae	P					
Synedra sp.		P	P	P	P	P
Rhodophyta						
Rhodophyceae						
Goniotrichales						
Chroodactylon ramosum		R				
Namalionales						
Rhodochorton violaceum	W					
Cyanophyta						
Cyanophyceae						
Chroococcales						
Aphanothece sp.				R	R	
Microcystis sp.				R	R	
Oscillatoriales						
Haplosiphon hibernicus	W					
Lyngbya sp.		M	W	W,R	R	
Oscillatoria tenera	W					
Oscillatoria sp.		M,R	M	W	R	V
Phormidium inundatum	W					
Phormidium sp.		R		W		

[a] Sampling Periods: Sp = Spring, Su = Summer

[b] Substrate Designations: M = Mud or soil
R = Rock
W = Wood
V = Vascular macrophyte
P = Present in sample; substrate type undetermined

[c] Two varieties of this species were observed

Table 5.4-3

Zooplankton Collected from the White River in the Site Area

Species	Station Number/Sampling Period[a,b]											
	1			2			3			4	5	
	F	Sp	Su	F	Sp	Su	F	Sp	Su	F	Sp	Su
Rotatoria	1.38	1.41	2.8	1.84	1.56	2.8	2.00	2.42	3.6	5.68	1.98	3.4
Asplanchna sp.						0.2			0.2			0.2
Bdelloidea sp.		0.24			0.50			0.44			0.22	
Brachionus bidentata		0.02									0.04	
B. calyciflorus		0.02						0.02			0.02	
B. caudatus									1.2			
B. haranaensis												0.2
B. quadridentatus		0.12			0.04			0.06			0.04	
Brachionus sp.			0.6			0.6			0.4			0.6
Cephalodella sp.		0.16			0.12			0.12			0.26	
Conochloides sp.			0.2									0.8
Conochilus sp.			0.6			0.8			0.4			0.6
Euchlanis sp.			0.4									
Filinia longiseta		0.36			0.46			0.62			0.82	
Hexarthra sp.		0.04			0.06			0.14			0.04	
Monostyla sp.		0.02			0.06	0.2		0.12			0.24	
Mytilina sp.		0.35			0.26			0.76			0.10	
Notholca sp.		0.02				0.4		0.02	1.2			0.6
Platyias quadricornis								0.02				
Polyarthra sp.		0.06	0.8			0.2					0.08	
Trichocerca cylindrica					0.04						0.02	
Trichocerca sp.						0.4			0.2			0.4
Trichotria sp.					0.02			0.10			0.10	
Unidentified sp.			0.2									
Cladocera	0.01	0.30	0	0.01	0.78	0	0.01	1.08	0.2	0.03	1.08	0.2
Alona guttata		0.04			0.16			0.16			0.06	
A. rectangula		0.04			0.44			0.62			0.58	
Bosmina longirostris		0.08			0.08			0.16			0.22	
Bosmina sp.												0.2
Chydorus sphaericus		0.06			0.08			0.08			0.04	
Daphnia pulex		0.06			0.02						0.02	
Leydigia quadrangularis		0.02									0.08	
Ilocryptus sordidus								0.06			0.02	
Immature cladoceran											0.06	
Unid. Chydorinae sp.									0.2			
Copepoda	0.04	1.66	0.4	0.04	1.70	0	0.06	1.52	0.6	0.22	4.44	0.8
Cyclops bicuspidatus		0.02			0.04			0.02			0.18	
Cyclops spp.									0.2			0.4
Cyclopoid copepodite		0.28			0.26			0.22			0.22	
Calanoid copepodite		0.02			0.10			0.04			0.14	
Harpacticoid copepodite					0.04			0.04			0.02	
Nauplii		1.34	0.4		1.26			1.20	0.4		3.88	0.4
Total Density	1.43	3.37	3.2	1.89	4.04	2.8	2.07	5.02	4.4	5.93	7.50	4.4

[a] Densities expressed as average number of organisms/liter

[b] Sampling Periods: F = Fall; Sp = Spring; Su = Summer.

Table 5.4-4

Benthic Macroinvertebrates Collected from Waterways in the Site Area[a]

Species	Station Number/Sampling Period[b]/Bottom Substrate[c]												
	1		1A	2		2A	3			5		6	7
	F	Su	Sp	F	Su	Sp	F[d]	Sp	Su	Sp	Su	Su	Su
	S	S,G	CL,S,O	S	S,G	CL,O	S,G	S,O	C	S	S,G	M	M
Diptera	P[e]	787	442	P	185	230		2141	1563	1063	602	8826	1076
Chironomidae													
Chironomus spp.			172			144		1710		115			
Coelotanypus sp.												1352	847
Cricotopus spp.						14			37	14			
Cryptochironomus demeiji									14				
Cryptochironomus sp.		115			43				179	58	57		14
Demicryptochironomus sp.			14										
Dicrotendipes sp.									296		43		
Harnischia spp.			14							115			
Micropsectra sp.		14							37				
Microtendipes aberrans									88				
Orthocladius sp.									37		29		
Paracladopelma sp.		29	14		14						43		
Paralauterborniella spp.		14								43			
Paratanytarsus sp.					14				37				
Paratendipes spp.									29	14			
Pentaneura sp.					14								
Phaenopsectra sp.									14				
Polypedilum spp.		416	129		57	58			438	489	187		
Procladius spp.			14					431					
Pseudochironomus spp.			14			14			37				
Rheotanytarsus spp.			14							158	14		
Tanypus sp.												7374	115
Tanytarsus coracina											14		
Tanytarsus spp.		99	43		43				254		172		
Tribelos sp.			14							14			
Trichocladius sp.										14			
Unidentified chironomid spp.	P			P									
Unidentified chironomid pupa										29			
Chironominae (unid. sp.)		57							52		43		
Tanypodinae (unid. sp.)		43							14				
Culicidae													
Chaoborus sp.													43
Ceratopogonidae													
Probezzia sp.												100	57
Tabanidae													
Tabanus sp.	P												
Ephemeroptera	P							14	14		86		
Baetidae													
Baetis spp.	P												
Caenidae													
Caenis Sp.									14		86		

Table 5.4-4 (Continued)

Species	1		1A	2		2A	3			5		6	7
	F	Su	Sp	F	Su	Sp	F	Sp	Su	Sp	Su	Su	Su
	S	S,G	CL,S,O	S	S,G	CL,O	S,G	S,O	C	S	S,G	M	M
Ephemeridae													
Hexagenia sp.								14	P				
Hemiptera			14			14						14	43
Corixidae													
Trichocorixa sp.												14	43
Unidentified sp.						14							
Gerridae													
Trepobates sp.						P							
Gerris sp.						P							
Notonectidae (unid. sp.)			14										
Odonata									P				
Unidentified sp.									P				
Trichoptera									14				14
Hydroptilidae (unid. sp.)									14				
Molannidae													
Molanna sp.													14
Coleoptera						P		14					
Elateridae (unid. sp.)								14					
Gyrinidae													
Gyrinus sp.						P							
Decapoda							P		P				
Astacidae													
Palaemonetes sp.							P		P				
Oligochaeta			259			172		1335	72	315	14	1076	1205
Lumbriculidae (unid. sp.)						14							
Naididae													
Nais sp.						14		14					
Paranais frici										14			
Tubificidae													
Aulodrilus pigueti						14				14			
Branchiura sowerbyi													29

Station Number/Sampling Period[b]/Bottom Substrate[c]

Table 5.4-4 (Continued)

Species	Station Number/Sampling Period[b]/Bottom Substrate[c]												
	1		1A	2		2A	3			5		6	7
	F	Su	Sp	F	Su	Sp	F	Sp	Su	Sp	Su	Su	Su
	S	S,G	CL,S,O	S	S,G	CL,O	S,G	S,O	C	S	S,G	M	M
Limnodrilus cervix								230					
L. clapardeanus										14			
L. hoffmeisteri						72		129	29	72		875	330
L. udekemianus								14					
Immature tubificids			259			58		948	43	201	14	201	832
Unidentified sp.													14
Nematoda			14			14				29			
Unidentified sp.			14			14				29			
Pelecypoda	P	28									14		
Corbiculidae													
Corbicula sp.	P	28									14		
Unionidae													
Amblema perplicata											P		
Fusconaia ebena											P		
Proptera laevissima											P		
Total Organism Density		815	729		185	430		3504	1663	1407	716	9916	2338

[a] Density values reported as the average number of organisms/m^2 in three replicate samples

[b] F=Fall; Sp=Spring; Su=Summer

[c] S=Sand; G=Gravel; CL=Clay; O=Organic detritus; C=Cobble; M=Muck

[d] During the fall and summer periods, samples were collected from the main river channel; in the spring, samples were taken in the slough mouth.

[e] Species present; sampled qualitatively only

Table 5.4-5

Fishes Collected From the White River Near the Site

During 1976-1977 Field Sampling Surveys

Station Number/Sampling Period [a,b]

Common Name	1			1A		2		3			4			5	
	F	Sp	Su	Sp	Su	F	Su	F	Sp	Su[c]	F	Sp	Su	Sp	Su
Shortnose gar														2A	
Bowfin								1						1A	
Gizzard shad									1A	1A				2A	
Threadfin shad									1A						
Stoneroller					1				2J						
Carp									1A					1A	
Silvery minnow			10		40				1A						
Speckled chub															1
Bigeye chub		1A,1Y													
Gravel chub		1A													
Hornyhead chub	1														
Golden shiner										8					
Emerald shiner		101A,2Y	16	2A,3Y			24		41A,88Y	1	1	3Y			24
Bigeye shiner		1Y				1			3A,37Y						
Striped shiner						1									
Pugnose minnow										103					
Whitetail shiner				1A		1					1		2		
Wedgespot shiner															2
Duskystripe shiner					3					1			1		2
Rosyface shiner		4A													6
Telescope shiner			1												
Weed shiner								3							
Blacktail shiner		145A,2Y	18	2A	283	71	1090	10	204A,104J	182	115		159		139
Mimic shiner		2A							16A	1	1				3
Steelcolor shiner									2J						
Bluntnose minnow					7	2		5		1	3				
Bullhead minnow										8					

Table 5.4-5 (Continued)

Station Number/Sampling Period[a,b]

Common Name	1			1A		2		3			4			5	
	F	Sp	Su	Sp	Su	F	Su	F	Sp	Su[c]	F	Sp	Su	Sp	Su
River carpsucker			2Y				807Y	1	2A	6Y			3Y	2A	
Northern hog sucker		1Y			2Y				5Y					1A	
Smallmouth buffalo		6Y		5Y					1Y			10Y			
Ictiobus sp.											7				
Spotted sucker			2Y		3Y					6Y					
Black redhorse				1A											
Moxostoma sp.		6Y		27Y					484Y			67Y			
Northern studfish	1	1A			2		12				1	55			
Blackspotted topminnow										7					
Mosquitofish					3	9	1	13		16			2		
Brook silverside			8				3			20					
Warmouth								1							
Bluegill					1Y			3	1J	2J,298Y					
Longear sunfish					3Y			1		4Y					1Y
Spotted bass			1Y		2Y										
Largemouth bass								2							
Rainbow darter	4	2A													
Bluntnose darter										14					
Freshwater drum														1A	
Total Number of Individuals	6	276	58	41	350	85	1937	40	994	679	129	80	222	10	178
Total Number of Species	3	12	8	6	12	6	6	10	15	17	7	3	6	7	8

[a] F - Fall sampling period; Sp - Spring period; Su - Summer period

[b] Some species numbers for the spring and summer efforts are categorized by life stage: A - adult and subadult; J - juvenile; Y - young-of-year and postlarval stage.

[c] Sample partially destroyed in shipment to the laboratory.

Table 5.4-6

Length and Weight of Selected Fish Collected During 1976-1977 Field Sampling Surveys

Common Name	Collection Period: Station[a]	Length:Weight (cm:g)
Shortnose gar	Sp:5	69.0:1476
		67.7:872
Bowfin	F:3	49.5:1220
	Sp:5	44.5:1305
Gizzard shad	Sp:3	20.0:227[b]
	Su:3	17.8: -
	Sp:5	29.2:212
		27.0:160
Carp	Sp:3	38.9:511
	Sp:5	69.8:4200
River carpsucker	F:3	37.5:630
	Sp:3	40.4:851
		31.0:341
	Sp:5	41.2:1022
		22.5:192
Northern hog sucker	Sp:5	42.2:571
Black redhorse	Sp:1A	35.0:378
Freshwater drum	Sp:5	24.2:180

[a]F = Fall
Sp = Spring
Su = Summer

[b]Estimated length and weight; fish partly destroyed by predator

Table 5.4-7

Fishes Observed in the White River in the Site Area

Scientific Name	Common Name	Investigator Observing Species[a]
Petromyzontidae		
Ichthyomyzon castaneus	Chestnut lamprey	AE
I. gagei	Southern brook lamprey	B
Polyodontidae		
Polyodon spathula	Paddlefish	B
Lepisostidae		
Lepisosteus osseus	Longnose gar	B
L. platostomus	Shortnose gar	B,P
L. spatula	Alligator gar	B
Amiidae		
Amia calva	Bowfin	P
Clupeidae		
Alosa chrysochloris	Skipjack herring	B
Dorosoma cepedianum	Gizzard shad	AE,B,P
D. petenense	Threadfin shad	B,P
Hiodontidae		
Hiodon alosoides	Goldeye	B
H. tergisus	Mooneye	B
Esocidae		
Esox lucius	Northern pike	B
E. niger	Chain pickerel	B
Cyprinidae		
Campostoma anomalum	Stoneroller	AE,B,P
C. oligolepis	Largescale stoneroller	B
Carassius auratus	Goldfish	B

Scientific Name	Common Name	Investigator Observing Species[a]
Cyprinidae (cont'd)		
Cyprinus carpio	Carp	B,P
Dionda nubila	Ozark minnow	AE,B
Hybognathus hayi	Cypress minnow	D
H. nuchalis	Silvery minnow	AE,B,P
Hybopsis aestivalis	Speckled chub	P
H. amblops	Bigeye chub	AE,B,P
H. dissimilis	Streamline chub	AE,B
H. storeriana	Silver chub	B
H. x-punctata	Gravel chub	AE,B,P
Nocomis biggutatus	Hornyhead chub	B,P
Notemigonus chrysoleucas	Golden shiner	B,P
Notropis atherinoides	Emerald shiner	AE,B,D,P
N. boops	Bigeye shiner	AE,B,P
N. chrysocephalus	Striped shiner	B,P
N. emiliae	Pugnose minnow	B,P
N. galacturus	Whitetail shiner	AE,B,P
N. greenei	Wedgespot shiner	AE,B,P
N. ozarcanus	Ozark shiner	AE,B
N. pilsbryi	Duskystripe shiner	AE,B,P
N. rubellus	Rosyface shiner	AE,B,P
N. sabinae	Sabine shiner	B
N. telescopus	Telescope shiner	B,P
N. texanus	Weed shiner	P
N. umbratilis	Redfin shiner	B
N. venustus	Blacktail shiner	AE,B,D,P
N. volucellus	Mimic shiner	AE,B,D,P
N. whipplei	Steelcolor shiner	B,P
Phoxinus erythrogaster	Southern redbelly dace	B
Pimephales notatus	Bluntnose minnow	AE,B,P
P. promelas	Fathead minnow	B
P. tenellus	Slim minnow	B
P. vigilax	Bullhead minnow	B,D,P
Semotilus atromaculatus	Creek chub	B

Scientific Name	Common Name	Investigator Observing Species[a]
Catostomidae		
Carpiodes carpio	River carpsucker	AE,B,D,P
C. cyprinus	Quillback	B
C. velifer	Highfin carpsucker	B
Erimyzon oblongus	Creek chubsucker	B
Hypentelium nigricans	Northern hog sucker	B,P
Ictiobus bubalus	Smallmouth buffalo	B,P
I. cyprinellus	Bigmouth buffalo	B
I. niger	Black buffalo	B
Minytrema melanops	Spotted sucker	B,P
Moxostoma carinatum	River redhorse	B
M. duquesnei	Black redhorse	B,P
M. erythrurum	Golden redhorse	B
M. macrolepidotum	Shorthead redhorse	B
Ictaluridae		
Ictalurus furcatus	Blue catfish	D
I. melas	Black bullhead	B
I. natalis	Yellow bullhead	B
I. punctatus	Channel catfish	B
Noturus exilis	Slender madtom	B
N. flavater	Checkered madtom	B
N. gyrinus	Tadpole madtom	B
N. miurus	Brindled madtom	B
Pylodictis olivaris	Flathead catfish	D
Aphredoderidae		
Aphredoderus sayanus	Pirate perch	B
Cyprinodontidae		
Fundulus catenatus	Northern studfish	AE,B,P
F. olivaceus	Blackspotted topminnow	AE,B,P
Poeciliidae		
Gambusia affinis	Mosquitofish	AE,B,D,P

Scientific Name	Common Name	Investigator Observing Species[a]
Atherinidae		
Labidesthes sicculus	Brook silversides	AE,B,D,P
Percicthyidae		
Morone chrysops	White bass	AE,B
Centrarchidae		
Ambloplites rupestris	Rock bass	B
Elassoma zonatum	Banded pygmy sunfish	B
Lepomis cyanellus	Green sunfish	AE,B
L. gulosus	Warmouth	P
L. humilis	Orangespotted sunfish	B
L. macrochirus	Bluegill	AE,B,D,P
L. marginatus	Dollar sunfish	B
L. megalotis	Longear sunfish	AE,B,P
L. microlophus	Redear sunfish	B
L. punctatus	Spotted sunfish	B
Micropterus dolomieui	Smallmouth bass	B
M. punctulatus	Spotted bass	B,P
M. salmoides	Largemouth bass	AE,B,D,P
Pomoxis annularis	White crappie	AE,B
P. nigromaculatus	Black crappie	B
Percidae		
Ammocrypta asprella	Crystal darter	B
A. clara	Western sand darter	B
A. vivax	Scaly sand darter	AE,B
Etheostoma blennioides	Greenside darter	B
E. caeruleum	Rainbow darter	AE,B,P
E. chlorosomum	Bluntnose darter	P
E. euzonum	Arkansas saddled darter	B
E. histrio	Harlequin darter	B
E. punctulatum	Stippled darter	B
E. spectabile	Orangethroat darter	B

Table 5.4-7 (Continued)

Scientific Name	Common Name	Investigator Observing Species[a]
Percidae (cont'd)		
E. stigmaeum	Speckled darter	B
E. whipplei	Redfin darter	B
E. zonale	Banded darter	B
Percina caprodes	Logperch	AE,B
P. evides	Gilt darter	B
P. maculata	Blackside darter	B
P. nasuta	Longnose darter	B
P. phoxocephala	Slenderhead darter	B
P. sciera	Dusky darter	B
P. shumardi	River darter	B
P. uranidea	Stargazing darter	AE,B
Stizostedion canadense	Sauger	B
S. vitreum	Walleye	B
Sciaenidae		
Aplodinotus grunniens	Freshwater drum	AE,B,P
Cottidae		
Cottus bairdi	Mottled sculpin	B
C. carolinae	Banded sculpin	AE,B

[a]Species observed in White River system between Batesville and Black River confluence by:

AE - Arkansas Eastman (1974)
B - Buchanan (1973)
D - Davis (1971)
P - Present survey by Dames & Moore (1976-1977)

Table 5.4-8

Mussels Collected from the White River[a]
(River Miles 261 to 276)

River Mile	Approx. Water Depth (ft)	No. Hauls	Distance Brailed (yd)	Area Brailed (yd)	Name of Species Collected: Scientific Name	Name of Species Collected: Common Name	Number Collected
261-262	8-14	3	250	833	-	-	0
262-263	3-10	3	250	833	-	-	0
263-264	8	2	100	333	-	-	0
264-265	6-8	2	200	667	-	-	0
265-266	12-14	2	200	667	Quadrula metanevra	Monkey face	1
					Proptera alata	Blue Mucket	1
266-267	5-8	1	100	333	Lampsilis ovata	Grandma	1
267-268	2-12	6	500	1667	Plagiola lineolata	Butterfly	1
268-269	6-8	3	200	667	-	-	0
269-270	7-12	6	500	1667	Ligumea recta	Black sandshell	1
					P. lineolata	Butterfly	1
270-271	10	1	50	167	-	-	0
271-272	-	0	0	0	-	-	0
272-273	4-15	4	300	1000	-	-	0
273-274	12	1	40	133	-	-	0
274-275	12-40	1	50	167	Fusconaia ebenus	Black niggerhead	1
275-276	4-12	5	350	1167	Amblema costata[b]	Three-ridge	2
					Fusconaia undata	Pig-toe	1
					Quadrula quadrula	Maple-leaf	1
					Tritogonia verrucosa[b]	Pistolgrip	1
					Actinonais carinata	Mucket	2
					L. ovata	Grandma	1
					Leptodea fragilis[c]	Fragile paper shell	1
					Obovaria olivaria	Eggshell	4
Total: 261-276		40	3090	10301			20

[a] Unless otherwise noted, all specimens were collected by brailing.

[b] One specimen collected by diving.

[c] Collected by hand in shallows.

5.5 REFERENCES

Arkansas Eastman Company, 1974, Environmental impact assessment.

Buchanan, Thomas M., 1973, Key to fishes of Arkansas.

Davis, Bill, 1971, Department of Zoology, Louisiana Tech University, Ruston, Louisiana, unpublished data.