3.0 SUBSURFACE SITES

There are a number of advantages in constructing an antenna of this type in a deep tunnel or mine. The antenna would be naturally isolated from many vibration sources, such as aircraft, railway and highway traffic. Temperatures at depth fluctuate much less than at the ground surface. The need to provide buildings to house support facilities might also be reduced.

For these reasons, a survey of existing mines and tunnels was performed to determine whether one or more of these facilities would be a suitable site for an L-shaped antenna with arms 5 km long. If no passages of this length exist, the study would identify the longest potentially suitable passages that might be available.

3.1 SITING CRITERIA FOR CANDIDATE SUBSURFACE SITES

The criteria for evaluating subsurface sites differs significantly from those for the surface sites. The major considerations for the subsurface sites are line-of-sight distances and configurations of passages. Additionally, other factors have been investigated.

Many mines are horizontally extensive, but few contain passages with substantial line-of-sight passages because this offers no inherent mining advantage. Most mineral deposits have irregular configurations, and the mines conform to those configurations. The mine site survey was directed toward those deposits which tend to form as planar ore bodies. Mineral occurrences that could be grouped in this category would include lead, zinc, copper, gypsum, salt, potash, limestone, trona (impure sodium carbonate), and coal. [1,2,3]

3.1.1 Passage Dimensions

Mine operators were asked for details concerning the existing underground passages. Additionally, operators were asked about the possibilities of modifying existing passages to give line-of-sight passages. The cross-sectional area of passages was also considered.

3.1.2 Passage Configuration

The right angle or near right angle configuration of the two passages was discussed. This configuration was not limited to the horizontal plane.

3.1.3 Type of Access

The type of access for transport tunnels, such as railroad, highway, and water is apparent. For mines, the type of access was discussed. Access to a mine can be by a horizontal passage (adit), inclined passage (decline or incline), or a vertical passage (shaft). Additionally, limitations were discussed that would have to be considered for movement of antenna equipment and material; for example, lengths of pipe to be used for the antenna.

3.1.4 Ground Stability and Groundwater Flow

Since mines are frequently located in areas of geological disturbances, such as mountainous regions, questions were asked concerning ground and rock stability. Groundwater flows and potential for water problems were also discussed.

3.1.5 Mining Activity

The projected levels of short-term and long-term mining activities were investigated. The possibility of utilizing disused mines to house the antenna was investigated.

The issue of projected mine activity is a complex one. Mine operators routinely make short-term projections about mining activities. Long-term projection are much more difficult to make since the operation of a mine is based upon the profitability of the operation. For many minerals a modest price change can cause the owner to change areas of mining activity or put the operation on standby status. A mine shutdown would not be as significant to a mine with a horizontal access passage as it would be to a mine with shaft access.

Also, projections of mining activity apply directly to the matter of mine maintenance. If a mine is situated in particulary stable rock, such as limestone, ground stability considerations are relatively unimportant. In mines with more complex geology and associated rock stability problems, mine maintenance is a major consideration and could represent a significant cost.

Maintenance costs of passages in an inactive mine would be higher than in an active mine due to the added costs of mobilization of equipment and personnel.

Depending upon the rock type and its acoustical characteristics, ambient vibration levels would probably be lower in a disused mine.

This question of projected mine activity and integrity of the passages has to be assessed carefully and on a mine by mine basis.

3.1.6 Depth Below Surface

Depths of passages below the surface were investigated.

3.1.7 Vibration and Seismicity

Depending upon the magnitude of the mining operation, techniques employed, proximity to potential host passages, rock type, and other variables, local mining activity may or may not produce significant vibration. The consideration of regional seismicity would be of the same importance as for surface sites. Zones of seismicity are shown in Figure 2.1-1. Most of the mines considered in this study are not found in these seismic zones.

3.1.8 Potential for Passage Modification

The possibility of passage modification including alteration of size or extension of length was discussed with the mine operators. The responses ranged from "not possible" due to rock stability or mineral claim boundaries to "possible" with the unit cost of excavation being the only real consideration.

3.1.9 Disposition Towards Participation

The willingness to provide a mine site for the antenna was discussed with those mine operations that met the majority of criteria already discussed. Of all of the criteria to be met in this study the length of time required to construct and operate the antenna was the most difficult consideration for the mine operators. Most operators were favorably disposed toward providing a site for a short time period. However, for the anticipated length of time for this experiment, only a few mines were interested. As it happens, these mines are among the most extensive of the underground facilities considered.

3.2 PROCEDURE

The mine site investigation began with telephone discussions with representatives of federal and state agencies and concluded with specific discussions with individual mine operators. Federal and state agencies contacted are listed below.

- The U.S. Bureau of Mines has responsibilities in mineral and mining statistics, mining technological research, minerals specialists, and other services related to the minerals industry.

- The U.S. Corps of Engineers has a direct involvement in major geotechnical projects concerning surface and subsurface facilities and was a source of subsurface information.

- The U.S. Bureau of Reclamation is involved in tunneling operations for major water supply projects, particularly in the western states.

- The U.S. Mine Safety and Health Administration (MSHA) is directly responsible for administering Federal mining regulations and inspecting all surface and subsurface mines.

- Contacts were made with various state mine inspectors. These inspectors have direct knowledge of all mining operations within their respective states.

Information provided by the federal and state agencies confirmed that mining operations were the only type of underground development that might offer the opportunity of locating a suitable long-term subsurface site for the antenna. Telephone calls were made to mining companies that might operate mines of any substantial extent. Information pertaining to the criteria in Section 3.1 was obtained. Discussions with company personnel indicated quickly that only a limited number of underground operations could be considered for the antenna.

At this point in the subsurface survey, a list was assembled compiling the underground mines that might house the antenna. The mines and subsurface facilities are grouped by state (see Table 3.2-1).

3.3 DESCRIPTION OF CANDIDATE SITES

The candidate sites have been grouped into two categories: sites which meet many of the criteria and sites that can be considered for further investigation.

Mining operations can be found that have one passage with a length exceeding 5 km. However, as Table 3.3-1 indicates, there are no underground mines in the United States that have two orthogonal passages 5 km in length. This paucity of potential underground sites is a general reflection of attempts to minimize significant underground hauling distances. There is a point in mine development where it makes economic sense to sink a new shaft or drive a new opening from the surface in order to reach outlying portions of the mineral deposit.

Also, there are few developed mineral deposits that are so planar and undisturbed that significant line-of-sight distances can be excavated. There are a few mines that, due to specific mining considerations or surface ownership, have two passages 5 km in length, but these are not linear for a significant distance. Basically, underground mine passages are developed to best accommodate the local geological condition such as, local faulting and offset of the ore body, competency of the immediate rock, changing economics of mine development, and exploitation of portions of the ore body which might be mined at a profit.

Those mines that are listed in Table 3.3-1 have met the criteria of certain mine passage size, orthogonality or near orthogonality, ground stability, groundwater control, and general vibration levels. Portions of most of these mines are actively mined. For the purpose of this report, the mines are grouped by decrements of 1 km.

Only six of these mines appeared to warrant further investigation. The other mines were eliminated due to reasons such as limited life of the mine, serious long-term ground stability conditions, and major cost of maintaining those passages that would house the antenna. The locations of these six mines are shown in Figure 4-1. The mines and their current status are given below:

- Cleveland Mine, Ohio - active mining
- Randolph Mine, Missouri - active mining
- Nash Draw Mine, New Mexico - active mining
- Barberton Mine, Ohio - inactive

- Jonathan Mine, Ohio - inactive

- Mullins Mine, Kentucky - inactive

The following briefly describes the six mines that were considered:

3.3.1 Cleveland Mine

The Cleveland Mine is located in Cleveland, Ohio, at the mouth of the Cuyahoga River and extends under both the city and Lake Erie. This is a salt mine operated by the International Salt Company. With the present mine configuration, the operators could provide two orthogonal passages, each 1.7 km in length and apparently line-of-sight (see Figure 3.2-2). Access to the mine is by vertical shaft, with the mine about 1,765 ft below land surface. The salt is mined by the room and pillar method.

The salt is mined from passages 45 ft wide and 18 to 22 ft high. Pillars are 105 ft square, and are left to provide permanent support. The salt is blasted and mined by diesel-powered equipment and transported to underground hoisting facilities. The mine temperature is a constant 72°F.

Rock stability is not a major problem, although portions of the mine roof are supported with rock bolts. The mine is dry, so dewatering is not a consideration. The present mineral claim boundaries limited the possibilities of passage extension to about 0.2 km in one direction, and about 0.7 km in the other direction.

3.3.2 Randolph Mine

The mine is located near Kansas City, Missouri. This is a limestone mine operated by Midwest Mining Corporation. It would be possible to provide passage 1.6 km in length and another 1.4 km in length (see Figure 3.2-3). Portions of this mine have been developed as a subsurface industrial and business complex. Access is at street level, and the developed area has roads, utilities, and rail directly into the mine. There are a number of businesses located in the complex, including a post office, warehouses, and small manufacturing plants. The mine has been developed by quarrying horizontally into a limestone bluff. The mine is 140 ft below the surface. The passages are 65 ft wide and 12 to 16 ft high. The mine is supported by pillars which are 90 ft square. The temperature ranges from 58 to 62°F. The northern portion of the mine is actively being excavated by drilling and blasting methods.

Due to the proximity of the mine to the surface, groundwater does enter the mine. The small quantities of incoming water are removed via a drainage ditch and sump system. Since entrance to the mine is horizonital and the whole mine is at that elevation, the chances of flooding are nonexistent.

3.3.3 Nash Draw Mine

The Nash Draw Mine is located near Carlsbad, New Mexico. This mine was developed to extract potash, and is operated by the Duval Corporation. The longest orthogonal line-of-sight passages that are currently open are each 1.5 km in length (see Figure 3.2-4). The potash deposit is reached by vertical shafts extending approximately 1,100 ft below the surface. The potash is mined by the room and pillar method with passages 30 ft wide and 6 to 8 ft high. The pillars provide permanent support. The mine temperature is a constant 68°F. There is some possibility at this mine of extending the passages through mining and pillar alteration. The mine is dry with no groundwater problems. The location of mineral claim boundaries is such that passage lengths could be doubled without difficulty.

Duval Corporation indicated as this report was going to press that it wishes the Nash Draw Mine to be withdrawn from further consideration as an antenna site.

3.3.4 Barberton Mine

This inactive mine is owned by PPG Industries. The mine was deactivated in 1976 and all equipment, with the exception of the hoisting system, was removed. The mine produced limestone for glass production. The mine is near Akron, Ohio. Access to the mine, a room and pillar operation 2,600 ft below the surface, is by vertical shaft. Two orthogonal passages, one 0.6 km and the other 0.8 km, could be used. The passages are 32 ft wide and 17 ft high. The mine is completely dry with only minor water leakage at the shaft collars. The rock stability is very good with only some precautionary rock bolting at previous stationary equipment sites. The company has no plan to reopen the mine as the company ceased using limestone in their glass production in 1975. Mineral claim boundaries are sufficiently distant so that passage lengths could be doubled without difficulty.

3.3.5 Jonathan Mine

This inactive mine was previously operated and is still owned by the Columbia Cement Company. The mine, a limestone producer for cement production, is located near Zanesville, Ohio. The firm now mines limestone from a quarry in proximity to the underground mine. The mine has been developed by the room and pillar method. There are two orthogonal passages, each with a length of about 0.8 km, that might be suitable for the antenna. The mineral claim boundary distances are such that the passages could potentially be lengthened an additional 0.6 km in both directions.

Access to the mine is by horizontal adit entry. Thickness of the overlying rock is at least 150 ft. Rock stability is moderately good with the whole mine roof secured with rock bolts on 5 ft centers. The mine has no groundwater problems. The passages are 20 ft high and 30 ft wide with pillar dimensions ranging from 25 ft by 25 ft to 50 ft by 100 ft.

3.3.6 Mullins Mine

This inactive mine was previously operated and is currently controlled by Kentucky Stone Company. The mine is located near Mt. Vernon, Kentucky, and produced limestone during its 23 year lifetime before ceasing production 1979. It was mined by the room and pillar method. The present configuration would allow the placement of two 0.6 km orthogonal arms of the antenna. The passages could potentially be extended an additional 0.6 km before encountering mineral rights boundaries.

Access to the mine is by horizontal adit passages. The mine is situated in the side of a steep hill with a minimum thickness of overlying rock of at least 200 ft. The rock stability is very good with no need for rock bolts. There are no water problems; minor seepage is handled by ditch and sump. The passages are about 25 ft high and 50 ft wide with pillar dimensions of about 50 ft by 50 ft. Vibration monitoring has been done only in conjunction with blasting.

3.4 REFERENCES FOR MINE SITES

3.4.1 LITERATURE CITED

1. Engineering and Mining Journal, "International Directory of Mining and Mineral Processing Operations". New York, NY, 1982.

2. Coal Mining Directory, "Mining Informational Services", New York, NY, 1982.

3. Mineral Commodity Summaries, U.S. BUREAU OF MINES, WASHINGTON, DC, 1983.

3.4.2 Organizations Contacted

Agency, Company, or Mine	Contact	Location and Telephone No.
Allied Chemical Corp., Alchem Mine	C. MacLinden, Chief Mining Engineer	Green River, WY 307/875-3350
AMAX Chemical Corp., Eddy Mine	R. Kirby, General Manager	Carlsbad, NM 505/885-3157
AMAX Moly Corp. Henderson Mine and Tunnel	Chief Engineer	Golden, CO 303/234-9020
AMAX, Lead & Zinc Division	J. Peters, Chief Mining Engineer	Clayton, MO 314/626-4221
ASARCO, Inc.	Vice President, Mining	New York, NY 212/669-1000

Agency, Company, or Mine	Contact	Location and Telephone No.
Bethlehem Mining Co.	L. Shutty, Manager of Underground Mining	Ebbensburg, PA 814/472-8102
Black River Co., Inc., Black River Mine	R. Kuhneman, Mine Superintendent	Butler, KY 606/472-7721
Bunker Hill Co., Inc., Bunker Hill Mine	M. Swanson, Mine Manager	Kellogg, ID 208/784-1261
Coal Age Magazine	D. Brezovec, Mining Specialist	New York, NY 212/997-2196
Carbon County Coal Co.	D. Rauton, Mine Manager	Lander, WY 307/325-9471
Cargill Corp., Cayuga Mine	G. Peterson, Mine Manager	Lansing, NY 607/533-4221
Cominco American, Inc., Magmont Mine	P. Sweeney, Chief Geologist	Bixby, MO 314/626-4231
CONOCO, Coal Division	D. Petrie, Director of Coal Mining	Morgantown, WV 304/983-2251
Consolidated Coal Co.	W. Furtall, Asst. Mine Manager	Acton, PA 412/746-3400
Consultant	Robert Thoms	Baton Rouge, LA 504/769-5277
FMC, Westvaco Mine	M. Fenton, Mine Superintendent	Green River, WY 307/875-2580
IMC, Ltd., Esterhazy Mine	E. Sidler, Chief Engineer	Esterhazy, Saskatchewan 306/745-3931
International Minerals & Chemicals Corp., IMC Mine	R. Hougland, General Manager	Carlsbad, NM 505/887-2871
Mississippi Chemical Co., Mississippi Mine	J. Walls, Manager	Carlsbad, NM 505/887-5591
Mississippi Lime Co., St. Genevieve Mine	L. Fieg, Mine Manager	St. Genevieve, MO 314/883-5731
Mississippi Limestone Producers Association	N. McDonald, President	St. Louis, MO 314/635-0208

Agency, Company, or Mine	Contact	Location and Telephone No.
Morton Salt Co., Chicago Mine	J. Head, Chief Mining Engineer	Chicago, IL 312/621-5884
Morton Salt Co.	F. Elder, Senior Mining Engineer	Paynesville, OH 216/354-9901
National Crushed Stone Association	E. Renninger, President	Washington, DC 202/342-1100
PCA, Inc., PCA Mine	T. Donaldson, Mine Manager	Carlsbad, NM 505/887-2844
Peabody Coal Co.	S. Sorrell, Director of Mining Engineering	Pittsburgh, PA 618/398-7950
Jack Parker Consultants	Jack Parker, President	White Pine, MI 906/885-5445
PCA, Ltd., Rokainville Mine	M. Wooley, Chief Engineer	Rokainville, Saskatchewan 306/645-2870
St. Joe Minerals Co., Inc.	P. Meyers, Chief Geologist	Bonne Terre, MO 314/244-5261
Society of Mining Engineers	T. O'Niel, Editor	Boulder, CO 303/973-9550
State Mine Inspectors	A. Hanson Mine Inspector	Knoxville, TN 615/673-4581
	L. Kimmel, Director	Pittsburgh, PA 412/439-7460
	R. Gatti Mine Inspector	Columbus, OH 614/466-4248
	D. Hanna Mine Inspector	Rock Springs, WY 307/362-5222
Tennessee Chemical Co., Gordonsville Mine	Chief Mining Engineer	Gordonsville, TN 615/496-3331
Union Carbide Corp., Bishop Mine	M. Sherman, Mine Superintendent	Bishop, CA 619/387-2501
U.S. Gypsum Co.	Mining Engineering Division	Chicago, IL 312/321-4000

Agency, Company, or Mine	Contact	Location and Telephone No.
U.S. Steel Corp.	F. Neely, Chief Mining Engineer	Uniontown, PA 412/430-2249
U.S. Committee of Tunneling Technology	J. Wagner, Chairman	Washington, DC 202/334-3136
U.S. Bureau of Mines	J. Presseu, Gypsum Specialist	Washington, DC 202/634-1206
	W. Miller, Mining Research	Washington, DC 202/634-1233
	J. Burlison, Mining Management Services	Carlsbad, NM 505/885-8881
	D. Kostick, Salt Specialist	Washington, DC 202/634-1177
	M. Jolley, Copper Specialist	Washington, DC 202/634-1071
	R. Schmidt, Div. of Research	Minneapolis, MN 612/725-3455
	D. Bolstad, Div. of Research	Spokane, WA 509/404-1610
	J. Paron, Limestone Specialist	Washington, DC 202/634-1185
	J. Paone, Experimental Studies	Brucetor, PA 202/634-4740
	J. Searls, Potash Specialist	Washington, DC 202/634-1190
	D. Barna, Div. of Mining Technology	Washington, DC 202/634-1233
	S. Guys, Engineering Research	Washington, DC 202/343-4054
	C. Wang, Mining Research	Washington, DC 202/634-1268
U.S. Bureau of Reclamation	K. Schulman, Water Conveyance Branch	Denver, CO 303/234-4379
U.S. Corp of Engineers	Planning Division of Civil Works	Washington, DC 202/272-0115

Agency, Company, or Mine	Contact	Location and Telephone No.
U.S. Mine Safety & Health Administration	J. Coldwell, Regional Office	Topeka, KS 913/205-2636
	C. Ellis, Central Office	Washington, DC 202/235-2146
	North Central Office	Vincennes, IN 812/882-0696
Vulcan Materials Co., Inc., Frederick Mine	Mine Superintendent	Frederick, KY 606/266-1176
White Pine Copper Co., Inc., White Pine Mine	Mining Engineering Dept.	White Pine, MI 906/885-5111

TABLE 3.2-1

CANDIDATE AREAS FOR SUBSURFACE SITES

State	Mine or Facility	Comments (1,2,3)
Arizona	Lakeshore Mine	0.2 km × 0.2 km
	Superior Mine	0.1 km × 0.3 km
California	Bishop Mine	0.6 km × 1.0 km - the long passage is a haulage tunnel
Colorado	Henderson Mine	0.2 km × 0.3 km
	Henderson East Tunnel	16.3 km - Curvature of earth haulage tunnel with no significant Orthogonal passage
Idaho	Bunker Hill Mine	0.8 km × 0.9 km - one passage is a haulage tunnel
	Lucky Friday Mine	0.4 km × 0.8 km
Illinois	U.S. Gypsum Co.	maximum of 0.6 km × 0.6 km in the largest of their six mines
	Mississippi Lime Mine	0.7 km × 0.7 km
	Chicago Mine	1.6 km × 1.6 km - to be abandoned; significant rock stability problems, very extensive maintenance
	Prairie du Rocher Mine	0.3 km × 0.4 km
	Vulcan Mine	0.4 km × 0.4 km
Indiana	Shoals Mine	0.4 km × 0.4 km
	Chicago Metro Sewer Comm.	0.8 km × 1.4 km - lack of availability (sewer system)
	Coal Mines - general	0.2 km × 0.2 km
Iowa	Sperry Mine	0.3 km × 0.3 km
Kentucky	Dravo Mine	0.3 km × 0.3 km
	Black River Mine	0.4 km × 0.5 km
	Princeton Mine	0.6 km × 0.6 km
	Mullins Mine	0.5 km × 0.5 km - disused mine
	Frederick Mine	1.0 km × 1.1 km
Louisiana	Jefferson Island	
	Avery Island	
Michigan	White Pine Mine	0.3 km × 0.9 km - the long passage is a haulage tunnel
	Detroit Mine (International Salt)	1.0 km × 1.0 km

(1) Unless otherwise noted, the distances indicated are line-of-sight.
(2) Unless otherwise noted, the mines and passages are actively used.
(3) States not listed do not contain any mines or subsurface passages that could be considered for the antenna.

TABLE 3.2-1

CANDIDATE AREAS FOR SUBSURFACE SITES (Cont)

State	Mine or Facility	Comments (1,2,3)
Missouri	Randolph Mine (Great Midwest Mining)	1.4 km x 1.6 km
	Buick Mine	0.3 km x 4.0 km - the long passage is a haulage tunnel
	St. Genevieve Mine	0.6 km x 0.6 km
	Magmont Mine	0.3 km x 2.0 km - one passage is a haulage tunnel
	Viburnum Mine	0.3 km x 1.5 km - the long passage is a haulage tunnel
	Fletcher Mine	0.6 km x 2.0 km - haulage passages
	Brock Mine	0.4 km x 0.7 km
	Heath Mine	0.3 km x 3.0 km - the long passage is a haulage tunnel
New Jersey	Sterling Hill Mine	0.1 km x 0.1 km
New Mexico	Eddy Mine	0.7 km x 0.8 km - mine on standby status, to be reactivated with improved market
	Nash Draw Mine (Duval Corp.)	1.5 km x 1.5 km
	Mississippi Chem. Mine	0.4 km x 0.4 km - abandoned, hoisting equipment removed
	IMC Mine	0.2 km x 0.2 km - no interest by management
	PCA Mine	0.2 km x 0.3 km - no interest by management
New York	Retsof Mine (International Salt)	1.0 km x 1.0 km
	Cayuga Mine(Lansing)	0.9 km x 1.0 km
	Seneca Mine	0.6 km x 0.7 km
Ohio	Cleveland Mine (International Salt)	1.7 km X 1.7 km
	U.S. Corp. of Engineers	Underground shelter study
	Jonathan Mine	0.8 km X 0.9 km
	Fairport Mine	0.6 km x 0.9 km - disused mine
	Barberton Mine	0.6 km X 0.8 km - disused mine
	Zanesville Mine	0.7 km X 1.1 km
	Paynesville Mine	0.6 km X 0.9 km
Pennsylvania	Bethlehem Corp.	0.5 km x 0.5 km - the most extensive configuration in their mines
	Peabody Coal Co.	0.2 km x 0.3 km - the most extensive configuration in their mines
	CONOCO	0.7 km X 0.5 km - the most extensive configuration in their mines
	Consolidated Coal Co.	0.4 km X 4.2 km - the long passage is a haulage tunnel
	U.S. Steel Co.	0.3 km X 0.3 km - the most extensive configuration in their mines
	U.S. Corp. of Engineers	Underground shelter study
South Dakota	Homestake Mine	0.3 km x 0.4 km - haulage passages

(1) Unless otherwise noted, the distances indicated are line-of-sight.
(2) Unless otherwise noted, the mines and passages are actively used.
(3) States not listed do not contain any mines or subsurface passages that could be considered for the antenna.

TABLE 3.2-1

CANDIDATE AREAS FOR SUBSURFACE SITES (Cont)

State	Mine or Facility	Comments (1,2,3)
Tennessee	Mascot Mine	0.4 km X 0.4 km
	New Market Mine	0.2 km x 0.3 km
	Gleason Mine	0.3 km x 0.3 km
	Gordonsville Mine	0.3 km x 0.3 km
Utah	Park City Mine	0.3 km x 0.3 km
	Bat Tunnel (Bur. of Reclam.)	12.8 km - one passage only (water tunnel)
	Hades Tunnel (Bur. of Reclam.)	7.2 km - one passage only (water tunnel)
Virginia	Kimballton Mine	0.2 km x 0.3 km
Washington	Pend Orielle Mine	0.1 km x 0.2 km
West Virginia	Consolidated Coal	0.2 km x 0.2 km - the most extensive configuration in their mines
Wyoming	Westvaco Mine	0.2 km x 0.3 km
	Alchem Mine	0.2 km x 0.4 km - no interest by management
	Carbon County Coal Co.	0.6 km x 0.8 km - mining technique employed not suitable for passage excavation

(1) Unless otherwise noted, the distances indicated are line-of-sight.
(2) Unless otherwise noted, the mines and passages are actively used.
(3) States not listed do not contain any mines or subsurface passages that could be considered for the antenna.

TABLE NO. 3.3-1

DECREMENTAL LIST OF SUBSURFACE SITES

Length	Sites
5.0 km or longer	None
4.0 km to 5.0 km	None
3.0 km to 4.0 km	None
2.0 km to 3.0 km	None
1.0 km to 2.0 km	Cleveland mine, 1.7 km x 1.7 km, Cleveland, Ohio, International Salt Co.
	Nash Draw mine, 1.5 km x 1.5 km, Carlsbad, NM, Duval Corp.
	Randolph mine, 1.4 km x 1.6 km, Kansas City, MO, Great Midwest Mining Corp.
0.5 km to 1.0 km	Jonathan mine, 0.8 km x 0.8 km, near Zanesville, OH, Columbia Cement Co.
	Barberton mine, 0.6 km x 0.6 km, near Akron, OH, PPG Industries, Inc.
	Mullins mine, 0.6 km x 0.6 km, Mt. Vernon, KY, the Kentucky Stone Co.

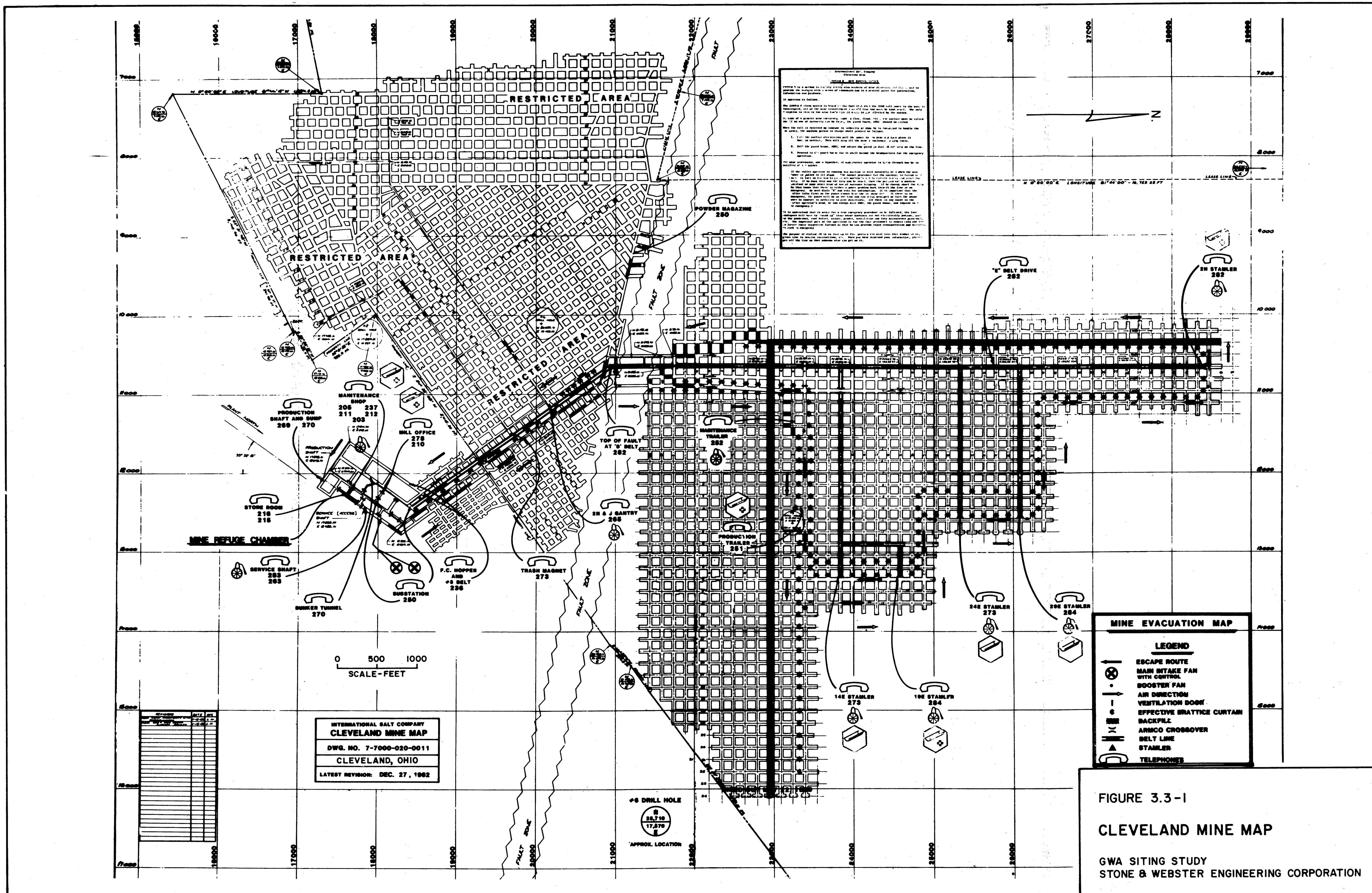

FIGURE 3.3-1

CLEVELAND MINE MAP

GWA SITING STUDY
STONE & WEBSTER ENGINEERING CORPORATION

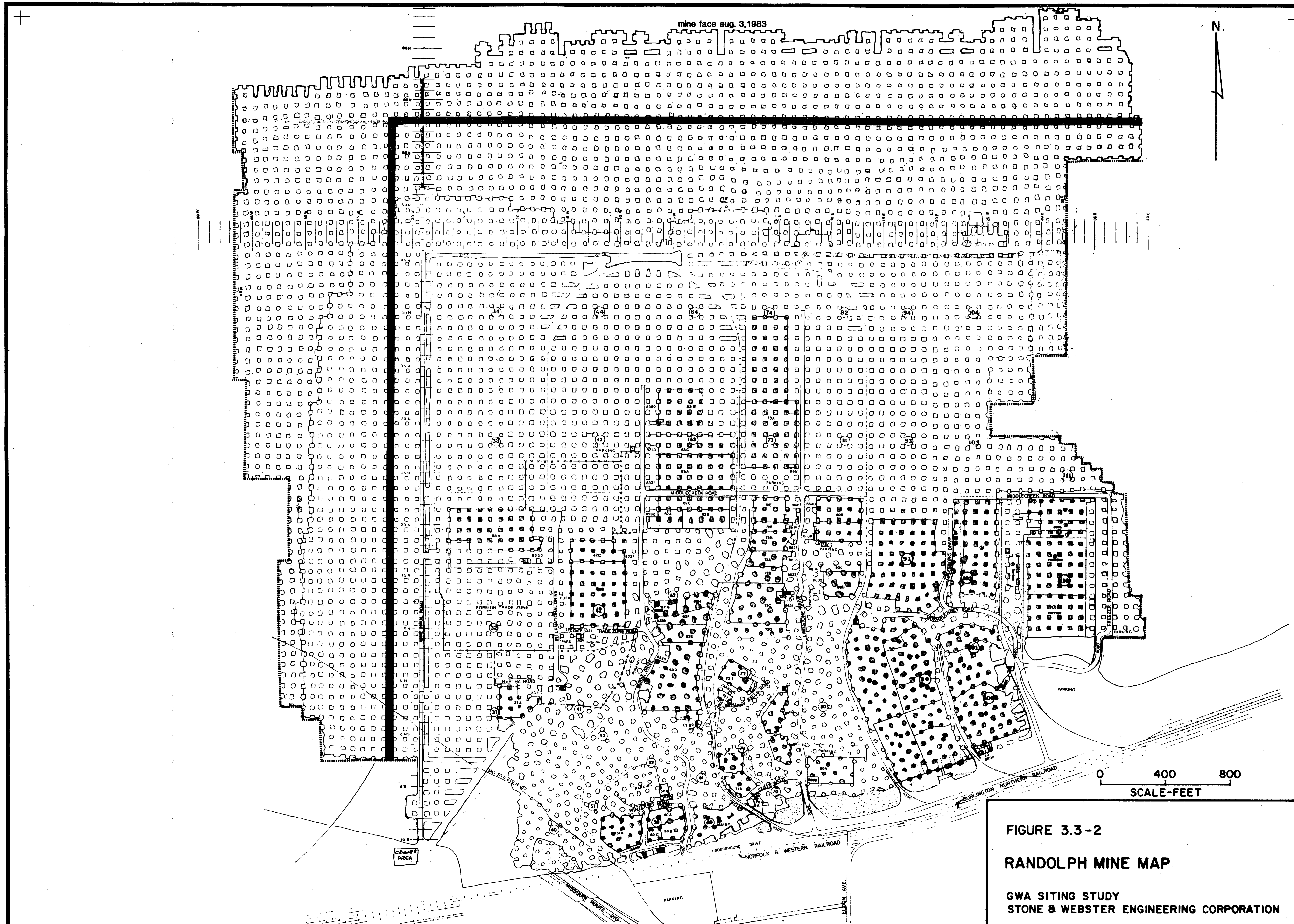

FIGURE 3.3-2

RANDOLPH MINE MAP

GWA SITING STUDY
STONE & WEBSTER ENGINEERING CORPORATION

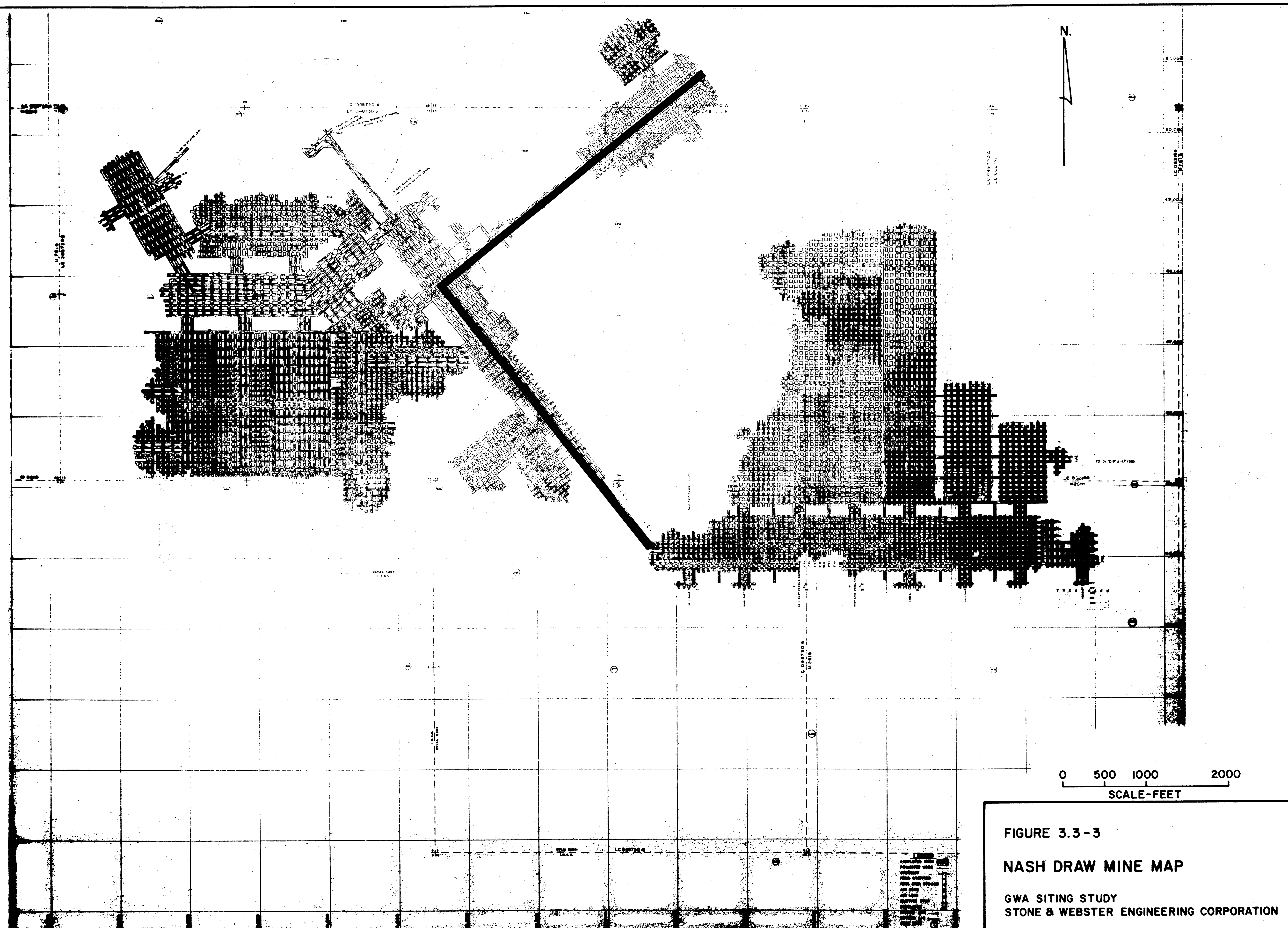

FIGURE 3.3-3

NASH DRAW MINE MAP

GWA SITING STUDY
STONE & WEBSTER ENGINEERING CORPORATION

4.0 SUMMARY AND RECOMMENDATIONS FOR FURTHER STUDY

This study examined the possibility of siting one or more 5 km by 5 km L-shaped antennas at the ground surface or in underground mines within the continental United States. It was a preliminary study involving review of maps and literature; no onsite investigations were performed. Conclusions and recommendations for surface and underground sites are given separately below.

4.1 Surface Sites

The study considered federal government installations of appropriate size throughout the continental United States, and private lands in New England, New York, New Jersey, North Carolina, Colorado, Nebraska, and parts of Utah and Arizona. From these candidate areas, thirteen candidate sites were selected for closer study. The site locations are shown in Figure 4-1. The conditions at these candidate sites can be used to develop realistic input to preliminary estimates of site development costs for an antenna installation.

The sites described herein are not the only sites which should be considered, nor is the optimum site necessarily among them. It may be possible to identify sites in areas not considered in this study. Other areas that would be likely candidate areas are the northern portions of Ohio, Indiana, and Illinois, and the "Panhandle" and western portions of Texas. Lands administered by the United States Bureau of Land Management might also be considered. A map of public lands administered by the Bureau of Land Management is given in Figure 4.2.

There are no sites within New England, New York, New Jersey, North Carolina, or Nebraska that meet the criteria that were established for a surface site. The primary reasons for excluding lands in these areas are topography and land use. There are no relatively flat or uniformly sloping areas that are not crossed by major roads within those states. If the length of the antenna could be shortened from 5 km to 2 to 3 km, there would be a better possibility of siting the antenna in these or other areas.

With respect to the thirteen candidate sites described in Section 2.3, it should be noted that six of these are on military installations (Edwards Air Force Base, Eglin Air Force Base, Fort Bliss, Fort Stewart, Luke Air Force Range, and White Sands Missile Range.) The extent of nearby military operations would have to be determined before these sites are given further consideration. Edwards Air Force Base can be eliminated from further study because it is in an active seismic area.

The study identified potential sources of ground vibrations in the area surrounding the candidate sites. Detailed studies of specific sites should include measurement of ground vibrations at potential antenna locations. These studies should be performed for a time period sufficiently long to include most of the conditions that could be encountered during the life of the antenna.

4.2 SUBSURFACE SITES

The investigation of subsurface sites for the antenna considered locations in mines, water tunnels, and railway and vehicular tunnels. None of the locations investigated provides 5 km or longer line-of-sight passages with an orthogonal configuration. It is highly unlikely that any such site exists in the continental United States. The longest potential passages that were identified are only 1.4 to 1.7 km long, and these are found in mines that are still being actively exploited. These mines are:

- Cleveland Mine, 1.7 km by 1.7 km, Cleveland, Ohio
- Nash Draw Mine, 1.5 km by 1.5 km, Carlsbad, New Mexico
- Randolph Mine, 1.4 km x 1.6 km, Kansas City, Missouri

Duval Corporation indicated as this report was going to press that it wishes the Nash Draw Mine to be withdrawn from further consideration as an antenna site.

A number of inactive mines were located, but the passage lengths in these mines are less than at the above-mentioned sites.

- Jonathan Mine, 0.8 km by 0.8 km, Zanesville, Ohio
- Barberton Mine, 0.6 km by 0.8 km, Akron, Ohio
- Mullins Mine, 0.6 km by 0.6 km, Mt. Vernon, Kentucky

The owners of these mines generally expressed a willingness to consider extending the length of the existing passages, but detailed evaluation of this option was not within the scope of this study. The maximum potential passage length will depend on how far the ends of the existing passages are from the claim boundary, and on the geology of the areas into which the passages would extend. One factor affecting unit costs is whether the excavated material can be sold or must be disposed of as spoil material. Another factor is the availability of equipment at the mine.

If any of the mine sites is given further consideration, it is recommended that vibration levels be measured at the proposed antenna location.

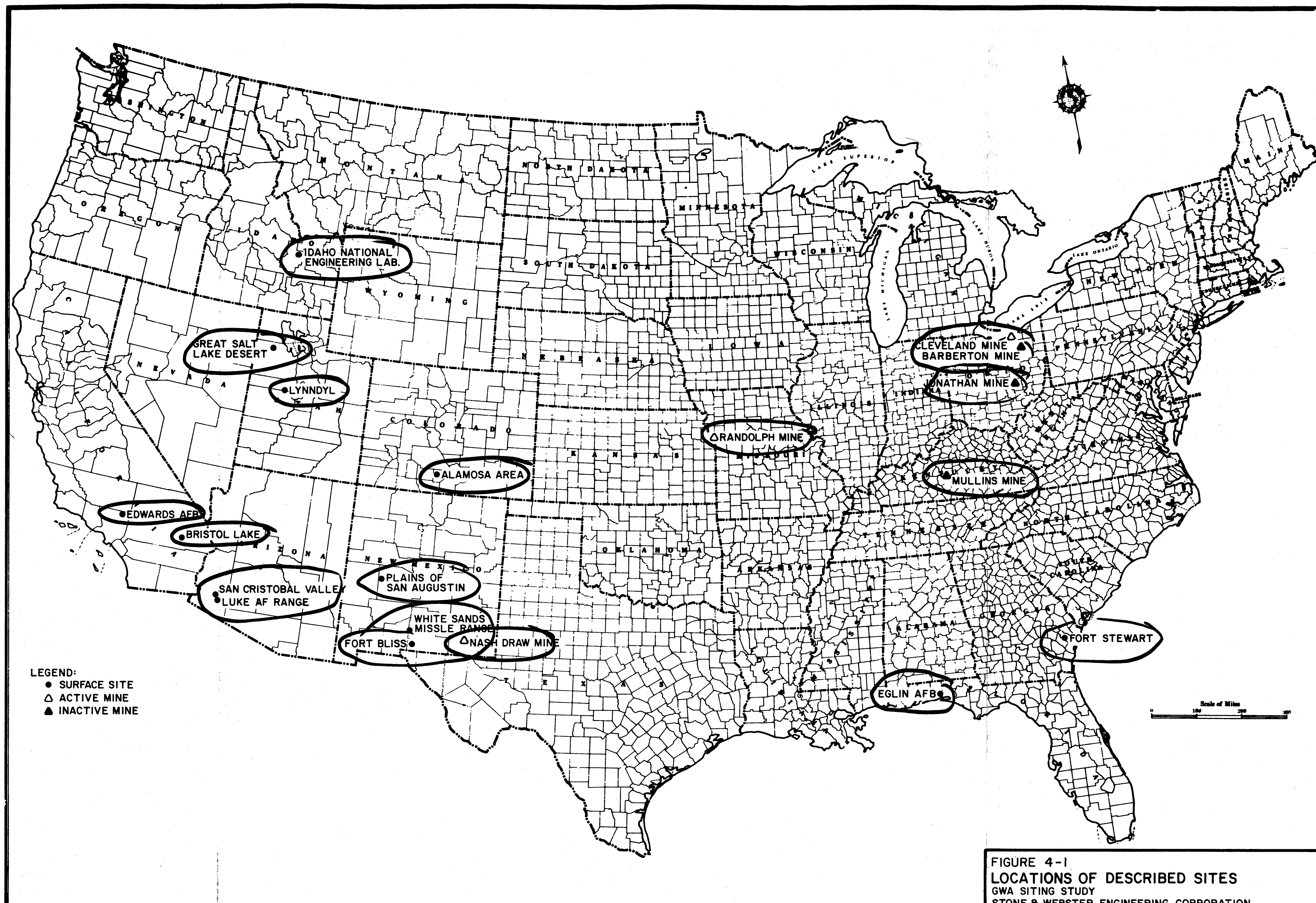

FIGURE 4-1
LOCATIONS OF DESCRIBED SITES
GWA SITING STUDY
STONE & WEBSTER ENGINEERING CORPORATION