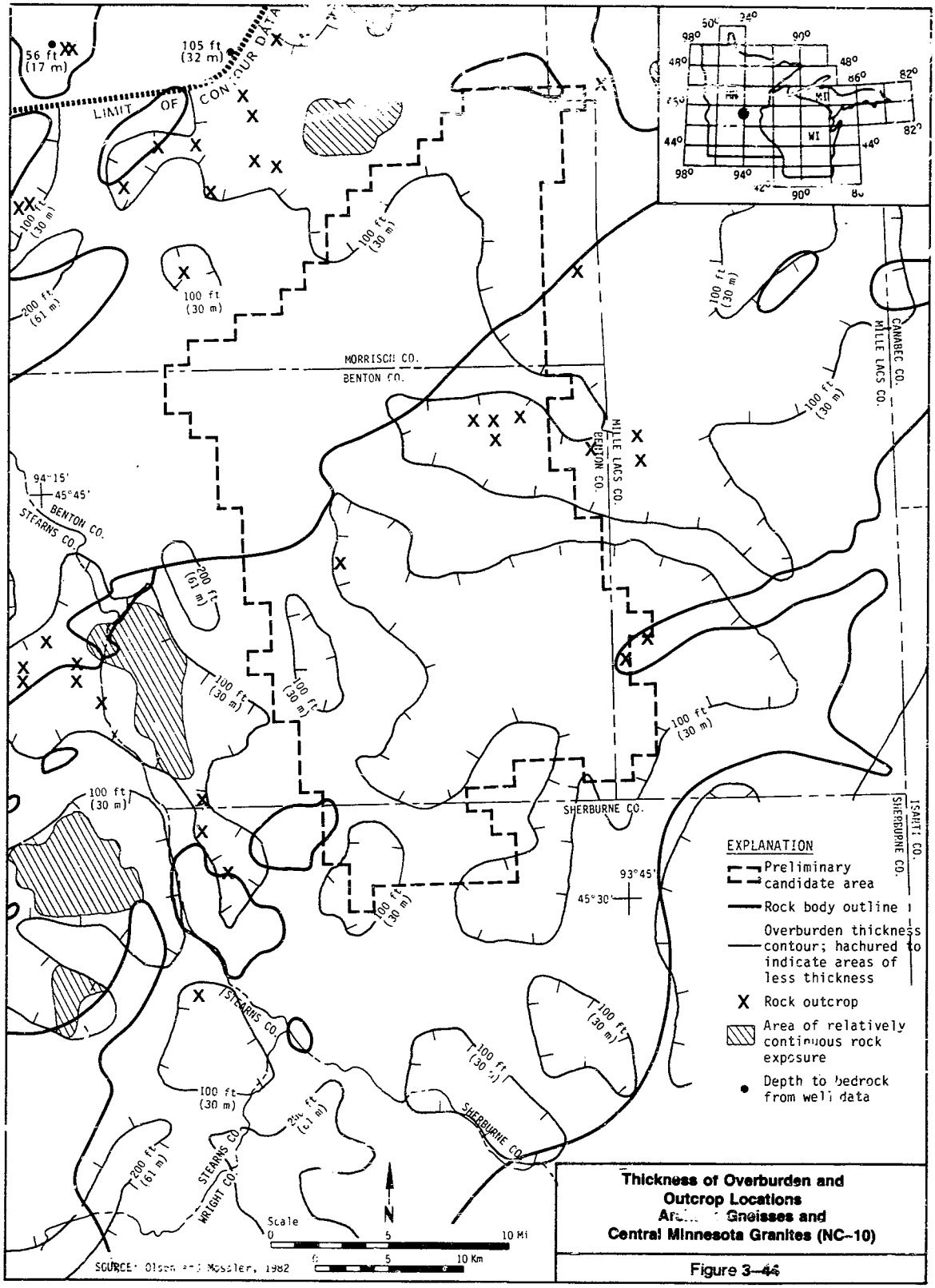


Thickness of Overburden and Outcrop Locations Ar... Gneisses and Central Minnesota Granites (NC-10)

Figure 3-44

laterally extensive to allow significant flexibility in selecting the depth, configuration, [illegible] of the underground facility to ensure isolation.

3.2.1.7.2 Lithology and Tectonics. The Archean gneisses and central Minnesota granites are composed of undivided gneissic rocks, Sartell gneiss, Hillman migmatite, Reformatory granite, and St. Cloud granite (Figure 3-43) (Morey et al., 1981). The undivided gneissic rocks are poorly exposed and lithologic details are lacking. The Sartell gneiss is composed of interlayered medium- to coarse-grained, quartzofeldspathic gneiss and fine- to medium-grained garnet- and cordierite-bearing biotite schist that have been metamorphosed to the upper amphibolite facies. The Hillman migmatite is composed of light- to dark-gray, medium- to coarse-grained, foliated biotite-garnet-cordierite schist, hornblende schist, and metagraywacke that exhibit dominantly amphibolite facies metamorphism. The neosome of the Hillman migmatite consists of gray, medium-grained, foliated and locally cataclastized tonalite that may be Proterozic in age. The Reformatory granite consists of gray, medium-grained porphyritic biotite and hornblende-bearing granite of generally sodic composition (Morey et al., 1981). The St. Cloud granite consists of red, medium-grained, locally porphyritic granite of generally potassic composition (Morey et al., 1981). These rocks contain plagioclase, potassium feldspar, quartz, hornblende, augite, biotite, orthopyroxene, clinopyroxene, garnet, cordierite, and minor amounts of apatite, zircon, sphene, magnetite, ilmenite, pyrite, chalcopyrite, tourmaline, and rutile (Morey, 1978; Goldich et al., 1980a, 1980b).

The Archean gneisses underlie the northern one-third of the preliminary candidate area and the central Minnesota granites underlie the southern two-thirds (Figure 3-43). The undivided gneisses occupy the northwestern portion of the preliminary candidate area and are bordered by the Sartell gneiss and St. Cloud granite to the south and the Hillman migmatite to the north. The St. Cloud granite occupies the central portion of the preliminary candidate area and the Reformatory granite

forms a narrow belt along the southern border of the area (Figure 3-43) (Morey et al., 1981). Small outliers of Cretaceous shale and sandstone overlie the St. Cloud granite along the western border of the preliminary candidate area (Morey et al., 1981).

The Archean gneisses are part of the Archean gneiss terrane of southern Minnesota that formed 2,600 to 3,550 million years ago (Morey and Sims, 1976; Morey et al., 1982). The Archean gneisses have been metamorphosed to the upper amphibolite or lower granulite facies (Goldich and Wooden, 1980). Similar gneisses in the Minnesota River valley to the south of the preliminary candidate area were metamorphosed and deformed several times during the period 2,600 to 3,050 million years ago (Bauer, 1980; Goldich et al., 1980a, 1980b), and intruded by granitic magmas about 2,600 million years ago (Goldich and Wooden, 1980). Rocks of the Archean gneiss terrane were tectonically remobilized periodically until about 1,600 million years ago. (Sims et al., 1980).

The Archean gneisses of the preliminary candidate area were intruded by the central Minnesota granites during the waning stages of the Penokean orogeny at about 1,800 to 1,850 million years ago (Keighin et al., 1972; Morey, 1978). Subsequent to this granitic emplacement, several generations of felsic and mafic dikes intruded these rocks (Morey, 1978). The effect of the development of the Midcontinent rift system at 1,110 million years ago (Van Schmus et al., 1982) on the rocks of the preliminary candidate area was limited to the intrusion of Keweenawan mafic dikes in the Archean gneisses to the north (Morey, 1978).

Morey et al. (1981) mapped foliation in the Archean gneisses north of the preliminary candidate area and layering in the St. Cloud granite within the preliminary candidate area. Foliation in the Hillman migmatite north of the preliminary candidate area strikes northeasterly and dips steeply southeast, vertical, or steeply southwest. Layering in the St. Cloud granite in the east-central portion of the preliminary candidate area trends east-northeast and dips 30 to 70 degrees to the southeast (Morey et al., 1981). Although joints are expected to be

present, they have not been reported in the literature. There are no faults within the preliminary candidate area (Figure 3.4-3). The closest fault is approximately 10 km (6 mi) east of the preliminary candidate area. There is no evidence of Quaternary activity along this fault or within the geologic setting.

One measurement of stress was made at St. Cloud, approximately 15 km (9 mi) southwest of the preliminary candidate area. The measurement was made at a depth of 15 m (50 ft) using the hydrofracturing technique which produced the following results: least horizontal compressive stress (σH_{min}) of 0.05 MPa, largest horizontal compressive stress (σH_{max}) of 0.14 MPa, vertical stress (σ_V) of 0.004 MPa, and the direction of σH_{max} as N 40° E (Haimson, 1977). While this stress data have been taken at a rather shallow depth, it does not appear to pose any significant concern to shaft or near-surface construction.

The discussion of rate of recent crustal uplift is presented in the regional geologic setting (Section 3.2.1.1.1.3). There is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that this uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for the vicinity of the preliminary candidate area.

The absence of any igneous activity in and near the preliminary candidate area for the last 1,000 million years and the absence of Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicate that future igneous activity in the area is highly unlikely.

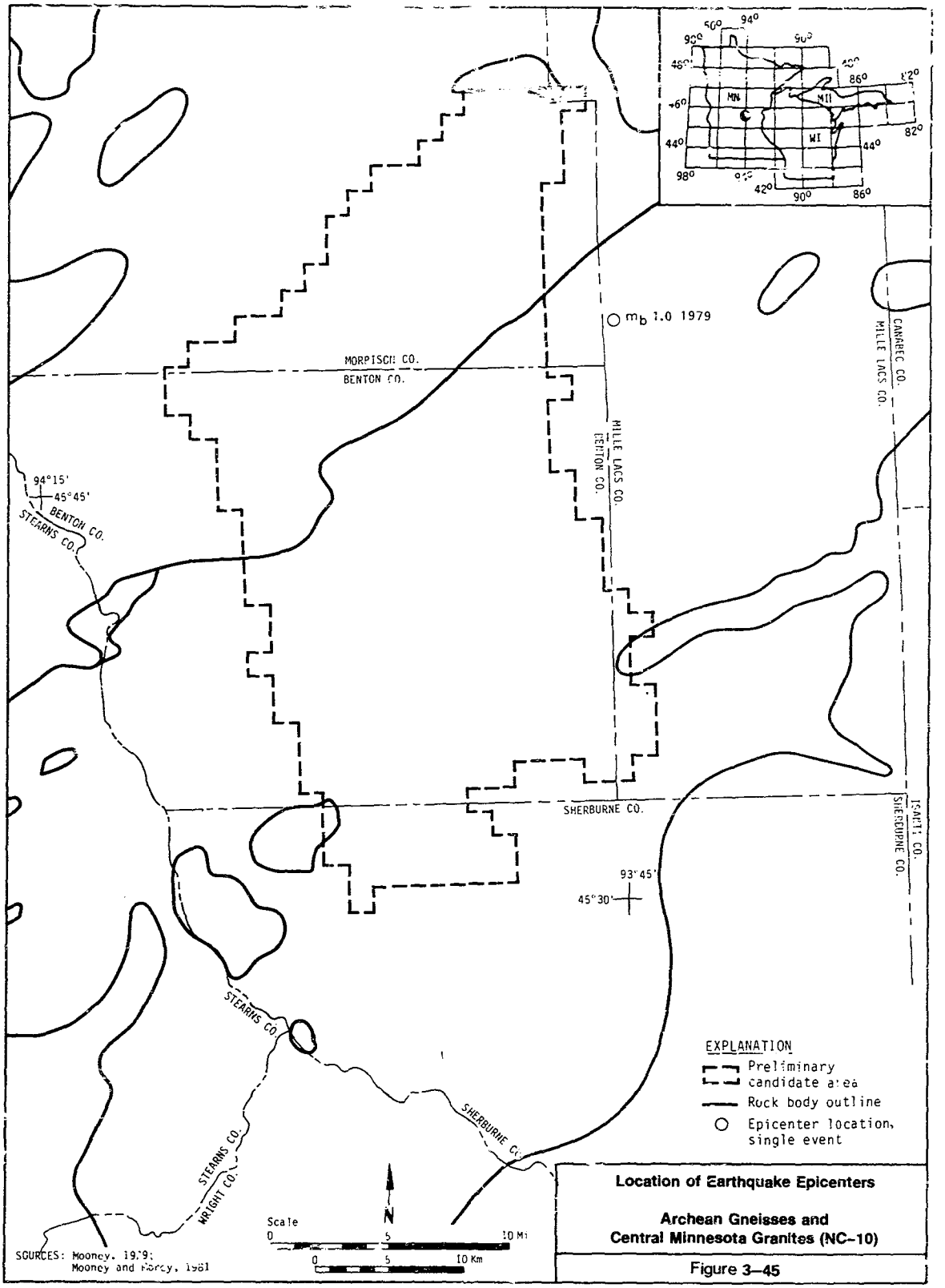
There is no evidence of igneous activity, folding, faulting, uplift, subsidence, or other tectonic processes within the geologic setting during the Quaternary Period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.1.7.3 Seismicity. One historical microearthquake is located approximately 5 km (3 mi) east of the preliminary candidate area (Figure 3-45). Mooney and Morey (1981) identified this epicenter as the m_b 1.0 Milaca event which occurred on March 6, 1979. They note that no felt reports exist for this event (Mooney and Morey, 1981). The regional seismicity is discussed in Section 3.2.1.1.1.3.

Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the preliminary candidate area will increase in the future.

3.2.1.7.4 Mineral Resources. There are no strategic, metallic, or energy-related mineral resources known to occur either in or within 10 km (6 mi) of the preliminary candidate area (Schwartz and Prokopovich, 1966; Walton, 1976; USBM, 1983). No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mine or quarry is the Charcoal Gray granite quarry, located approximately 14 km (9 mi) southwest of the preliminary candidate area. Other natural resources within and near the preliminary candidate area (i.e., quarries and marl deposits) are shallow and widely available throughout the region.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources in the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation, and no information is currently available to indicate that deep exploration drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

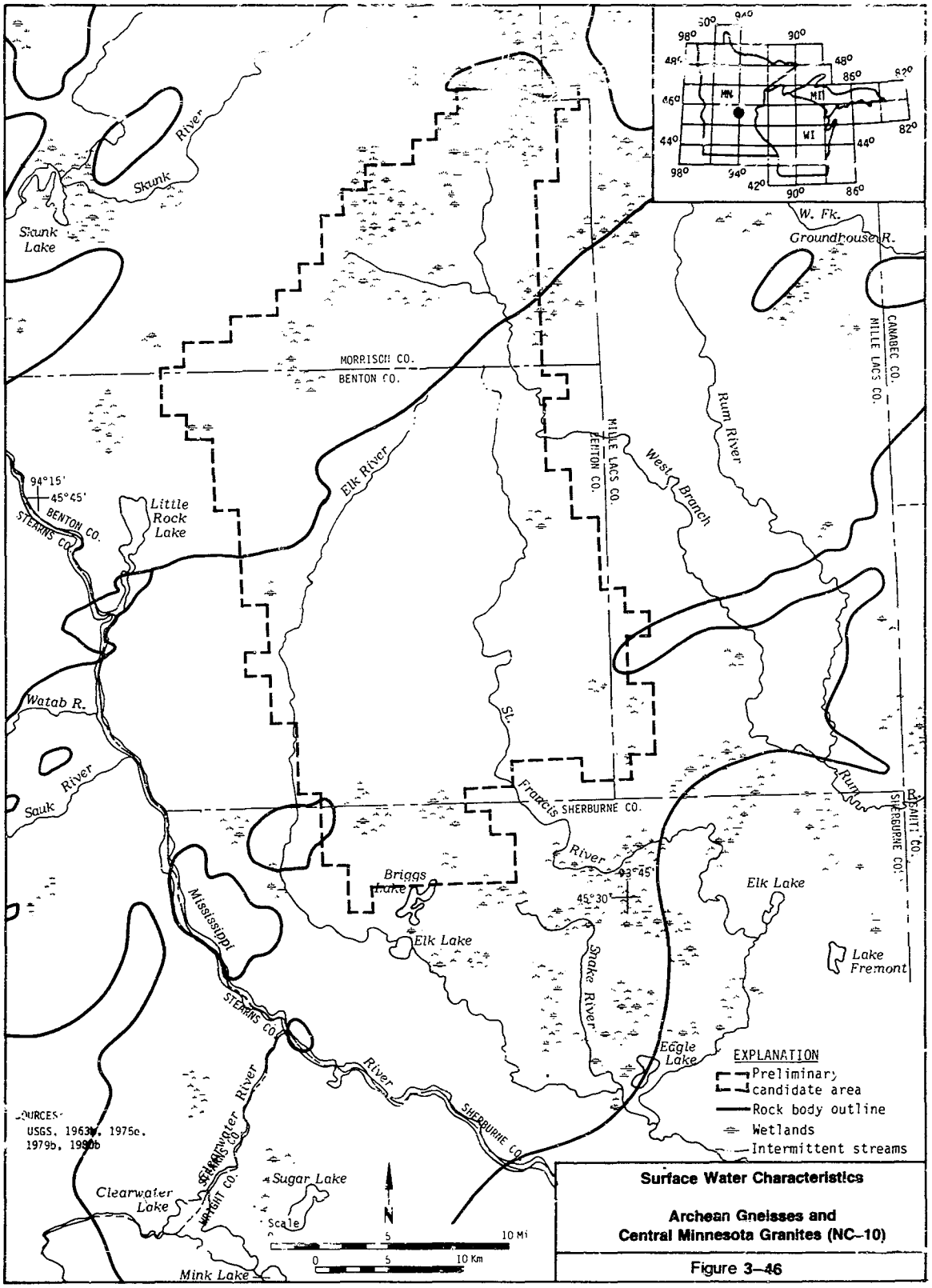

mb 1.0 1979
MORRISON CO.
BENTON CO.
MILLE LACS CO.
CROW WING CO.
94°15'
45°45'
BENTON CO.
STEARNS CO.
SHERBURNE CO.
93°45'
45°30'
STEARNS CO.
SHERBURNE CO.
STEARNS CO.
WRIGHT CO.
EXPLANATION
Preliminary candidate area
Rock body outline
Epicenter location, single event
Scale
0 5 10 Mi
0 5 10 Km
N
SOURCES: Mooney, 1979; Mooney and Morey, 1981
Location of Earthquake Epicenters
Archean Gneisses and Central Minnesota Granites (NC-10)
Figure 3-45

3.2.1.7.5 Topography and Surface Flow Characteristics. The topographic relief of the preliminary candidate area is generally low with elevations between 305 and 402 m (1,000 and 1,320 ft). The preliminary candidate area does not appear to contain large areas of floodplain. Examination of topographic maps indicates that only localized portions of the preliminary candidate area along major drainages and small stream valleys are potentially flood prone. No reservoirs or impoundments are known to exist in or upstream of the area.

The central Minnesota granites and the Archean gneisses are drained mainly by the west branch of the Rum River, St. Francis River, and Elk River, which drain south-southeast to the Mississippi River. As represented by the region-to-area screening data base, the preliminary candidate area is covered by approximately 2% surface water and 4% wetland (USGS, 1965; USGS, various dates; Minnesota State Planning Agency, 1984). The locations of lakes, rivers, and marshlands in the preliminary candidate area on Figure 3-46 are based on surface water features shown on USGS 1:250,000 Stillwater, Saint Cloud, Duluth, and Brainerd topographic maps. Major surface water bodies within the preliminary candidate area include the Elk, west branch of the Rum, and St. Francis Rivers. Other surface water bodies near the preliminary candidate area include the Mississippi River, Skunk River, Rum River, Snake River, Little Rock Lake, Elk Lake, Briggs Lake, and numerous other lakes and streams.

The data presented in this section indicate that the relief of the preliminary candidate area is generally low and the terrain is generally well drained. Evaluation of topographic maps of the preliminary candidate area indicate that only localized portions of the area are potentially flood prone.

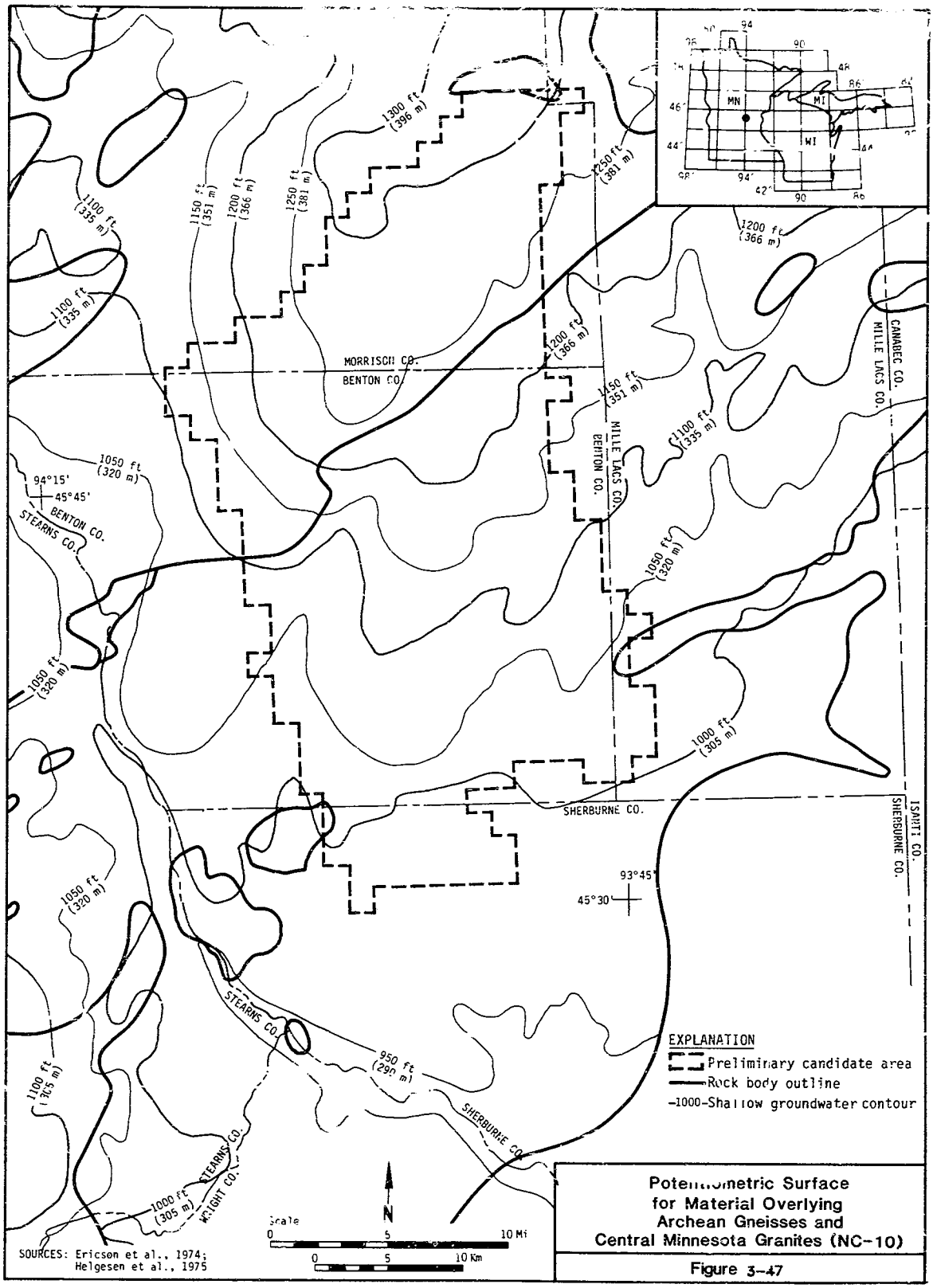
3.2.1.7.6 Ground-Water Resources. The regional hydrology is discussed in Section 3.2.1.1.5. Shallow ground-water movement is generally toward the Mississippi River in the western portion of the basin and southeastward toward the Rum River in the eastern portion.

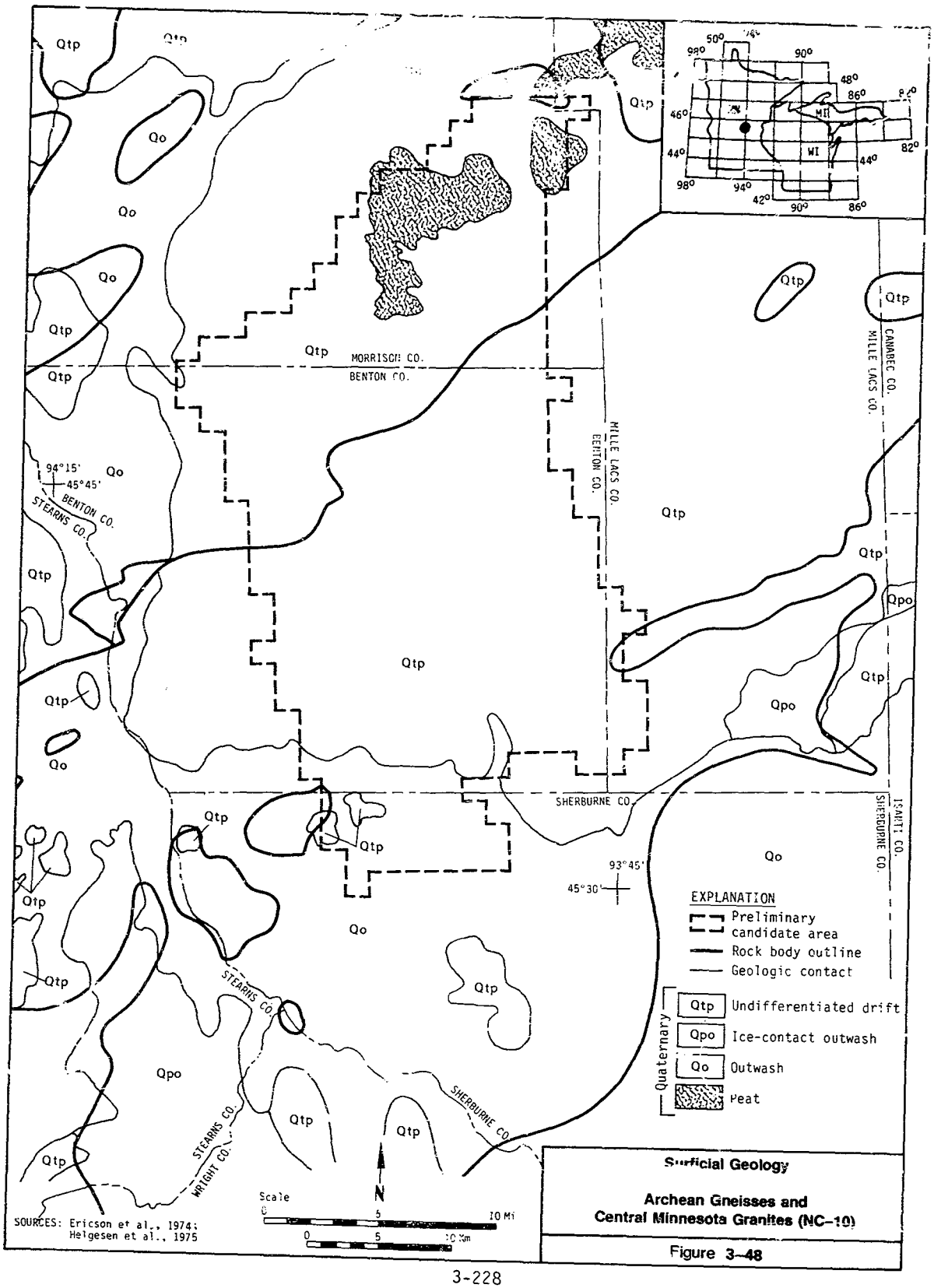

Skunk River
Skunk Lake
MORRISON CO.
BENTON CO.
Elk River
Little Rock Lake
94°15'
45°45'
BENTON CO.
STEARNS CO.
Watab R.
Sauk River
Mississippi
STEARNS CO.
Briggs Lake
Elk Lake
St. Francis River
SHERBURNE CO.
Rum River
MILLE LACS CO.
West Branch Rum River
CANABEC CO.
W. Fk. Groundhouse R.
93°45'
45°30'
Elk Lake
Lake Fremont
Snake River
Eagle Lake
River
SHERBURNE CO.
Clearwater River
WRIGHT CO.
Clearwater Lake
Sugar Lake
Mink Lake
Scale
10 Mi
10 Km
N
EXPLANATION
Preliminary candidate area
Rock body outline
Wetlands
Intermittent streams
SOURCES:
USGS, 1963b, 1975c, 1979b, 1980b
Surface Water Characteristics
Archean Gneisses and Central Minnesota Granites (NC-10)
Figure 3-46

Locally, ground water [illegible] toward nearby rivers and streams. Figure 3-47 shows [illegible] ground-water contours reported by Ericson et al., (19[illegible]) and Helgesen et al., (1975a). No deep drillholes (exploration or water, greater than 100 m [328 ft] in depth) have been reported in the literature reviewed for this preliminary candidate area. Areas that displayed convergence of shallow water-table contours, based on a 30-m (100-ft) contour interval, were considered potential major discharge zones. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that include: 1) surficial outwash deposits of stratified sand and gravel, commonly moderately to well sorted; 2) undifferentiated drift, primarily calcareous till or sandy till, usually unstratified and unsorted, containing stratified sand and gravel bodies of varying extent and thickness; and 3) ice contact-pitted outwash deposits, comprised primarily of gravel and sand, that are commonly stratified with variable sorting, and some till (Helgesen et al., 1975a; Ericson et al., 1974). The horizontal extent of surficial deposits is shown in Figure 3-48.

Well yields presented in the North Central RGCR (DOE,1985c) were estimated from maps by Kanivetsky (1978, 1979) and Kanivetsky and Walton (1979), and are shown in Figure 3-49a. Additional detailed well yield information has been reported by Helgesen et al., (1975a) and Ericson et al., (1974) in USGS Hydrologic Atlases and is shown in Figure 3-49b. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison. Surficial outwash in some areas is a potential source of large ground-water supplies where, if the saturated thickness is sufficient, well yields in excess of 63 L/s (1,000 gpm) are theoretically possible. Small to moderate quantities of water are possible from the ice contact-pitted outwash deposits. Well yields in


MN
WI
MI
1300 ft (396 m)
1250 ft (381 m)
1200 ft (366 m)
1150 ft (351 m)
1100 ft (335 m)
1050 ft (320 m)
1000 ft (305 m)
950 ft (290 m)
MORRISON CO.
BENTON CO.
MILLE LACS CO.
CANABEC CO.
ISANTI CO.
SHERBURNE CO.
STEARNS CO.
WRIGHT CO.
94°15'
45°45'
93°45'
45°30'
EXPLANATION
Preliminary candidate area
Rock body outline
-1000-Shallow groundwater contour
Scale
0 5 10 Mi
0 5 10 Km
N
SOURCES: Ericson et al., 1974; Helgesen et al., 1975
Potentiometric Surface for Material Overlying Archean Gneisses and Central Minnesota Granites (NC-10)
Figure 3-47


Qtp
Qo
Qpo
MORRISON CO.
BENTON CO.
MILLE LACS CO.
CANABEC CO.
SHERBURNE CO.
ISANTI CO.
STEARNS CO.
WRIGHT CO.
94°15'
45°45'
93°45'
45°30'
MI
WI
EXPLANATION
Preliminary candidate area
Rock body outline
Geologic contact
Quaternary
Undifferentiated drift
Ice-contact outwash
Outwash
Peat
Scale
0 5 10 Mi
0 5 10 Km
N
SOURCES: Ericson et al., 1974; Helgesen et al., 1975
Surficial Geology
Archean Gneisses and Central Minnesota Granites (NC-10)
Figure 3-48

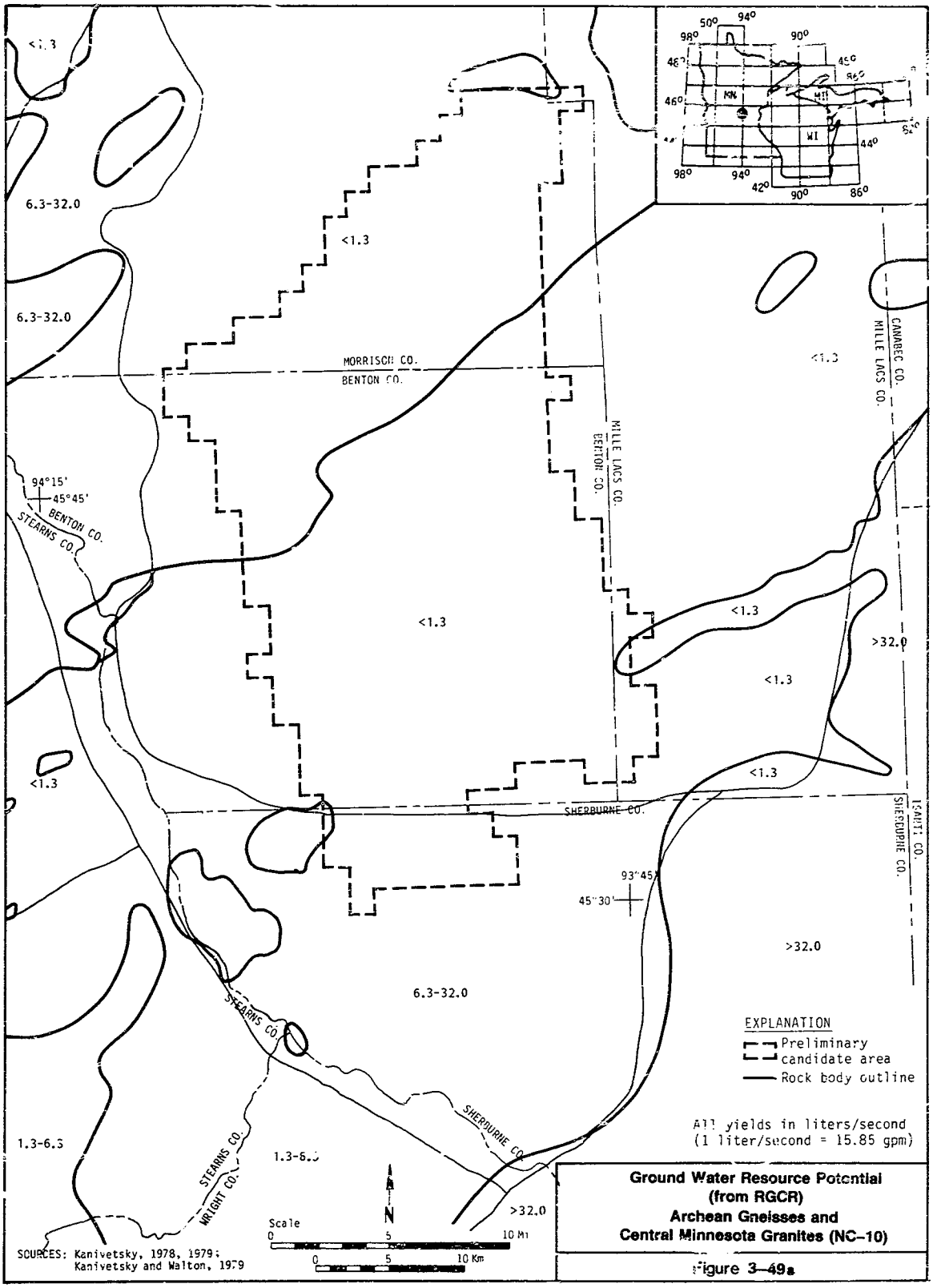
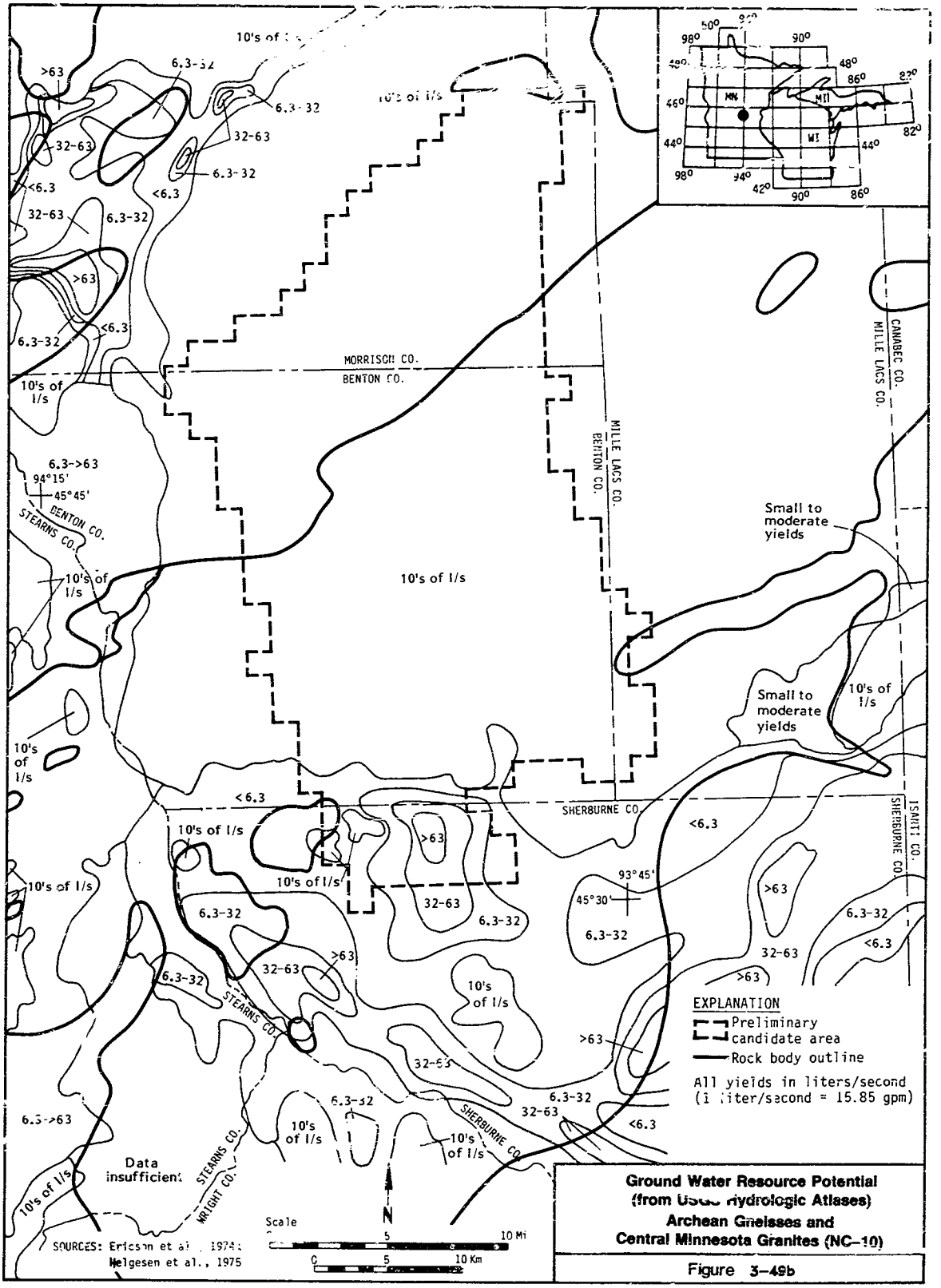

<1.3
6.3-32.0
<1.3
6.3-32.0
MORRISON CO.
BENTON CO.
MILLE LACS CO.
CANABEC CO.
MILLE LACS CO.
<1.3
94°15'
45°45'
BENTON CO.
STEARNS CO.
<1.3
<1.3
>32.0
<1.3
<1.3
SHERBURNE CO.
ISANTI CO.
SHERBURNE CO.
93°45'
45°30'
>32.0
6.3-32.0
STEARNS CO.
SHERBURNE CO.
1.3-6.3
STEARNS CO.
WRIGHT CO.
1.3-6.3
>32.0
Scale
0 5 10 Mi
0 5 10 Km
N
SOURCES: Kanivetsky, 1978, 1979;
Kanivetsky and Walton, 1979
EXPLANATION
Preliminary candidate area
Rock body outline
All yields in liters/second
(1 liter/second = 15.85 gpm)
Ground Water Resource Potential
(from RGCR)
Archean Gneisses and
Central Minnesota Granites (NC-10)

Figure 3-49a


MORRISON CO.
BENTON CO.
MILLE LACS CO.
CANABEC CO.
SHERBURNE CO.
ISANTI CO.
STEARNS CO.
WRIGHT CO.
10's of l/s
6.3->63
6.3-32
32-63
>63
<6.3
Small to moderate yields
94°15'
45°45'
93°45'
45°30'
Data insufficient
EXPLANATION
Preliminary candidate area
Rock body outline
All yields in liters/second
(1 liter/second = 15.85 gpm)
Scale
0 5 10 Km
0 5 10 Mi
SOURCES: Ericson et al., 1974;
Helgesen et al., 1975
Ground Water Resource Potential
(from USGS Hydrologic Atlases)
Archean Gneisses and
Central Minnesota Granites (NC-10)
Figure 3-49b

the undifferentiated [illegible] on the thickness and extent of stratified zones. Well yields of several [illegible] of liters per second (hundreds of gallons per minute) are possible.

The data indicate that relatively shallow Quaternary aquifers that contain potable ground water are present within the preliminary candidate area. No deep wells (i.e., greater than 100 m [328 ft] in depth) have been reported in the literature. Therefore, local ground water conditions in the deeper crystalline rock are currently unknown.

3.2.1.7.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition and vertical crustal movements, is in Section 3.2.1.1.1.1.

3.2.1.7.8 Federal Lands. There are no Federal lands greater than 130 ha (320 ac) in size located within the boundaries of the preliminary candidate area. The Sherburne National Wildlife Refuge, which is greater than 130 ha (320 ac) in size, abuts the southeastern edge of the preliminary candidate area. This feature is depicted on Plate 2A of the North Central RECR (DOE 1985d) (see also Figure 3-50). There is no evidence in the data base that any Federal lands less than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.

3.2.1.7.9 State Lands. There are three State land units within the boundary of the preliminary candidate area. Benlacs Wildlife Management Area occupies approximately 170 ha (420 ac) of the preliminary candidate area's southeast corner. In addition, the Bibles Wildlife Management Area, covering 27 ha (68 ac), is located within the southeastern portion of the preliminary candidate area and an unnamed parcel of State forest land, covering approximately 260 ha (640 ac), is located within the northern portion. The three State land parcels occupy a total of 457 ha (1,128 ac) or less than 1% of the preliminary candidate area. Two wildlife management areas, each greater than 130 ha (320 ac) in size, are

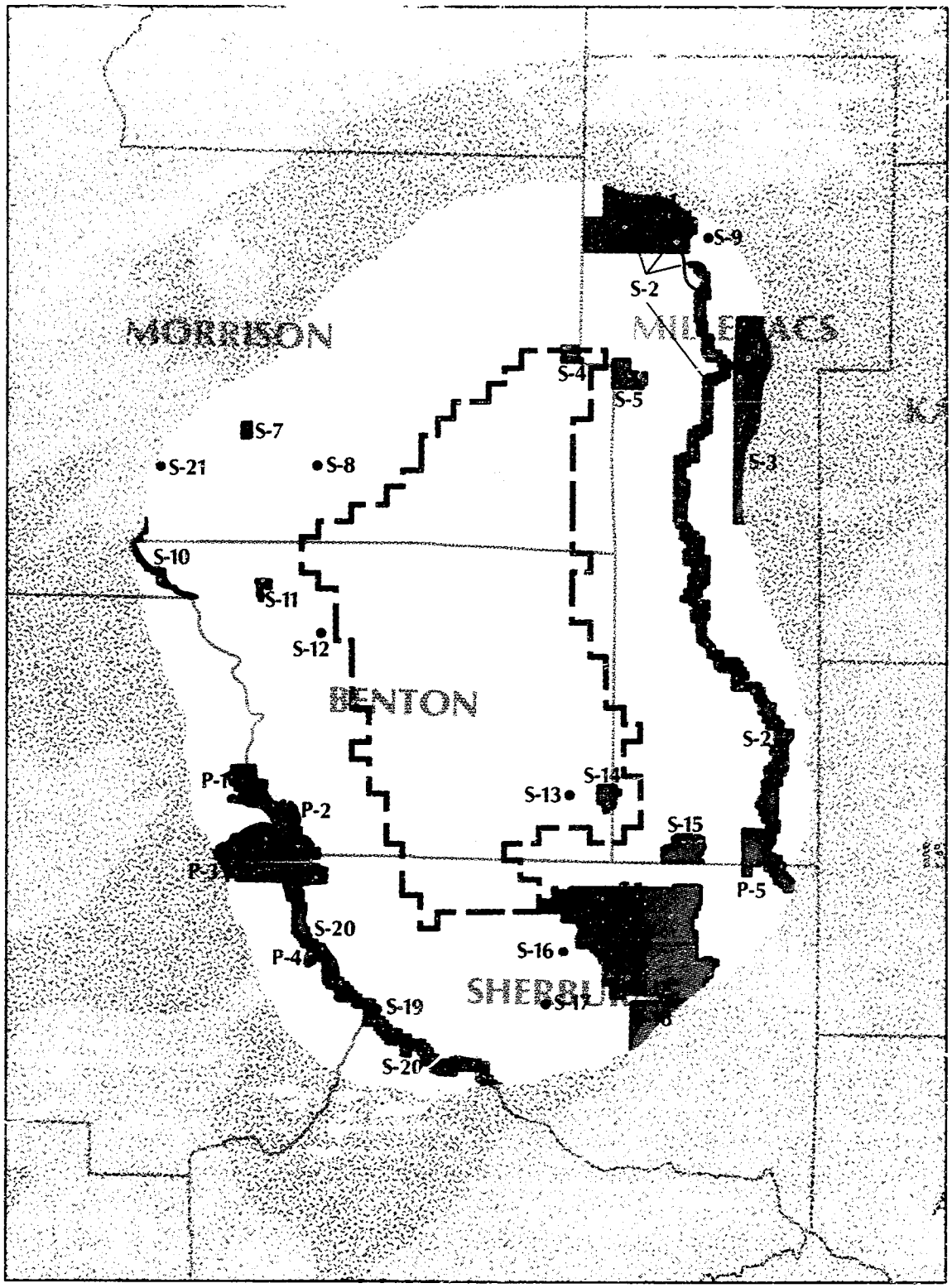


Figure 3–50 Sheet 1

Environmental Features
Archean Gneisses and Central
Minnesota Granites (NC-10)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3–50 Sheet 2

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI)
OF [illegible] CANDIDATE AREA NC-10*

Code	Feature
Population Features	
P-1	Sartell Highly Populated Area (HPA)**
P-2	Sauk Rapids HPA**
P-3	Waite Park HPA**
P-4	St. Cloud HPA**
P-5	Princeton HPA
Federal Lands	
F-1	Sherburne National Wildlife Refuge
State Lands	
S-1	Mille Lacs Kathio State Park
S-2	Rum Wild and Scenic River
S-3	Rum River State Forest
S-4	Unnamed State Forest Parcel (SFO)
S-5	SFO
S-6	Mille Lacs Wildlife Management Area (WMA)
S-7	Rice-Skunk WMA
S-8	Coon WMA
S-9	Onamia WMA
S-10	Mississippi Headwaters Wild and Scenic River
S-11	Sartell WMA
S-12	Wisneski WMA
S-13	Bibles WMA

Figure 3-50, Sheet 3

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI)
PRELIMINARY CANDIDATE AREA MC-10*

Code	Feature
State Lands (Continued)	
S-14	Benlacs WMA
S-15	Kunkel WMA
S-16	Santiago WMA
S-17	Foxhole WMA
S-18	Sand Dunes State Forest
S-19	Clear Lake Scientific and Natural Area (SNA)
S-20	Mississippi Wild and Scenic River
S-21	Popple WMA
Indian Reservations	
None	

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* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

** Area with a population density greater than or equal 1,000 persons per square mile.

Figure 3-50, Sheet 4

located within 10 km (6 mi) of the preliminary candidate area: Kunkel, 2.4 km (1.5 mi) southeast; and Sartell, .4 km (1.5 mi) west. Four wildlife management areas, each less than 130 ha (320 ac) in size, are located within 10 km (6 mi) of the preliminary candidate area boundary. The Mississippi and Rum Wild and Scenic Rivers are 8 km (5 mi) southwest and 8 km (5 mi) east of the preliminary candidate area boundary, respectively. The Clear Lake Scientific and Natural Area, which is less than 130 ha (320 ac) in size, is located 10 km (6 mi) southwest of the preliminary candidate area boundary. A section of the Rum River State Forest greater than 130 ha (320 ac) in size, is located 10 km (6 mi) north of the preliminary candidate area boundary. One unnamed parcel of State forest land, also greater than 130 ha (320 ac) in size, is located less than 1.6 km (1 mi) from the preliminary candidate area's northeast corner. All of the features described above are either depicted on Plates 3A or 4A of the North Central RECR or are listed in Appendix B of that report (DOE, 1985d).

In summary, three State lands (two greater than and one less than 130 ha [320 ac]) are located within the preliminary candidate area and cover a total of 457 ha (1,128 ac) or less than 1% of the preliminary candidate area. Eleven State lands (six greater than and five less than 130 ha [320 ac]) are located within 10 km (6 mi) of the preliminary candidate area (see Figure 3-50).

3.2.1.7.10 Environmental Compliance. Parts of Benton and Sherburne Counties are nonattainment areas for carbon monoxide. Space heaters, automobiles, trucks, and buses are the primary contributor to the nonattainment status for carbon monoxide. No Prevention of Significant Deterioration (PSD) Class I Areas are located in or within 40 km (25 mi) of the preliminary candidate area (40 CFR 81). Three sites listed on the National Register of Historic Places (NRHP) are located within the preliminary candidate area: Esselman Brothers General Store northwest of the town of Gilman (48 FR 8646, 1983); Sts Peter and Paul Catholic Church complex in the town of Gilman (48 FR 8646, 1983); and the Ronneby Charcoal Kiln west of the town of Ronneby (48 FR 8646, 1983), all in

Benton County, Minnesota. There are no proposed NRHP sites within the preliminary candidate area. In the regional data base, there are no known existing archaeological sites or districts nor any proposed for designation within the preliminary candidate area. No National Trails are located in or within 40 km (25 mi) of the preliminary candidate area.

3.2.1.7.11 Population Density and Distribution. The preliminary candidate area contains no highly populated areas. There are five highly populated areas within 16 km (10 mi) of the preliminary candidate area (Princeton, Sartell, St. Cloud, Sauk Rapids, and Waite Park) (see Figure 3-50). Princeton, with a population of 3,146, is located 10 km (6 mi) east of the preliminary candidate area. Sauk Rapids, with a population of 5,793, Sartell, with a population of 3,427, St. Cloud, with a population of 42,566, and Waite Park, with a population of 3,496, are located 6 km (4 mi), 10 km (6 mi), 6 km (4 mi), and 10.5 km (6.5 mi) west of the preliminary candidate area, respectively. The preliminary candidate area contains no areas with population densities greater than or equal to 1,000 persons per square mile. There are four areas with population densities greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area These are Sartell, St. Cloud, Sauk Rapids, and Waite Park, which are also highly populated areas (see Figure 3-50). The western fringe of the greater metropolitan Minneapolis/St. Paul area is located approximately 24 km (15 mi) southeast of the preliminary candidate area. The average population density of the preliminary candidate area is 25 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area is approximately 132 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.1.7.12 Site Ownership. There are no Federal or DOE-owned lands located within the preliminary candidate area. Mille Lacs Indian Reservation is 18.4 km (11.5 mi) north of the preliminary candidate area (see Plate NC-1A).

3.2.1.7.13 Offsite installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Monticello, which is approximately 21 km (13 mi) to the south (Michelewicz and Vann, 1983; DOE, 1984c). The nearest commercial nuclear reactor under construction is Byron 2, approximately 540 km (335 mi) to the southeast (Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.7.14 Transportation. The nearest interstate highway is I94 which is about 13 km (8 mi) to the southwest of the preliminary candidate area. I35 is about 64 km (40 mi) to the east of the preliminary candidate area. U.S. 10 is the nearest U.S. highway and is west of the preliminary candidate area. U.S. 10 roughly parallels the western edge of the preliminary candidate area at a distance of about 8 km (5 mi). Another nearby U.S. highway is U.S. 169, which is from 8 to 15 km (5 to 8 mi) east of the preliminary candidate area. Both of these highways are four-lane divided highways in the vicinity of the preliminary candidate area. Four State highways cross portions of the preliminary candidate area. State Route 23 angles across the south central portion of the preliminary candidate area from St. Cloud, where it intersects with U.S. 10, northeastward to Milaca, where it intersects with U.S. 169. State Route 23 is a principal highway in this area. State Route 25 winds through the preliminary candidate area passing through Foley which is in the center of the preliminary candidate area. State Route 95 runs east and west across the southern portion of the preliminary candidate area. State Route 95 intersects U.S. 169 at Princeton and State Route 23 east of St. Cloud. State Route 27 crosses the extreme northern portion of the preliminary candidate area.

The nearest mainline railroad is the Burlington Northern between Minneapolis and Fargo/Moorehead. This line parallels the western edge of the preliminary candidate area at a distance of about 8 km (5 mi). The nearest branchline railroad is the Soo/Milwaukee line that runs from

Duluth/Superior [illegible] Brooten, Minnesota, where it meets the mainline between Minneapolis and Minot, North Dakota. This branchline crosses the northern edge of the preliminary candidate area. About 3 years ago, a Burlington Northern branchline paralleled State Route 23, but this line has now been abandoned.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.1.7.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-10 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggests that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]

- absence of [illegible] earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could provide ground motion in excess of reasonable design limits [960.4-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repositiory construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within or in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area (960.5-2-5(c)(3)]

- limited presence of State lands less than 130 ha (320 ac) within (i.e., one) and in proximity to (i.e., five within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- a majority of the preliminary candidate area is beyond 16 km [10 mi] from highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(b)(2)]
- low population density within its boundaries [960.5-2-1(b)(1)]
- absence of nuclear installations (960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings [960.4-2-8-2(c) and 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2) and (b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-10 at this time.

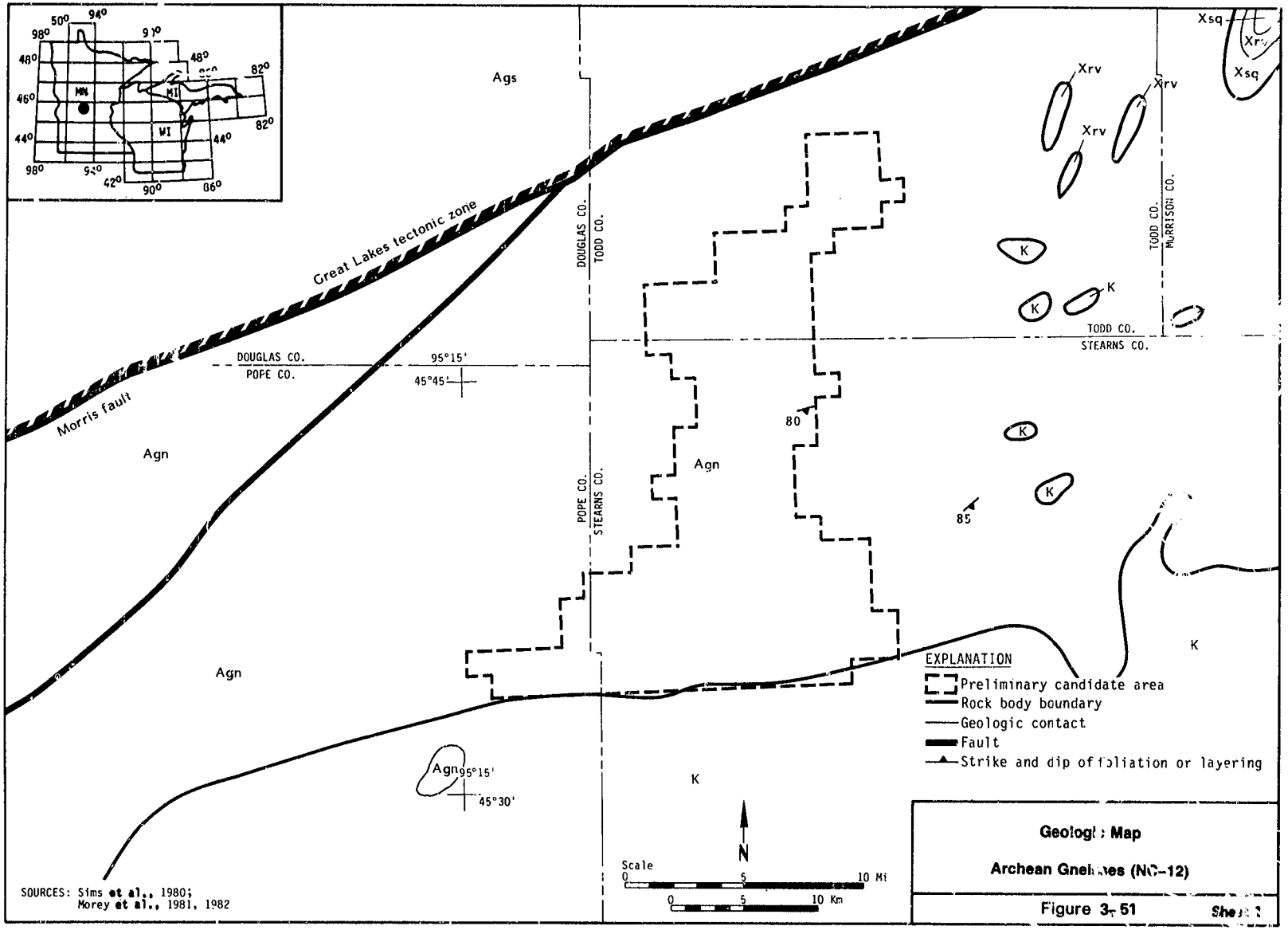
3.2.1.8 Preliminary Candidate Area Description - Archean Gneisses (NC-12)

The Archean gneisses are located within the Central Minnesota Moraine Complex Upland physiographic province in central Minnesota. The preliminary candidate area is located in Stearns, Todd, and Pope Counties at approximately 45°42' N latitude and 95°00' W longitude.

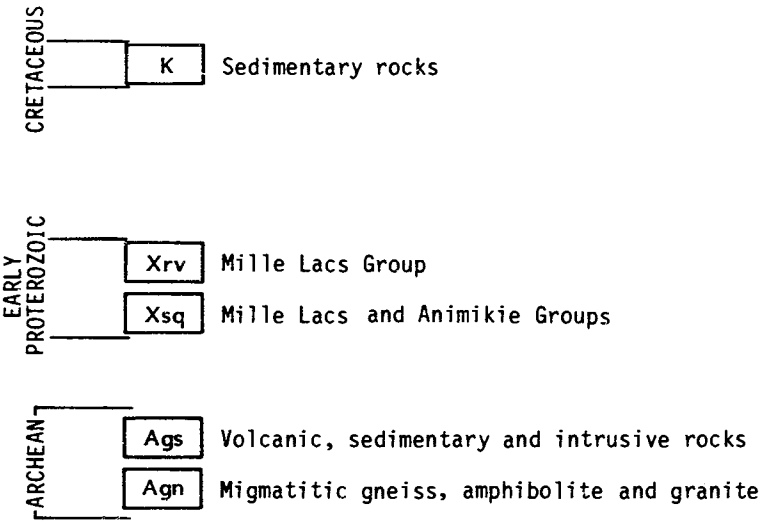
3.2.1.8.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-51 has an area of approximately 445 km^2 (171 mi^2) and overlies the Archean gneisses, which are largely inferred from geophysical data and scattered outcrops (Morey et al., 1982). The Archean gneisses that contain the preliminary candidate areas have a mapped extent of approximately 220 km (134 mi) long by 15 to 40 km (9 to 24 mi) wide. Seismic reflection data in the preliminary candidate area suggest that the Archean gneisses extend down to the asthenosphere (i.e., several tens of kilometers [miles]) (Gibbs et al., 1984).

Less than 1% of the preliminary candidate area has exposed bedrock. Contours of overburden thickness for the preliminary candidate area (Figure 3-52) indicate that the northern and southern portions are covered by 30 to 91 m (100 to 300 ft) (Olsen and Mossler, 1982); whereas, the central portion is covered by less than 30 m (100 ft) of overburden.

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the rock of the preliminary candidate area is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.


Great Lakes tectonic zone
Morris fault
DOUGLAS CO.
POPE CO.
TODD CO.
STEARNS CO.
MURRISON CO.
95°15'
45°45'
45°30'
Ags
Agn
K
Xrv
Xsq
80
85
EXPLANATION
Preliminary candidate area
Rock body boundary
Geologic contact
Fault
Strike and dip of foliation or layering
Scale
0 5 10 Mi
0 5 10 Km
N
SOURCES: Sims et al., 1980;
Morey et al., 1981, 1982
Geologic Map
Archean Gneisses (NC-12)
Figure 3-51

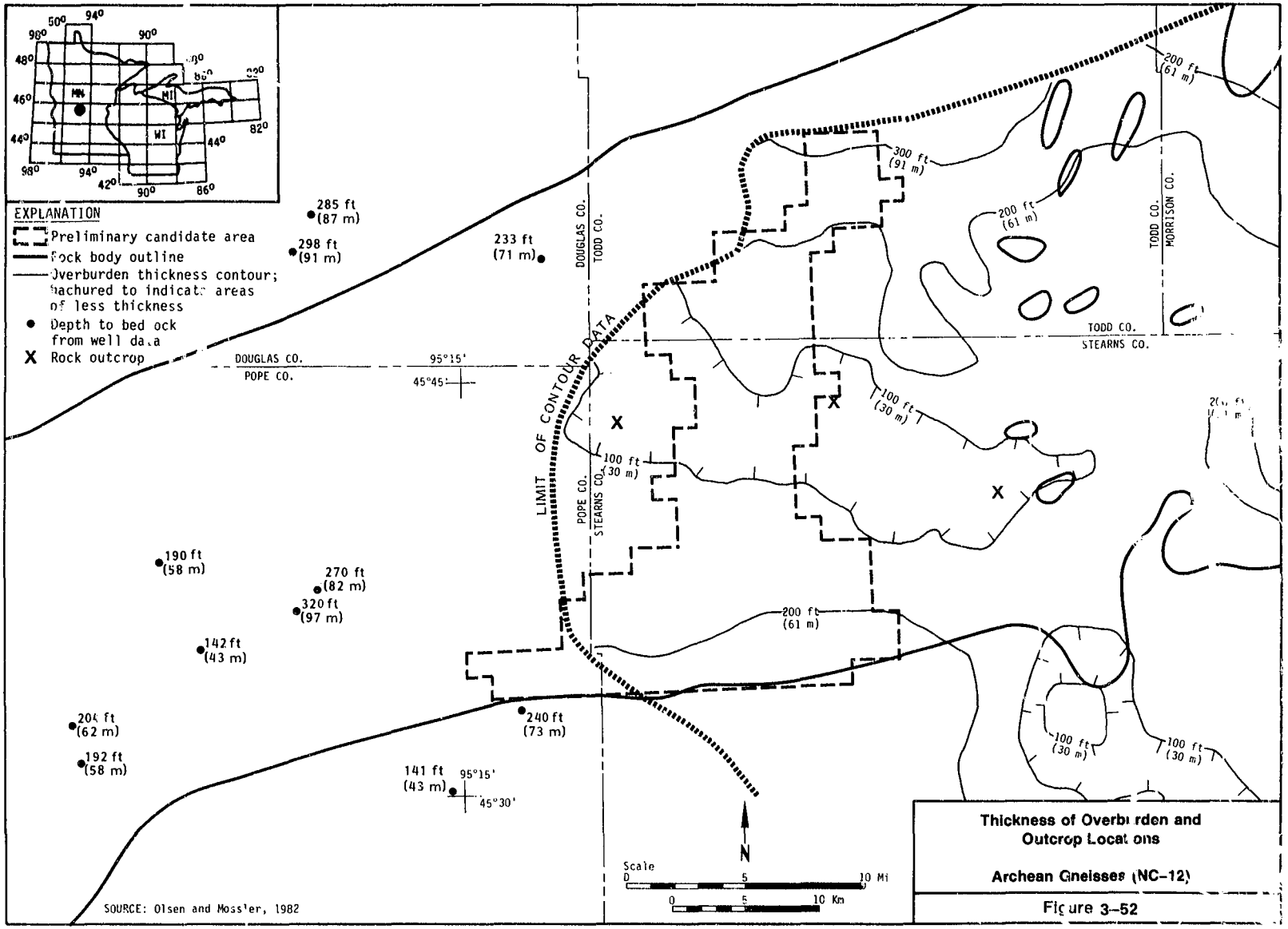
EXPLANATION OF GEOLOGIC UNITS



Explanation for Figure 3-51

Archean Gneisses (NC-12)

Figure 3-51 Sheet 2



Thickness of Overburden and Outcrop Locations

Archean Gneisses (NC-12)

Figure 3-52

3.2.1.8.2 Lithology and Petrology. The Archean gneisses consist of migmatitic gneiss, amphibolite, and granite (Figure 3-51). To the north, these rocks are in fault contact with early Proterozoic felsic to intermediate volcanic and volcaniclastic rocks, mica schist, phyllite, and granitoid rocks that have been cataclastically deformed within the Great Lakes tectonic zone. To the south, these rocks are unconformably overlain by Cretaceous shale and sandstone (Morey et al., 1982). The Archean gneisses have been metamorphosed to the upper amphibolite or lower granulite facies (Goldich and Wooden, 1980).

The Archean gneisses are part of the Archean gneiss terrane of southern Minnesota that formed 2,600 to 3,550 million years ago (Morey and Sims, 1976; Morey et al., 1982). The Archean gneisses have been metamorphosed to the upper amphibolite or lower granulite facies (Goldich and Wooden, 1980). Similar gneisses in the Minnesota River valley to the south of the preliminary candidate area were metamorphosed and deformed several times during the period 2,600 to 3,050 million years ago (Bauer, 1980; Goldich et al., 1980a, 1980b) and intruded by granitic magma about 2,600 million years ago (Goldich and Wooden, 1980). Rocks of the Archean gneiss terrane were periodically tectonically remobilized until about 1,600 million years ago (Sims et al., 1980).

Faults near the preliminary candidate area include the northeast-trending Morris fault, which forms the southern boundary of the Great Lakes tectonic zone, approximately 4 km (2.5 mi) north of the preliminary candidate area (Figure 3-51) (Sims et al., 1980; Morey et al., 1982). This fault is inferred on the basis of aeromagnetic data to be at least 220 km (134 mi) long (Mooney and Morey, 1981; Morey et al., 1982). Sims et al. (1980) interpreted the Morris fault as a southeast-dipping, high-angle reverse fault. According to Mooney and Morey (1981), the July 9, 1975, Morris earthquake (m_b 4.6) occurred on this fault. The preferred focal plane solution is N 60° E, dip 70° SE, parallel to the orientation of the Morris fault (Mooney and Morey, 1981). A 54-km (33-mi) long, northeast-trending fault is located

approximately 9 km (5.6 mi) northwest of the preliminary candidate area and intersects the Morris fault (Figure 3-51) (Morey et al., 1982). There is no surface evidence of Quaternary activity along these faults or within the geologic setting.

The north-south-trending COCORP seismic-reflection profile of Gibbs et al. (1984) crossed the central portion of the preliminary candidate area. Gibbs et al. (1984) interpreted several low-angle, north-dipping thrust faults (north side upthrown) in the Archean gneisses that underlie the preliminary candidate area and suggested these thrusts were formed by the collision and joining of the Archean gneiss terrane with the Archean greenstone-granite terrain to the north during the Algoman orogeny 2,600 to 2,700 million years ago.

No structural features exclusive of faults have been reported in the literature for the preliminary candidate area. However, similar Archean gneisses to the south in the Minnesota River valley have foliation, lineations, and folds. The description of these structures is included here because similar structures may occur in the gneisses of the preliminary candidate area. The gneisses of the Minnesota River valley are moderately to well foliated. Foliation is defined by compositional banding, oriented planar minerals, flat quartz lenses, and hornblende segregations. The lineations are defined by elongate minerals, minor fold axes, crenulations on foliation planes, and boudins and generally parallel the major F_2 fold axes, which trend N 87° E and plunge 15 degrees. Another group of lineations are oriented approximately normal to the fold axes (Himmelberg, 1968; Bauer, 1980). Bauer (1980) recognized four phases of folding in the gneisses of the Minnesota River valley. The second phase (F_2) is the most prominent and forms broad, gently east-plunging antiforms and synforms. The other three phases are deduced from the analysis of minor structures and are not readily evident on a regional scale (Himmelberg, 1968; Bauer, 1980).

A discussion of [illegible] uplift is presented in the regional geologic setting (Section [illegible]); there is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that this uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for the vicinity of the preliminary candidate area.

The absence of any igneous activity in and near the preliminary candidate area for the last 1,000 million years and the absence of Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicates that future igneous activity in the area is highly unlikely.

There is no evidence of igneous activity, folding, faulting, uplift, subsidence, or other tectonic processes within the geologic setting during the Quaternary Period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.1.8.3 Seismicity. Stover et al. (1981) located an earthquake epicenter approximately 1 km (0.6 mi) northwest of the preliminary candidate area on the basis of data by Mooney (1979). Mooney (1979) originally interpreted this earthquake as the m_b 2.6 Sauk Centre (West Union) event. In a June 1, 1980 update to his 1979 report, Mooney concluded after restudy of the data that the Sauk Centre event should have been placed approximately 100 km (61 mi) farther east, near Milaca (Mooney, 1979, update sheet, 1980). The Milaca location is also assigned to this event by Mooney and Morey (1981). The regional seismicity is discussed in Section 3.2.1.1.1.3.

The July 9, 1975, Morris earthquake (m_b 4.6) occurred on the Morris fault approximately 7[illegible] km (45 mi) west of the preliminary candidate area (See page 3-278) (Mooney, 1979; Mooney and Morey, 1981). This earthquake

occurred at a depth of 5 to 10 km (3 to 6 mi), had a maximum intensity of MM VI, and a felt area of 82,000 km^2 (31,700 mi^2) (Mooney, 1979; Mooney and Morey, 1981). Stover et al. (1981) located the epicenter for this event 65 km (40 mi) west of the preliminary candidate area and listed it as a magnitude 5.0 earthquake.

Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the area will increase in the future.

3.2.1.8.4 Mineral Resources. There are no strategic, metallic, or energy-related mineral resources known to occur either in or within 10 km (6 mi) of the preliminary candidate area (Schwartz and Prokopovich, 1966; Walton, 1976; USBM, 1983). No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mine or quarry is the Crystal Gray granite quarry, located approximately 45 km (28 mi) southeast of the preliminary candidate area. Other natural resources within and near the preliminary candidate area (i.e., quarries, gravel pits, and marl deposits) are shallow and widely available throughout the region.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources in the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation and no information is currently available to indicate that deep exploration drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

3.2.1.8.5 Topography and Surface Water Characteristics. The topographic relief of the preliminary candidate area is very low with

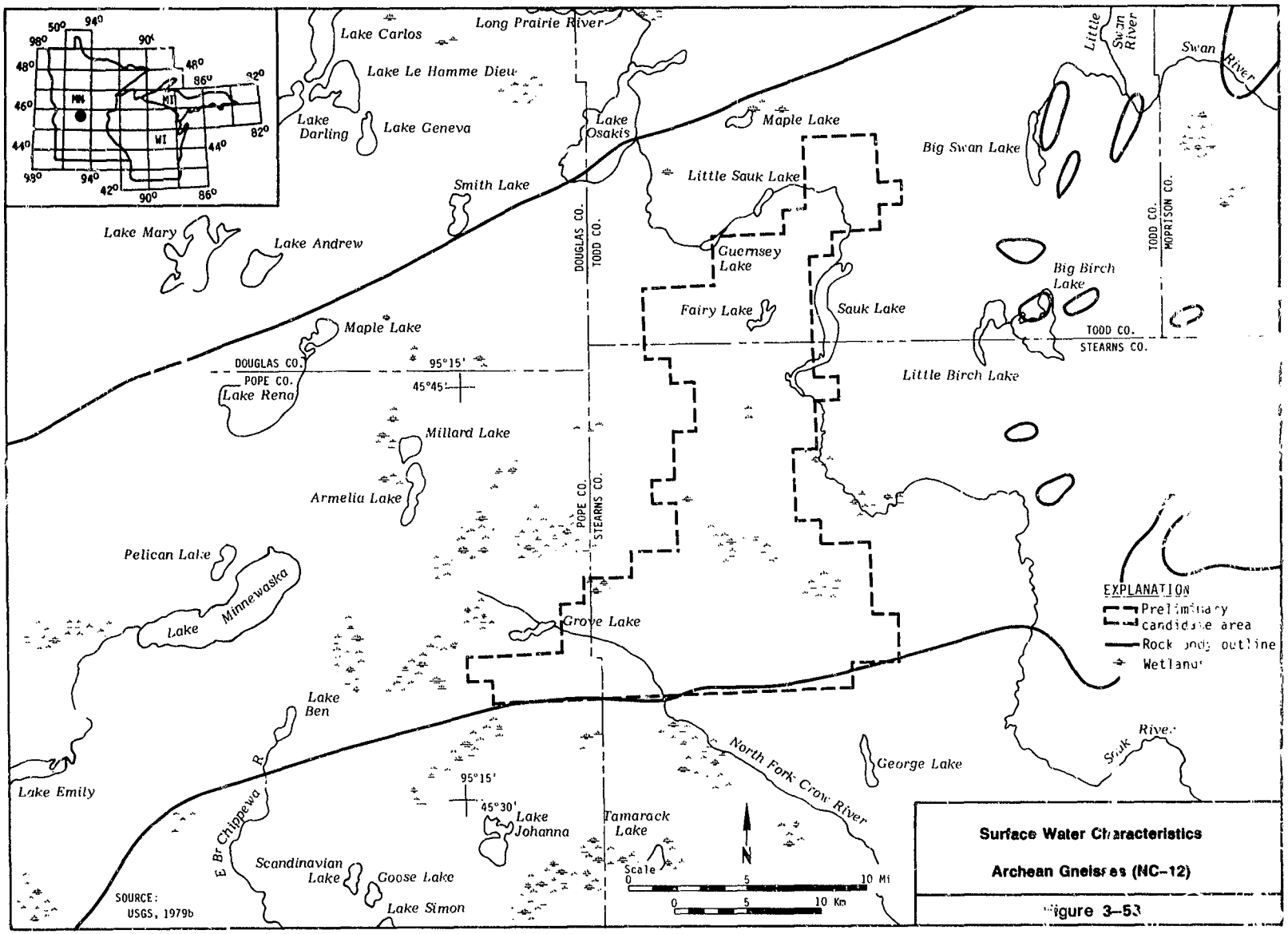
elevations between 381 and 438 m (1,250 and 1,435 ft). The preliminary candidate area does not appear to contain large areas of floodplain. Examination of topographic maps indicates that only localized portions of the preliminary candidate area along major drainages and small stream valleys are potentially flood prone. Lakes in the area are effective in reducing peak flows (Cotter et al., 1968). No reservoirs or impoundments are known to exist in or upstream of the preliminary candidate area.

The preliminary candidate area is drained mainly by the Sauk River and the North Fork of the Crow River, which drain south-southeast to the Mississippi River. As represented by the region-to-area screening data base, the preliminary candidate area is covered by approximately 2% surface water and 1% wetland (USGS, 1966; USGS, various dates; Minnesota State Planning Agency, 1984). The locations of lakes, rivers, and marshlands in the preliminary candidate area on Figure 3-53 are based on surface water features shown on the USGS 1:250,000 St. Cloud topographic map. Major surface water bodies within the preliminary candidate area include the Sauk River, North Fork of the Crow River, and Fairy Lake, Guernsey Lake, and Sauk Lake. Other surface water bodies near the preliminary candidate area include the Little Sauk Lake, Lake Osakis, Maple Lake, Grove Lake, Millard Lake, Armelia Lake, Big Birch Lake, George Lake, Tamarack Lake, Lake Johanna, Smith Lake, Little Birch Lake, Big Swan Lake, and numerous other lakes and streams.

The data presented in this section indicate that the relief of the preliminary candidate area is generally low and the terrain is well drained with scattered small wetlands.

3.2.1.8.6 Ground-Water Resources. The regional hydrology is discussed in Section 3.2.1.1.1.5.

Shallow ground-water movement is generally eastward toward the Sauk River in the eastern portion of the preliminary candidate area and southward toward the North Fork of the Crow River in the western



Surface Water Characteristics

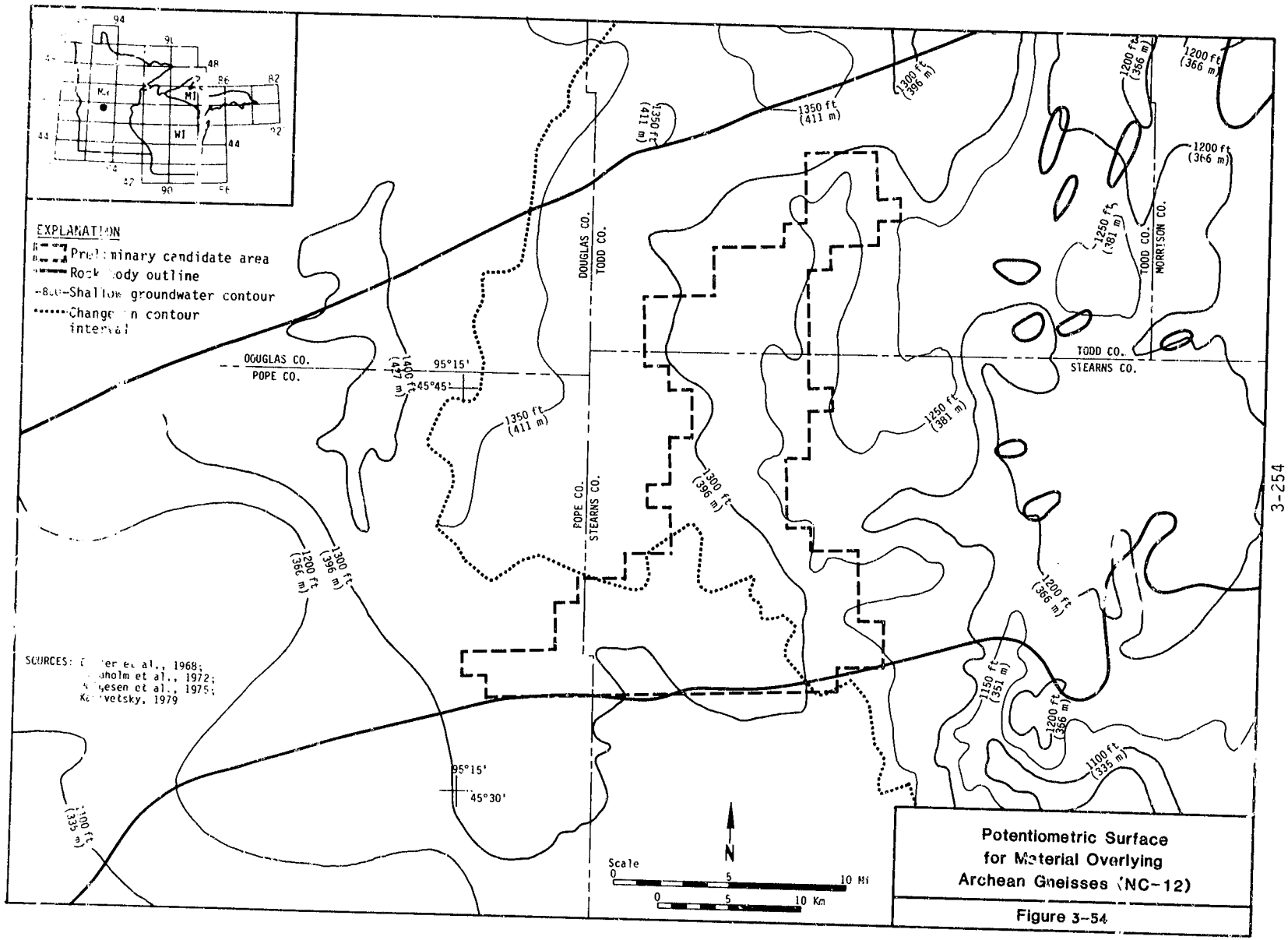
Archean Gneisses (NC-12)

Figure 3-53

portion. Figure 3-54 shows shallow ground-water contours reported by Helgesen et al. (1975), Cotter et al. (1968), Kanivetsky (1979), and Lindholm et al. (1972). Areas that displayed convergence of shallow water-table contours, based on a 30-m (100-ft) contour interval, were considered potential major discharge zones. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that include: 1) surficial outwash deposits of fine- to coarse-grained, commonly moderately to well sorted stratified sand and gravel; 2) undifferentiated drift, primarily gray, calcareous, silty till, usually unstratified and unsorted, containing stratified sand and gravel bodies of varying extent and thickness; 3) ice-contact outwash sand and gravel deposits, mostly stratified with variable sorting and some till; 4) morainal glacial drift deposits of sandy heterogeneous till, sand and gravel in ice-contact features and as local concentrations within till; and 5) buried sand and gravel lenses or pods contained in till (Helgesen et al., 1975; Lindholm et al., 1972, 1974; Cotter et al., 1968). The horizontal extent of surficial deposits is shown on Figure 3-55.

Well yields presented in the North Central RGCR (DOE, 1985c) were estimated from maps by Kanivetsky (1978, 1979) and Kanivetsky and Walton (1979), and are shown on Figure 3-56a. Additional detailed well yield information has been reported by Cotter et al. (1968), Helgesen et al. (1975), and Lindholm et al. (1972, 1974b), and in USGS Hydrologic Atlases, and is shown on Figure 3-56b. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison. Surficial outwash in some areas is a potential source of large ground-water supplies where, if the saturated thickness is sufficient, well yields in excess of 63 L/s (1,000 gpm) are theoretically possible. Small to moderate quantities of

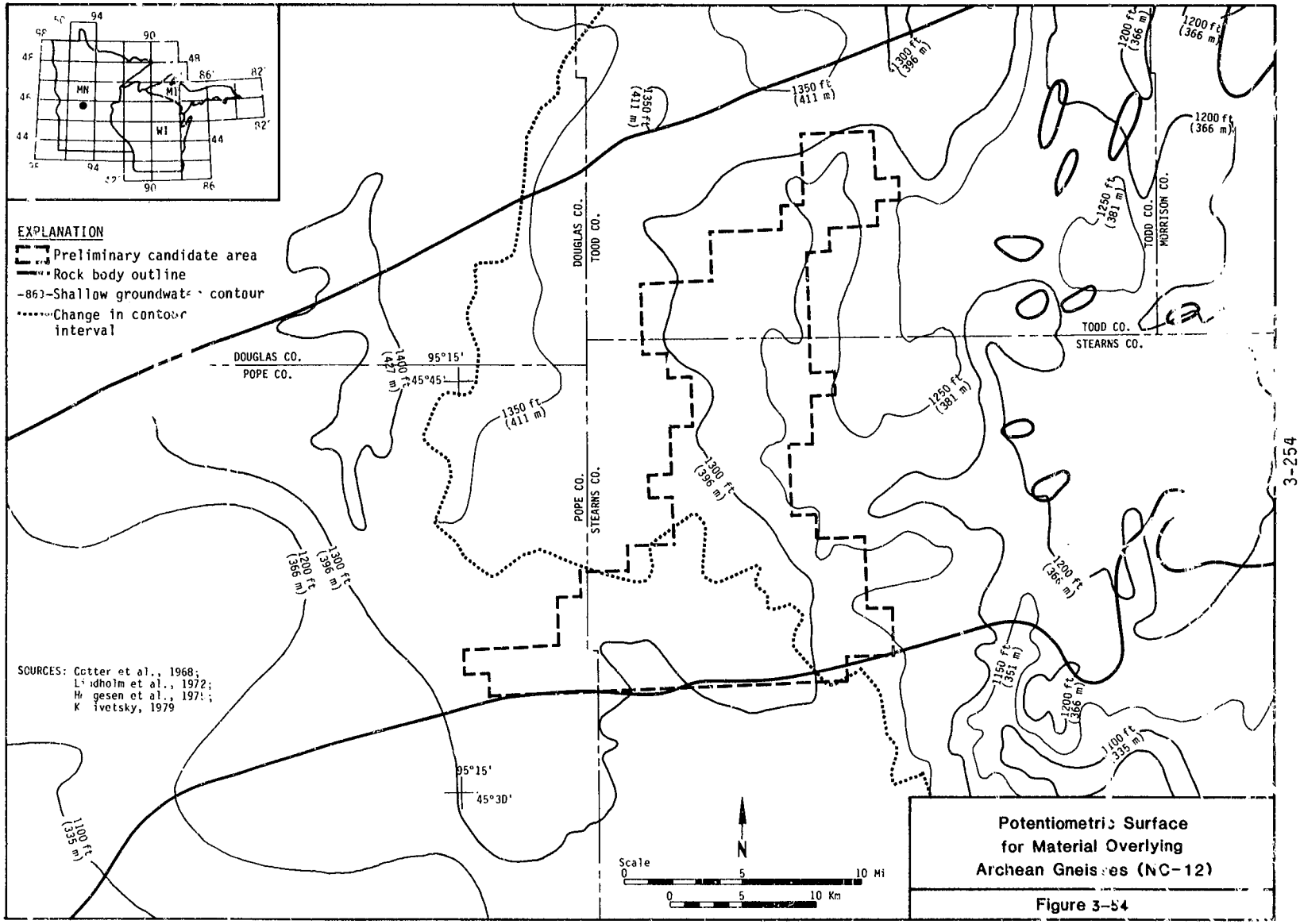


Potentiometric Surface for Material Overlying Archean Gneisses (NC-12)

Figure 3-54

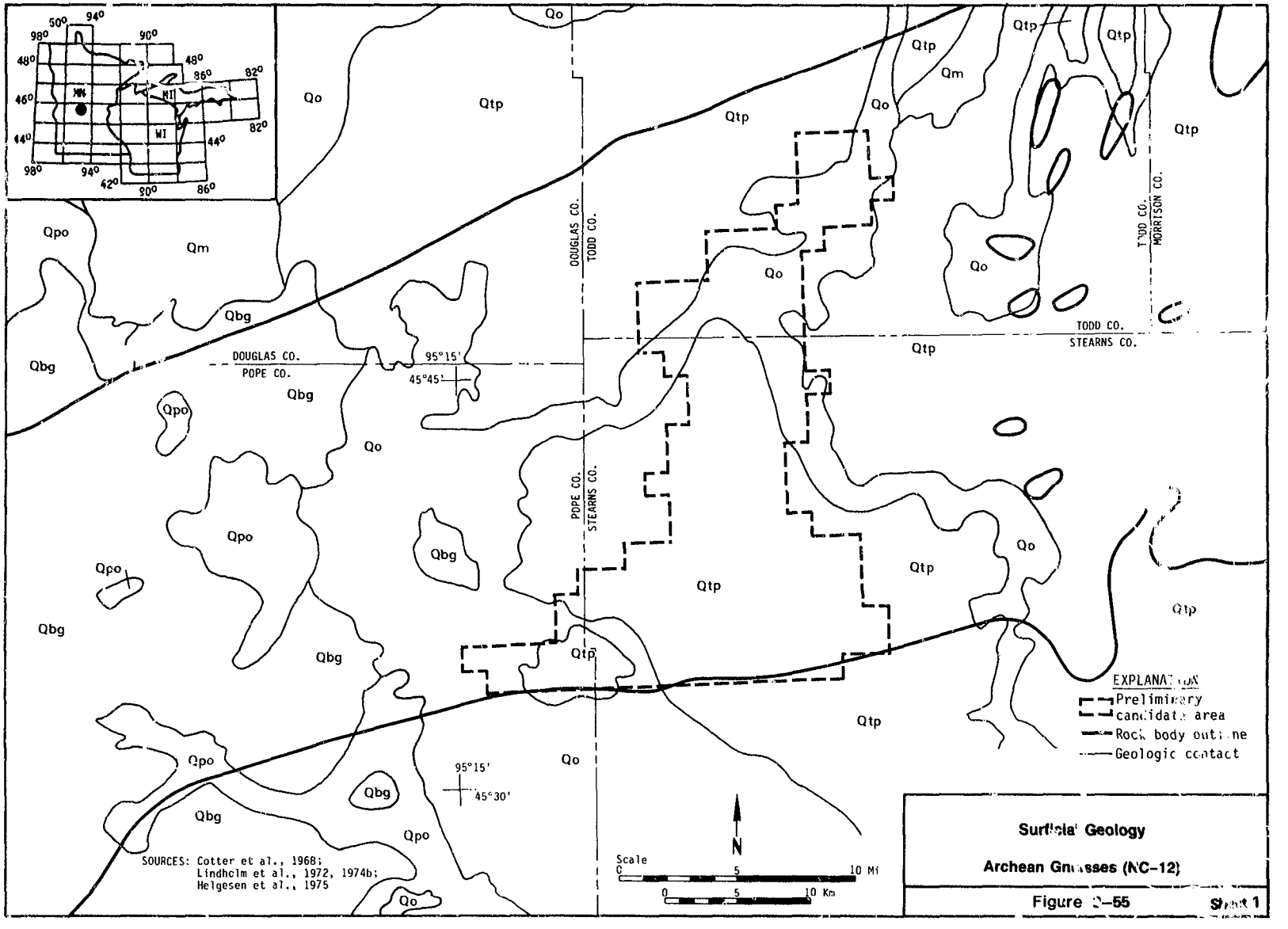
CORRECTION

The preceding document(s) has been refilmed to assure legibility and its image appears immediately hereafter.

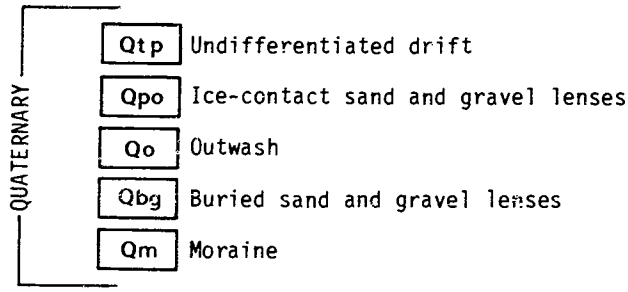


Potentiometric Surface for Material Overlying Archean Gneisses (NC-12)

Figure 3-54


Qo
Qtp
Qm
Qpo
Qbg
DOUGLAS CO.
POPE CO.
TODD CO.
STEARNS CO.
MORRISON CO.
95°15'
45°45'
45°30'
EXPLANATION
Preliminary candidate area
Rock body outline
Geologic contact
N
Scale
0 5 10 Mi
0 5 10 Km
SOURCES: Cotter et al., 1968;
Lindholm et al., 1972, 1974b;
Helgesen et al., 1975
Surficial Geology
Archean Gneisses (NC-12)
Figure 2-55
Sheet 1

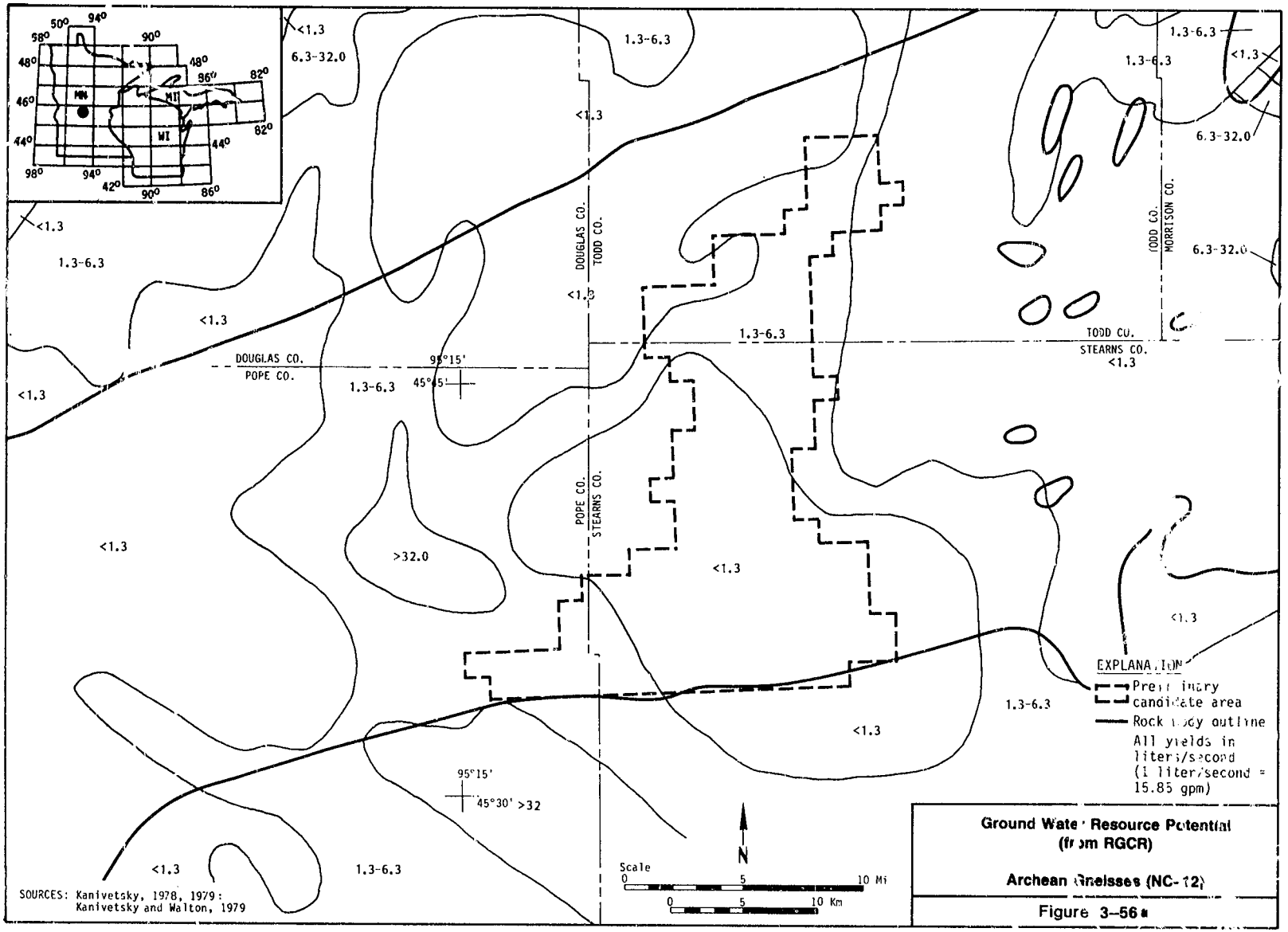
EXPLANATION OF SURFICIAL UNITS



Explanation for Figure 3-55

Archean Gneisses (NC-12)

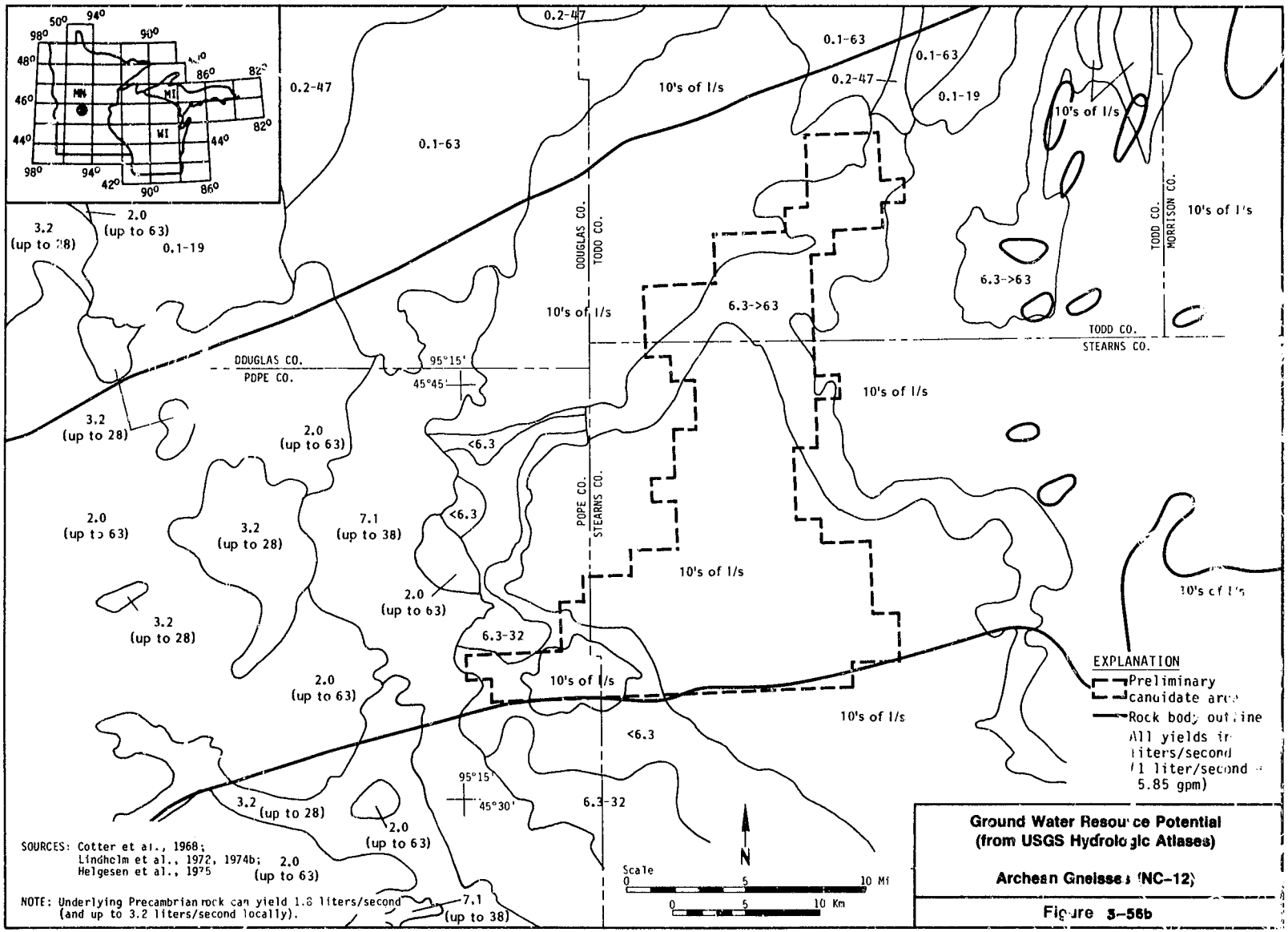
Figure 3-55 **Sheet 2**



Ground Water Resource Potential (from RGCR)

Archean Gneisses (NC-12)

Figure 3-56



Ground Water Resource Potential (from USGS Hydrologic Atlases)

Archean Gneisses (NC-12)

Figure 3-56b

water are possible from the ice contact, till, outwash deposits. Well yields in the undifferentiated drift depend on the thickness and extent of stratified zones. Well yields of several tens of liters per second (hundreds of gallons per minute) are possible (Lindholm et al., 1972).

The data indicate that relatively shallow Quaternary aquifers that contain potable ground water are present within the preliminary candidate area. No deep wells (i.e. greater than 100 m [328 ft] in depth) have been reported in the literature. Therefore, local ground-water conditions in the deeper crystalline rock are currently unknown.

3.2.1.8.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition and vertical crustal movements, is discussed in Section 3.2.1.1.1.1.

3.2.1.8.8 Federal Lands. Two Federal waterfowl production areas, each greater than 130 ha (320 ac) in size, are centrally located within the preliminary candidate area and have a total area of 295 ha (730 ac). There are also ten waterfowl production areas, which are each less than 130 ha (320 ac) in size, scattered throughout the Stearns County and Pope County portions of the preliminary candidate area totaling approximately 567 ha (1,400 ac). Additionally, 16 waterfowl production areas, each greater than 130 ha (320 ac), and 52 waterfowl production areas, each less than 130 ha (320 ac), are located within 10 km (6 mi) of the preliminary candidate area. These lands are concentrated to the west and southwest of the preliminary candidate area. All of these features are either depicted on Plate 2A of the North Central RECR or are in Appendix A of that report (DOE, 1985d).

In summary, 12 Federal waterfowl production areas (two greater than and ten less than 130 ha [320 ac]) lie within the preliminary candidate area and cover approximately 862 ha (2,130 ac) or less than 2% of the preliminary candidate area. A total of 68 waterfowl production areas (16 greater than and 52 less than 130 ha or [320 ac]) are located within 10 km (6 mi) of the preliminary candidate area (see Figure 3.7).

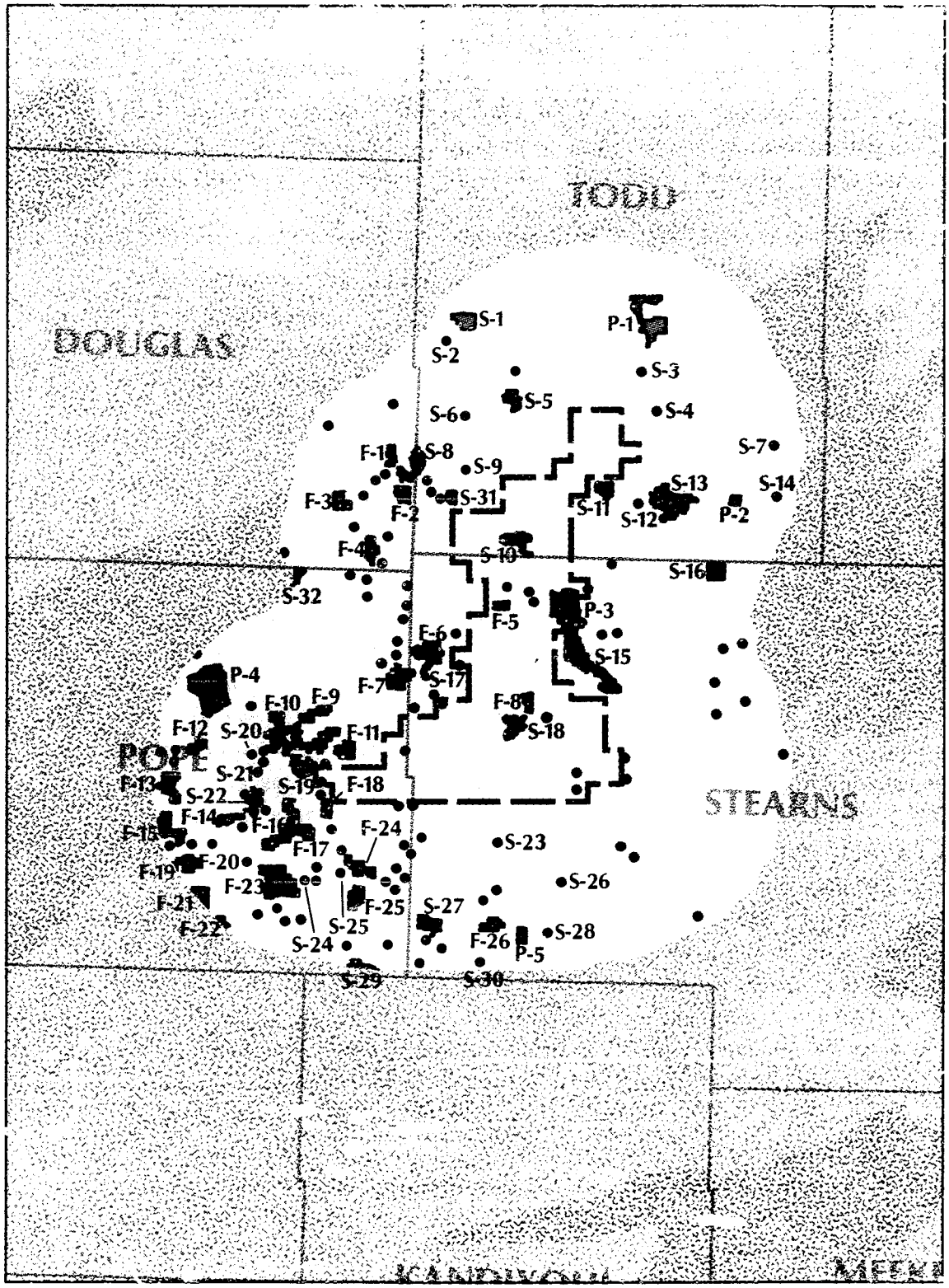


Figure 3–57 Sheet 1

Environmental Features
Archean Gneisses (NC-12)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3–57 Sheet 2

[illegible] FEATURES WITHIN 16 KM (10 MI)
OF PP[illegible] [illegible] AREA [illegible]2*

Code	Feature
Population Features	
P-1	Long Prairie Highly Populated Area (HPA)**
P-2	Grey Eagle**
P-3	Sauk Centre HPA
P-4	Glenwood HPA
P-5	Belgrade**
Federal Lands* **	
F-1	Waterfowl Production Area (WPA)
F-2	WPA
F-3	WPA
F-4	WPA
F-5	WPA
F-6	WPA
F-7	WPA
F-8	WPA
F-9	WPA
F-10	WPA
F-11	WPA
F-12	WPA
F-13	WPA
F-14	WPA
F-15	WPA
F-16	WPA
F-17	WPA
F-18	WPA
F-19	WPA
F-20	WPA
F-21	WPA
F-22	WPA
F-23	WPA
F-24	WPA
F-25	WPA
F-26	WPA
State Lands	
S-1	Long Prairie River Wildlife Management Area (WMA)
S-2	Hollister WMA
S-3	Lasher WMA
S-4	Center WMA
S-5	Owen-Hinz WMA

Figure 3-57, Sheet 3

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI)
OF PRELIMINARY CANDIDATE AREA NC-12*

Code	Feature
State Lands - Continued	
S-6	Randall WMA
S-7	Ireland WMA
S-8	Osakis WMA
S-9	Spohn WMA
S-10	Ashley Creek WMA
S-11	Mystery Lake WMA
S-12	Elgin Woods WMA
S-13	Grey Eagle WMA
S-14	Buckhorn WMA
S-15	Sauk River WMA
S-16	Birch Lakes State Forest
S-17	Tower WMA
S-18	Padua WMA
S-19	Sedan Lake WMA
S-20	Sedan Pond WMA
S-21	Heinks WMA
S-22	Chippewa Falls WMA
S-23	Milton Kjeldahl WMA
S-24	Skarpness WMA
S-25	Bangor WMA
S-26	Gravel Pit 1676 WMA
S-27	Tamarac WMA
S-28	Gravel Pit 1062 WMA
S-29	Little Jo WMA
S-30	Normam T. Dahlman WMA
S-31	West Union WMA
S-32	Volkman WMA
Indian Reservations	
None	

* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

** Area with a population density greater than or equal 1,000 persons per square mile.

*** Waterfowl production areas less than 130 ha (320 ac) are displayed as dots on the map but are not coded due to lack of space.

Figure 3-57, sheet 4

3.2.1.8.9 [illegible] two state land units of greater than 130 ha (320 ac) in size lie within the preliminary candidate area. Padua Wildlife Management Area is located in the south central portion of the preliminary candidate area and covers 245 ha (602 ac). Ashley Creek Wildlife Management Area is located in the north central portion of the preliminary candidate area and covers 299 ha (736 ac). In addition, the Sauk River Wildlife Management Area, which is 887 ha (2,191 ac) in size, slightly overlaps (approximately 65 ha [160 ac]) of the preliminary candidate area at one point along the eastern border. These three units occupy a total of 608 ha (1,498 ac) or less than 2% of the preliminary candidate area. Eight wildlife management areas, each greater than 130 ha (320 ac) in size, are located within 10 km (6 mi) of the preliminary candidate area boundary: Grey Eagle, Mystery Lake, Owen Hinz, West Union, Osakis, Tower, Sedan Lake, and Chippewa Falls. In addition, 11 wildlife management areas, each less than 130 ha (320 ac) in size, are located within 10 km (6 mi) of the preliminary candidate area boundary. All the features described above are either depicted on Plates 3A or 4A of the North Central RECR or are listed in Appendix B of that report (DOE, 1985d).

In summary, two State wildlife management areas, each greater than 130 ha (320 ac) lie within the preliminary candidate area, and one State wildlife management area, also greater than 130 ha (320 ac), slightly overlaps the preliminary candidate area. These areas occupy a total of 608 ha (1,498 ac) or less than 2% of the preliminary candidate area. In addition, 19 wildlife management areas, eight greater than and 11 less than 130 ha (320 ac) are located within 10 km (6 mi) of the preliminary candidate area (see Figure 3-57).

3.2.1.8.10 Environmental Compliance. Part of Stearns County is a nonattainment status area for carbon monoxide. Space heaters, automobiles, trucks, and buses are the primary contributors to the nonattainment status for carbon monoxide. No Prevention of Significant Deterioration (PSD) Class I Areas are located within the preliminary

candidate area. Additionally, there are no PSD Class I areas within 40 km (25 mi) of the preliminary candidate area (40 CFR 81). Three sites listed on the National Register of Historic Places (NRHP) are located within the preliminary candidate area: Iverson-Urjans Cabin near the town of Sedan, Pope County (48 FR 8647, 1983) and the Sinclair Lewis Boyhood Home and the Palmer House Hotel, both in the town of Sauk Centre, Stearns County (44 FR 7512, 1979; 48 FR 8648, 1983). There are no proposed NRHP sites within the preliminary candidate area. In the regional data base, there are no known existing archaeological sites or districts nor any proposed for designation within the preliminary candidate area. No National Trails are located in or within 40 km (25 mi) of the preliminary candidate area.

3.2.1.8.11 Population Density and Distribution. The preliminary candidate area contains one highly populated area (Sauk Centre). Sauk Centre is located in the east central portion of the preliminary candidate area and has a population of 3,709. There are two highly populated areas within 16 km (10 mi) of the preliminary candidate area (Glenwood and Long Prairie). Glenwood, with a population of 2,523, is located 10 km (6 mi) west of the preliminary candidate area; Long Prairie, with a population of 2,859, is located 6 km (4 mi) north of the preliminary candidate area (see Figure 3-57). Sauk Centre is the only area with a population density greater than or equal to 1,000 persons per square mile within the preliminary candidate area and is also a highly populated area. In addition, there are three areas with population densities greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area. These are Belgrade, Grey Eagle, and Long Prairie. Belgrade, located 11 km (7 mi) south of the preliminary candidate area, has a population of 805, and Grey Eagle, located 10 km (6 mi) east of the preliminary candidate area, has a population of 338. Long Prairie is also a highly populated area (see Figure 3-57). St. Cloud is located approximately 56 km (35 mi) east of the preliminary candidate area. The average population density of the preliminary candidate area is 37 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area

is approximately 35 [illegible] square mile. Low population density is defined as a density in the area region of the site less than the average population density for the conterminous Unites States (76 persons per square mile) based on the 1980 census.

3.2.1.8.12 Site Ownership. There are no DOE-owned lands located within the preliminary candidate area. As mentioned in Section 3.2.1.8.8, the only Federal lands within the preliminary candidate area are 14 Federal waterfowl production areas which occupy a total of 862 ha (2,130 ac) or less than 2% of the preliminary candidate area. The Mille Lacs Indian Reservation is located 91 km (57 mi) to the northwest of the preliminary candidate area, and the Upper Sioux Indian Reservation is located 91 km (57 mi) to the southwest of the preliminary candidate area (see Plate NC-1A).

3.2.1.8.13 Offsite Installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Monticello which is approximately 88 km (55 mi) to the southeast (Michelewicz and Vann, 1983; DOE, 1984c). The nearest commercial nuclear reactor under construction is Byron 2, which is 530 km (325 mi) to the southeast (Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.8.14 Transportation. Highway I94 passes directly through the northern edge of the preliminary candidate area. I94 is the main route between Minneapolis and the Pacific Northwest. U.S. 71 passes over the eastern portion of the preliminary candidate area and intersects I94 at Sauk Centre. No other U.S. highways are near this preliminary candidate area. State Route 28, a principal highway, crosses the northern portion of the preliminary candidate area intersecting I94 at Sauk Centre. State Route 55 passes over the extreme southwestern portion of the preliminary candidate area.

The Soo/Milwaukee Minne[illegible] North Dakota, mainline railroad parallels State Route 55 and crosses the extreme southwestern portion of the preliminary candidate area. The Soo/Milwaukee branchline from Duluth Superior crosses the southeastern portion of the preliminary candidate area about 16 km (10 mi) before it joins the mainline at Brooten, Minnesota. The Burlington Northern has a branchline which roughly parallels I94 through the northern portion of the preliminary candidate area. There are several abandoned rail lines that were once part of the Burlington Northern which, at one time, crossed the preliminary candidate area. One of these lines roughly paralleled State Route 28 west of Sauk Centre and crossed the Soo/Milwaukee mainline at Glenwood.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.1.8.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-12 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, and in the absence of further evaluation, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]

- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggests that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could produce ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]

- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of State lands less than 130 ha (320 ac) within the preliminary candidate area and limited presence in proximity to (i.e., 11 within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfer of title, or Federal condemnation proceedings [960.4-2-8-2(c) and 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2), 960.5-2-7(b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]
- presence of Federal lands less than 130 ha (320 ac) within (i.e., 10) and in proximity to (i.e., 52 within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)].
- a majority of the preliminary candidate area is within 16 km [10 mi] of highly populated areas or areas containing more than 1,000 persons per square mile) [960.5-2-1(c)(2)].

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-12 at this time.

3.2.1.9 Preliminary Candidate Area Description - Archean Gneisses (NC-13)

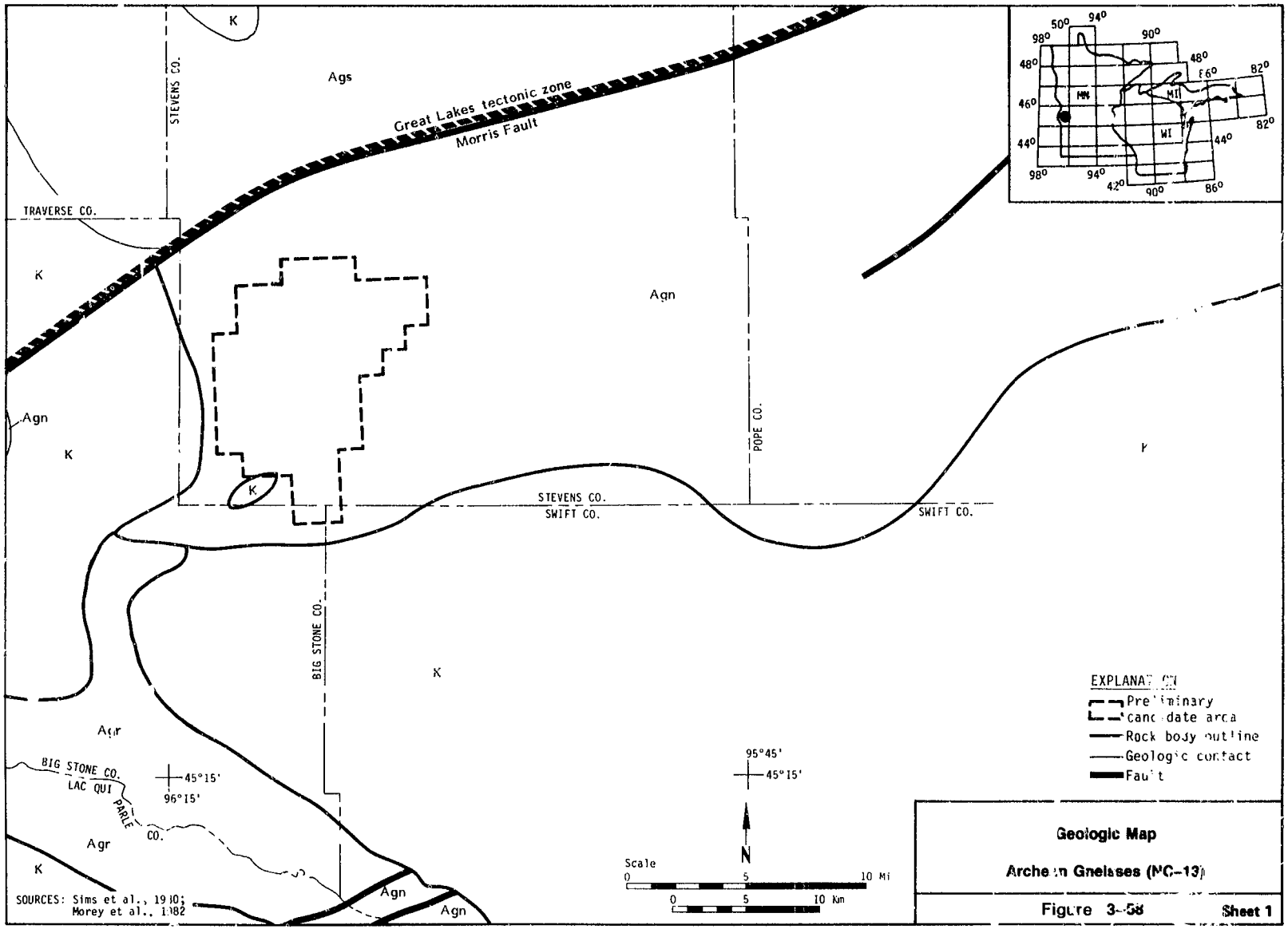
The Archean gneisses are located within the Central Minnesota Moraine Complex Upland and the Minnesota River Lowland physiographic province in west central Minnesota. The preliminary candidate area is located in Stevens, Big Stone, and Swift Counties at approximately 45°29 N latitude and 96°07' W longitude.

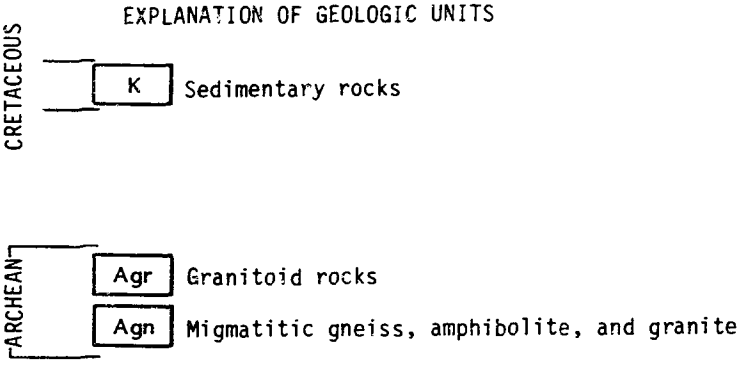
3.2.1.9.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-58 has an area of approximately 156 km^2 (60 mi^2) and overlies the Archean gneisses, which are largely inferred from geophysical data and scattered outcrops (Morey et al., 1982). The Archean gneisses that contain the preliminary candidate area have a mapped extent of approximately 220 km (134 mi) by 15 to 40 km (9 to 24 mi) wide. Seismic reflection data in the vicinity of the preliminary candidate area suggest that the Archean gneisses extend down to the asthenosphere (i.e., several tens of kilometers [miles]) (Gibbs et al., 1984).

There is no exposed bedrock in the preliminary candidate area. Contour data on overburden thickness are not available; however, there is one drillhole to bedrock within the preliminary candidate area and several in the vicinity of the preliminary candidate area (Figure 3-59). The single drillhole within the preliminary candidate area penetrated 98 m (323 ft) of overburden, and drillholes in the vicinity penetrated overburden ranging from 70 to 119 m (229 to 391 ft) in thickness.

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the Archean gneisses are sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

3.2.1.9.2 Lithology and Tectonics. The Archean gneisses consist of migmatitic gneiss, amphibolite, and granite (Figure 3-58). To the north,

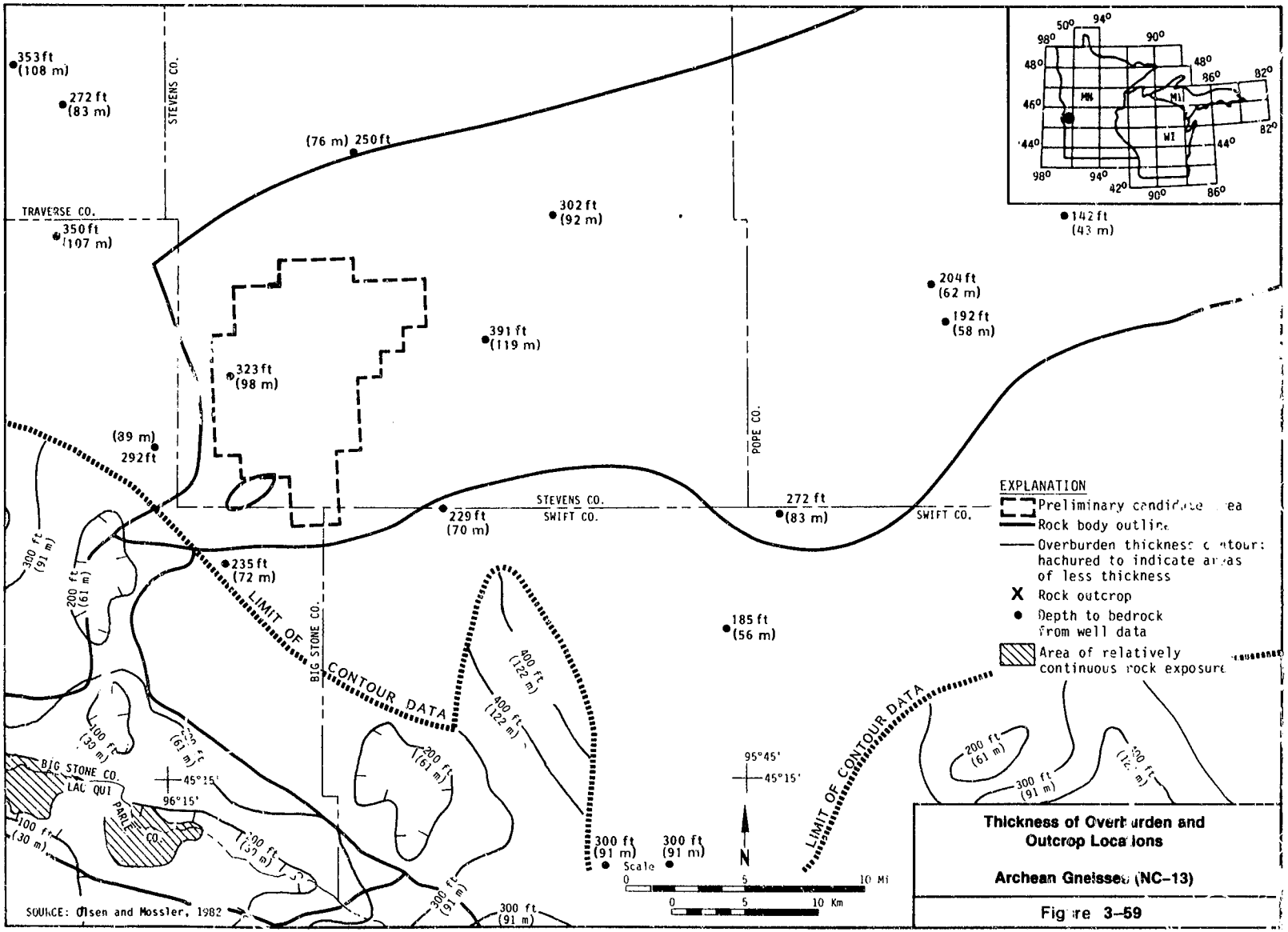

K
Ags
STEVENS CO.
Great Lakes tectonic zone
Morris Fault
TRAVERSE CO.
K
Agn
K
K
Agn
POPE CO.
K
STEVENS CO.
SWIFT CO.
SWIFT CO.
BIG STONE CO.
K
Agr
BIG STONE CO.
LAC QUI PARLE CO.
45°15'
96°15'
Agr
K
Agn
Agn
SOURCES: Sims et al., 1980; Morey et al., 1982
95°45'
45°15'
N
Scale
0 5 10 Mi
0 5 10 Km
EXPLANATION
Preliminary candidate area
Rock body outline
Geologic contact
Fault
MN
WI
MI
Geologic Map
Archean Gneisses (NC-13)
Figure 3-58
Sheet 1



Explanation for
Figure 3–58

Archean Gneisses (NC–13)

Figure 3–58 Sheet 2


353 ft (108 m)
272 ft (83 m)
STEVENS CO.
(76 m) 250 ft
TRAVERSE CO.
350 ft (107 m)
302 ft (92 m)
142 ft (43 m)
204 ft (62 m)
192 ft (58 m)
391 ft (119 m)
323 ft (98 m)
POPE CO.
(89 m)
292 ft
STEVENS CO.
SWIFT CO.
229 ft (70 m)
272 ft (83 m)
SWIFT CO.
235 ft (72 m)
LIMIT OF CONTOUR DATA
BIG STONE CO.
185 ft (56 m)
400 ft (122 m)
400 ft (122 m)
200 ft (61 m)
100 ft (30 m)
BIG STONE CO.
LAC QUI PARLE CO.
45°15'
96°15'
95°45'
45°15'
300 ft (91 m)
300 ft (91 m)
Scale
0 5 10 Mi
0 5 10 Km
N
LIMIT OF CONTOUR DATA
SOURCE: Olsen and Mossler, 1982
EXPLANATION
Preliminary candidate area
Rock body outline
Overburden thickness contours; hachured to indicate areas of less thickness
X Rock outcrop
Depth to bedrock from well data
Area of relatively continuous rock exposure
Thickness of Overburden and Outcrop Locations
Archean Gneisses (NC–13)
Figure 3–59

these rocks are in fault contact with early Proterozoic felsic to intermediate volcanic and sedimentary rocks, mica schist, phyllite, and granitoid rocks that have been cataclastically deformed within the Great Lakes tectonic zone. To the west and south, these rocks are unconformably overlain by Cretaceous shale and sandstone. The Late Archean Ortonville granite intruded the Archean gneisses southwest of the preliminary candidate area (Morey et al., 1982).

The Archean gneisses are part of the Archean gneiss terrane of southern Minnesota that formed 2,600 to 3,550 million years ago (Morey and Sims, 1976; Morey et al., 1982). The Archean gneisses have been metamorphosed to the upper amphibolite or lower granulite facies (Goldich and Wooden, 1980). Similar gneiss in the Minnesota River valley to the south of the preliminary candidate area was metamorphosed and deformed several times during the period 2,600 to 3,050 million years ago (Bauer, 1980; Goldich et al., 1980a, 1980b), and intruded by granitic magma about 2,600 million years ago (Goldich and Wooden, 1980). Rocks of the Archean gneiss terrane were periodically tectonically remobilized until about 1,600 million years ago (Sims et al., 1980).

The northeast-trending Morris fault forms the southern boundary of the Great Lakes tectonic zone, which is approximately 4 km (2.5 mi) northwest of the preliminary candidate area (Figure 3-58) (Morey et al., 1982; Sims et al., 1980). This fault is inferred on the basis of aeromagnetic data to be at least 216 km (134 mi) long (Mooney and Morey, 1981; Morey et al., 1982). Sims et al., (1980) interpreted the Morris fault as a southeast-dipping, high-angle reverse fault.

The north-south-trending COCORP seismic-reflection profile of Gibbs et al., (1984) crossed the Archean gneisses approximately 79 km (49 mi) east of the preliminary candidate area. Gibbs et al., (1984) interpretedseveral low-angle, north-dipping thrust faults (north side upthrown) in the subsurface within the Archean gneisses and suggested that these thrusts were formed by the collision and joining of the

Archean gneiss terrane [illegible] Archean greenstone-granite terrane to the north during the Algoman [illegible] ny 2,600 to 2,700 million years ago (Gibbs et al., 1984; Sims, 1980). Because of inferred similarities of lithology and tectonic setting between the gneisses of the preliminary candidate area and those to the east, similar thrust faults may be present in the Archean gneisses that underlie the preliminary candidate area. There is no surface evidence of Quaternary activity along these faults or within the geologic setting.

No structural features exclusive of faults have been reported in the literature for the preliminary candidate area. However, similar Archean gneisses to the south in the Minnesota River valley have foliation, lineations, and folds. The description of these structures is included here because similar structures may occur in the gneisses of the preliminary candidate area. The gneisses of the Minnesota River valley are moderately to well foliated. Foliation is defined by compositional banding, oriented planar minerals, flat quartz lenses, and hornblende segregations. The lineations are defined by elongate minerals, minor fold axes, crenulations on foliation planes, and boudins, and are generally parallel to the major F_2 fold axes, which trend N 87° E and plunge 15 degrees. Another group of lineations are oriented approximately normal to the fold axes (Himmelberg, 1968; Bauer, 1980). Bauer (1980) recognized four phases of folding in the gneisses of the Minnesota River valley. The second phase (F_2) is the most prominent and forms broad, gently east-plunging antiforms and synforms. The other three phases are deduced from the analysis of minor structures and are not readily evident on a regional scale (Himmelberg, 1968; Bauer, 1980).

A discussion of recent crustal uplift is presented in the regional geologic setting. (Section 3.2.1.1.1.3) There is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that this uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for the vicinity of the preliminary candidate area.

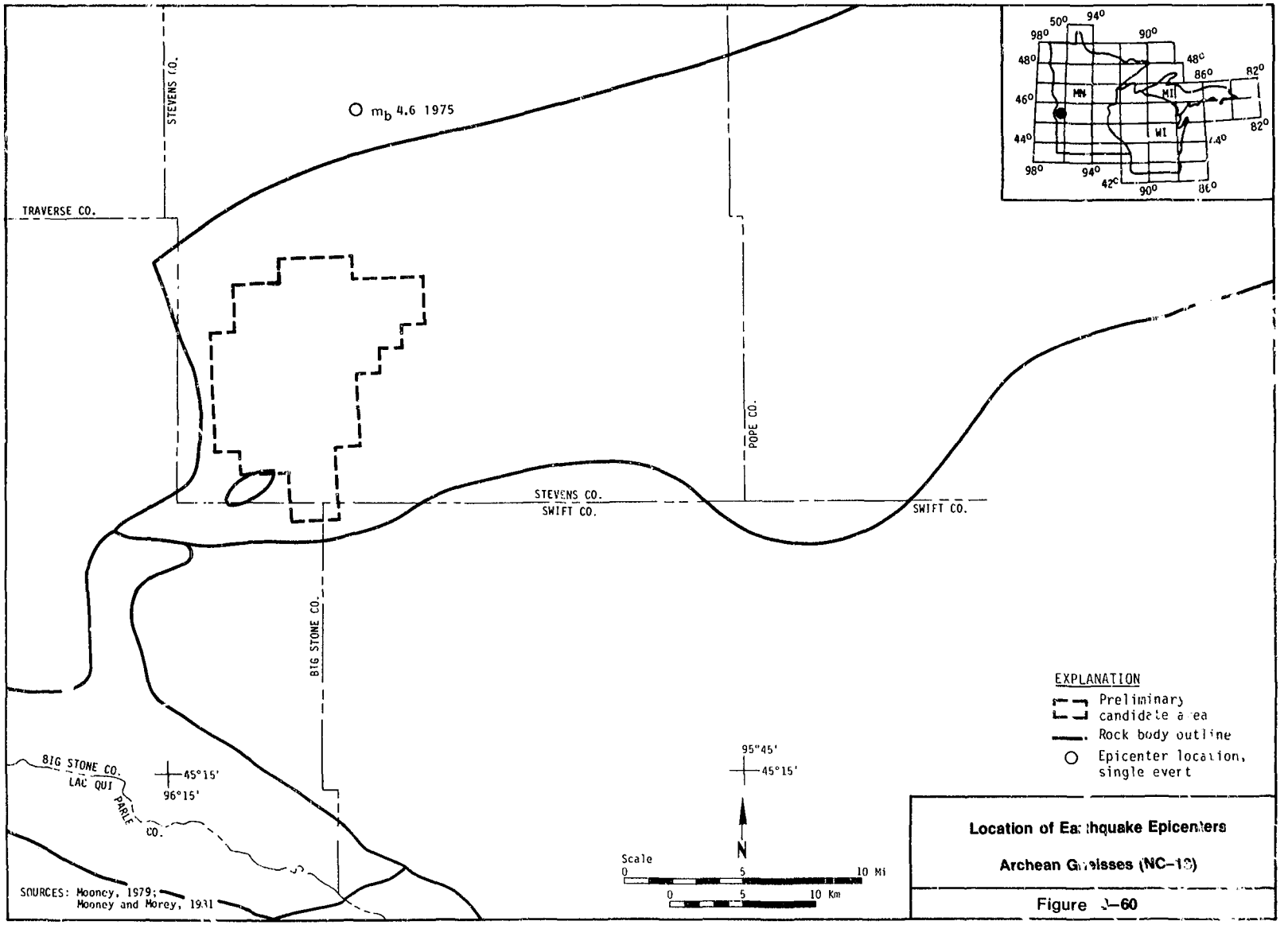
The absence of [illegible]ivity in and near the preliminary candidate area for the last [illegible] years and the absence of Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicate that future igneous activity in the area is highly unlikely.

There is no evidence of igneous activity, folding, faulting, uplift, subsidence, or other tectonic processes within the geologic setting during the Quaternary Period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.1.9.3 Seismicity. The July 9, 1975, Morris earthquake (m_b 4.6) occurred on the Morris fault approximately 10 km (6 mi) north of the preliminary candidate area (Figure 3-60) (Mooney, 1979; Mooney and Morey, 1981). The preferred focal plane solution for the Morris earthquake is N 60°E, dip 70° SE, parallel to the orientation of the Morris fault (Mooney and Morey, 1981). This earthquake occurred at a depth of 5 to 10 km (3 to 6 mi), had a maximum intensity of MM VI, and a felt area of 82,000 km^2 (31,700 mi^2) (Mooney, 1979; Mooney and Morey, 1981). Stover et al. (1981) located the epicenter for this event 20 km (12 mi) northeast of the preliminary candidate area and listed it as a magnitude 5.0 earthquake. The regional seismicity is discussed in Section 3.2.1.1.1.3.

Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity would produce ground motion in excess of reasonable designlimits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the preliminary candidate area will increase in the future.

3.2.1.9.4 Mineral Resources. There are no strategic, metallic, or energy-related mineral resources known to occur either in or within 10 km



Location of Earthquake Epicenters

Archean Gneisses (NC–1?)

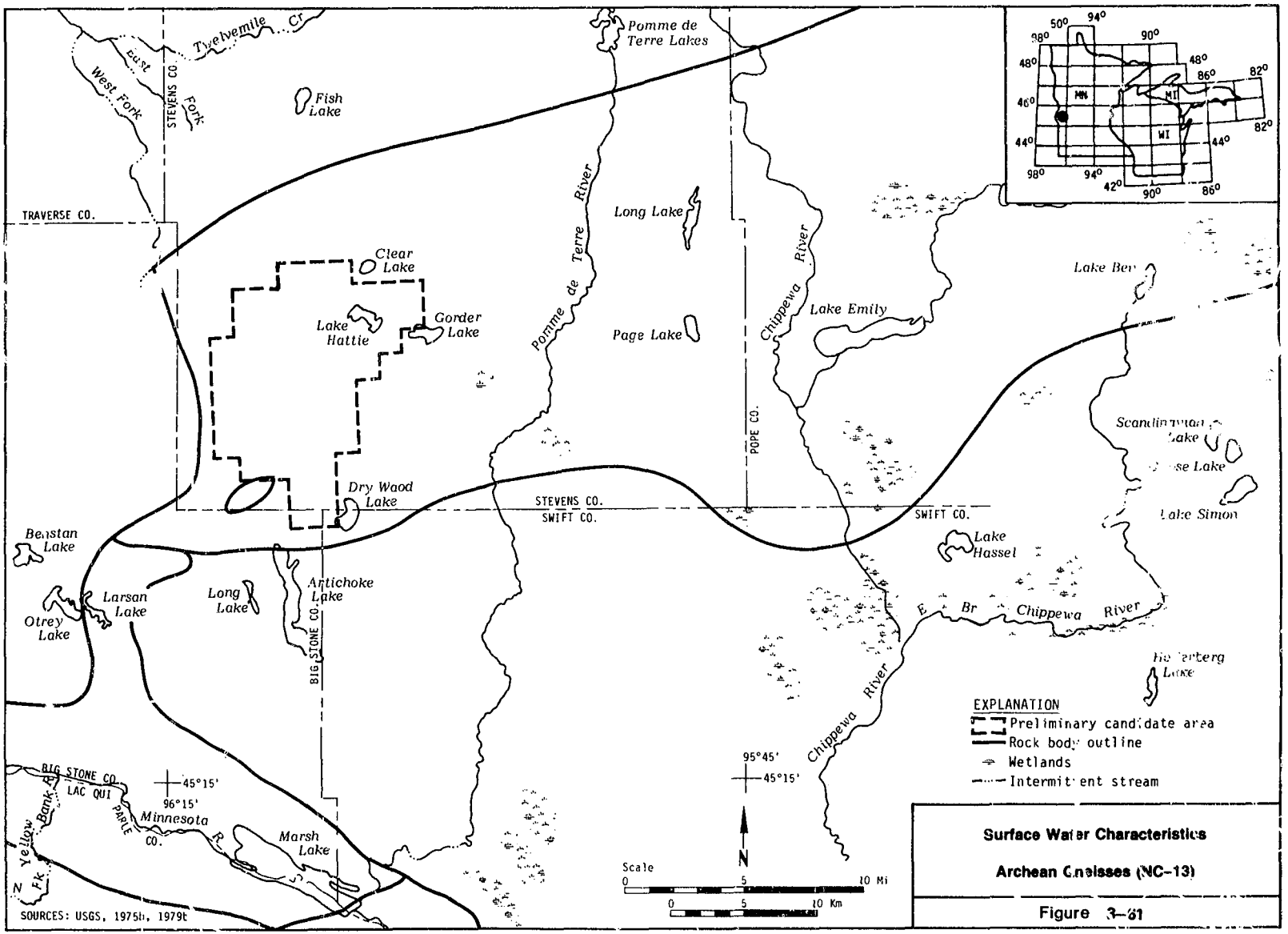
Figure 3–60

(6 mi) of the preliminary candidate area (Schwartz and Prokopovich, 1966; Walton, 1976; USBM, 1985). No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mine or quarry is the Ortonville granite quarry, located approximately 25 km (15 mi) southwest of the preliminary candidate area. Other natural resources within and near the preliminary candidate area (i.e., quarries and gravel pits) are shallow and widely available throughout the region.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources within the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation, and no information is currently available to indicate that deep exploration drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

3.2.1.9.5 Topography and Surface Water Characteristics. The topographic relief within the preliminary candidate area is very low, with elevations ranging from 350 to 353 m (1,150 to 1,160 ft). The preliminary candidate area does not appear to contain large areas of floodplain. Examination of topographic maps indicates that only localized portions of the area along major drainages and small stream valleys are potentially flood prone. No reservoirs or impoundments are known to exist in or upstream of the preliminary candidate area.

The Archean gneisses of the preliminary candidate area are drained mainly by the Pomme de Terre River, which ultimately drains south to the Mississippi River (Figure 3-61). Major surface water bodies within thepreliminary candidate area are Lake Hattie, Dry Wood Lake, and Gorder Lake. As represented by the region-to-area screening data base, the preliminary candidate area has no surface water or wetlands (USGS, 1965; USGS, various dates; Minnesota State Planning Agency, 1984). The locations of lakes, rivers, and marshlands in the preliminary candidate area shown on Figure 3-61 are based on surface water features shown on USGS 1:250,000 Milbank and Saint Cloud topographic maps. Surface water



Surface Water Characteristics

Archean Gneisses (NC-13)

Figure 3-61

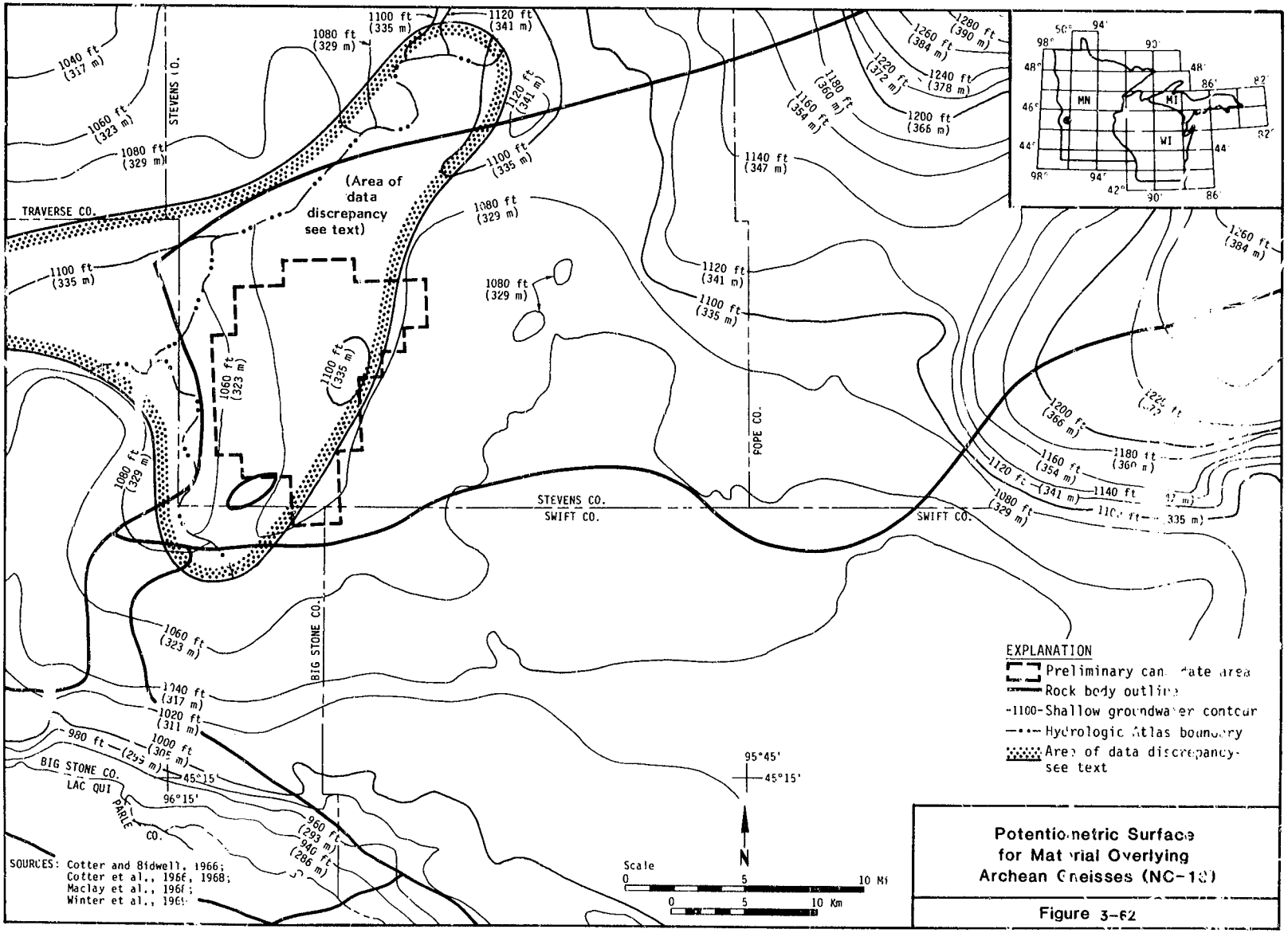
bodies near the preliminary candidate area include the Pomme de Terre River, Clear Lake, Artichoke Lake, Barsness Lake, Benstan Lake, Long Lake, Otrey Lake, Fish Lake, and numerous other lakes and intermittent streams.

The data presented in this section indicate that the relief of the preliminary candidate area is generally low and the terrain is well drained. Evaluation of topographic maps of the preliminary candidate area indicate that only localized portions of the area are potentially flood prone.

3.2.1.9.6 Ground-Water Resources. The regional hydrology is discussed in Section 3.2.1.1.1.5. Shallow ground-water movement is generally toward the Pomme de Terre and Minnesota Rivers. Figure 3-62 shows shallow ground-water contours reported by Cotter et al., (1966, 1968), Cotter and Bidwell (1966), Maclay et al., (1968), and Winter et al., (1969). It should be noted that the contours in the area of data discrepancy on this figure do not agree across source map boundaries and do not appear to be consistent with the regional gradient. However, there is currently no basis for determining which data set is more representative of actual conditions. Areas that displayed convergence of shallow water-table contours, based on a 30-m (100-ft) contour interval, were considered potential major discharge zones. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

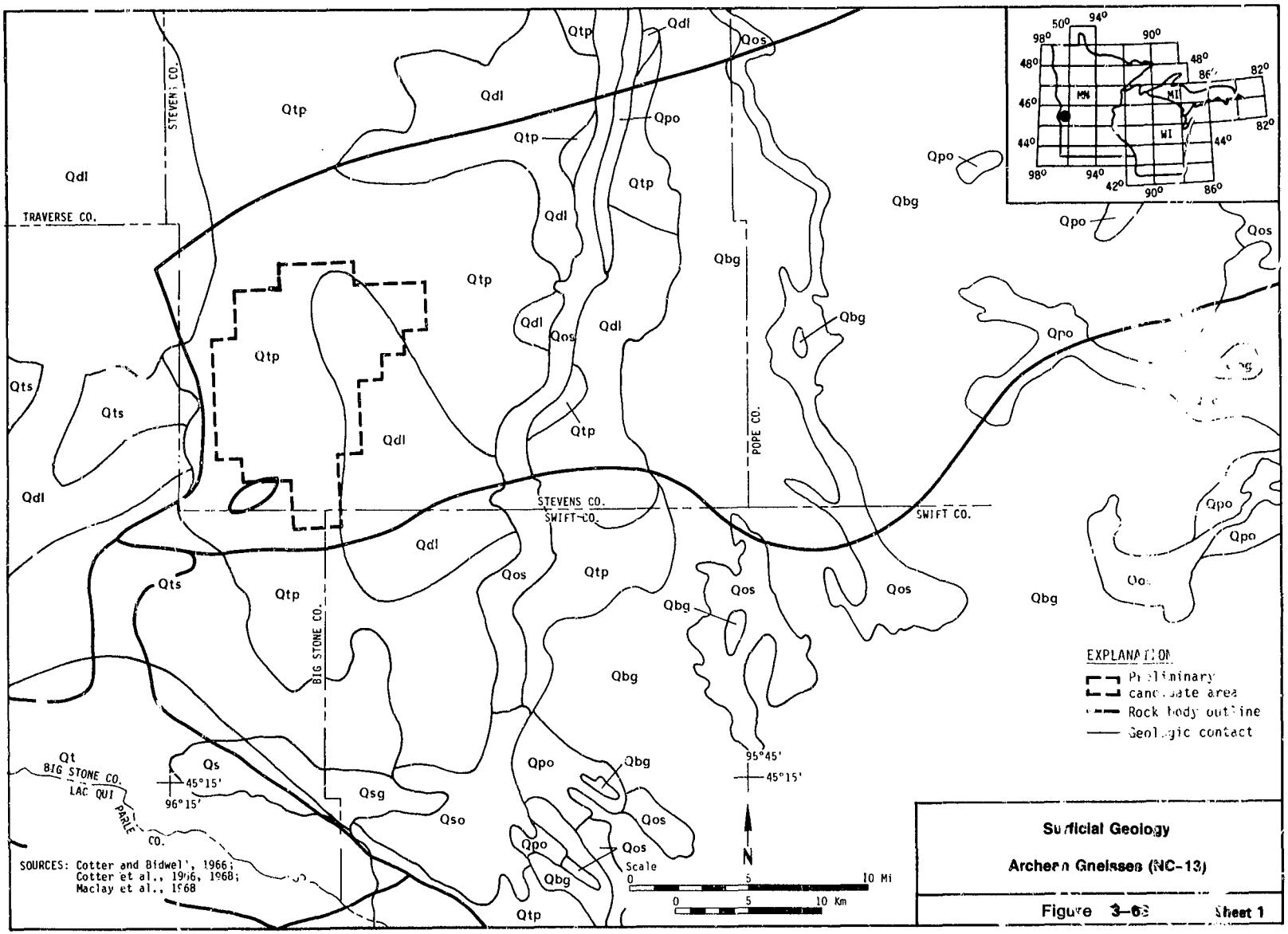
Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that include till containing lenses of sand and gravel within ground and end moraines. The horizontal extent of surficial deposits is shown in Figure 3-63.

Well yields presented in the North Central RGCR (DOE, 1985c) were estimated from maps by Kanivetsky (1978, 1979) and Kanivetsky and Walton (1979) and are shown on Figure 3-64a. Additional detailed well yield information has been reported by Cotter and Bidwell (1966), Cotter et al., (1966, 1968), and Maclay et al., (1968) in the USGS Hydrologic



Potentiometric Surface for Material Overlying Archean Gneisses (NC-1&2)

Figure 3-62


Qtp
Qdl
Qos
Qpo
Qbg
Qts
Qt
Qs
Qsg
Qso
STEVENS CO.
TRAVERSE CO.
BIG STONE CO.
POPE CO.
SWIFT CO.
LAC QUI PARLE CO.
45°15'
96°15'
95°45'
N
Scale
0 5 10 Mi
0 5 10 Km
EXPLANATION
Preliminary candidate area
Rock body outline
Geologic contact
SOURCES: Cotter and Bidwell, 1966; Cotter et al., 1966, 1968; Maclay et al., 1968
Surficial Geology
Archean Gneisses (NC-13)
Figure 3-63
Sheet 1

EXPLANATION OF SURFICIAL UNITS

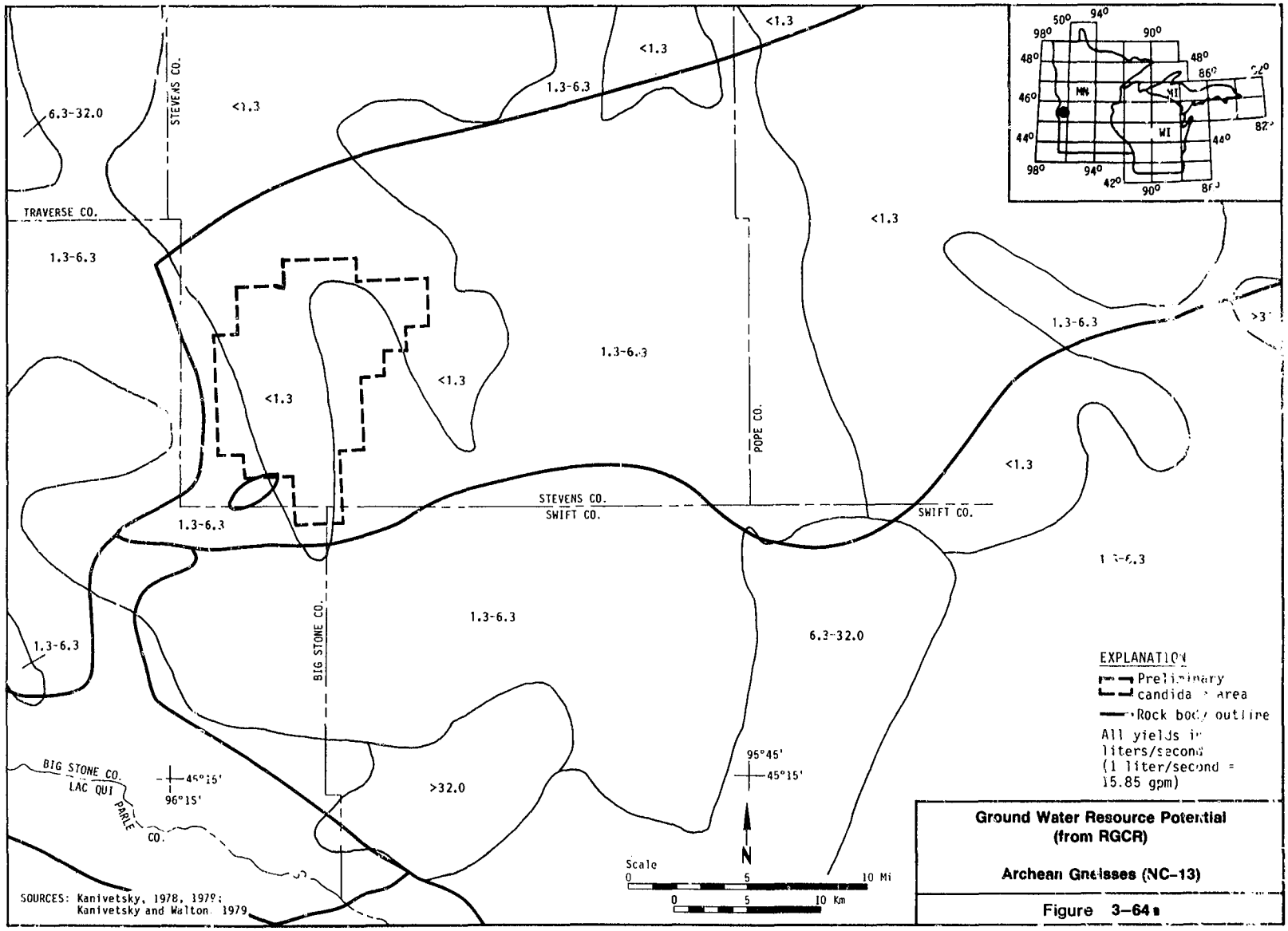
QUATERNARY

	Qtp	Till moraine, mainly clay and silt
	Qdl	Till moraine, with sand and gravel lenses
Qt	Qts	Till, Qts underlain by shale and sandstone deposits
	Qpo	Ice-contact sand and gravel
	Qos	Outwash sand and gravel
Qs	Qsg	Near-surface sand and gravel, Qsg underlain by shale and sandstone deposits
	Qso	Silty outwash sand and gravel
	Qbg	Buried sand and gravel

Explanation for
Figure 3-63

Archean Gneisses (NC-13)

Figure 3-63 Sheet 2



Ground Water Resource Potential (from RGCR)

Archean Gneisses (NC-13)

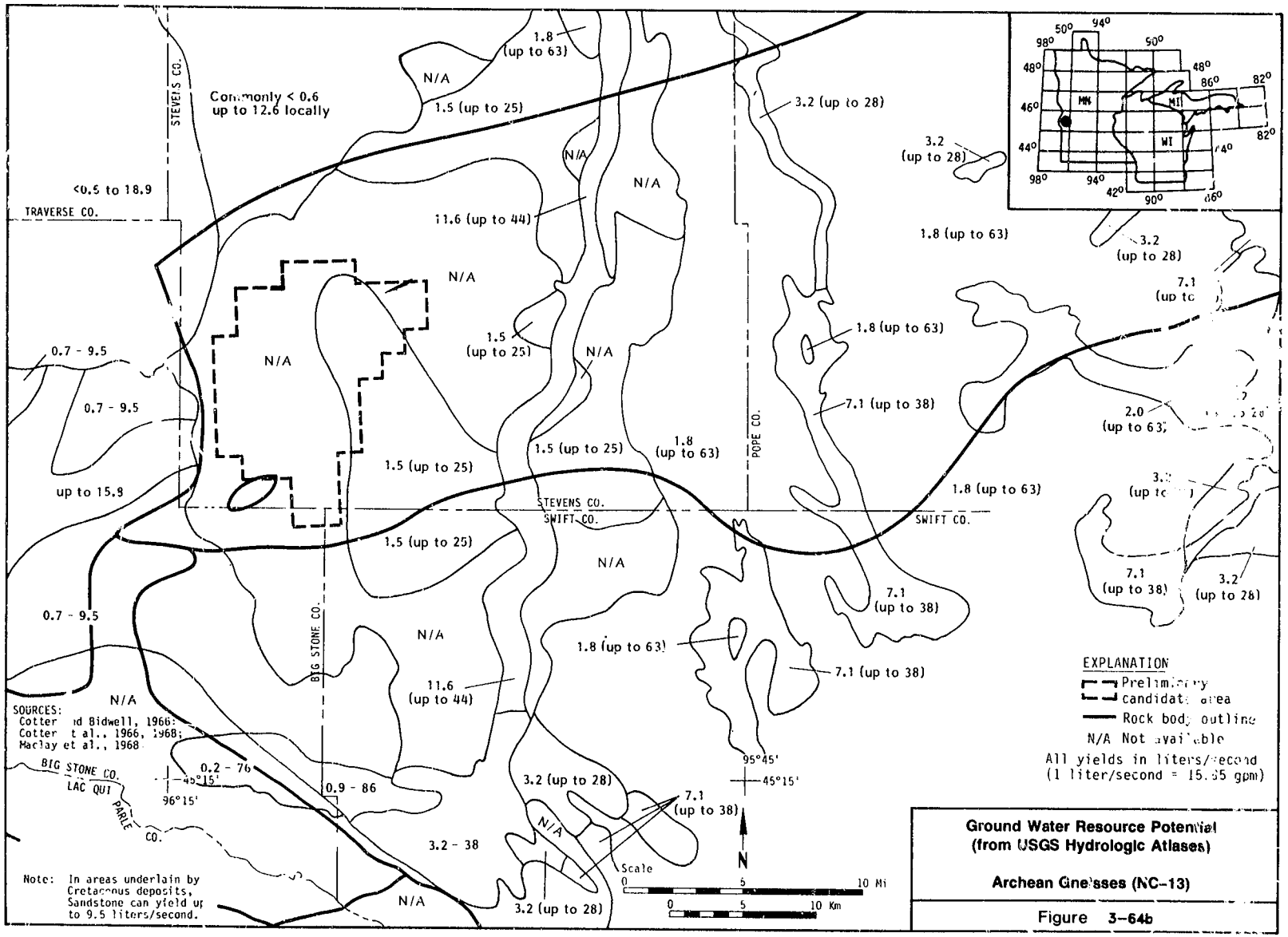
Figure 3-64

Atlases and is shown in Figure 3-64b. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison. Water availability from glacial deposits varies widely. Where lenses of sand and gravel are present, local yields of up to 25 L/s (400 gpm) have been reported (Cotter and Bidwell, 1966). Outwash sands and gravels located along the Pomme de Terre River can yield up to 44 L/s (700 gpm) (Cotter and Bidwell, 1966).

The data indicate that relatively shallow Quaternary aquifers that contain potable ground water are present within the preliminary candidate area. No deep wells (i.e., greater than 100 m [328 ft] in depth) have been reported in the literature to be present within the preliminary candidate area. Therefore, local ground-water conditions in the deeper crystalline rock are currently unknown.

3.2.1.9.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition and vertical crustal movement is in Section 3.2.1.1.1.1.

3.2.1.9.8. Federal Lands. One Federal waterfowl production area greater than 130 ha (320 ac) in size overlaps the preliminary candidate area near the southern boundary and occupies 81 ha (200 ac) of the preliminary candidate area. Additionally, there are two waterfowl production areas, each less than 130 ha (320 ac) in size, located in the northern half of the preliminary candidate area. These two waterfowl production areas cover a total of approximately 89 ha (220 ac). In total, the three waterfowl production areas occupy 170 ha (420 ac) or approximately 1% of the preliminary candidate area. There are also 11 waterfowl production areas, each greater than 130 ha (320 ac) in size, and 37 waterfowl production areas, each less than 130 ha (320 ac) in size, within 10 km (6 mi) of the preliminary candidate area. All of these features are depicted on Plate 2A of the North Central RECR or are listed in Appendix A of that report (DOE, 1985d).


STEVENS CO.
TRAVERSE CO.
POPE CO.
BIG STONE CO.
LAC QUI PARLE CO.
SWIFT CO.
Commonly < 0.6
up to 12.6 locally
<0.5 to 18.9
up to 15.9
0.7 - 9.5
0.2 - 76
0.9 - 86
3.2 - 38
1.8 (up to 63)
1.5 (up to 25)
3.2 (up to 28)
11.6 (up to 44)
7.1 (up to 38)
2.0 (up to 63)
N/A
95°45'
45°15'
96°15'
Scale
0 5 10 Mi
0 5 10 Km
N
SOURCES:
Cotter and Bidwell, 1966;
Cotter et al., 1966, 1968;
Maclay et al., 1968
Note: In areas underlain by Cretaceous deposits, Sandstone can yield up to 9.5 liters/second.
EXPLANATION
Preliminary candidate area
Rock body outline
N/A Not available
All yields in liters/second
(1 liter/second = 15.85 gpm)
Ground Water Resource Potential
(from USGS Hydrologic Atlases)
Archean Gneisses (NC-13)
Figure 3-64b

In summary, three [illegible] waterfowl production areas (one greater than and two less [illegible] (320 ac]) lie within the preliminary candidate area, covering a total of [illegible] (320 ac) or approximately 1% of the preliminary candidate area. In addition, 48 waterfowl production areas (11 greater than and 37 less than 130 ha [320 ac]) are located within 10 km (6 mi) of the preliminary candidate area (see Figure 3-65).

3.2.1.9.9 State Lands. There are four wildlife management areas which are each less than 130 ha (320 ac) in size within the preliminary candidate area: Eul, 44 ha (108 ac); Haunted House, 67 ha (166 ac); Mathison, 25 ha (62 ac); and Robertson, 35 ha (86 ac). In total, these areas occupy 171 ha (422 ac) or 1% of the preliminary candidate area. Two wildlife management areas, each greater than 130 ha (320 ac) in size, are located within 10 km (6 mi) of the preliminary candidate area. These are the Dismal Swamp Wildlife Management Area, located 3.2 km (2 mi) west of the preliminary candidate area boundary, and the Bill Freeman Wildlife Management Area, located 8 km (5 mi) east of the preliminary candidate area. In addition, 12 wildlife management areas, each less than 130 ha (320 ac) in size, are located within 10 km (6 mi) of the preliminary candidate area boundary. All of the features described above are either depicted on Plate 4B or listed in Appendix B of the North Central RECR (DOE, 1985d).

In summary, four State wildlife management areas (each less than 130 ha [320 ac]) lie within the preliminary candidate area and occupy a total of 171 ha (422 ac) or approximately 1% of the area. A total of 14 wildlife management areas (two greater than and 12 less than 130 ha [320 ac]) are located within 10 km (6 mi) of the preliminary candidate area (see Figure 3-65).

3.2.1.9.10 Environmental Compliance. There are no nonattainment areas or Prevention of Significant Deterioration (PSD) Class I Areas in or within 40 km (25 mi) of the preliminary candidate area (40 CFR 81). No sites listed on the National Register of Historic Places (NRHP) and no National Trails are located within the preliminary candidate area. No National Trails are located within 40 km (25 mi) of the preliminary

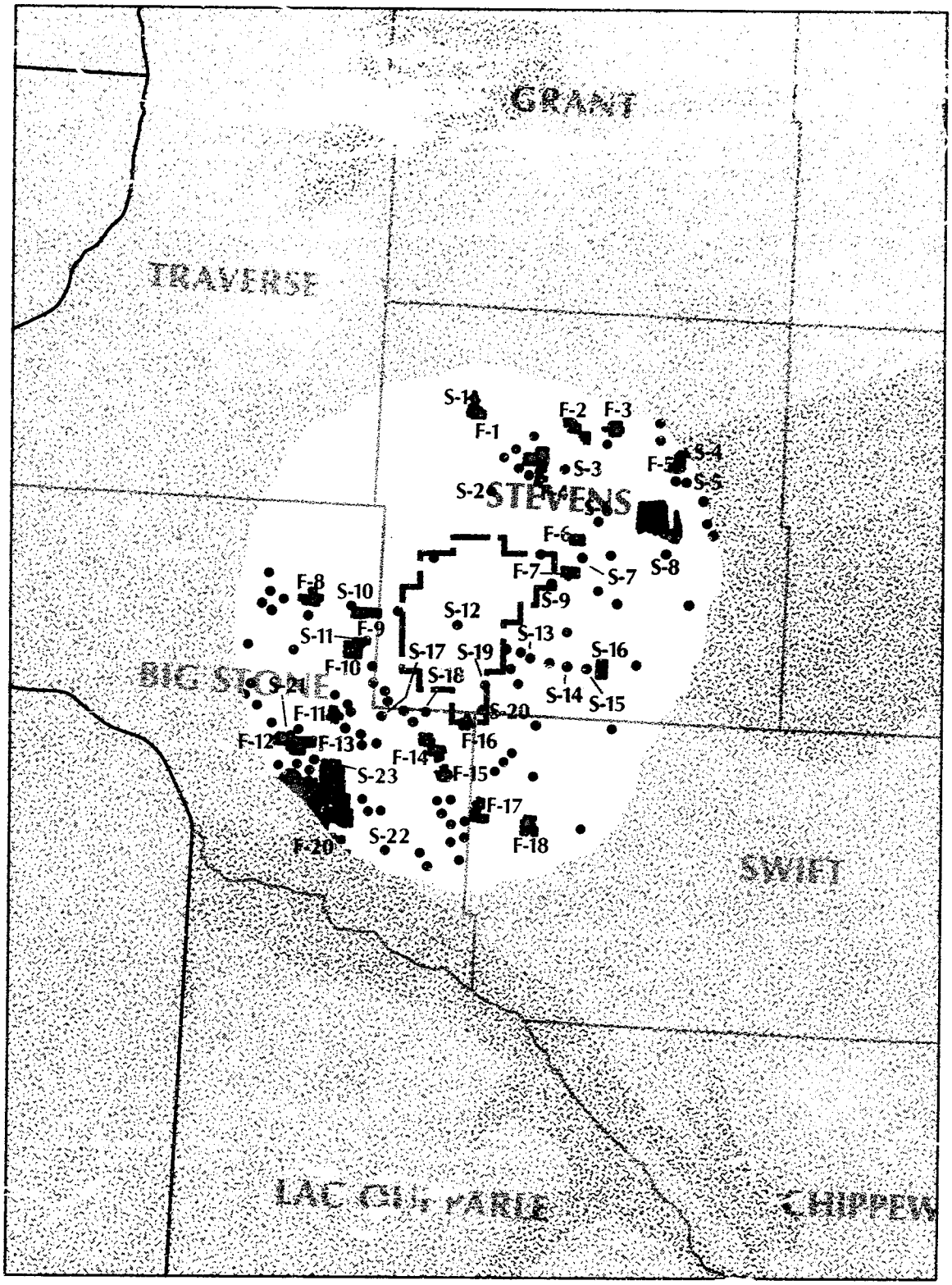


Figure 3–65 Sheet 1

Environmental Features
Archean Gneisses (NC-13)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3-65 Sheet 2

[illegible] NEIGHBORS WITHIN 16 KM (10 MI)
OF PRE[illegible] CANDIDATE AREA NC-13*

Code	Feature
Population Features	
P-1	Morris Highly Populated Area**
Federal Lands* **	
F-1	Waterfowl Production Area (WPA)
F-2	WPA
F-3	WPA
F-4	WPA
F-5	WPA
F-6	WPA
F-7	WPA
F-8	WPA
F-9	WPA
F-10	WPA
F-11	WPA
F-12	WPA
F-13	WPA
F-14	WPA
F-15	WPA
F-16	WPA
F-17	WPA
F-18	WPA
F-19	WPA
F-20	WPA
State Lands	
S-1	Everglade Wildlife Management Area (WMA)
S-2	Cin WMA
S-3	Kline WMA
S-4	Klason WMA
S-5	Dolven WMA
S-6	Brouillet WMA
S-7	Muddy Creek WMA
S-8	Coleman WMA
S-9	Mathison WMA
S-10	Freed WMA
S-11	Dismal Swamp WMA
S-12	Eul WMA
S-13	Dablow WMA
S-14	Reimers WMA

Figure 3-65, Sheet 3

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI)
OF PRELIMINARY CANDIDATE AREA NC-13*

Code	Feature
State Lands - Continued	
S-15	Hennen WMA
S-16	Bill Freeman WMA
S-17	Klages WMA
S-18	Old Gravel Pit WMA
S-19	Robertson WMA
S-20	Haunted House WMA
S-21	Thomeon WMA
S-22	Malta WMA
S-23	Lindquist WMA
Indian Reservations	
None	

* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

** Area with a population density greater than or equal 1,000 persons per square mile.

*** Waterfowl production areas less than 130 ha (320 ac) are displayed as dots on the map but are not coded due to lack of space.

Figure 3-65, Sheet 4

candidate area. There are [illegible] proposed NRHP sites within the preliminary candidate area. In the regional data base, there are no known existing archaeological sites or districts nor any proposed for designation within the preliminary candidate area.

3.2.1.9.11 Population Density and Distribution. The preliminary candidate area contains no highly populated areas. There is one highly populated area (Morris) within 16 km (10 mi) of the preliminary candidate area (see Figure 3-65). Morris is located 8 km (5 mi) northeast of the preliminary candidate area and has a population of 5,367. The preliminary candidate area does not contain any areas with population densities greater than or equal to 1,000 persons per square mile. Morris, which is also a highly populated area, is the only area with a population density greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area (see Figure 3-65). St. Cloud is located approximately 144 km (90 mi) east of the preliminary candidate area. The average population density of the preliminary candidate area is 5 persons per square mile. The average population density within 80 km (50 mi) is approximately 16 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.1.9.12 Site Ownership. There are no DOE-owned lands located within the preliminary candidate area. As mentioned in Section 3.2.1.9.8, the only Federal lands within the preliminary candidate area are three waterfowl production areas covering a total of 170 ha (420 ac) or approximately 1% of the preliminary candidate area. The Upper Sioux Indian Reservation is approximately 86 km (54 mi) southeast of the preliminary candidate area (see Plate NC-1A).

3.2.1.9.13 Offsite Installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Monticello, which is approximately 296 km (110 mi) southeast of the preliminary candidate area (Michalewicz and

Vann, 1983; DOE, [illegible] nearest commercial nuclear reactor under construction is Byron 2, [illegible] km (425 mi) to the southeast (Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.9.14 Transportation. The nearest interstate highway (I94) is about 56 km (35 mi) northeast of the preliminary candidate area in central Minnesota. I29 in eastern South Dakota is about 64 km (40 mi) to the west. The nearest U.S. highway to the preliminary candidate area is U.S. 59 which is located about 8 km (5 mi) to the east of the preliminary candidate area. U.S. 75 is approximately 16 km (10 mi) to the west. U.S. 12 is located about 13 km (8 mi) to the south of the preliminary candidate area. State Route 28, a principal highway, is about 1.6 km (1 mi) north of the preliminary candidate area. State Route 28 joins U.S. 59 at Morris and also intersects U.S. 75 at Graceville. This is the only State highway in the vicinity of the preliminary candidate area; however, there are a number of county roads in the area.

The Burlington Northern has a mainline railroad located approximately 8 km (5 mi) northeast of the preliminary candidate area. This line runs between Minneapolis and Fargo, North Dakota. The Soo/Milwaukee has a rail line which is located about 19 km (12 mi) south of the preliminary candidate area. The Burlington Northern has a branchline that comes within 1.6 km (1 mi) of the extreme northern edge of the preliminary candidate area. This branchline leaves the mainline at Morris, which is only 8 km (5 mi) east of the preliminary candidate area.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.1.9.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on

preliminary candidate [illegible] that could affect DOE's decision to defer further consideration [illegible] the area [illegible] on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggests that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could produce ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]

- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- limited presence of State lands less than 130 ha (320 ac) within (i.e., 4) and in proximity to (i.e., 12 within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2), 960.5-2-7(b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]
- presence of Federal lands less than 130 ha (320 ac) with (i.e., two) and in proximity to (i.e., 37 within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)
- a majority (approximately 50%) of the preliminary candidate area is within 16 km (10 mi) of highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(c)(2)].

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-13 at this time.

3.2.1.10 Preliminary Candidate Area Description - Archean Gneisses (NC-14)

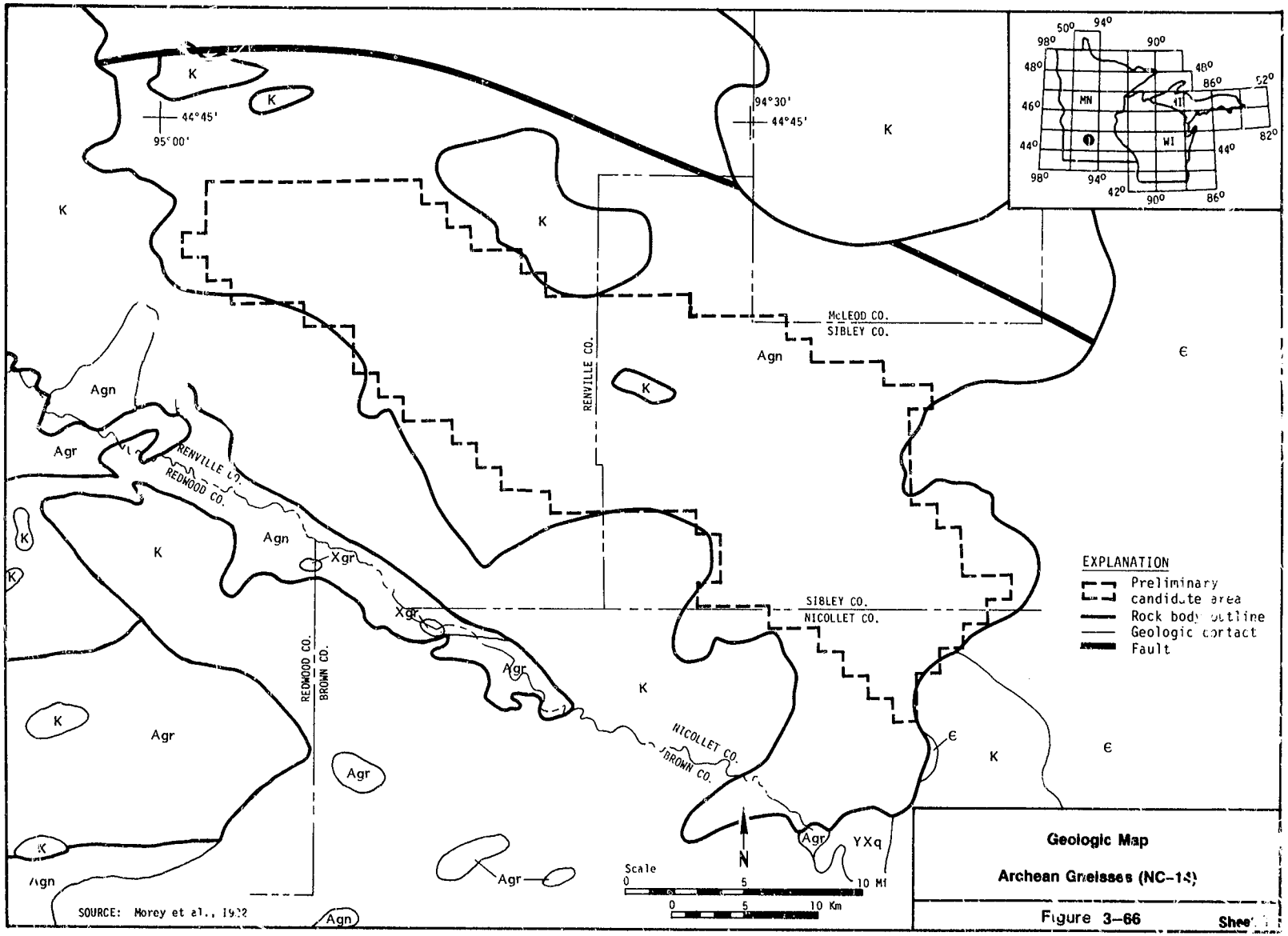
The Archean gneisses are located within the Minnesota River Lowland physiographic province in southern Minnesota. The preliminary candidate area is located in Renville, Sibley, McLeod, and Nicollet Counties at approximately 44°33' N latitude and 94°34' W longitude.

3.2.1.10.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-66 has an area of approximately 746 km^2 (287 mi^2), and overlies the Archean gneisses, the mapped extent which are largely inferred from geophysical data and scattered outcrops (Morey et al., 1982). The Archean gneisses that contain the preliminary candidate area have a mapped extent of approximately 100 km (61 mi) long by 10 to 30 km (6 to 18 mi) wide. Seismic reflection data in the vicinity of the preliminary candidate area suggest that the Archean gneisses extend down to the asthenosphere (i.e., several tens of kilometers [miles]) (Gibbs et al., 1984).

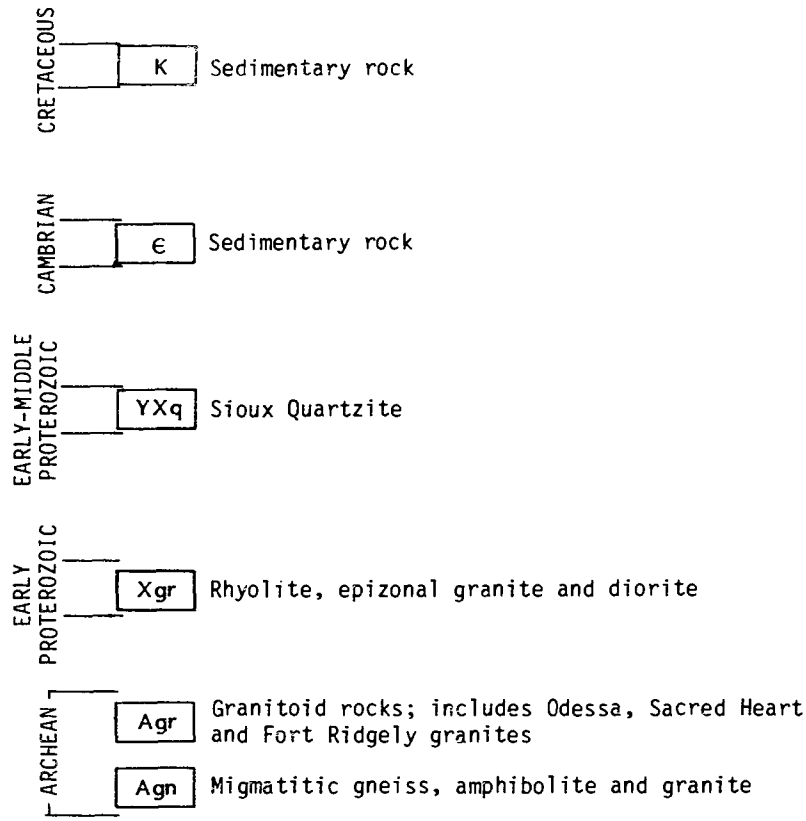
There is no exposed bedrock in the preliminary candidate area. Contours of overburden thickness indicate that a major portion of the preliminary candidate area is covered by 61 to 91 m (200 to 300 ft) of overburden (Figure 3-67).

On the basis of the data presented above, the Archean gneisses are sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

3.2.1.10.2 Lithology and Tectonics. The Archean gneisses consist of migmatitic gneiss, amphibolite, and granite (Figure 3-66). These rocks are unconformably overlain by Cretaceous shale and sandstone to the north, west, and south, and by Cambrian sandstone and siltstone to the


K
44°45'
95°00'
94°30'
44°45'
McLEOD CO.
SIBLEY CO.
RENVILLE CO.
Agn
Agr
REDWOOD CO.
Xgr
SIBLEY CO.
NICOLLET CO.
BROWN CO.
YXq
Є
EXPLANATION
Preliminary candidate area
Rock body outline
Geologic contact
Fault
Scale
0 5 10 MI
0 5 10 Km
N
SOURCE: Morey et al., 1972
Geologic Map
Archean Gneisses (NC-14)
Figure 3-66

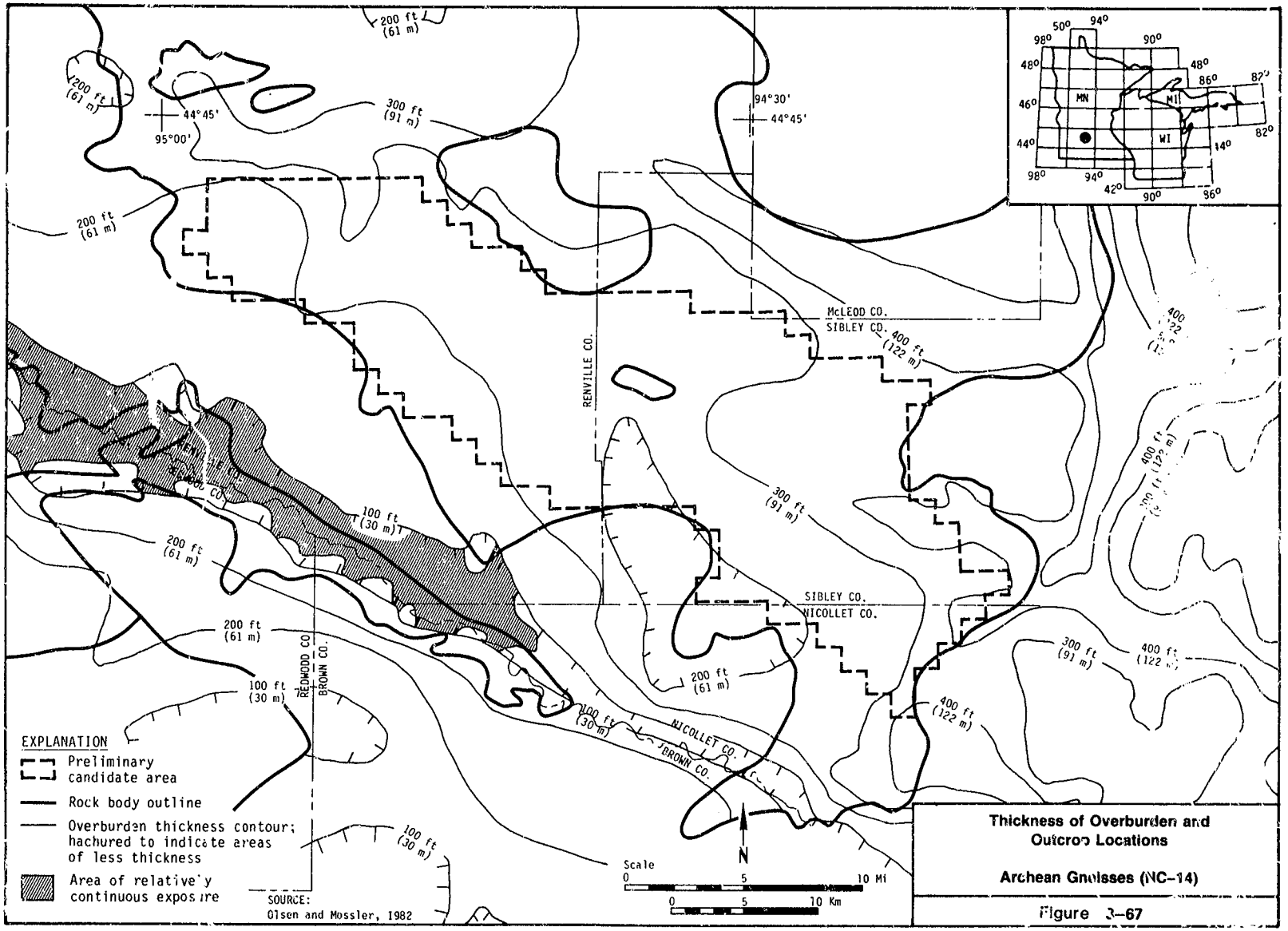
EXPLANATION OF GEOLOGIC UNITS



Explantion for
Figure 3-66

Archean Gneisses (NC-14)

Figure 3-66 Sheet 2



Thickness of Overburden and Outcrop Locations

Archean Gneisses (NC-14)

Figure 3-67

east. A small outlier of [illegible] Middle Proterozoic Sioux Quartzite unconformably overlies the Archean gneiss to the south (Morey et al., 1982).

The Archean gneisses are part of the Archean gneiss terrane of southern Minnesota that formed 2,600 to 3,550 million years ago (Morey and Sims, 1976; Morey et al., 1982). The Archean gneisses have been metamorphosed to the upper amphibolite or lower granulite facies (Goldich and Wooden, 1980). Similar gneiss in the Minnesota River valley to the south of the preliminary candidate area was metamorphosed and deformed several times during the period 2,600 to 3,050 million years ago (Bauer, 1980; Goldich et al., 1980a, 1980b), and intruded by granitic magma about 2,600 million years ago (Goldich and Wooden, 1980). Rocks of the Archean gneiss terrane were tectonically remobilized periodically until about 1,600 million years ago (Sims et al., 1980).

There are no mapped faults within the preliminary candidate area (Figure 3-66). An inferred fault approximately 70 km (43 mi) long and trending approximately northwest to southeast is inferred on the basis of geophysical data to be located approximately 8 km (5 mi) north of the preliminary candidate area (Morey et al., 1982). There is no evidence of Quaternary activity along this fault or within the geologic setting.

The north-south-trending COCORP seismic-reflection profile of Gibbs et al. (1984) crossed the Archean gneisses approximately 100 km (61 mi) north of the preliminary candidate area. Gibbs et al. (1984) interpreted several low-angle, north-dipping thrust faults (north side upthrown) in the subsurface within the Archean gneisses and they suggested that these thrusts were formed by the collision and joining of the Archean gneiss terrane with the Archean greenstone-granite terrane to the north during the Algoman orogeny 2,600 to 2,700 million years ago (Gibbs et al., 1984; Sims, 1980). Because of inferred similarities of lithology and tectonic setting between the gneisses of the preliminary

candidate area and [illegible] north, similar thrust faults may be present in the Archean g[illegible] that underlie the preliminary candidate area.

No structural features exclusive of faults have been reported in the literature for the preliminary candidate area. However, similar Archean gneisses to the south in the Minnesota River valley have foliation, lineations, and folds. The description of these structures is included here because similar structures may occur in the gneisses of the preliminary candidate area. The gneisses of the Minnesota River valley are moderately to well foliated. Foliation is defined by compositional banding, oriented planar minerals, flat quartz lenses, and hornblende segregations. The lineations are defined by elongate minerals, minor fold axes, crenulations on foliation planes, and boudins, and are generally parallel to the major F_2 fold axes, which trend N 87° E and plunge 15 degrees. Another group of lineations are oriented approximately normal to the fold axes (Himmelberg, 1968; Bauer, 1980). Bauer (1980) recognized four phases of folding in the gneisses of the Minnesota River valley. The second phase (F_2) is the most prominent and forms broad, gently east-plunging antiforms and synforms. The other three phases are deduced from the analysis of minor structures and are not readily evident on a regional scale (Himmelberg, 1968; Bauer, 1980).

A discussion of recent crustal uplift is presented in the regional geologic setting (Section 3.2.1.1.1.3). There is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that this uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for the vicinity of the preliminary candidate area.

The absence of any igneous activity in and near the preliminary candidate area for the last 1,000 million years and the absence of

Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicate that future igneous activity in the area is highly unlikely.

There is no evidence of igneous activity, folding, faulting, uplift, subsidence, or other tectonic processes within the geologic setting during the Quaternary Period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.1.10.3 Seismicity. There are no historical earthquakes within the vicinity of the preliminary candidate area. There are no known geologic structures near the preliminary candidate area that might be expected to induce seismic activity of greater frequency of intensity than that which is typical of the region. The regional seismicity is discussed in Section 3.2.1.1.1.3.

Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the preliminary candidate area will increase in the future.

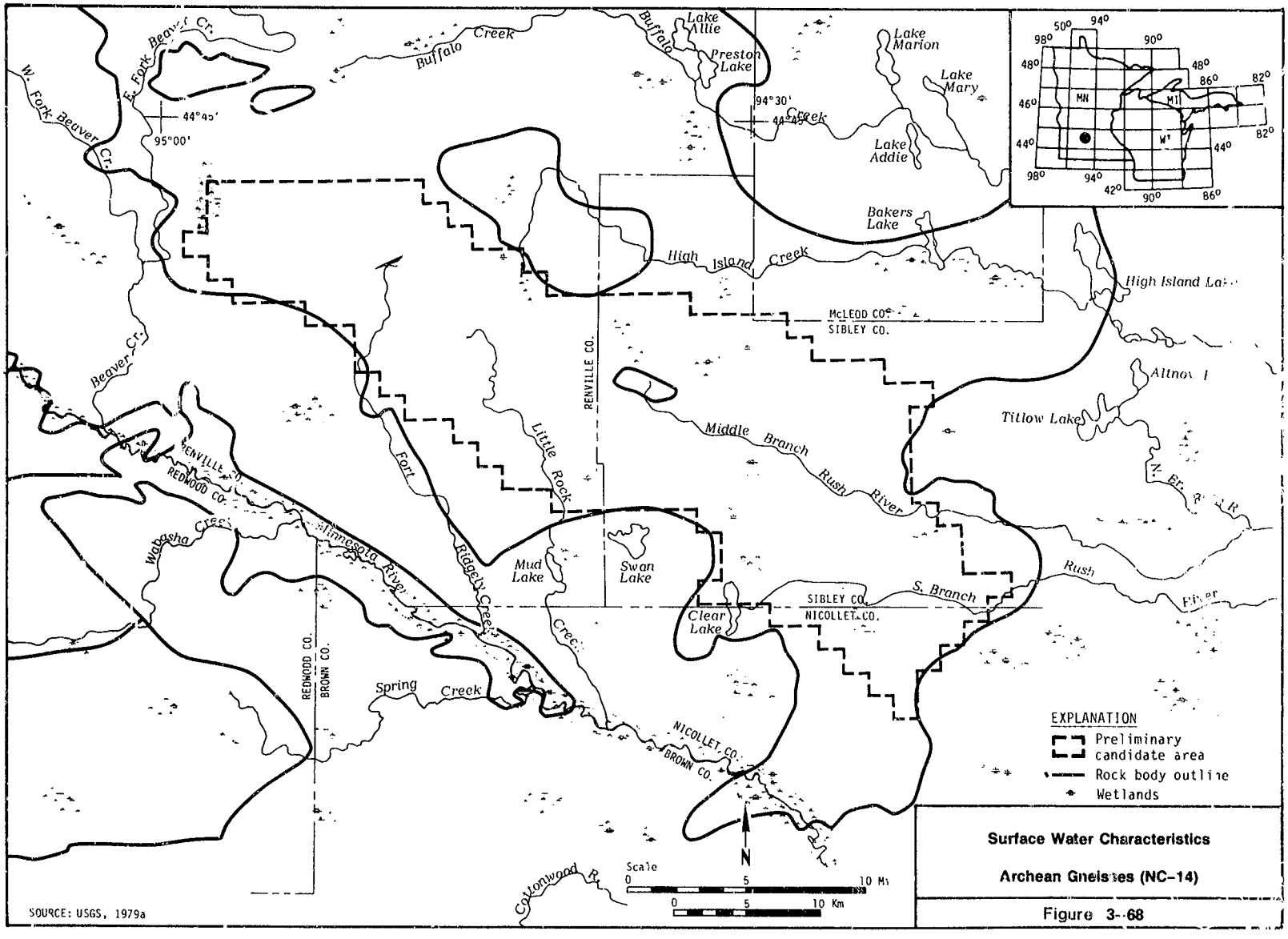
3.2.1.10.4 Mineral Resources. There are no strategic, metallic, or energy-related mineral resources known to occur either in or within 10 km (6 mi) of the preliminary candidate area (Schwartz and Prokopovich, 1966; Walton, 1976; USBM, 1983). No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mine or quarry is the View granite quarry located approximately 30 km (19 mi) west of the preliminary candidate area. Other natural resources within and near the preliminary candidate area (i.e., quarries and clay deposits) are shallow and widely available throughout the region.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources within the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation, and no information is currently available to indicate that deep exploration drillholes (greater than 100 m ([328 ft] in depth) are present in the preliminary candidate area.

3.2.1.10.5 Topography and Surface Water Characteristics. The topographic relief within the preliminary candidate area is generally low, with elevations ranging from 312 to 328 m (1,025 to 1,075 ft). The preliminary candidate area does not appear to contain large areas of floodplain. Examination of topographic maps indicates that only localized portions of the area along stream channels are potentially flood prone. No major reservoirs or impoundments are known to exist within or upstream of the area.

The Archean gneisses of the preliminary candidate area are drained primarily by the Middle and South Branches of the Rush River, which drain southeastward to the Minnesota River, and ultimately to the Mississippi River. As represented by the region-to-area screening data base, the preliminary candidate area is covered by approximately 6% surface water and no wetlands (USGS, 1965; USGS, various dates; Minnesota State Planning Agency, 1984). The locations of lakes, rivers and marshlands in the preliminary candidate area on Figure 3-68 are based on surface water features shown on the USGS 1:250,000 New Ulm topographic map. Major surface water bodies within the preliminary candidate area include the Middle and South Branches of the Rush River, Little Rock Creek, Fort Ridgely Creek, and Clear Lake. Other surface water bodies near the area include the Minnesota River, Swan Lake, Mud Lake, Titlow Lake, Bakers Lake, and many other creeks and small lakes.

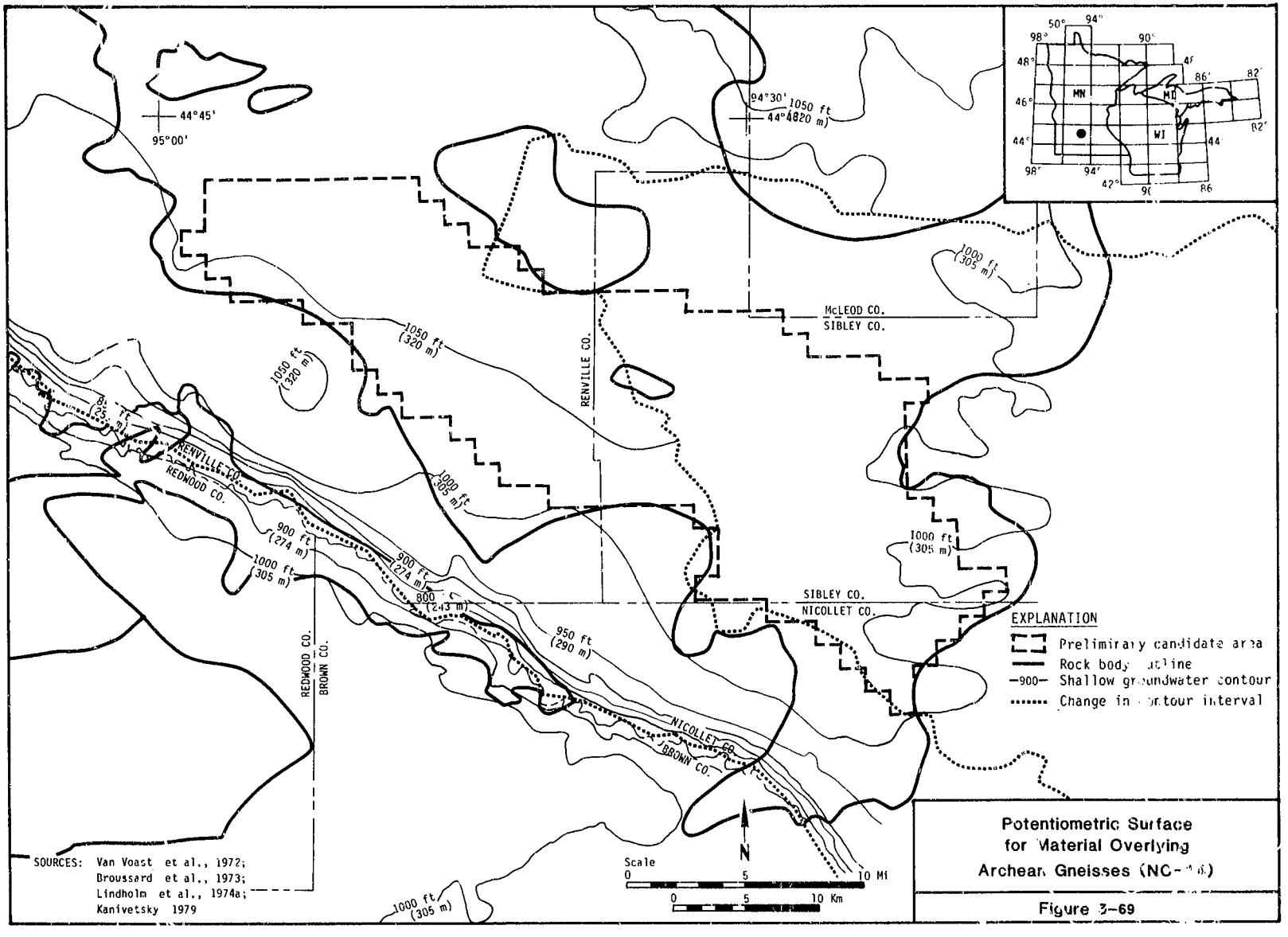
The data presented in this section indicate that the relief of the preliminary candidate area is generally low and the terrain is well drained with scattered small wetlands.


W. Fork Beaver Cr.
E. Fork Beaver Cr.
Buffalo Creek
Buffalo Creek
Lake Allie
Preston Lake
Lake Marion
Lake Mary
Lake Addie
94°30'
44°45'
44°45'
95°00'
Bakers Lake
High Island Creek
High Island Lake
McLEOD CO.
SIBLEY CO.
RENVILLE CO.
Beaver Cr.
Little Rock
Fort
Middle Branch Rush River
Titlow Lake
N. Fk. Rush River
RENVILLE CO.
REDWOOD CO.
Wabasha Creek
Minnesota River
Ridgely Creek
Mud Lake
Swan Lake
Clear Lake
SIBLEY CO.
NICOLLET CO.
S. Branch
Rush River
REDWOOD CO.
BROWN CO.
Spring Creek
NICOLLET CO.
BROWN CO.
Cottonwood R.
MN
MI
WI
50°
94°
98°
90°
48°
86°
82°
46°
44°
42°
EXPLANATION
Preliminary candidate area
Rock body outline
Wetlands
N
Scale
0 5 10 Mi
0 5 10 Km
SOURCE: USGS, 1979a
Surface Water Characteristics
Archean Gneisses (NC-14)
Figure 3-68

3.2.1.10.6 Ground-water Resources. The regional hydrology is discussed in Section 3.2.1.1.1.5. Ground-water movement is generally eastward or southwestward toward the Minnesota River. Figure 3-69 shows shallow ground-water contours reported by Van Voast et al. (1972), Broussard et al. (1973), Anderson et al (1974), Lindholm et al. (1974a), and Kanivetsky (1979), indicating the general direction of ground-water flow. Areas that displayed convergence of shallow water-table contours, based on a 30-m (100-ft) contour interval, were considered potential major discharge zones. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

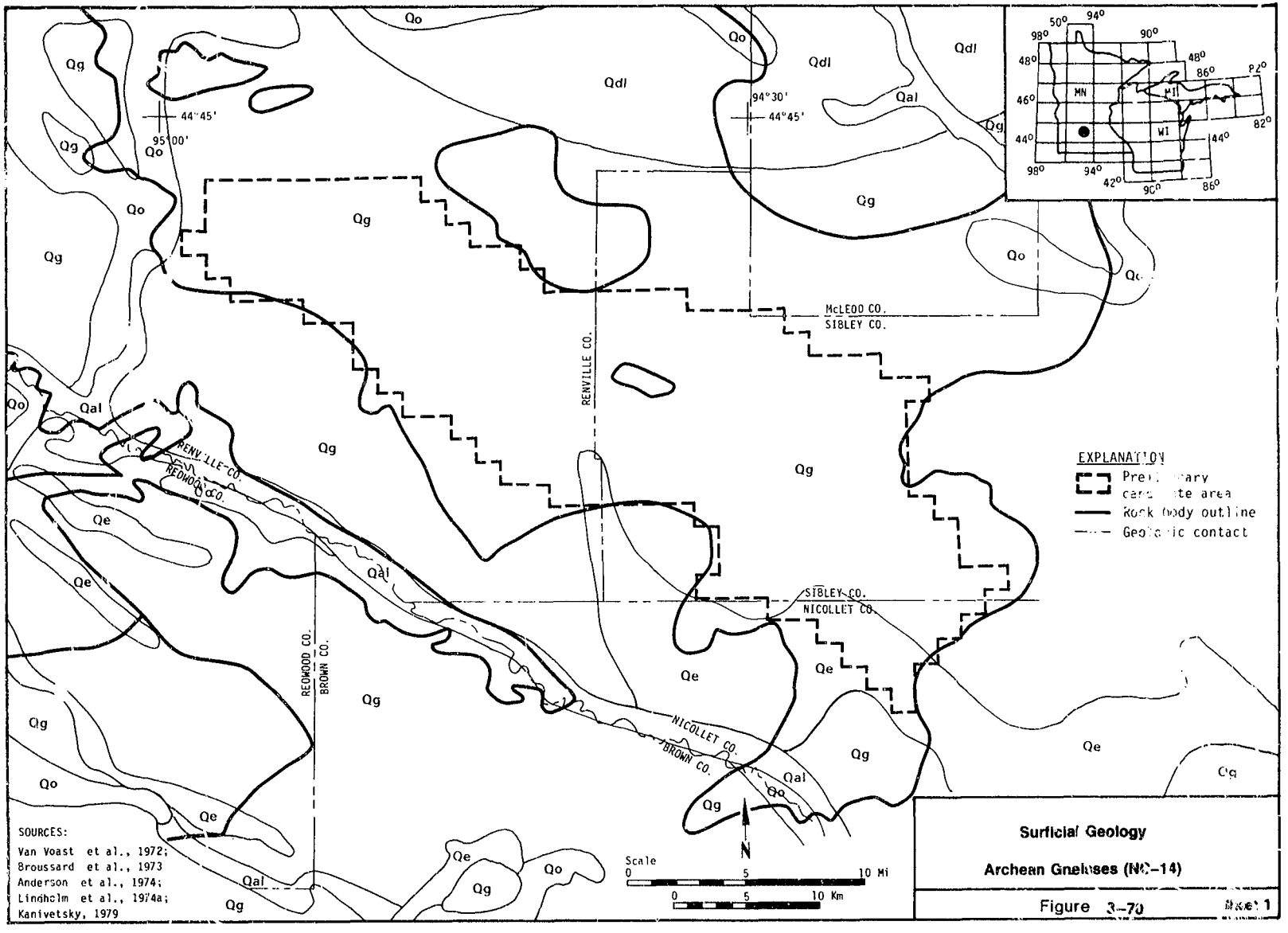
Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that include till, sand and gravel within ground and end moraines, and sand and gravel within outwash deposits (Van Voast et al., 1972; Broussard et al., 1973; Anderson et al., 1974; Lindholm et al., 1974a; and Kanivetsky, 1979). The horizontal extent of surficial deposits is shown on Figure 3-70.

Well yields presented in the North Central RGCR (DOE, 1985c) were estimated from maps by Kanivetsky (1978, 1979) and Kanivetsky and Walton (1979) and are shown on Figure 3-71a. Additional detailed well yield information has been reported by Van Voast et al. (1972), Broussard et al. (1973), Anderson et al. (1974), and Lindholm et al. (1974) in USGS Hydrologic Atlases, and is shown on Figure 3-71b. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison. The majority of the preliminary candidate area is characterized by ground moraine and glacial deposits, which have relatively low yields (less than 0.1 L/s [1.6 gpm]). Locally, these deposits can yield 1.6 to 6.4 L/s (25 to 100 gpm), especially where buried sand and gravel lenses are present. Water availability from glacial deposits differs greatly over short

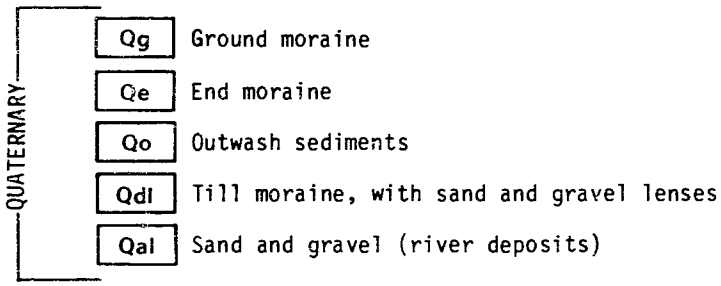


Potentiometric Surface for Material Overlying Archean Gneisses (NC-4.6)

Figure 3-69


Qo
Qdl
Qg
Qal
Qe
44°45'
95°00'
94°30'
44°45'
McLEOD CO.
SIBLEY CO.
RENVILLE CO.
REDWOOD CO.
BROWN CO.
NICOLLET CO.
EXPLANATION
Preliminary carbonate area
Rock body outline
Geologic contact
SOURCES:
Van Voast et al., 1972;
Broussard et al., 1973
Anderson et al., 1974;
Lindholm et al., 1974a;
Kanivetsky, 1979
Scale
0 5 10 Mi
0 5 10 Km
N
MN
WI
MI
Surficial Geology
Archean Gneisses (NC-14)
Figure 3-70
Sheet 1

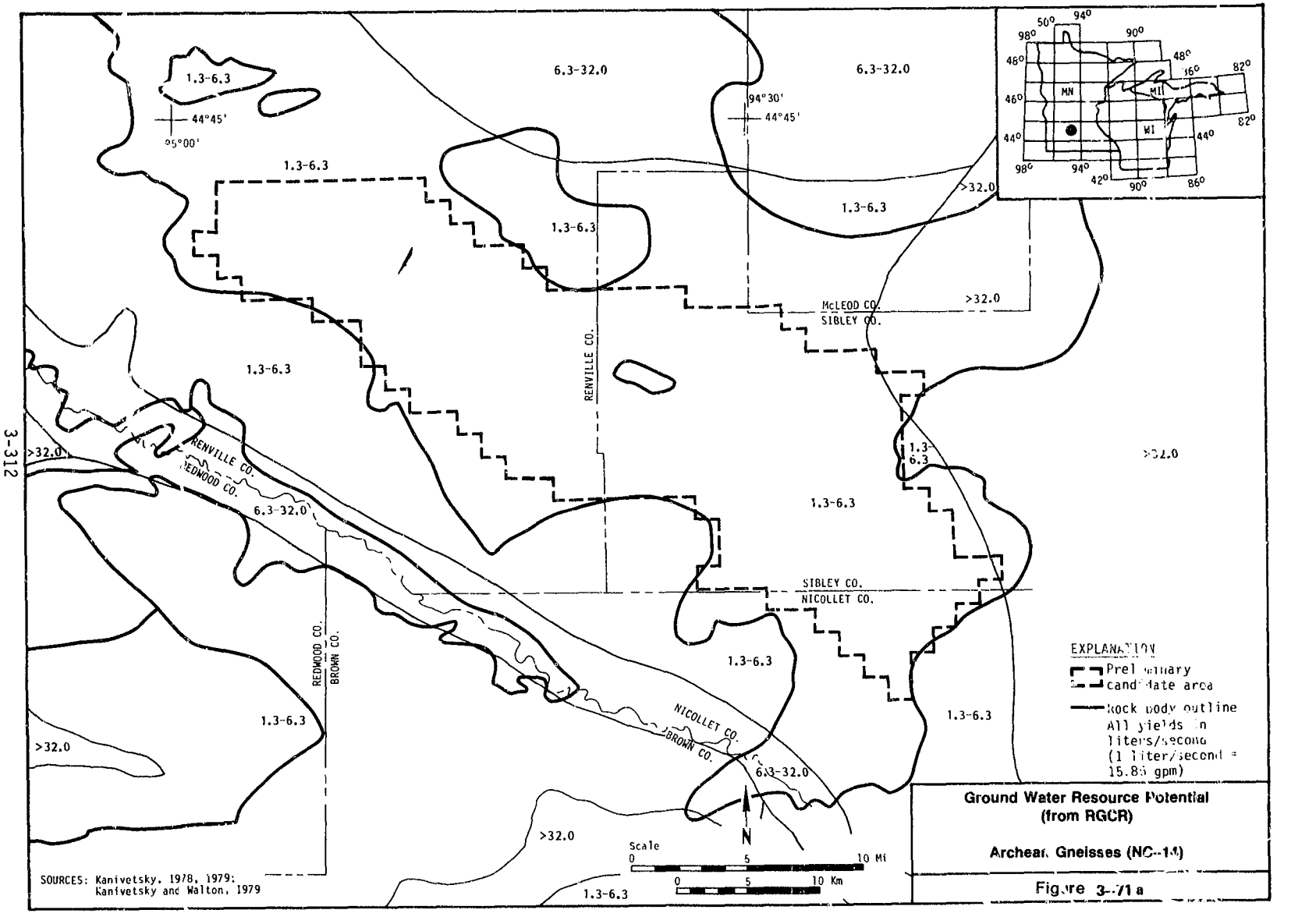
EXPLANATION OF SURFICIAL UNITS

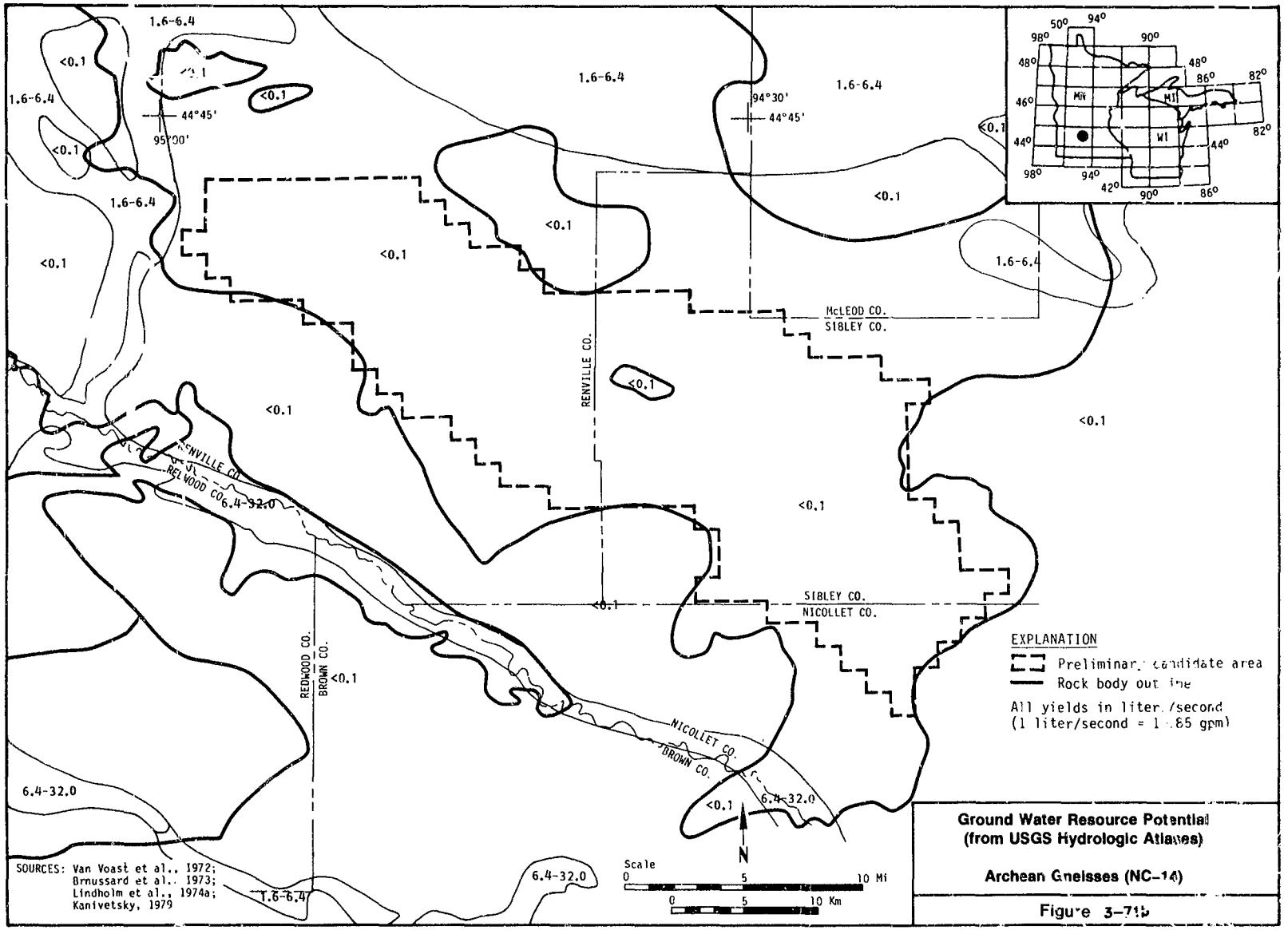


Explanation for Figure 3-70

Archean Gneisses (NC-14)

Figure 3-70 **Sheet 2**


1.3-6.3
6.3-32.0
>32.0
44°45'
95°00'
94°30'
McLEOD CO.
SIBLEY CO.
RENVILLE CO.
REDWOOD CO.
BROWN CO.
NICOLLET CO.
EXPLANATION
Preliminary candidate area
Rock body outline
All yields in liters/second (1 liter/second = 15.85 gpm)
Scale
0 5 10 Mi
0 5 10 Km
N
SOURCES: Kanivetsky, 1978, 1979; Kanivetsky and Walton, 1979
Ground Water Resource Potential (from RGCR)
Archean Gneisses (NC-14)
Figure 3-71a



Ground Water Resource Potential
(from USGS Hydrologic Atlases)

Archean Gneisses (NC-14)

Figure 3-715

distances. Surficial deposits and alluvium located north of the preliminary candidate area generally yield 1.6 to 6.4 L/s (25 to 100 gpm), whereas outwash and alluvium along the Minnesota River to the south may yield up to 32 L/s (500 gpm).

The data indicate that relatively shallow Quaternary aquifers that contain potable ground water are present within the preliminary candidate area. No deep wells (greater than 100 m [328 ft] in depth) have been reported in the literature. Consequently, local ground-water conditions in the deeper crystalline rock are currently unknown.

3.2.1.10.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition and vertical crustal movement, is in Section 3.2.1.1.1.1.

3.2.1.10.8 Federal Lands. There are no Federal lands greater than 130 ha (320 ac) in size located in or within 10 km (6 mi) of the preliminary candidate area. Federal lands of greater than 130 ha (320 ac) in size located in Minnesota are depicted on Plate 2A of the North Central RECR (DOE, 1985d). In addition, there is no evidence in the data base that Federal lands less than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.

3.2.1.10.9 State Lands. There are two wildlife management areas, each less than 130 ha (320 ac) in size, within the preliminary candidate area: Alfsborg, 22 ha (55 ac) and Grundmeyer, 38 ha (94 ac). Together, these areas occupy 60 ha (149 ac) or less than 1% of the preliminary candidate area. Fort Ridgely State Park, which is greater than 130 ha (320 ac) in size, is located 6 km (4 mi) south of the preliminary candidate area. There are two wildlife management areas of greater than 130 ha (320 ac) within 10 km (6 mi) of the preliminary candidate area: Bakers, 8 km (5 mi) east and Norwegian Grove, 6 km (3.5 mi) east. In addition, there are eight wildlife management areas, each less than 130 ha (320 ac) in size, within 10 km (6 mi) of the preliminary candidate

area boundary. The Minn[illegible] Wild and Scenic River which is greater than 130 ha (320 ac) [illegible] located 8 km (5 mi) south of the preliminary candidate area. All of the features described above are either depicted on Plates 3A or 4A of the North Central RECR or are listed in Appendix B of that report (DOE 1985c).

In summary, two State wildlife management areas each less than 130 ha or (320 ac) lie within the preliminary candidate area and cover a total of 60 ha (149 ac) or less than 1% of the preliminary candidate area. There are 12 State lands four greater than and eight less than 130 ha (320 ac) within 10 km (6 mi) of the preliminary candidate area (see Figure 3-72).

3.2.1.10.10 Environmental Compliance. There are no nonattainment areas or Prevention of Significant Deterioration (PSD) Class I Areas in or within 40 km (25 mi) of the preliminary candidate area (40 CFR 81). One site on the National Register of Historic Places (NRHP), Gibbon City Hall, located in the town of Gibbon, Sibley County, Minnesota, lies within the preliminary candidate area (48 FR 8642, 1983). There are no proposed NRHP sites within the preliminary candidate area. In the regional data base, there are no known existing archaeological sites or districts nor any proposed for designation within the preliminary candidate area. No National Trails are located in or within 40 km (25 mi) of the preliminary candidate area.

3.2.1.10.11 Population Density and Distribution. The preliminary candidate area contains no highly populated areas. However, there are three highly populated areas within 16 km (10 mi) of the preliminary candidate area (New Ulm, Olivia, and Redwood Falls) (see Figure 3-72). New Ulm, with a population of 13,755, is located 10 km (6 mi) south of the preliminary candidate area; Olivia, with a population of 2,802, is located 5.5 km (3.5 mi) north; and Redwood Falls, with a population of 5,210, is located 14.5 km (9 mi) southwest. The preliminary candidate area does not contain any areas with population densities greater than or equal to 1,000 persons per square mile. There are eight areas with

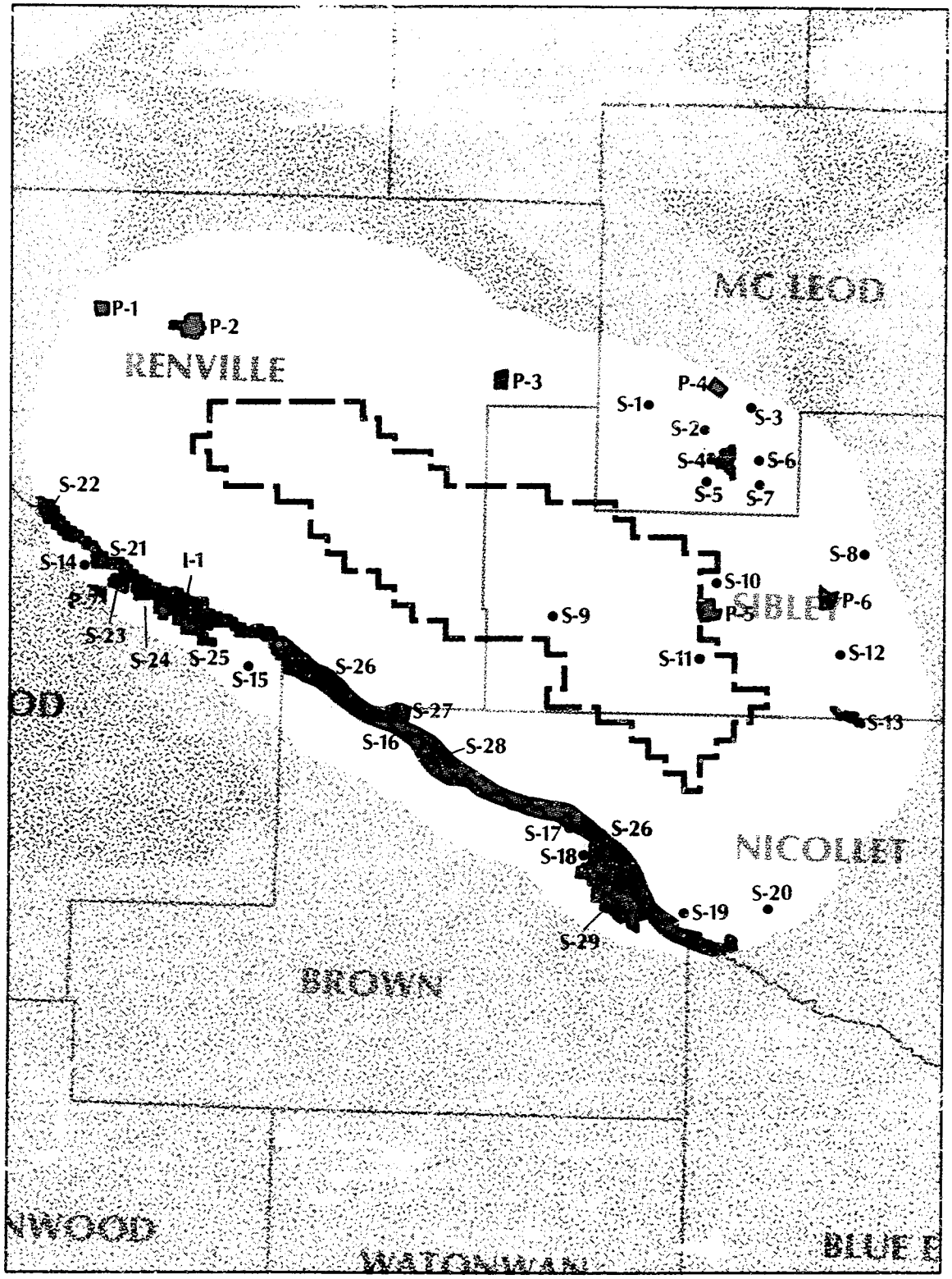


Figure 3—72 Sheet 1

Environmental Features
Archean Gneisses (NC-14)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

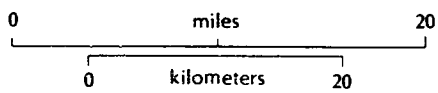


Figure 3–72 Sheet 2

ENVIRONMEN[illegible] FEATURES WITHIN 16 KM (10 MI)
OF PRELIMINARY CANDIDATE AREA NC-14*

Code	Feature
Population Features	
P-1	Danube**
P-2	Olivia Highly Populated Area (HPA)**
P-3	Buffalo Lake**
P-4	Brownton**
P-5	Winthrop**
P-6	Gaylord**
P-7	Redwood Falls HPA**
P-8	New Ulm HPA**
Federal Lands	
None	
State Lands	
S-1	Peebles Wildlife Management Area (WMA)
S-2	Deutsch WMA
S-3	Schaefer Prairie Scientific and Natural Area (SNA)
S-4	Bakers WMA
S-5	Kujas WMA
S-6	Speiring WMA
S-7	Penn WMA
S-8	Altnow WMA
S-9	Grundmeyer WMA
S-10	Indian Lake WMA
S-11	Alfsborg WMA
S-12	Typha WMA
S-13	Norwegian Grove WMA
S-14	Red Dog Lake WMA
S-15	Acclivous WMA
S-16	Minnriver WMA
S-17	Boesch WMA
S-18	Somsen WMA
S-19	Courtland WMA
S-20	Brooke Island WMA
S-21	Minnesota Wild and Scenic River
S-22	Cedar Rock WMA
S-23	Honner WMA
S-24	Tiger Lake WMA
S-25	Eider WMA

Figure 3-72, Sheet 3

[illegible] FEATURES WITHIN 16 KM (10 MI)
OF PRELIMINARY [illegible] (Continued)

Code	Feature
State Lands - Continued	
S-26	Minnesota Project Riverbend Wild and Scenic River
S-27	Fort Ridgely State Park
S-28	Cactus Rock WMA
S-29	Flandrau State Park
Indian Reservations	
I-1	Lower Sioux Indian Reservation

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* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

** Area with a population density greater than or equal to 1,000 persons per square mile.

Figure 3-72, Sheet 4

population densities ... than or equal to 1,000 persons per square mile within 16 km (10 mi, ... preliminary candidate area (see Figure 3-72). Buffalo Lake, with a population of 787, is located 10 km (6 mi) north of the preliminary candidate area; Danube, with a population of 590, is located 13 km (8 mi) northwest; Gaylord, with a population of 1,933, is located 11 km (7 mi) east; Winthrop, with a population of 1,376, is located less than 1.6 km (1 mi) east; and Brownton, with a population of 697, is located 14 km (8.5 mi) north. New Ulm, Olivia, and Redwood Falls are also highly populated areas. The western fringe of the greater metropolitan Minneapolis/St. Paul area is located approximately 60 km (40 mi) northeast of the preliminary candidate area. The average population density of the preliminary candidate area is 15 persons per square mile. The average population density within 80 km (50 mi) is approximately 46 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.1.10.12 Site Ownership. There are no Federal or DOE-owned lands located within the preliminary candidate area. The Lower Sioux Indian Reservation is approximately 12 km (7.5 mi) southwest of the preliminary candidate area (see Figure 3-72).

3.2.1.10.13 Offsite Installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Monticello, which is approximately 96 km (60 mi) northeast of the preliminary candidate area (Michelewicz and Vann, 1983; DOE, 1984c). The nearest commercial nuclear reactor under construction is Byron 2, which is 530 km (325 mi) southeast (Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.10.14 Transportation. Two interstate highways are approximately 80 km (50 mi) from the preliminary candidate area. I35 is

to the east, while I-90 is south of the preliminary candidate area. A third interstate highway (I-35) is approximately 88 km (55 mi) to the northeast. U.S. 71 is approximately 1.6 km (1 mi) west of the preliminary candidate area. U.S. 212 ranges between 5 and 16 km (3 and 10 mi) from the northern edge of the preliminary candidate area. U.S. 14 is about 11 km (7 mi) south. The major U.S. Highway in this area is U.S. 169, a four-lane divided highway. U.S. 169 is about 24 km (15 mi) east of the preliminary candidate area. State Route 4 runs north and south through the central portion of the preliminary candidate area. State Route 4 intersects U.S. 212 at Hector, Minnesota, and further south it crosses U.S. 14 at Sleepy Eye, Minnesota. State Route 14 also runs north-south, but only crosses the eastern portions of the preliminary candidate area. State Route 14 is the principal north-south highway through south central Minnesota. State Route 19 runs across the preliminary candidate area. To the east, State Route 19 intersects I35 west of Northfield, Minnesota, and meets U.S. 71 west of the preliminary candidate area at Morton, Minnesota.

The Soo/Milwaukee mainline railroad between Minneapolis and Ortonville, Minnesota, is located from 5 to 16 km (3 to 10 mi) north of the preliminary candidate area. The other mainline near this preliminary candidate area is a Chicago and Northwestern line located 3.2 km (20 mi) to the east. The nearest branchline is a Chicago and Northwestern line between Mankato and New Ulm, Minnesota. This line is about 11 km (7 mi) from the southern edge of the preliminary candidate area. At one time, the Chicago and Northwestern had a line which paralleled State Route 19 through the preliminary candidate area, but it was abandoned several years ago.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.1.10.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in

Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-i4 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggests that the regional ground-water flow systems should not be significantly effected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]

- absence of historical earthquakes that, if they recurred, could provide ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repositiory construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area (960.5-2-5(c)(3)]
- limited presence of State lands less than 130 ha (320 ac) within the preliminary candidate area (i.e., 2) and limited presence in proximity to (i.e., 8 within 10 km [6 mi] of) the preliminary candidate area (960.5-2-5(c)(4)]
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area (960.5-2-1(b)(1)]
- absence of nuclear installations (960.5-2-4(b) and (c)(2)]

- no project [illegible] ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings [960.4-2-8-2(c) and 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2) and (b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]
- a majority of the preliminary candidate area is within 16 km (10 mi) of highly populated areas or areas containing more than 1,000 persons per square mile (960.5-2-1(c)(2)].

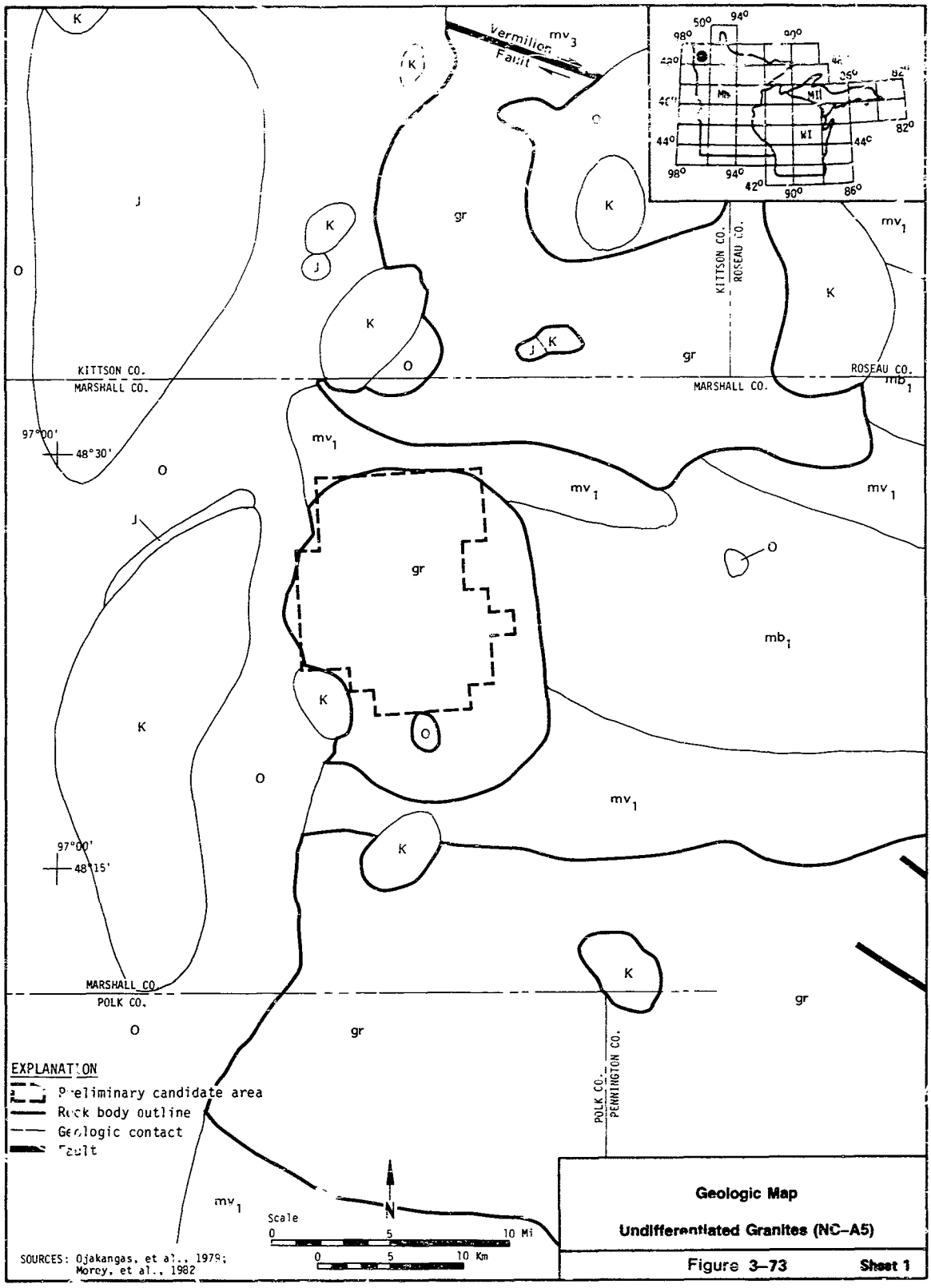
The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-14 at this time.

3.2.1.11 Preliminary Candidate Area Description, Undifferentiated Granites

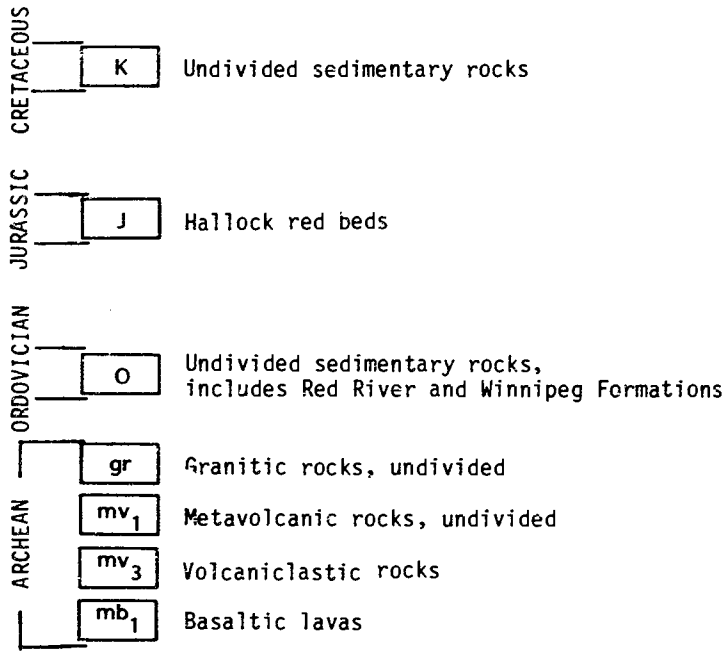
These undifferentiated granites are located within the Lake Agassiz Lowland physiographic province in northern Minnesota. The preliminary candidate area is located in Marshall County at approximately 48°25' N latitude and 96°33' W longitude.

3.2.1.11.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-73 has an area of approximately 182 km^2 (70 mi^2) and overlies a batholith of undifferentiated granites the rocks of which are not exposed and the mapped extent of which is largely inferred from geophysical data (Ojakangas et al., 1979; Morey et al., 1982). The batholith is approximately 21 km (13 mi) long and 15 km (9 mi) wide. Data on the vertical extent of the batholith are not available, but it is inferred to extend to a depth of several kilometers (miles) based on the present understanding of the mode of emplacement of batholiths and seismic reflection studies in batholithic terranes. This information suggests that most batholiths are tabular in shape and extend to a depth of 6 to 10 km (4 to 6 mi) (Hamilton and Myers, 1967; Lynn et al., 1981). Furthermore, no postemplacement deformational processes such as large-scale thrust faulting are known to have diminished the vertical extent of the batholith.

There is no exposed bedrock in the preliminary candidate area. Contours of overburden thickness (Figure 3-74) for the preliminary candidate area indicate the western portion is covered by 61 to 91 m (200 to 300 ft), and the eastern portion is covered by between 91 to less than 122 m (300 to less than 400 ft) of overburden.


Vermilion Fault
mv3
KITTSON CO.
MARSHALL CO.
ROSEAU CO.
MARSHALL CO.
POLK CO.
PENNINGTON CO.
97°00'
48°30'
97°00'
48°15'
gr
mv1
mb1
K
J
O
EXPLANATION
Preliminary candidate area
Rock body outline
Geologic contact
Fault
Scale
0 5 10 Mi
0 5 10 Km
N
SOURCES: Ojakangas, et al., 1979; Morey, et al., 1982
Geologic Map
Undifferentiated Granites (NC-A5)
Figure 3-73 Sheet 1

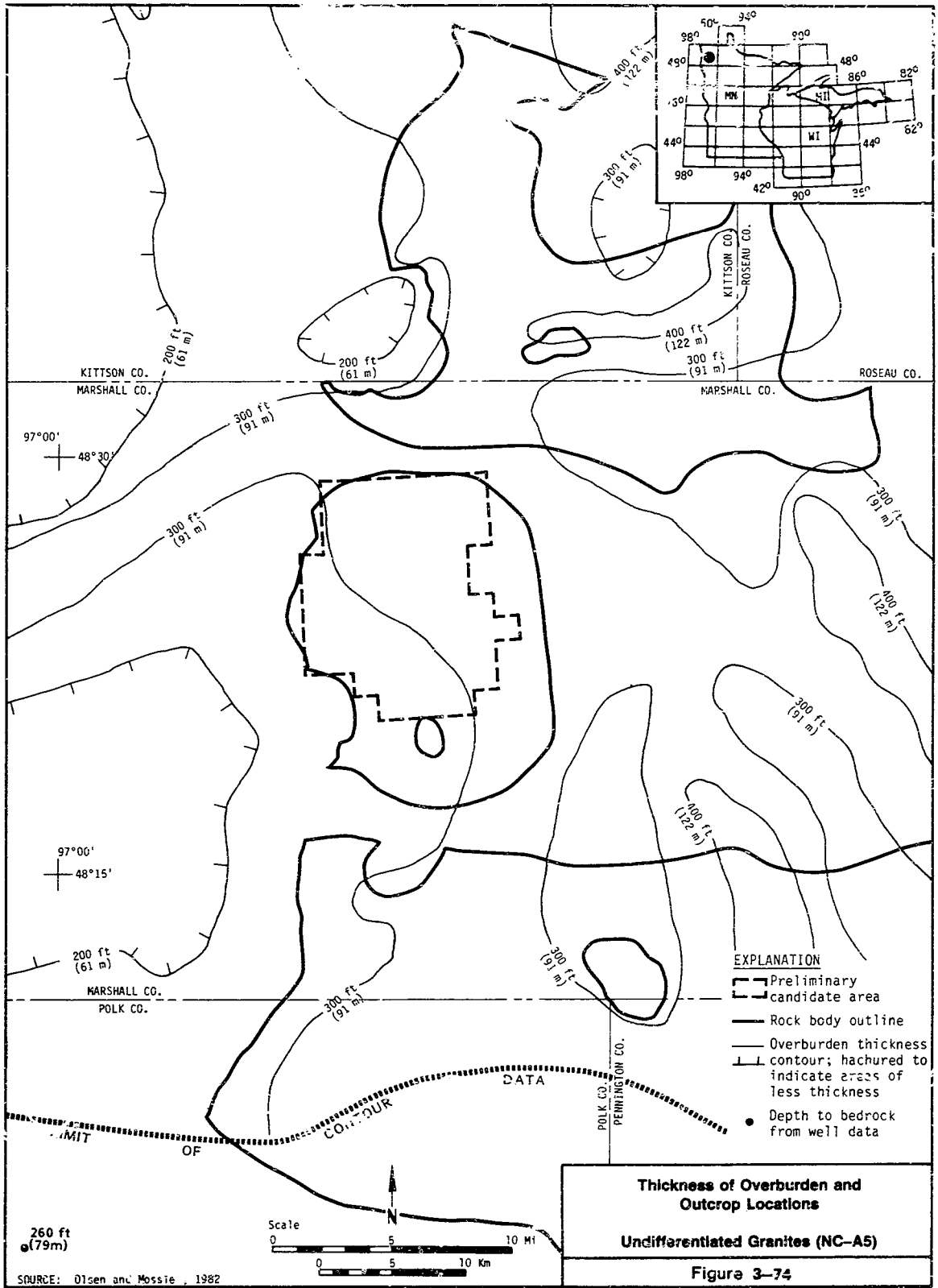
EXPLANATION OF GEOLOGIC UNITS



Explanation for
Figure 3-73

Undifferentiated Granites (NC-A5)

Figure 3-73 Sheet 2


KITTSON CO.
MARSHALL CO.
ROSEAU CO.
MARSHALL CO.
POLK CO.
PENNINGTON CO.
200 ft (61 m)
300 ft (91 m)
400 ft (122 m)
97°00'
48°30'
48°15'
EXPLANATION
Preliminary candidate area
Rock body outline
Overburden thickness contour; hachured to indicate areas of less thickness
Depth to bedrock from well data
DATA
CONTOUR
OF
260 ft (79m)
Scale
0 5 10 Mi
0 5 10 Km
N
SOURCE: Olsen and Mossie , 1982
Thickness of Overburden and Outcrop Locations
Undifferentiated Granites (NC-A5)
Figure 3-74

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the crystalline host rocks of the preliminary candidate area are sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of an underground facility to ensure isolation.

3.2.1.11.2 Lithology and Tectonics. The undifferentiated granites are inferred from geophysical data to be composed of granitoid rocks of the greenstone-granite terrane (Figure 3-73). These rocks are intrusive into mafic to intermediate metavolcanic rocks on the east, metasedimentary and metavolcaniclastic on the north and south, and are unconformably overlain by Ordovician limestone, sandstone, siltstone, and shale on the west. Several small outliers of Ordovician and Cretaceous sedimentary rocks overlie these rocks to the south of the preliminary candidate area (Ojakangas et al., 1979; Morey et al., 1982).

The undifferentiated granites are part of the Archean greenstone-granite terrane, which was deformed and metamorphosed to the greenschist facies, and locally to the upper amphibolite facies during the Algoman orogeny 2,600 to 2,700 million years ago (Morey and Sims, 1976; Sims, 1980). Deformation and metamorphism of the country rock during the Algoman orogeny was virtually synchronous with the emplacement of the granitic rocks and probably resulted from compression caused by the relative upwelling and convergence of the adjacent plutons (Morey and Sims, 1976). Following the intrusion of the granitic plutons, the alternating greenstone and granite belts were displaced by several generations of right-lateral, strike-slip faults (Sims, 1976). Subsequent to the Algoman orogeny, the greenstone-granite terrane has been essentially tectonically stable (Sims et al., 1980). One minor exception was the intrusion of a northwest-trending dike swarm in northern Minnesota about 2,120 million years ago (Southwick and Day, 1983).

There are no mapped faults within the preliminary candidate area (Figure 3-73). No structural features exclusive of faults have been reported in the literature for the preliminary candidate area. There is no evidence of Quaternary activity within the geologic setting.

A discussion of recent crustal uplift is presented in the regional geologic setting (Section 3.2.1.1.1.3). There is no evidence to suggest tectonic uplift. The uplift due to glacioisostatic rebound is relatively uniform and occurs at slow rates that will continue to decrease in the future such that this uplift is unlikely to result in any measurable changes in the regional ground-water flow system over the next 10,000 years. There are no in situ stress data available for within and in the vicinity of the preliminary candidate area.

The absence of any igneous activity in and near the preliminary candidate area for the last 1,000 million years and the absence of Quaternary volcanism in the geologic setting (Section 3.2.1.1.1.2) indicate that future igneous activity in the area is highly unlikely.

There is no evidence of igneous activity, folding, faulting, uplift, subsidence, or other tectonic processes within the geologic setting during the Quaternary Period. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.1.11.3 Seismicity. There are no historical earthquakes within the vicinity of the preliminary candidate area. There are no known geologic structures near the preliminary candidate area that might be expected to induce seismic activity of greater frequency or intensity than that which is typical of the region. The regional seismicity is discussed in Section 3.2.1.1.1.3.

Considering the low [illegible] magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the area will increase in the future.

3.2.1.11.4 Mineral Resources. There are no strategic, metallic, or energy-related mineral resources known to occur either in or within 10 km (6 mi) of the preliminary candidate area (Schwartz and Prokopovich, 1966; Walton, 1976; USBM, 1983). No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mines or quarries are the iron mines in the Mesabi Range, located more than 100 km (62 mi) southeast of the preliminary candidate area. Other natural resources within and near the preliminary candidate area (i.e., gravel pits) are shallow and widely available throughout the region.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources within the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation, and no information is currently available to indicate that deep exploration drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

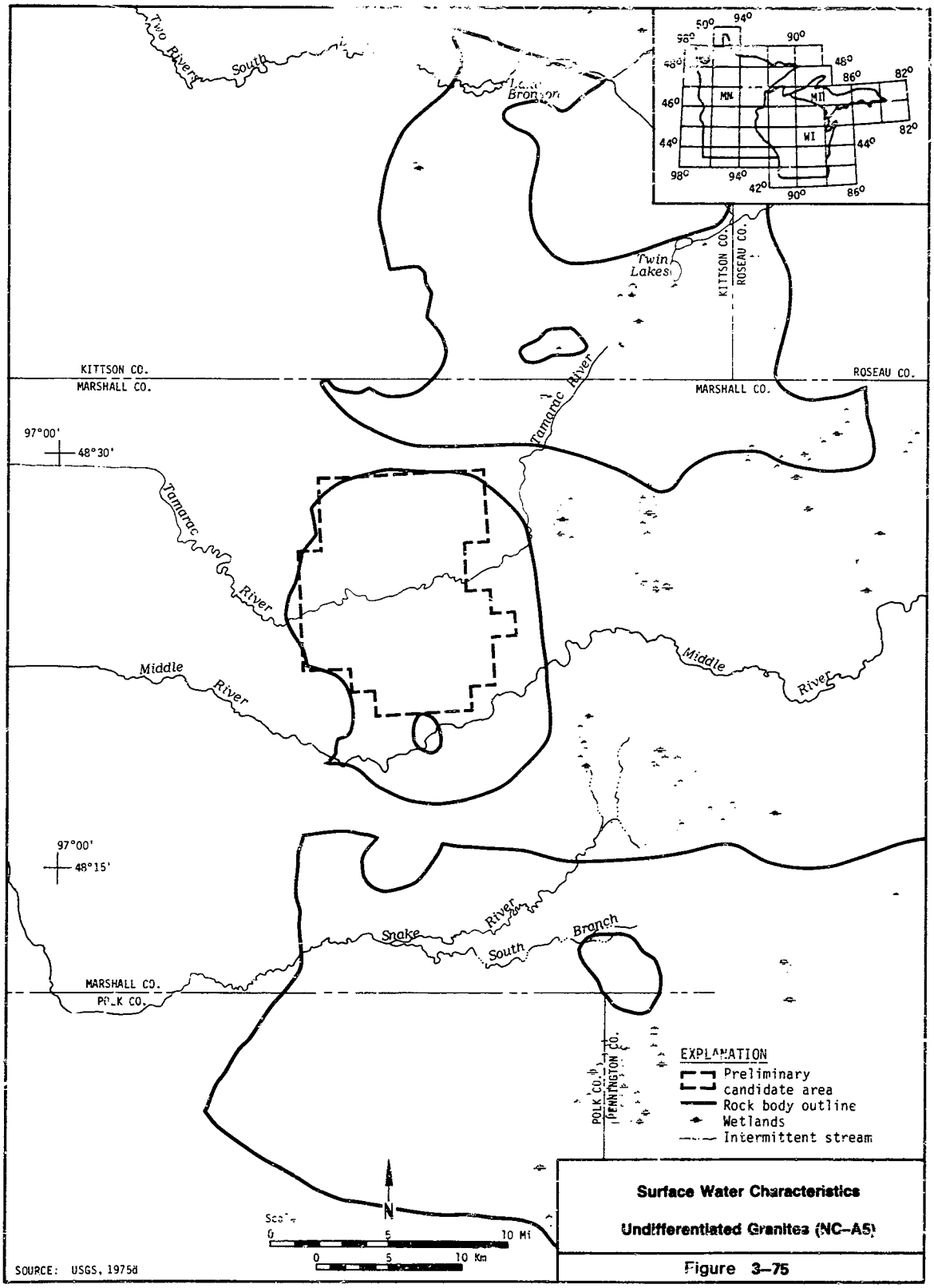
3.2.1.11.5 Topography and Surface Water Characteristics. The topographic relief of the preliminary candidate area is generally flat, with elevations ranging from 259 to 290 m (850 to 950 ft). The preliminary candidate area does not appear to contain large areas of floodplain. Examination of topographic maps indicates that only localized portions of the area within river and stream valleys are potentially flood prone. No reservoirs or impoundments are known to exist in or upstream of the area.

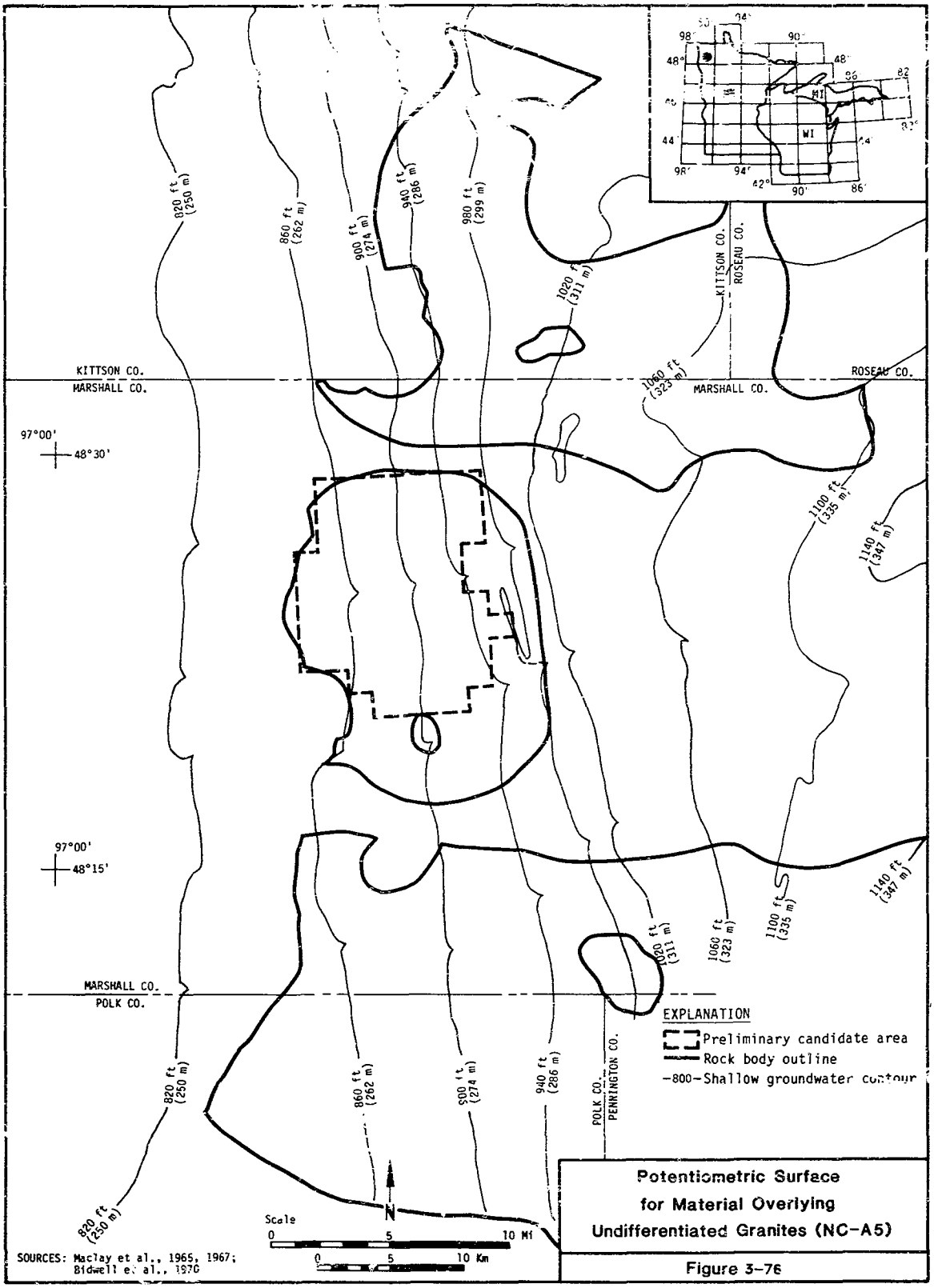
The preliminary candidate area is drained mainly by the Tamarac River, which flows westward to the Red River and then northward into Canada. As represented by the region-to-area screening data base, the preliminary candidate area is covered by approximately 4% surface water and no wetland (USGS, 1965; USGS, various dates; Minnesota State Planning Agency, 1984). The locations of lakes, rivers, and marshlands in the preliminary candidate area on Figure 3-75 are based on surface water features shown on the USGS 1:250,000 Thief River Falls topographic map. The only major surface water body within the preliminary candidate area is the Tamarac River. Other surface water bodies near the preliminary candidate area include the Middle River and the Snake River and several intermittent streams.

The data presented in this section indicate that the relief of the preliminary candidate area is generally flat and the terrain is well drained.

3.2.1.11.6 Ground-Water Resources. The regional hydrology is discussed in Section 3.2.1.1.1.5. Shallow ground-water movement is generally westward toward the Red River. Figure 3-76 shows shallow ground-water contours reported by Maclay et al. (1965, 1967) and Bidwell et al. (1970). Areas that displayed convergence of shallow water-table contours, based on a 30-m (100-ft) contour interval, were considered potential major discharge zones. These generally correspond to locations of major streams and rivers. No major discharge zones have been identified in the preliminary candidate area (DOE, 1985c).

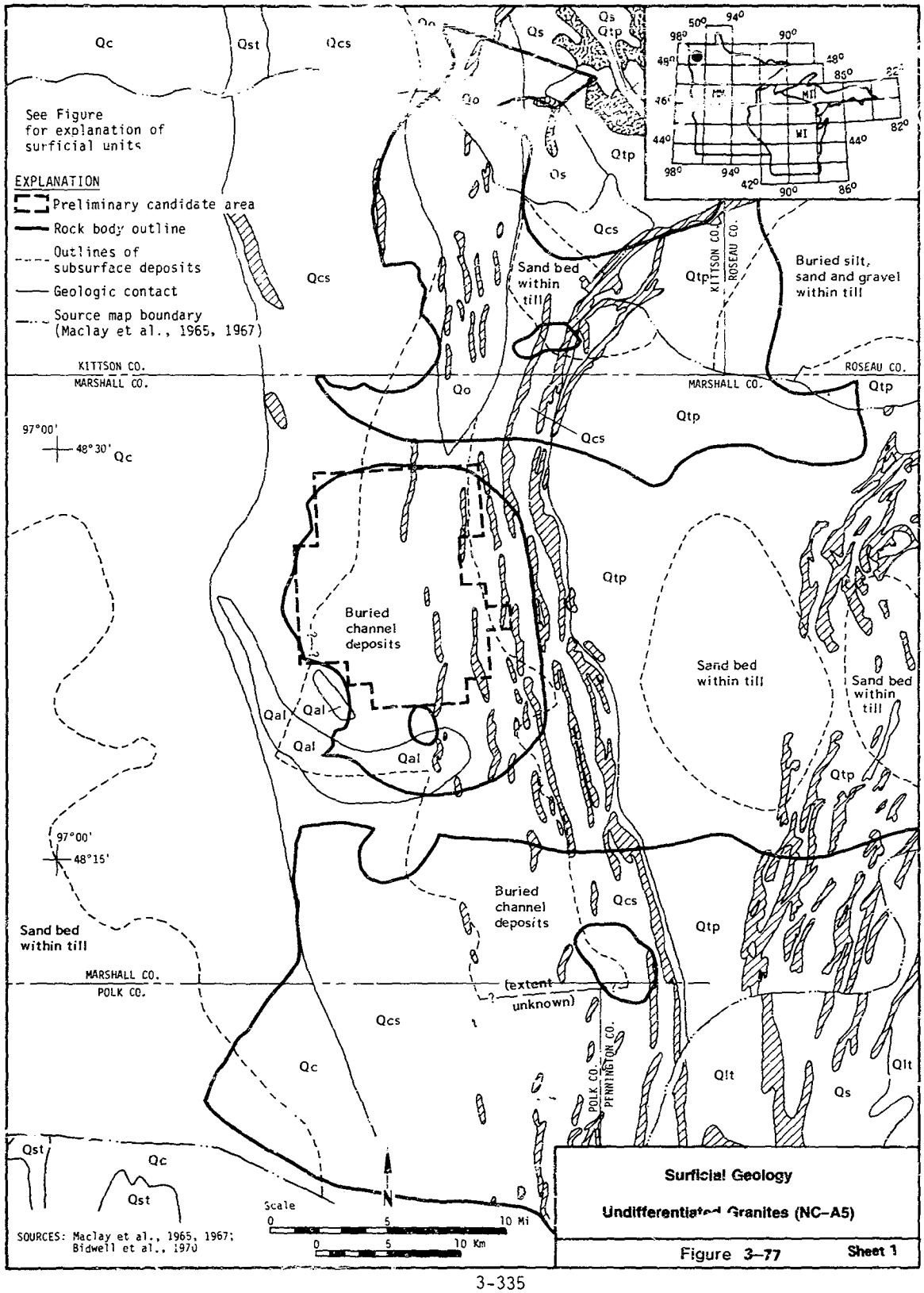
Ground water in and near the preliminary candidate area is primarily obtained from glacial sediments that include till; silt, sand, and gravel deposits buried within till; outwash deposits comprised of sand and gravel overlying till; and beach and bar deposits overlying till (Maclay et al., 1965, 1967; Bidwell et al., 1970). The horizontal extent of surficial deposits is shown in Figure 3-77.


Two River South
Lake Bronson
Twin Lakes
KITTSON CO.
ROSEAU CO.
KITTSON CO.
MARSHALL CO.
MARSHALL CO.
ROSEAU CO.
Tamarac River
97°00'
48°30'
Tamarac River
Middle River
Middle River
97°00'
48°15'
Snake River
South Branch
MARSHALL CO.
POLK CO.
POLK CO.
PENNINGTON CO.
EXPLANATION
Preliminary candidate area
Rock body outline
Wetlands
Intermittent stream
N
0 5 10 Mi
0 5 10 Km
SOURCE: USGS, 1975d
Surface Water Characteristics
Undifferentiated Granites (NC-A5)
Figure 3-75



Potentiometric Surface for Material Overlying Undifferentiated Granites (NC-A5)

Figure 3-76


See Figure for explanation of surficial units
EXPLANATION
Preliminary candidate area
Rock body outline
Outlines of subsurface deposits
Geologic contact
Source map boundary (Maclay et al., 1965, 1967)
Qc
Qst
Qcs
Qo
Qs
Qtp
Qal
Sand bed within till
Buried silt, sand and gravel within till
Buried channel deposits
Qlt
KITTSON CO.
MARSHALL CO.
ROSEAU CO.
POLK CO.
PENNINGTON CO.
97°00'
48°30'
48°15'
(extent unknown)
Scale
0 5 10 Mi
0 5 10 Km
SOURCES: Maclay et al., 1965, 1967; Bidwell et al., 1970
Surficial Geology
Undifferentiated Granites (NC-A5)
Figure 3-77
Sheet 1

EXPLANATION OF SURFICIAL UNITS

QUATERNARY

- Qc — Deep-water lake clay deposits
- Qcs — Shallow-water clay, silt, and fine sand overlying till
- Qtp — Undifferentiated till
- Qs — Sand
- Qst — Silt
- Qal — Alluvial and lake bar deposits
- Qo — Channel outwash sand and gravel
- Qlt — Lake-washed till
- Peat
- Beach and bar sand and gravel

Explanation for Figure 3-77

Undifferentiated Granites (NC-A5)

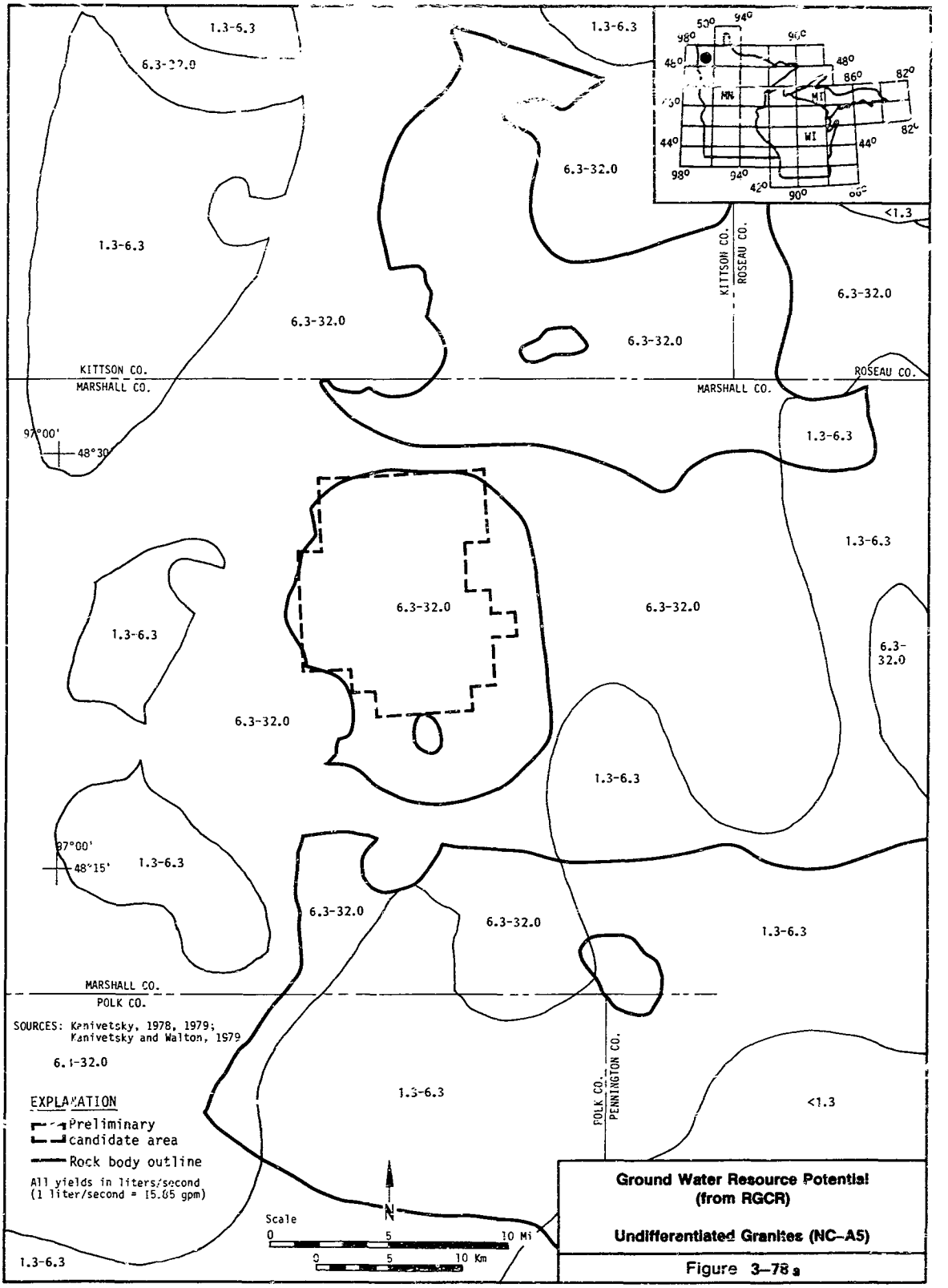
Figure 3-77 Sheet 2

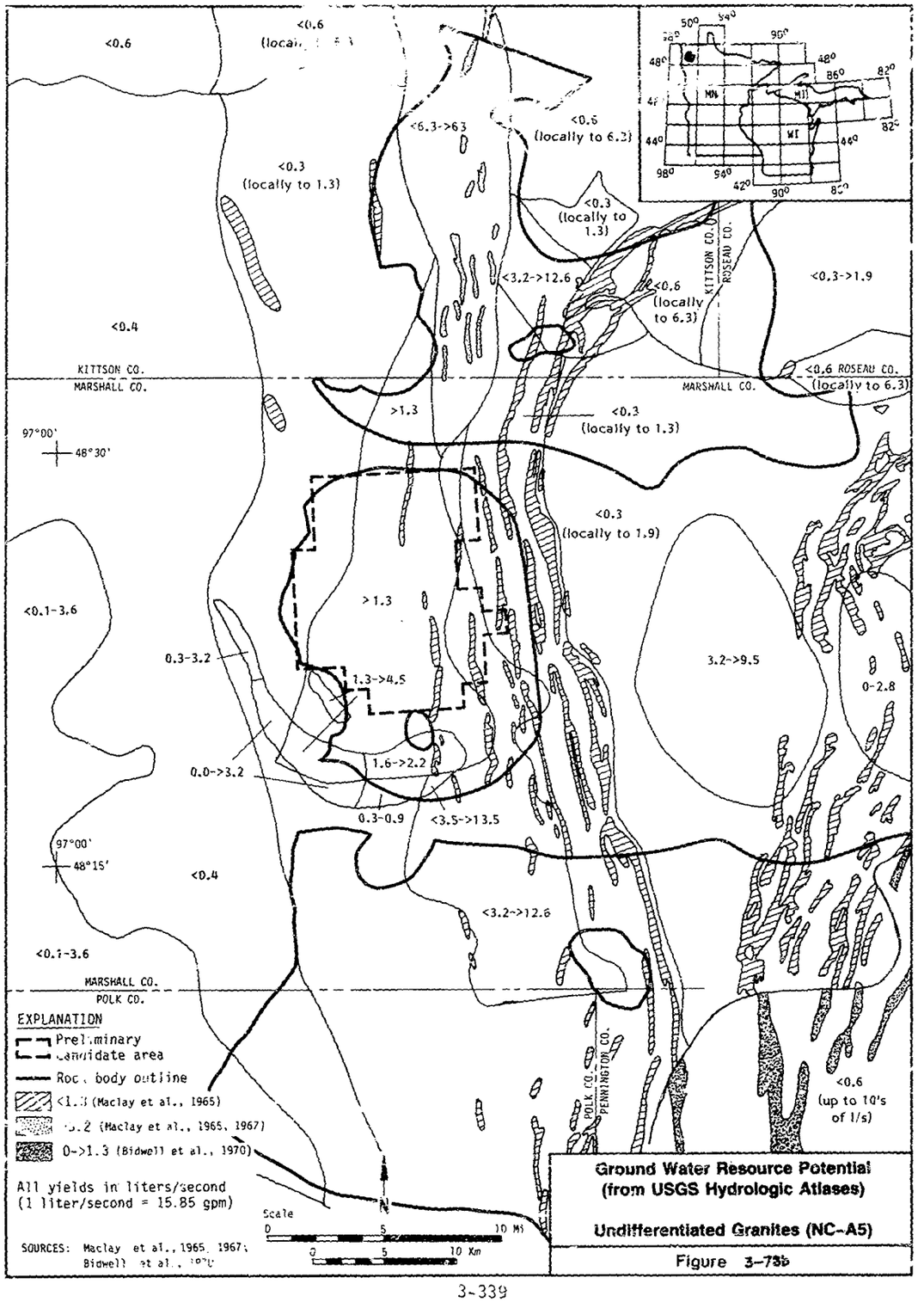
Well yields [illegible] the North Central RGCW (DOE 1985c) were estimated from maps by Kanivetsky (1975, [illegible]) and Kanivetsky and Walton (1979) and are shown in Figure 3-78a. Additional detailed well yield information has been reported by Maclay et al. (1965, 1967) and Bidwell et al. (1970) in USGS Hydrologic Atlases and is shown in Figure 3-78b. Some estimated well yields shown on these two figures may not agree; however, there is currently no basis for determining which data set is more representative of actual well yields. Both data sets are shown for comparison. The majority of the preliminary candidate area is characterized by undifferentiated till containing buried sand and gravel lenses. These deposits have moderate yields (0.2 to 1.9 L/s [3 to 30 gpm]). Water availability from glacial deposits differs greatly over short distances. Surficial outwash deposits that are located just beyond the northern edge of the preliminary candidate area are known to yield from 3.2 to 64 L/s (50 to 1,000 gpm). Alluvial deposits in the southern portion of the preliminary candidate area yield between 0.3 and 3.2 L/s (5 to 50 gpm); whereas areas of thin drift with few sand and gravel deposits generally yield less than 0.6 L/s (10 gpm).

The data indicate that relatively shallow Quanternary aquifers that contain potable ground water are present within the preliminary candidate area. No deep wells (i.e. greater than 100 m [328 ft] in depth) have been reported in the literature. Therefore, local ground-water conditions in the deeper crystalline rock are currently unknown.

3.2.1.11.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion deposition, and vertical crustal movement, and changes in sea level is in Section 3.2.1.1.1.1.

3.2.1.11.8 Federal Lands. There are no Federal lands greater than 130 ha (320 ac) in size located in or within 10 km (6 mi) of the preliminary candidate area. Federal lands of greater than 130 ha (320 ac) which occur in Minnesota are depicted on Plate 2A of the North


1.3-6.3
6.3-32.0
<1.3
KITTSON CO.
MARSHALL CO.
ROSEAU CO.
POLK CO.
PENNINGTON CO.
97°00'
48°30'
48°15'
SOURCES: Kanivetsky, 1978, 1979;
Kanivetsky and Walton, 1979
EXPLANATION
Preliminary candidate area
Rock body outline
All yields in liters/second
(1 liter/second = 15.85 gpm)
Scale
0 5 10 Mi
0 5 10 Km
N
MN
WI
MI
Ground Water Resource Potential
(from RGCR)
Undifferentiated Granites (NC-A5)
Figure 3-78


<0.6
<0.6 (locally to 6.3)
<6.3->63
<0.6 (locally to 6.3)
<0.3 (locally to 1.3)
<0.3 (locally to 1.3)
<3.2->12.6
<0.6 (locally to 6.3)
KITTSON CO.
ROSEAU CO.
<0.3->1.9
<0.4
KITTSON CO.
MARSHALL CO.
MARSHALL CO.
<0.6 ROSEAU CO. (locally to 6.3)
>1.3
<0.3 (locally to 1.3)
97°00'
48°30'
<0.3 (locally to 1.9)
<0.1-3.6
>1.3
0.3-3.2
1.3->4.5
3.2->9.5
0-2.8
0.0->3.2
1.6->2.2
0.3-0.9
<3.5->13.5
97°00'
48°15'
<0.4
<3.2->12.6
<0.1-3.6
MARSHALL CO.
POLK CO.
POLK CO.
PENNINGTON CO.
<0.6 (up to 10's of l/s)
EXPLANATION
Preliminary candidate area
Rock body outline
<1.3 (Maclay et al., 1965)
0.3-3.2 (Maclay et al., 1965, 1967)
0->1.3 (Bidwell et al., 1970)
All yields in liters/second
(1 liter/second = 15.85 gpm)
SOURCES: Maclay et al., 1965, 1967; Bidwell et al., 1970
Scale
0 5 10 Mi
0 5 10 Km
Ground Water Resource Potential
(from USGS Hydrologic Atlases)
Undifferentiated Granites (NC-A5)
Figure 3-73b

Central RECR (DOE, 198[illegible] there is no evidence in the data base that Federal lands less than [illegible] (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.

3.2.1.11.9 State Lands. There are no State lands within the boundary of the preliminary candidate area. Three wildlife management areas, each greater than 130 ha (320 ac) in size, are located within 10 km (6 mi) of the preliminary candidate area. Florian and Wright Wildlife Management Areas are located 3 km (2 mi) east of the preliminary candidate area and Deerwood Wildlife Management Area is located 8 km (5 mi) northeast. Two unnamed State land parcels, each greater than 130 ha (320 ac) in size, are approximately 5 km (3 mi) east of the preliminary candidate area. Two State lands less than 130 ha (320 ac) in size are located within 10 km (6 mi) of the preliminary candidate area: Old Mill State Park, approximately 1.6 km (1 mi) southeast and the Adolf Elseth Memorial Wildlife Management Area, 8 km (5 mi) east. All the features described above are either depicted on Plates 3A or 4A of the North Central RECR or are listed in Appendix B of that report (DOE, 1985d).

In summary, there are no State lands within the preliminary candidate area. However, seven State lands (five greater than and two less than 130 ha or 320 ac) are located within 10 km (6 mi) of the preliminary candidate area (See Figure 3-79).

3.2.1.11.10 Environmental Compliance. There are no nonattainment areas or Prevention of Significant Deterioration (PSD) Class I Areas in or within 40 km (25 mi) of the preliminary candidate (40 CFR 81). No sites on the National Register of Historic Places (NRHP) and no National Trails are located within the preliminary candidate area, and no National Trails are located within 40 km (25 mi) of the preliminary candidate area. There are no proposed NRHP sites within the preliminary candidate area. In the regional data base, there are no known existing or proposed archaeological sites or districts nor any proposed for designation within the preliminary candidate area.

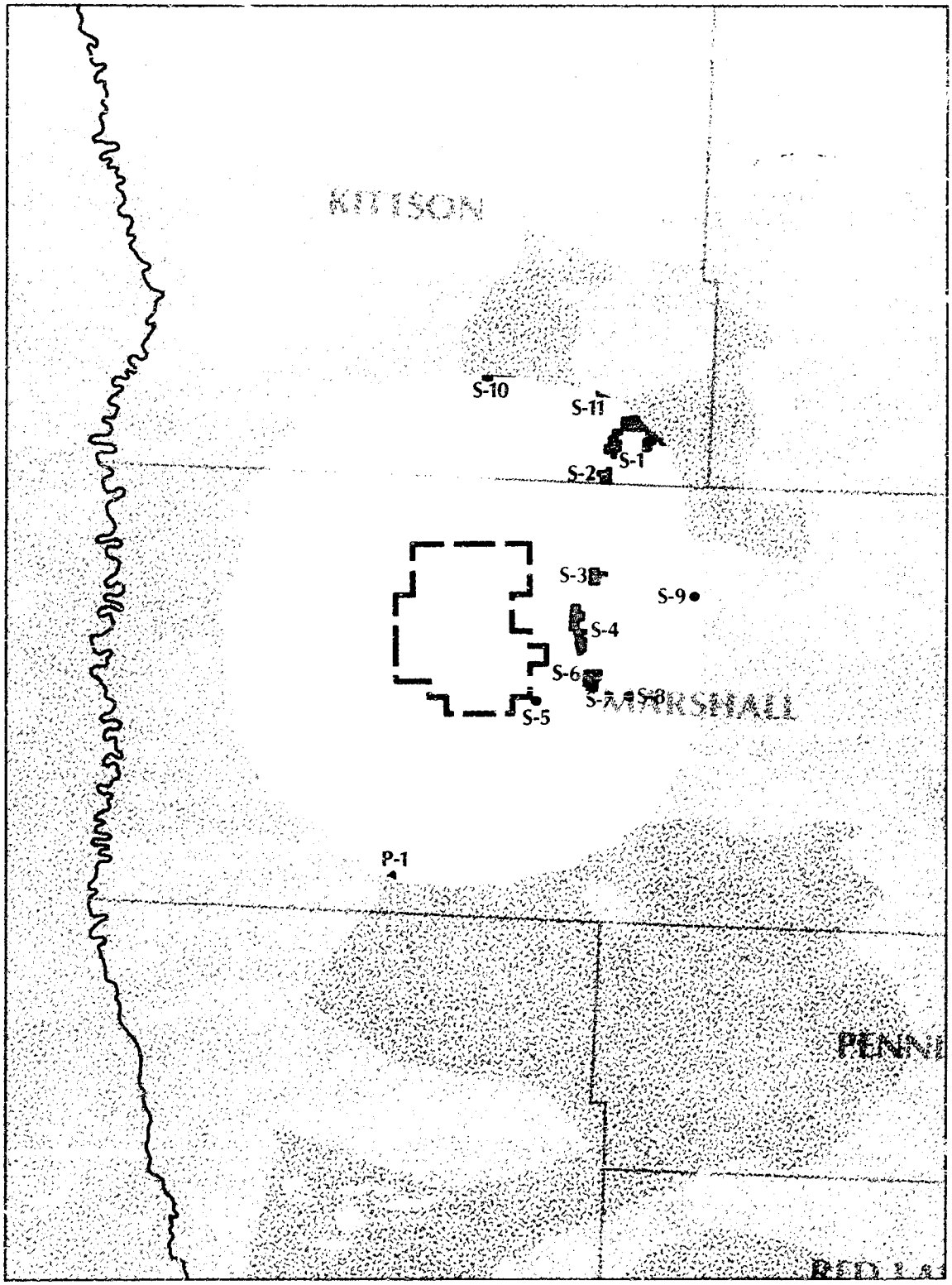


Figure 3–79 Sheet 1

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

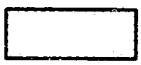
F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features



Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

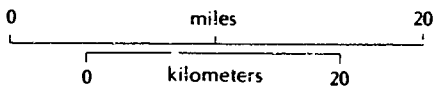


Figure 3-78 Sheet 2

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI)
OF PRELIMINARY CANDIDATE AREA NC-A5*

Code	Feature
Population Features	
P-1	Warren**
Federal Lands	
None	
State Lands	
S-1	Twin Lakes Wildlife Management Area (WMA)
S-2	Deerwood WMA
S-3	Unnamed State Forest Parcel (SFO)
S-4	Florian WMA
S-5	Old Mill State Park
S-6	Wright WMA
S-7	SFO
S-8	Adolph Elseth Memorial WMA
S-9	Strandquist WMA
S-10	Halma Swamp WMA
S-11	SFO
Indian Reservations	
None	

* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

** Area with a population density greater than or equal 1,000 persons per square mile.

Figure 3-79, Sheet 3

3.2.1.11.11 Population Density and Distribution. There are no highly populated areas located within 16 km (10 mi) of the preliminary candidate area. The highly populated areas located in Minnesota are depicted on Plate 5A of the North Central RECR (DOE, 1985d). The preliminary candidate area contains no areas with population densities greater than or equal to 1,000 persons per square mile. Warren, which is located 16 km (10 mi) southwest of the preliminary candidate area and has a population of 2,105, is the only area with a population density greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area (see Figure 3-79). Grand Forks, North Dakota, is located approximately 50 km (30 mi) southwest of the the preliminary candidate area. The average population density of the preliminary candidate area is 4 persons per square mile. The average population density within 80 km* (50 mi) is approximately 19 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.1.11.12 Site Ownership. There are no Federal or DOE-owned lands located within the preliminary candidate area. The Red Lake Indian Reservation is located approximately 77 km (48 mi) east of the preliminary candidate area (see Plate NC-1A).

3.2.1.11.13 Offsite Installation. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Monticello, which is approximately 395 km (250 mi) southeast of preliminary candidate area (Michelewicz and Vann, 1983; DOE, 1984c). The nearest commercial nuclear reactor under construction is Byron 2, which is 830 km (575 mi) to the southeast

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* The density calculation does not include the portion of the 80-km (50-mi) area that passes into Canada.

(Nuclear News, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.1.11.14 Transportation. The nearest interstate highway, which is about 32 km (20 mi) west of the preliminary candidate area, is I29 in eastern North Dakota. I94 at Morrehead is the next closest interstate, approximately 161 km (100 mi) to the south. The nearest U.S. highways are U.S. 59 and U.S. 75. U.S. 75 is the closer of the two highways, about 3.2 km (2 mi) west of the preliminary candidate area. U.S. 59 is east of the preliminary candidate area and is about 10 km (6 mi) away. State Route 11, a principal highway, is about 10 km (6 mi) north of the preliminary candidate area; this highway provides access to the two U.S. highways mentioned above. To the east, State Route 11 connects with U.S. 59 at Karlstad, Minnesota. West of the preliminary candidate area, State Route 11 intersects U.S. 75 at Donaldson, Minnesota, and further west it intersects I29 at Drayton, North Dakota. Another principal State highway, State Route 1, is approximately 18 km (11 mi) south of the preliminary candidate area. This highway also connects the U.S. and interstate highways mentioned above.

Two mainline railroads bracket the preliminary candidate area. To the west is the Burlington Northern mainline between Crookston, Minnesota, and Winnipeg. This line, which parallels U.S. 75, is approximately 3.2 km (2 mi) from the western edge of the preliminary candidate area. The eastern mainline is the Soo line's main track between Minneapolis and Winnipeg. This line parallels U.S. 59 and is approximately 10 km (6 mi) from the eastern boundary of the preliminary candidate area. There is a branchline railroad 13.2 km (8 mi) south of the preliminary candidate area, which is a part of the Soo line system. This branchline extends from the Soo mainline at Thief River Falls, Minnesota, westward into North Dakota.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.1.11.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NC-A5 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations that could adversely affect the regional ground-water flow system [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that either the frequency of occurrence of earthquakes within the geologic setting may increase [960.4-2-7(c)(3)]

- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could produce ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)]
- absence of State lands less than 130 ha (320 ac) within the preliminary candidate area and limited presence in proximity to (i.e., two within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]

- the preliminary candidate area is beyond 16 km (10 mi) from highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(b)(2) and (c)(2)]
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfers of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2), 960.5-2-7(b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NC-A5 at this time.

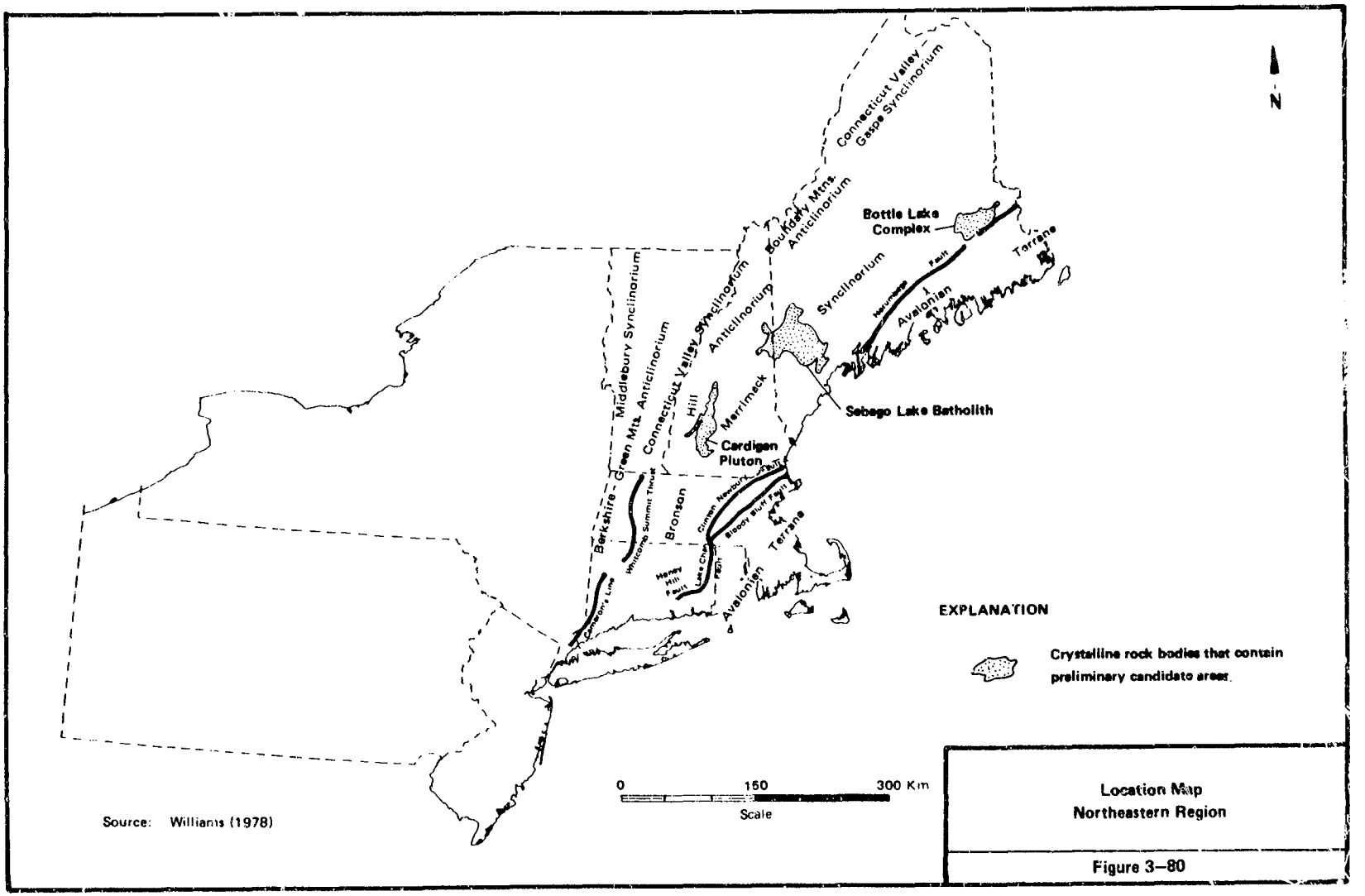
3.2.2 Northeastern Region

3.2.2.1 Regional Setting

3.2.2.1.1 Geological. The Northeastern Regional Geologic Characterization Report (RGCR) (DOE, 1985e) describes the regional geologic setting and related features. For the purposes of this report, the regional and geologic settings for the three preliminary candidate areas in the Northeastern Region are defined as the Northern Appalachian and the Merrimack Synclinorium, respectively (Figure 3-80).

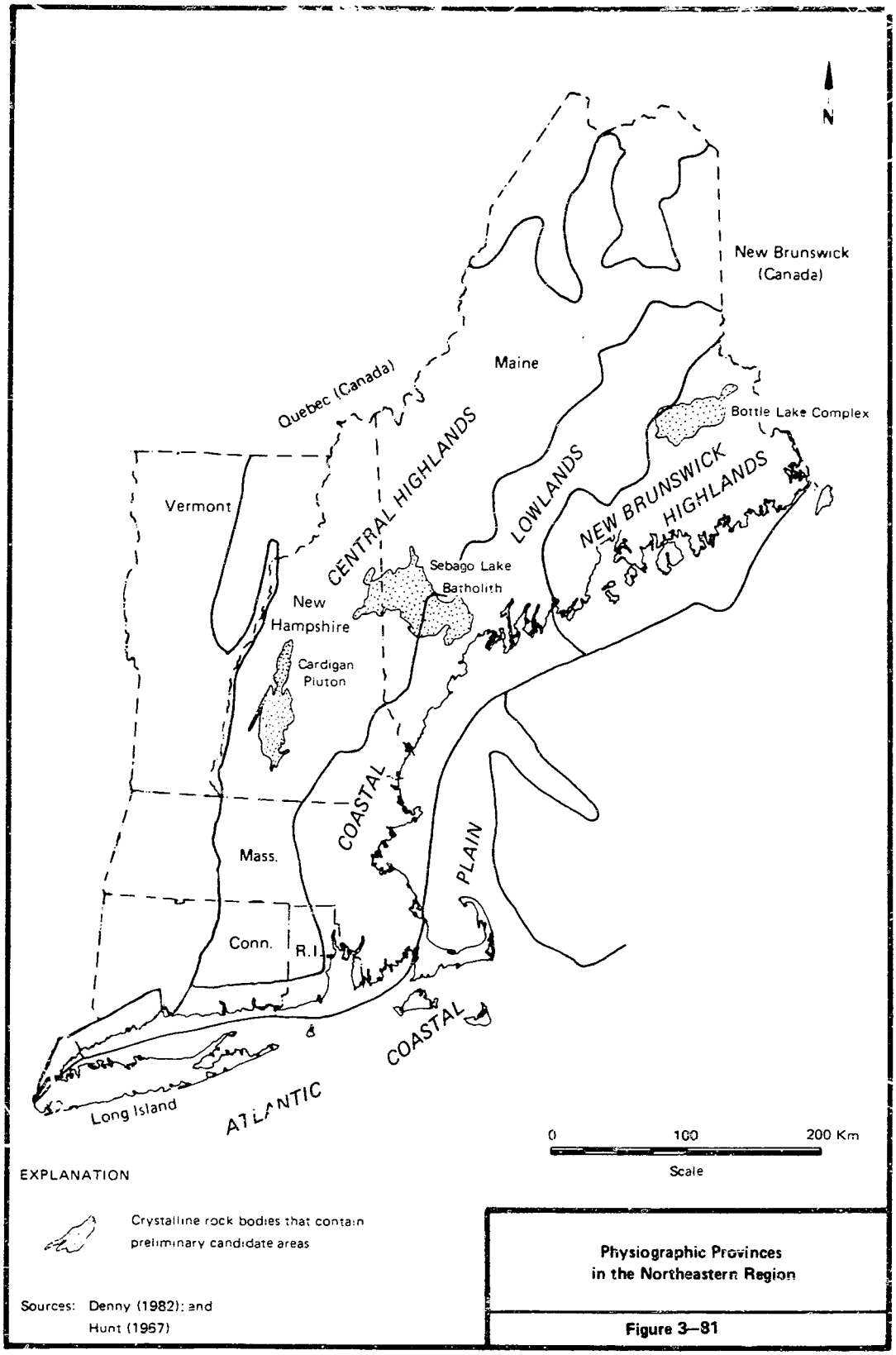
3.2.2.1.1.1 Physiography, Geomorphology, and Quaternary Geology. The three preliminary candidate areas identified in the Northeastern Region lie in three physiographic provinces: the Central Highlands, the Coastal Lowlands, and the New Brunswick Highlands (Figure 3-81). The Cardigan Pluton (NE-5) lies entirely within the Central Highlands. The Sebago Lake Batholith (NE-4) lies within the Central Highlands and the Coastal Lowlands provinces. The Bottle Lake Complex (NE-2) lies within the New Brunswick Highlands.

The Quaternary aspect of the region resulted from a series of Pleistocene glacial and interglacial cycles. The glacial maximum of the Wisconsinan, the latest glacial stage, occurred approximately 18,000 years ago (Flint, 1971; Mickelson et al., 1983) and the last advance before retreat was less than 12,000 years ago. This retreat was followed by an interglacial stage that has continued to present. The recurrence cycle of glaciation includes a wide range of possibilities. For example, Imbrie and Imbrie (1980) have predicted that the next glacial advance will occur approximately 23,000 years from now. This prediction, which is based on one of many equally rational models, suggests that during the next 100,000 years, a glacial advance and retreat may occur and that up to 10 glacial cycles could occur over the next 1 million years.



Location Map
Northeastern Region

Figure 3–80



Physiographic Provinces in the Northeastern Region

Figure 3–81

Glaciation, during the Pleistocene Epoch, generally smoothed and streamlined bedrock topography. The most conspicuous result of glaciation, insofar as erosion is concerned, was the removal of most of the preglacial mantle of weathered rock (Stewart, 1961). In some areas, linear topography results from differential erosion parallel to the foliation and structural grain of metamorphic rocks (Thornburg, 1985).

The majority of unconsolidated depositional material overlying bedrock in the Northeastern Region originated as a result of processes related to glaciation and deglaciation. Other deposits are related principally to weathering, local fluviatile deposition (Coates, 1976; Minard and Rhodehamel, 1969), or mass wasting.

Eustatic sea level changes occurred in the Northeastern Region in response to the accumulation and melting of the continental ice masses. Since the time of maximum global extent of (Wisconsinan) glaciation 18,000 years ago, sea level has risen between 80 and 130 m (260 and 425 ft) to within $\pm$ 5 m (16 ft) of its present level (Walcott, 1972). During the past 100 years, mean sea level has risen approximately 12 cm (4 in) (Gornitz et al., 1982, Emery, 1980) predicted that eustatic sea level could rise at a rate of 0.3 cm/yr (0.1 in/yr) during the next few decades.

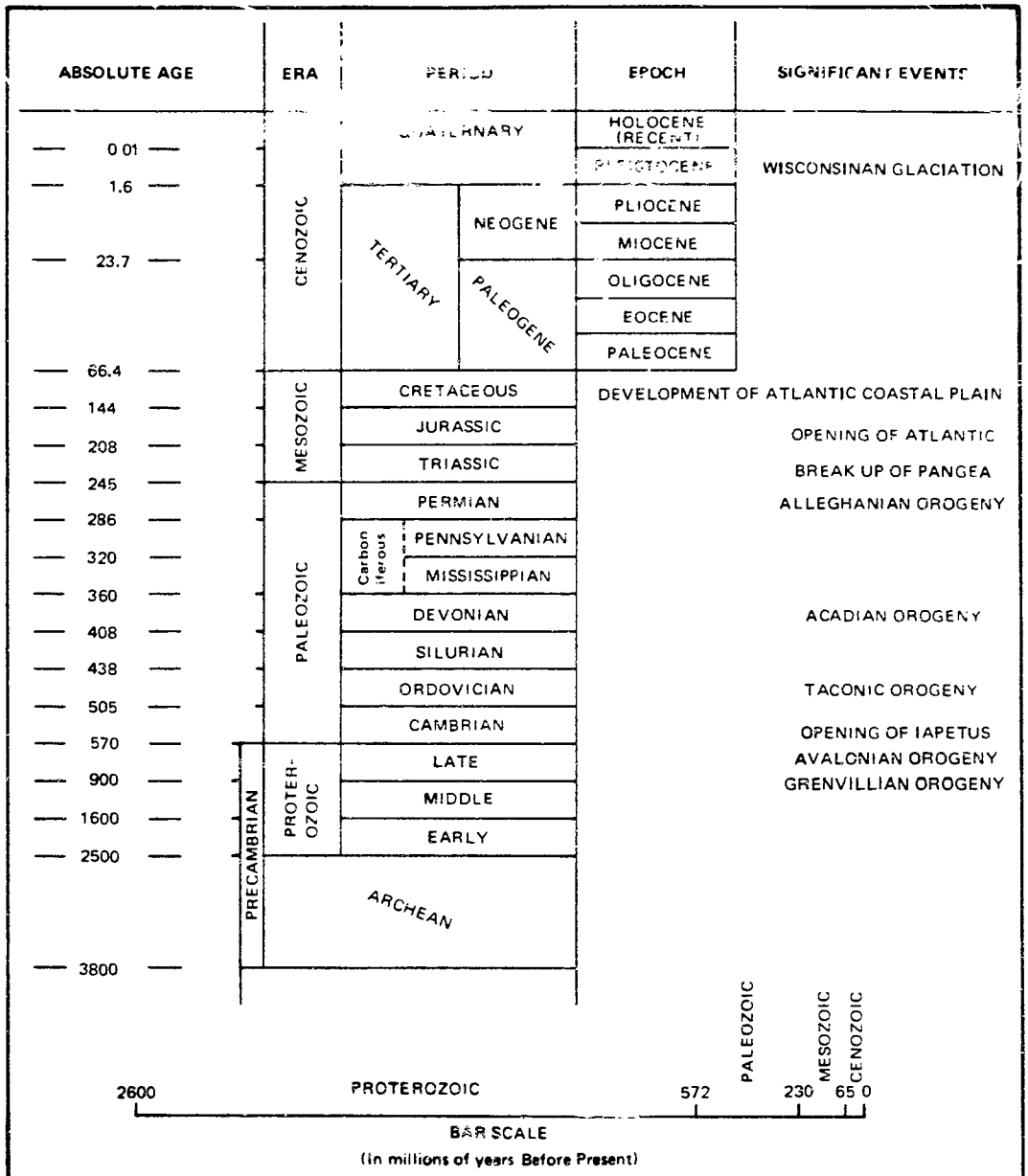
The Presumpscot Formation, a fossiliferous sand and silty marine clay, forms a discontinuous cover partially filling valleys and overlapping highlands to the altitude of maximum marine submergence. The Presumpscot was deposited during a late glacial marine transgression (Bornes, 1975; Thompson, 1979), which apparently took place between 13,000 and 12,700 years ago (Stuiver and Borns, 1975). This incursion of the sea inundated coastal Maine to a modern day elevation of 137 m (450 ft) and resulted in the partial submergence of the Bottle Lake Complex (NE-2) and the Sebago Lake Bath Kith (NE-4).

Low rates of denudation have been calculated for much of New England based on the measurement of suspended sediment and dissolved rock in rivers and on estuarine sedimentation rates. Judson and Ritter (1964) estimate a denudation rate for the North Atlantic states of 4.8 cm (1.9 in) per 1,000 years. This volume generally agrees with estimates of erosion derived from calculations of sediment volume representing the Cenozoic Period in the Atlantic Coastal Plain (Mathew, 1975). These rates imply that the land surface is being lowered 5 m (16 ft) per 100,000 years, if tectonism is not considered.

Bell and Laine (1985) concluded that a regional average of 120 m (390 ft) of erosion occurred since major glaciation began 3 million years ago. This estimate indicates an average rate of 40 m (130 ft) per million years. Assuming a glacial cycle every 100,000 years (Hays et al., 1976), there would be about 4 m (13 ft) of erosion per cycle, which is in general agreement with the other studies. Bell and Laine (1985) also concluded that the maximum total amount of erosion might be between 175 and 200 m (570 and 650 ft).

The information on maximum depth of glacial erosion of perhaps 200 m (650 ft) over 3 million years when compared to the assumed repository horizon (350 to 800 m or 1,148 to 2,624 ft) indicates that the integrity of a repository developed in the preliminary candidate area will not be affected by glacial erosion over the next 100,000 years. Although the geologic setting is one in which climatic changes have certainly affected the hydrologic system throughout the Quaternary Period, it is uncertain to what degree these changes have affected the hydrologic system.

3.2.2.1.1.2 Geology and Tectonics. The Northeastern Region was affected by four major episodes of mountain building (orogenesis) (Figure 3-82). The Acadian orogeny is of primary interest because igneous activity during or shortly after the main phase of this orogeny resulted in the emplacement of each rock body underlying the preliminary



EXPLANATION

Absolute age given in millions of years Before Present

Source: Palmer (1983)

Geologic Time Scale

Figure 3–32

candidate areas identified in the Northeast U.S. Region. The Acadian orogeny of Middle to Late Devonian time was an intense diastrophic episode, marked by multiple deformation events, high-grade regional metamorphism, and significant igneous activity (Robinson and Hall, 1980; Naylor, 1971). The intensity of Acadian age deformation and regional metamorphism increases southward from northern Maine to southern New England. Regional metamorphism ranges from subchlorite grade in eastern and northern Maine (Osberg et al., 1984) to upper amphilbolite grade in central Massachusetts (Zen, 1983).

The Cardigan Pluton (NE-5), Sebago Lake Batholith (NE-4), and Bottle Lake Complex (NE-2) are located within the central and northern portions of the Merrimack synclinorium (Figure 3-80) which developed during the Acadian orogeny. The Merrimack synclinorium consists of deformed metasedimentary Paleozoic rocks locally intruded by the plutons of the New Hampshire magma series. In Maine, it is bounded to the east by the Norumbega fault zone and to the west by the Bronson-Hill Boundary Mountains anticlinorium. In New Hampshire, the eastern boundary of the Merrimack synclinorium is defined by the Massabesic anticlinorium and to the west by the Bronson-Hill anticlinorium.

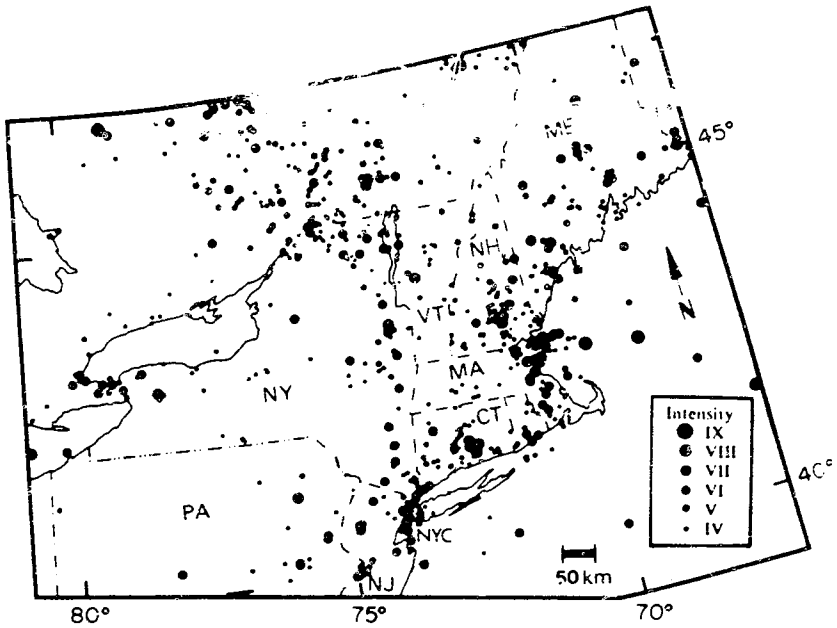
Major intrusions of granitic rocks occurred during Middle to Late Devonian time and continued into the Mississippian Period in some areas. Prominent among these intrusions are the Cardigan Pluton (NE-5) and Sebago Lake Batholith (NE-4) which belong to the New Hampshire magma series (Williams and Hatcher, 1983). The rocks of the New Hampshire magma series probably were differentiated at depth and intruded as individual bodies of distinct composition. The thickness of individual Devonian plutons is apparently related to the crustal level at which they intrude (Nielson et al., 1976). In areas of lower regional metamorphic grade (lower than sillimanite grade), such as northern Vermont and northern Maine, the plutons are thought to be thicker than those that intrude higher grade metamorphic rocks. In New Hampshire and western

Maine, New Hampshire series [illegible] thought to form sheets approximately 1 to 3 km (0.6 to 1.9 mi) thick (Moench et al., 1982). Southeast of the Norumbega fault zone, felsic intrusions may be on the order of 8 to 12 m (5 to 7.5 mi) thick (Hodge et al., 1982).

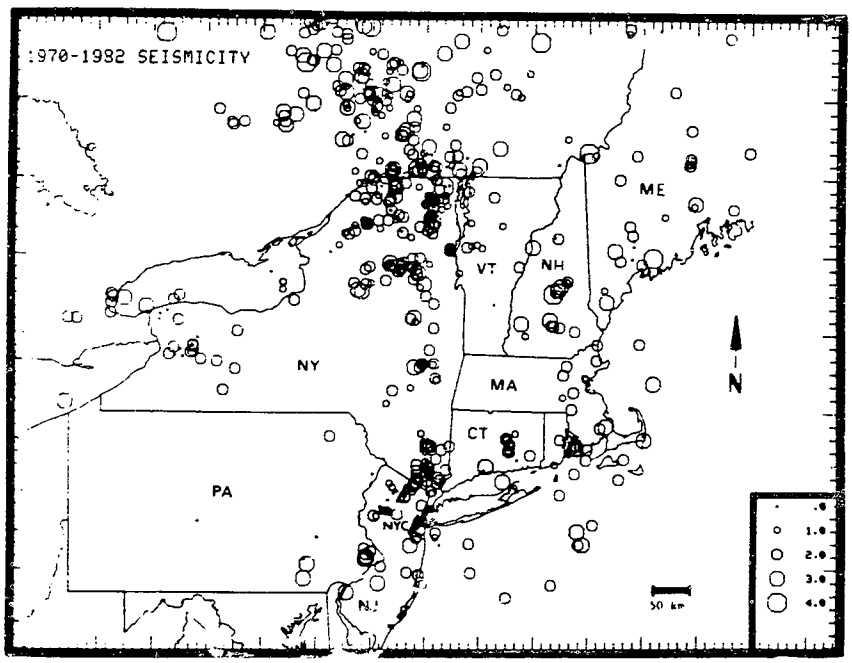
A number of Devonian intrusions (including the Bottle Lake Complex [NE-2]) that have not been correlated to the New Hampshire magma series crop out in the region, primarily in Maine. These rocks tend to be granitic in composition although a number of mafic bodies are exposed in western and southeastern Maine.

Within the Merrimack synclinorium of Maine and New Hampshire, the Acadian orogeny resulted in (1) the development of large-scale folds, (2) low- to high-grade regional metamorphism, (3) intrusion of granitic plutons, and (4) the development of large-scale ductile and brittle structures. The Alleghanian orogeny, which took place during Permian time (Mosher, 1983) subsequent to the intrusion of the plutons which underlie the preliminary candidate areas, was the last pulse of mountain building to affect eastern North America. In the northern Appalachians, the effects of this orogeny are localized and generally are expressed by deformation along strike-slip faults in northern New England (Lundgren and Ebblin, 1972; O'Hara and Gromet, 1983). No tectonic features in the candidate areas are related to Triassic or Cenozoic events.

3.2.2.1.1.3 Seismicity and Recent Crustal Movement. A number of significant earthquakes are documented in the historical seismic record for the northeastern United States and southeastern Canada. Figure 3-83 shows the historical and instrumentally recorded earthquakes in the Northeastern Region. In 1755, an earthquake affected a portion of the Atlantic coast from Halifax, Nova Scotia, to the Chesapeake Bay in Maryland. The earthquake produced a maximum intensity of MM VIII and is estimated to have a felt area of about 985,000 km^2 (385,000 mi^2).



A. Historical Earthquakes 1534 - 1959



B. Instrumentally Recorded Earthquakes 1970 - 1982

Seismicity in the Northeastern Region

Source: Kafka, Schlesinger-Miller and Barstow (1985)

Figure 3–83

Since the event is believed to have occurred offshore, the estimated felt area includes a large area of ocean and therefore has a large uncertainty associated with the MM intensity assignment. The body-wave magnitude (m_b) of this event, based on the felt area, is estimated to be about 6.0 (Street and Lacroix, 1979). In central New Hampshire, a pair of large earthquakes occurred in December of 1940. These events were felt from southern Canada to New Jersey. The events were similar in size and have estimated Richter magnitudes of about 5.25, based on felt areas of approximately 805,000 km^2 (311,000 mi^2) (Street and Lacroix, 1979). The maximum intensities produced were MM VII for both events. In 1982, a shock of Richter magnitude 5.7 occurred in New Brunswick, Canada. This event is located in a relatively uninhabited area of Canada and intensity reports from the epicentral region are therefore sparce. The maximum intensity for this event is reported as MM V, its felt area is about 600,000 km^2 (231,000 mi^2). Large events are also known from the LaMalbaie region of Quebec. The most recent large event from that area occurred in 1925 and had a Richter magnitude of about 6.6 and an epicentral intensity of MM IX.

Many attempts have been made to associate seismic activity in the eastern United States with specific geologic structures. None have met with general acceptance by the seismological community. Geologic structures observed at the surface often have little relation to the hypocenters of moderate-to-large earthquakes. There appears to be no spatial relationship between mapped bedrock faults and modern seismicity in Maine (Anderson et al., 1984). In addition, detailed studies of specific faults within the region (e.g., the Ramapo fault in New York and New Jersey and Norumbega fault in Maine) have produced no evidence of Quaternary offset (Ratcliffe, 1980; Thompson, 1981). Earthquakes along the Ramapo have fault plane solutions that show faulting oblique to the trend of the fault. Locational uncertainties, especially with depth, make correlation of seismic events with specific structures impossible in most cases. The uncertainties allow some structures to be within the error bar of any earthquake. To assess the uncertainties of a particular event, the circumstances and documentation must be critically evaluated.

For pre-instrumentally recorded events, conversions of intensity to magnitude or acceleration add to the uncertainties. Both small- and moderate-sized events can produce the same maximum intensity, but the spatial extent over which that intensity is experienced will be greater for the larger event.

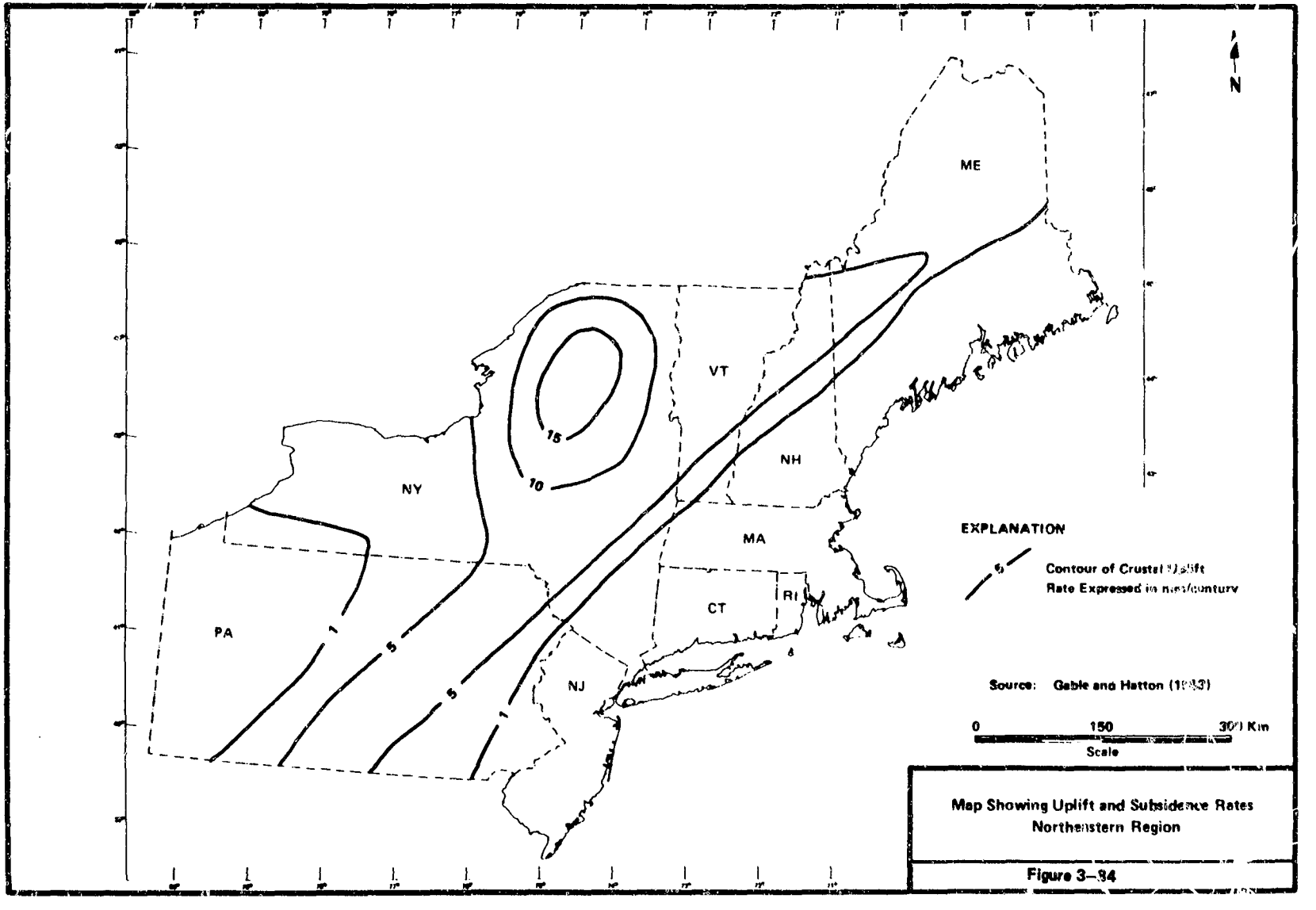
In general, the tectonic conditions at sites of past moderate-to-large earthquakes do not appear different from those at locations that have not experienced such an event. While earthquakes might recur only where they have occurred in the past, the long recurrence intervals for significant events (on the order of hundreds to thousands of years) and the relatively short duration of the historical record (about 300 years), leads to the conclusion that not all potential sites of moderate-to-large earthquakes have yet experienced one during historical times.

Since the causes of earthquakes in the eastern United States is still a subject being debated, methodologies to assess the seismic hazard at sites in this region must accommodate multiple working hypotheses and the recognition of uncertainty of results. To characterize the current understanding of eastern United States seismicity, the Electric Power Research Institute (EPRI, 1985a) has supported the development of a methodology that incorporates these uncertainties into an assessment of the seismic hazard. The approach attempts to base the hazard analysis as much as possible on a tectonic foundation while systematically documenting the associated uncertainties. Scientific uncertainty (the inability of models to represent the real earth) and informational uncertainty (the limitations of the current data base) are evaluated separately via a matrix formulation. Whereas the traditional approach allowed only one source zone to describe the occurrence of earthquakes in a region, the EPRI methodology allows multiple source zones that can overlap and have different recurrence parameters and maximum magnitudes. Thus, a more realistic representation of the current understanding of the region's seismicity can be incorporated in the hazard assessment. As an example of hazard assessment, Algermissen et al. (1982) indicated that

seismicity in the vicinity of the preliminary candidate areas will result in maximum (peak) horizontal accelerations at the surface of 0.1 to 0.2 g. These accelerations have a 90% probability of not being exceeded in 250 years (Algermissen et al., 1982).

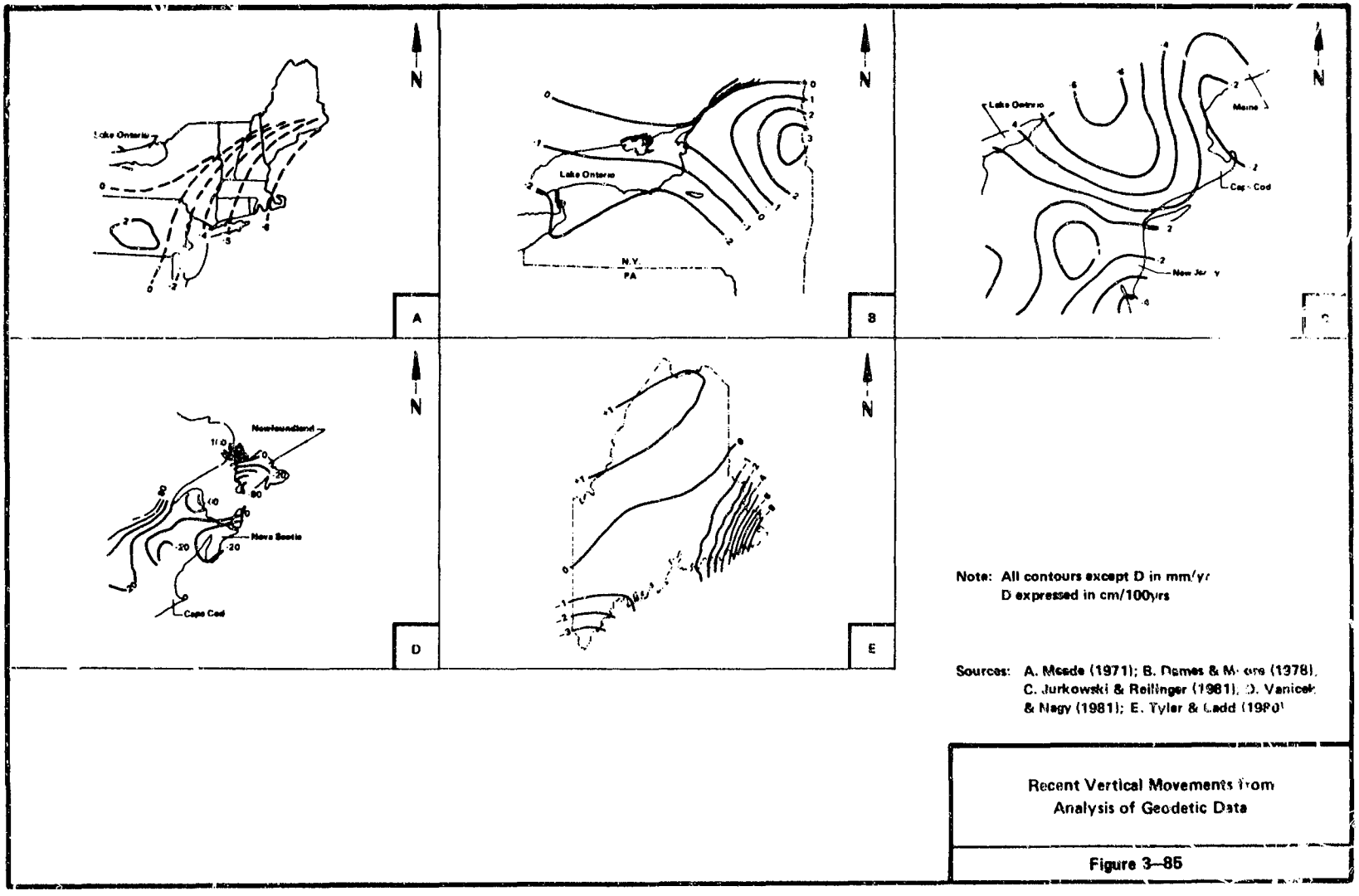
Vertical crustal movement in the region comprises several elements that each contribute to the net motion of the crust. These elements include movement induced by active tectonic processes, movement related to the release of loading produced by continental glaciers, and sea level fluctuations (which occur in response to each of the foregoing factors). A recent evaluation of vertical crustal movements over the past 10 million years was compiled by Gable and Hatton (1983). Figure 3-84 shows that average uplift rates for the Northeastern Region over a long period of geologic time approximate a fraction of a millimeter per year. Analysis of apatite crystals from the southeastern Pennsylvania Piedmont (Zimmerman, 1980), the Adirondack massif (Miller and Lakatos, 1983), and northern New England (Zimmermann et al., 1975) suggests rates of post-Mesozoic uplift on the order of 5 mm (0.20 in) per century, which agree with Gable and Hatton's (1983) results. In the Adirondacks, however, estimates based upon fission track rates are an order of magnitude lower.

Recent geodetic leveling studies for the Northeastern Region and adjacent Canada (Brown and Oliver, 1976; Brown, 1978; Vanicek and Nagy, 1979; and Jurkowski and Reilinger, 1981) suggest rates of vertical movement on the order of 10 mm (0.4 in) per year. Uncertainties arise from various types of error corrections that have been applied to the data and resulting interpretations of contemporary vertical movements vary widely (Figure 3-85). Whalen (1985) reports that leveling data collected after 1970 were obtained using a precise level susceptible to magnetically induced errors that can be larger than actual elevation changes measured between leveling stations. All of the interpretive maps in Figure 3-85 were prepared with at least some data collected with the error-prone level. These interpretations, therefore, must be considered



Map Showing Uplift and Subsidence Rates
Northeastern Region

Figure 3-94



Note: All contours except D in mm/yr
D expressed in cm/100yrs

Sources: A. Meade (1971); B. Dames & Moore (1978), C. Jurkowski & Reilinger (1981), D. Vanicek & Nagy (1981); E. Tyler & Ladd (1980)

Recent Vertical Movements from Analysis of Geodetic Data

Figure 3–85

suspect. Gable and Hatton (1983), for related reasons, have chosen to separate estimates of uplift based on geodetic data from those based on geologic indicators. Figure 3-84 is based on nongeodetic data.

Differential vertical uplift, as demonstrated by shoreline warping, suggests a postglacial component of ongoing tectonic processes (e.g., Anderson et al., 1984). Shoreline deformation in nonglaciated areas confirms that glacioisostatic movements are distinct from vertical crustal movements due to tectonism (Winker and Howard, 1977). Therefore, in the Northeastern Region, glacially induced vertical crustal movement and associated eustatic sea level effects might obscure or, in turn, be partly masked by, modern tectonism. Vertical crustal movements are thought to have potential influence on seismicity, but no absolute cause and effect relationship has been identified.

3.2.2.1.1.4 Strategic, Metallic, and Energy-Related Resources. An overview of the rock and mineral resources in the Northeastern Region is presented in the RGCR (DOE, 1985e). Resources discussed herein are those that occur within 10 km (6 mi) of the preliminary candidate area and include only strategic, metallic and energy-related prospects and operations. Nonmetallic and nonstrategic resources are not addressed because they are not considered to be unique (i.e., there are alternate sources within a comparable distance from the market).

There are no deep mines or quarries either in or within 10 km (6 mi) of any of the preliminary candidate areas. Prospects of metallic, strategic, and energy-related resources have been reported within crystalline rock bodies in the region, and minor occurrences are present within or near some of the preliminary candidate areas.

3.2.2.1.1.5 Hydrology. Preliminary candidate areas occur in the drainage areas of the Merrimack, Saco, Presumpscot, Androscoggin, Penobscot, and St. Croix Rivers. The Northeastern Region contains many large lakes and numerous rivers, streams, small lakes, and wetlands.

Ground water at all preliminary candidate areas can be discussed in terms of shallow (surficial) aquifers (i.e., alluvium and glacial till) which can be characterized as porous flow media and generally deeper crystalline bedrock aquifers which can be characterized as a fracture flow media, largely controlled by the geometry of secondary interstices (fractures, faults, etc). Information on bedrock well location, yield, and depth are available for the preliminary candidate areas located within the crystalline rock bodies. These data are primarily drawn from ground-water resource maps and State field investigations. The most abundant information is available for the Sebago Lake Batholith. Less detailed information is available for the other preliminary candidate areas.

Although yield data from wells are not individually conclusive as to aquifer characteristics, the aggregate of these data indicates that production of water from crystalline rocks decreases with depth. There is no evidence to suggest that this trend does not also hold for areas lacking data. Crystalline rocks may have locally high yields where wells intersect faults and major fracture zones. Yields are limited by the size of fractures and joints and their degree of interconnection. The abundance of interconnected fracture systems probably decreases with depth, as does their ability to transmit water.

Most surficial aquifers located in the preliminary candidate areas are valley fill sand and gravel deposits associated with streams and rivers. The potential for sustained high yields from these aquifers can be high because they are easily recharged by surface water systems. However, these aquifers are geographically constrained, generally being restricted to narrow zones in stream valleys. No large-scale surficial aquifers are present in the preliminary candidate areas.

Sparce data are available pertaining to ground-water flow in crystalline rocks at depth (100 to 1,000 m [328 to 3,280 ft]), with essentially no data available at the assumed repository depths in the Northeastern Region. Studies by Toth (1962, 1963), Freeze and

Witherspoon (1966; 19[illegible] (1978), and Gale (1982) indicate that, in general, ground-water tab[illegible] and grou[illegible] levels at depth may be a subdued replica of the topography, with flow generally moving from topographic highs to topographic lows. The inherent assumption in such studies is that ground water at depth is, on a regional basis, in hydraulic connection with the shallow ground-water table. The validity of this assumption is questionable where thick unconsolidated deposits may contain continuous confining layers over a large region. Because overburden is relatively thin in the three preliminary candidate areas described and there are currently no data to suggest the presence of regional confining layers within the surficial deposits, this assumption is probably valid. Accordingly, local ground-water flow would be expected to follow the direction of local surface-water drainage outlets.

3.2.2.1.2 Environmental. The environmental setting of the Northeastern Region is described in detail in the Northeastern Regional Environmental Characterization Report (RECR) (DOE, 1985f).

3.2.2.1.2.1. Climate. Controlling influences on the climate of the region include latitude, proximity to coastal areas, and terrain elevation. Mild or warm conditions are typical in summer with average July temperatures varying from 18° to 25°C (65° to 77°F). Winter weather can be severe with January temperatures in northern Maine averaging -12°C (11°F). Average annual snowfall (excluding highest terrain) varies from 53 to 280 cm (21 to 110 in). Excluding high terrain, annual average precipitation in the region varies from about 81 to 107 cm (32 to 42 in). Precipitation in high terrain areas can exceed 114 cm (45 in) per year. Severe weather in the form of tornadoes and high winds has occurred in all parts of the region, and damage due to tropical storms is also a threat.

3.2.2.1.2.2 Land Use. Rural land dominates the northern half of the Northeastern Region. Maine and New Hampshire contain 53 and 44% rural populations, respectively. The relatively few urban areas are scattered throughout these two states.

Compared to some other parts of the United States, the Federal government owns relatively little land in the Northeastern Region; the vast majority is in private or State ownership.

National forests account for more than 70% of the total Federal lands in the region; these are primarily regional resources, but to some degree they are also recreation areas of national significance. None of the preliminary candidate areas are located within a coastal zone or the Coastal Barrier Resource System.

All states in the region maintain extensive and varied systems of State recreation areas and other protected lands. In addition to numerous State parks, the Northeastern Region States have designated lands comparable to Federal wildlife refuges, wilderness preservation areas, wild and scenic rivers, and forests.

3.2.2.1.2.3 Demography. The northern half of the Northeastern Region has relatively few highly populated areas. Maine's highly populated areas are located near the Atlantic coast, most of which are centered around Portland, Bangor, and Portsmouth. The highly populated areas of New Hampshire are concentrated in the southeastern portion of the State. The population centers of Manchester and Nashua are contained entirely within New Hampshire, while those of Portsmouth-Dover-Rochester extend into Massachusetts.

3.2.2.1.2.4 Ecological Systems. Both State and Federal agencies have designated protection for a number of plant species in the Northeastern Region. These designations at the State level may reflect limits of range for a species rather than its potential for expiration at a national level. There are three Federally protected plants listed in the Northeastern Region. Several protected species of plants are also listed by the States.

The animals in the Northeastern Region listed by the U.S. Department of the Interior as threatened or endangered include four species of mammals, five species of birds, and one species of fish. Those States that have their own lists usually include these Federal species as well as many others of local concern. The Federal government has designated a critical habitat for one species in the region, the Robbins cinquefoil plant in New Hampshire. This critical habitat is neither within any of the preliminary candidate areas in the Northeastern Region nor within 10 km (6 mi) of these preliminary candidate areas.

3.2.2.1.2.5 Federal Indian Reservations. There are four Federal Indian Reservations within the Northeastern Region. These include the Mashontucket Indian Reservation in Connecticut, the Narragansett Indian Reservation in Rhode Island (see Plate 1B of the Northeastern RECR) (DOE, 1985f), and the Passamaquoddy and Penobscot Indian Reservations in Maine (see Plate NE-1A). None of the Indian Tribes associated with these four reservations have Federal off-reservation treaty rights.

3.2.2.1.3 Transportation. Transportation routes (highways and railroads) for the Northeastern Region are shown on Plate NE-6A.* Highway and railroad data bases used in the transportation analyses presented are derived from United States Geological Survey data and are updated (through 1985) by the Oak Ridge National Laboratory, Tennessee.** A brief description of highway and railroad networks in the vicinity of the preliminary candidate areas in the Northeastern Region is presented in Sections 3.2.2.2.14 through 3.2.2.4.14. The highway network is broadly classified as interstate highways, U.S. highways, and State

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* Because the base map used to generate the transportation plates is a different projection than the base map used to generate the other plates in the accompanying portfolio, there will be some distortion if the transportation plates are overlain on the other plates.

** Although the plates show only primary State highways, discussions provided in this report take into consideration additional State highways.

highways. The rail [illegible] classified based on the volume of freight movements as mainline railroads and branchline railroads. It should be emphasized that all references to distances are approximate and measured from the edges of the preliminary candidate area, not the center. Furthermore, all distance are "straight line" since specific access routes and regional routes for waste transportation to the preliminary candidate area are yet to be defined.

3.2.2.2 Preliminary [illegible] Description - Bottle Lake Complex (NE-2)

The Bottle Lake Complex (Figure 3-86) is located in the New Brunswick Highlands physiographic province in southeastern Maine and lies in Penobscot, Washington, and Hancock Counties. The preliminary candidate area contained within this rock body is located at approximately 45°13' N latitude and 68°13' W longitude.

Preliminary Candidate Area NE-2 is located approximately 27 miles west of Maine-New Brunswick (Canada) border. DOE believes that to adequately characterize the preliminary candidate area in the Area Phase sampling/field work will be carried out only within the United States, thus no field activities will be necessary in Canada.

3.2.2.2.1 Host Rock Geometry and Overburden Thickness. The size of the preliminary candidate area within the Bottle Lake Complex is approximately 239 km^2 (92 mi^2). The Bottle Lake Complex intrudes greenschist facies rocks in eastern Maine. Nielson et al. (1976) suggest that plutons intruding areas of low regional metamorphic grade may have thicknesses that exceed 3 km (2 mi). Wones (1980) proposed that the thickness of plutons that intrude low grade rocks in eastern Maine ranges from 4 to 9 km (2.5 to 5.6 mi).

An interpretive geologic cross-section from Osberg et al. (1984) shows the northeastern extension of the Bottle Lake Complex to be approximately 3.5 to 4 km (2.2 to 2.5 mi) thick (Figure 3-87). Although available thickness information is uncertain, most authors agree on a lower limit of 3 to 4 km (2 to 2.5 mi) for plutons emplaced in an upper crustal environment, such as that which the Bottle Lake intruded.

Bedrock is exposed or buried under less than 3 m (10 ft) of surficial deposits over approximately 25% of the areal extent of the Bottle Lake Complex (Figure 3-88). Detailed geologic mapping (Ayuso, 1984) indicates that outcrops are present throughout much of the preliminary candidate area.

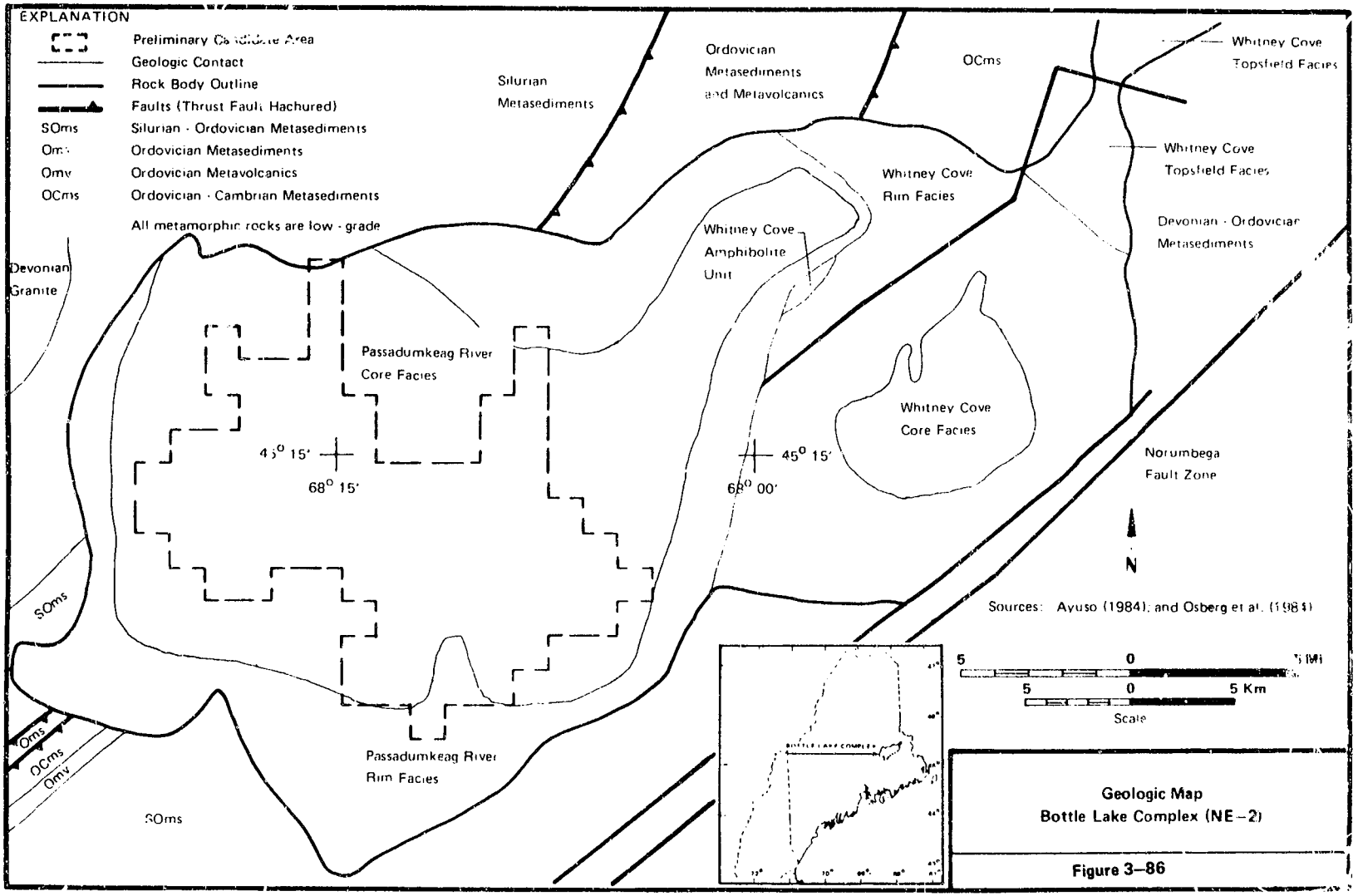
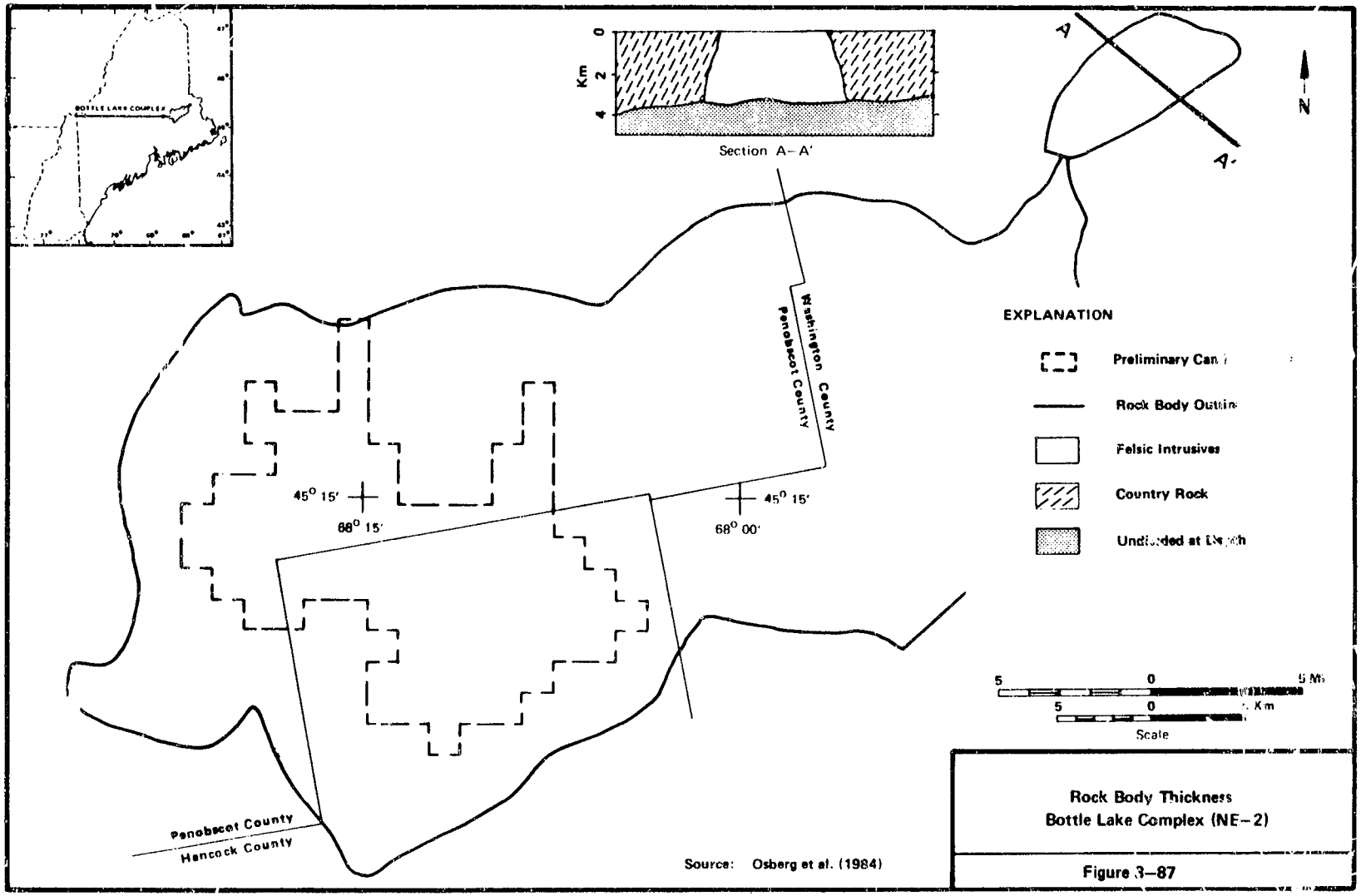
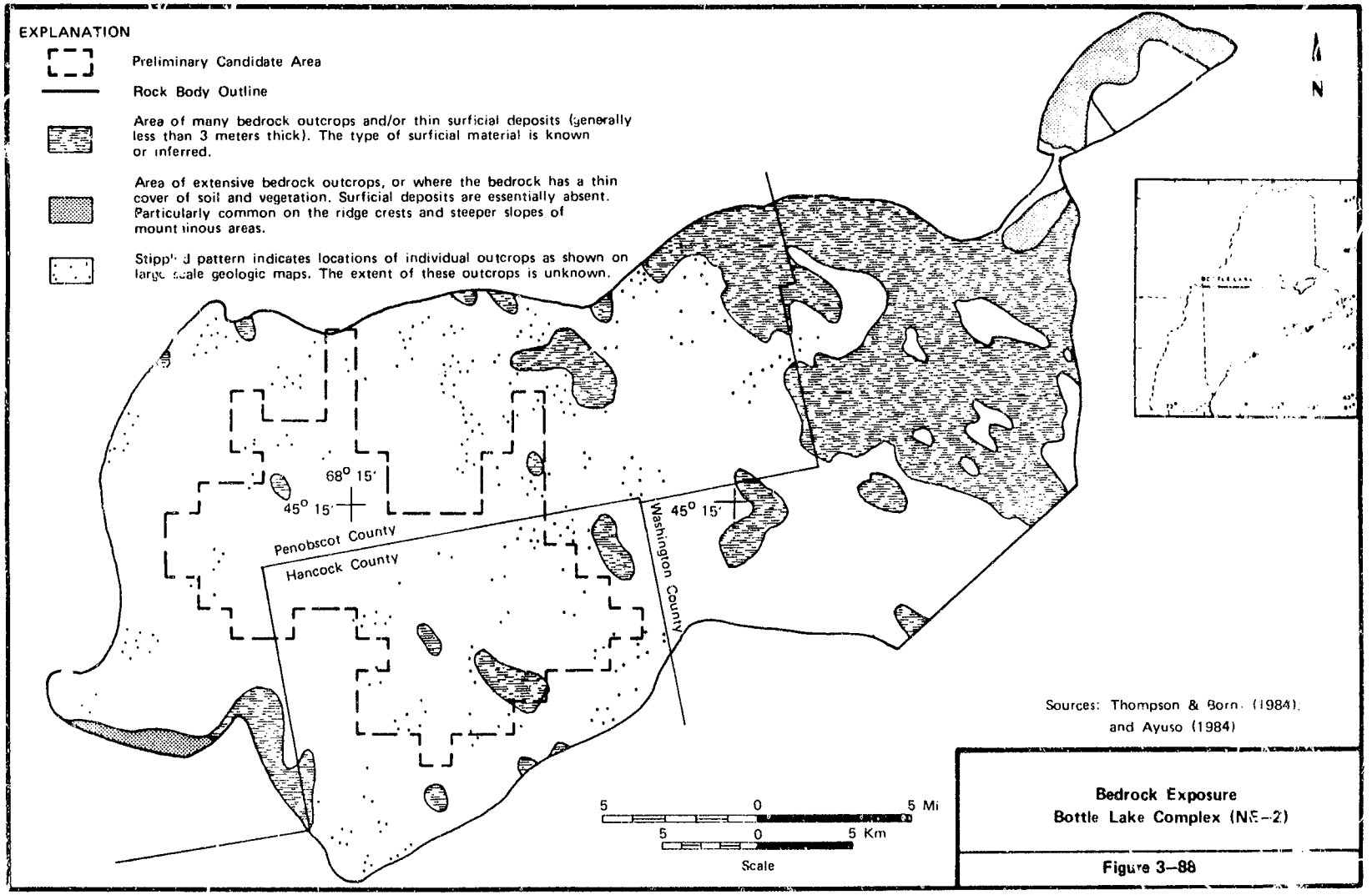

EXPLANATION
Preliminary Candidate Area
Geologic Contact
Rock Body Outline
Faults (Thrust Fault Hachured)
SOms Silurian - Ordovician Metasediments
Oms Ordovician Metasediments
Omv Ordovician Metavolcanics
OCms Ordovician - Cambrian Metasediments
All metamorphic rocks are low - grade
Silurian Metasediments
Ordovician Metasediments and Metavolcanics
OCms
Whitney Cove Topsfield Facies
Whitney Cove Topsfield Facies
Whitney Cove Rim Facies
Devonian - Ordovician Metasediments
Whitney Cove Amphibolite Unit
Devonian Granite
Passadumkeag River Core Facies
45° 15'
68° 15'
45° 15'
68° 00'
Whitney Cove Core Facies
Norumbega Fault Zone
N
SOms
Oms
OCms
Omv
Passadumkeag River Rim Facies
SOms
Sources: Ayuso (1984); and Osberg et al. (1984)
5 0 5 Mi
5 0 5 Km
Scale
Geologic Map
Bottle Lake Complex (NE-2)

Figure 3–86



Rock Body Thickness
Bottle Lake Complex (NE–2)

Figure 3–87

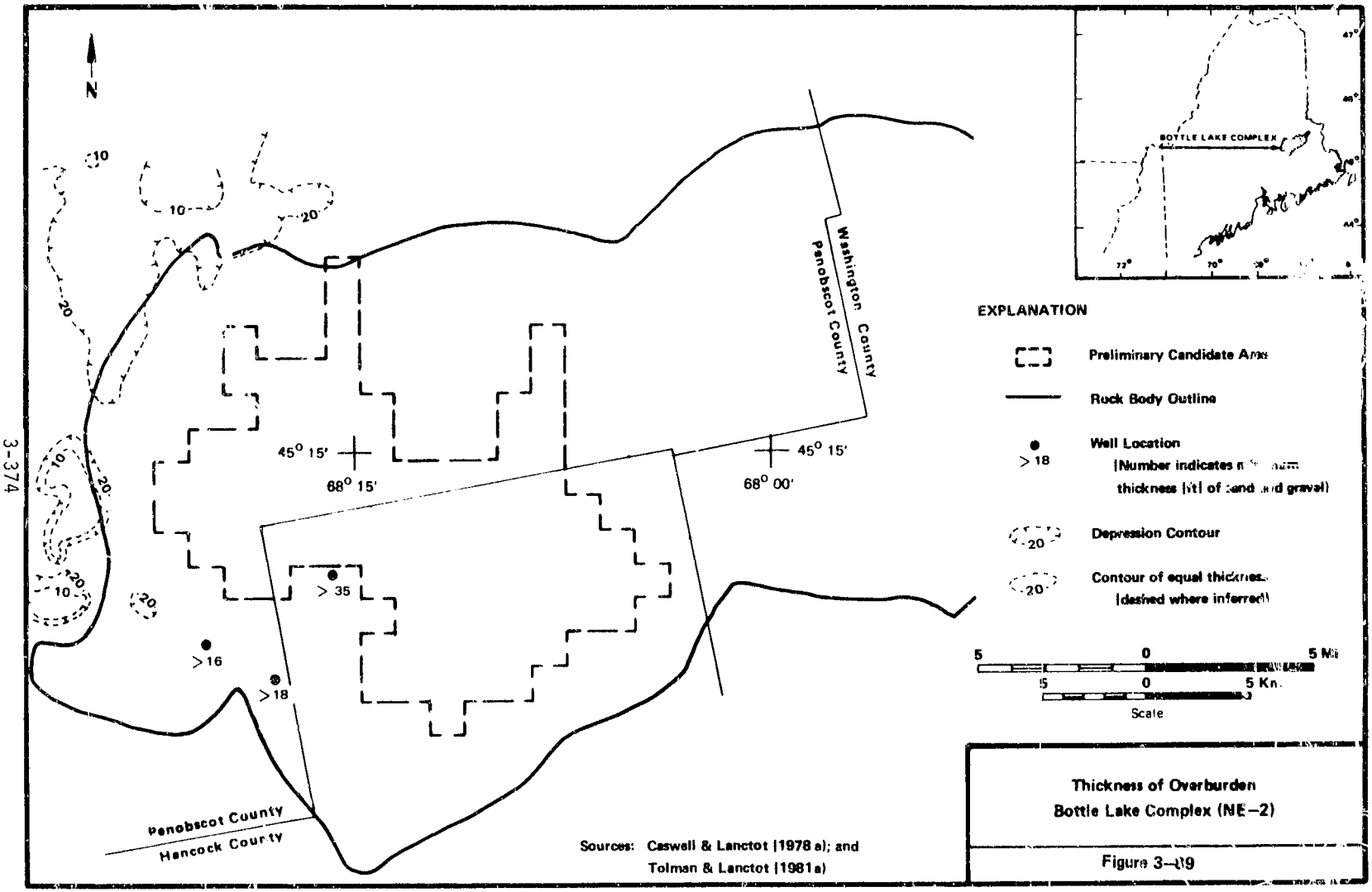

EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Area of many bedrock outcrops and/or thin surficial deposits (generally less than 3 meters thick). The type of surficial material is known or inferred.
Area of extensive bedrock outcrops, or where the bedrock has a thin cover of soil and vegetation. Surficial deposits are essentially absent. Particularly common on the ridge crests and steeper slopes of mountainous areas.
Stippled pattern indicates locations of individual outcrops as shown on large scale geologic maps. The extent of these outcrops is unknown.
N
68° 15'
45° 15'
45° 15'
Penobscot County
Hancock County
Washington County
5 0 5 Mi
5 0 5 Km
Scale
Sources: Thompson & Borns (1984), and Ayuso (1984)
Bedrock Exposure
Bottle Lake Complex (NE-2)
Figure 3-88

Available data for the [illegible] portion of the crystalline rock body indicate that overburden thickness (Figure 3-89) ranges from 6 to 15 m (20 to 50 ft) (Caswell and Lanctot, 1978c; Tolman and Lanctot, 1981e), and there are no indications that overburden thickness exceeds 15 m (50 ft) in the vicinity of the preliminary candidate area.

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the rock of the preliminary candidate area is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of an underground facility to ensure isolation.

3.2.2.2.2 Lithology and Tectonics. The Bottle Lake Complex is a generally massive composite batholith that consists of two reversely zoned granitic bodies, the Whitney Cove Pluton and the slightly younger Passadumkeag River Pluton. Each of the two plutons has been divided into a core and a rim facies.

The Passadumkeag River Pluton is exposed in the western portion of the Bottle Lake Complex and occupies an area of approximately 700 km^2 (270 mi^2). The preliminary candidate area lies entirely within the Passadumkeag River Pluton (Figure 3-86). The rocks of the Passadumkeag River rim facies are typically granitic in composition and show textures ranging from porphyritic to equidimensional. They are grayish-pink to grayish-orange-pink in color and contain alkali feldspar, plagioclase, quartz, biotite, amphibole, and accessory minerals. The core facies of the Passadumkeag River Pluton consists of a pale orange to yellowish-gray quartz monzonite exhibiting porphyritic to seriate textures. The core rocks are generally richer in plagioclase and mafic minerals than those of the rim. The nature of the contact between the core and rim facies of the Passadumkeag River Pluton is locally abrupt, but in general, it is unexposed and its overall nature is not well known (Ayuso, 1984).



Thickness of Overburden
Bottle Lake Complex (NE–2)

Figure 3–19

The Whitney Cove Pluton occupies the eastern portion of the Bottle Lake Complex. It is exposed over an area of approximately 400 km^2 (154 mi^2) and includes three distinct units: the Topsfield facies, the rim facies, and the core facies. Contacts between the three facies of the Whitney Cove Pluton are gradational. The rim and core facies of the Whitney Cove Pluton are similar in mineralogy and indicate a granitic composition for the pluton as a whole. The most distinguishing feature between these two facies is the characteristic seriate texture of the rim facies which is generally a medium- to coarse-grained, grayish-pink granite that contains alkali feldspar, plagioclase, quartz, and mafic minerals (Ayuso, 1984). The rocks of the core facies are grayish-pink to grayish-orange-pink in color and generally exhibit a porphyritic texture. These rocks are slightly enriched in plagioclase and depleted in alkali feldspar and quartz compared to those of the rim facies. The Topsfield facies of the Whitney Cove Pluton is exposed in the extreme northeastern portion of the Bottle Lake Complex. It consists of intensely weathered, medium- to coarse-grained, pinkish-red granitic rocks.

Mafic xenoliths are randomly distributed throughout both the Whitney Cove and the Passadumkeag River Plutons, but appear to be more common in the core facies of the Passadumkeag River Pluton (Ayuso, 1984). Felsic dikes with diffuse contacts are more abundant in the Whitney Cove Pluton, and are concentrated near the country rock-granite and granite-granite contacts (Ayuso and Wones, 1980). A greenish-black amphibolite unit of limited extent crops out along the northeastern contact of the Passadumkeag River and Whitney Cove Plutons. The amphibolite is intensely sheared and closely mixed with the granites of the Whitney Cove Pluton.

Contact relations between the Bottle Lake Complex and the country rock are discordant. Metasedimentary inclusions are concentrated near the contacts and decrease in size and abundance toward the interior of

the pluton. A 1.5-km (1 mile) contact metamorphic aureole surrounding the complex displays a well developed zonation. As distance from the pluton increases, contact metamorphic grade decreases from garnet through cordierite and biotite hornfels facies (Ayuso, 1984).

The Bottle Lake Complex represents a composite batholith derived from sequential melting, where the Passadumkeag River and Whitney Cove Plutons evolved as independent geochemical systems. Ayuso (1984) has postulated a shallow level of emplacement for this rock body based on the preservation of reverse zoning within the individual plutons.

The Bottle Lake Complex is a Devonian-aged granite. A rubidium-strontium age determination on the western portion of the pluton yielded an age of 381 million years (Ayuso and Arth, 1983). This pluton intrudes the Cambrian(?) to Devonian metasediments and Ordovician volcanic rocks of the southeastern limb of the Merrimack synclinorium that were regionally metamorphosed to greenschist facies during the Acadian orogeny (Ayuso and Wones, 1980).

At least four episodes of deformation affected the country rocks in this area. The earliest deformation occurred prior to the Acadian orogeny and is only observed in the Cambro-Ordovician rocks. It is characterized by small-scale, tight, isoclinal folding (Ludman, 1978). Early deformation was followed by the main phase of Acadian deformation which produced the northeast structural trends observed on geologic maps of the area (Ruitenberg and McCutcheon, 1978). This episode also produced characteristic small-scale, tight, isoclinal folds (Ludman and Griffin, 1974). The third major deformational event took place after the main phase Acadian orogeny,and may be related to regional-scale brittle deformation. It is characterized by steeply plunging, north-trending dextral asymmetric folds that are best developed near faults in the metasediments (Ludman, 1978b). The latest deformation is reflected by

east-west-trending [illegible] kink bands (Ludman and Griffin, 1974; Ruitenberg and McCutcheon, [illegible]). The Bottle Lake Complex intruded after the main phase of Acadian deformation (Ludman and Griffin, 1974).

The preliminary candidate area contained in the western half of the Bottle Lake Complex is not affected by any mapped faults. The eastern half of the Bottle Lake Complex is cut or partly bounded by three faults (Figure 3-86): a northeast-trending zone through the center of the Whitney Cove Pluton; an east-west-trending fault cutting the Topsfield facies; and the northeast-trending Norumbega fault zone (Ayuso, 1984). A northeast-trending cataclastic zone (northeast of the candidate area) is marked by a mylonitic foliation which cuts the Whitney Cove Pluton. It is approximately 19 km (12 mi) long and 1.5 to 3.0 km (1 to 2 mi) wide (Ayuso, 1984) and terminates against the Passadumkeag River Pluton (Ayuso and Wones, 1980). Outcrops in this zone are typically cataclastically deformed and cut by abundant veins of quartz and epidote (Ayuso, 1984). Evidence of up to 50 cm (20 in) of right-lateral displacement along east-trending fractures is observed in individual mylonitic zones (Ayuso, 1984).

An east-west-trending left-lateral fault separates the Topsfield facies from the main mass of the Whitney Cove Pluton (Figure 3-86). The fault zone is characterized by epidotized and intensely sheared red granitic rocks. Mylonitic veins are relatively common (Ayuso, 1984).

The Norumbega fault zone is a major northeast-trending fault system which forms part of the southern border of the Whitney Cove Pluton (Figure 3-86) (Ayuso, 1984; Osberg et al., 1984). It lies approximately 10 km (6 mi) to the southeast of the preliminary candidate area. The fault zone is 3 to 4 km (1.9 to 2.5 mi) wide, trends N45° to 60°E, and contains at least three subparallel faults (Wones and Thompson, 1979). The zone is characterized by breccias, mylonites, and abrupt changes in lithology. In the country rock, breccias and deformed, homogenized

pelites with abundant [illegible]s are observed. Dextral movements are suggested by minor drag [illegible] mylonites and slickensides, coupled with minor (1 to 5 cm or 0.4 to 2 in) sinistral offsets, suggesting an east-west compressive stress (Wones and Thompson, 1979). Minimal displacement is 10 km (6 mi), but maximum displacement is unknown. Detailed mapping of Quaternary features along the fault zone did not provide evidence of tectonically induced post-Pleistocene offset (Thompson, 1981).

The Bottle Lake Complex truncates five preintrusive faults. Four of these faults are north-northeast-trending, southeast-dipping thrust faults which place Cambrian to Ordovician rocks over Ordovician to Silurian rocks. The fifth pre-intrusive fault trends northeast and terminates against the eastern boundary of the Topsfield facies of the Whitney Cove Pluton (not shown on Figure 3-86). The south side is down-dropped, juxtaposing Ordovician and Devonian rocks (Osberg et al., 1984).

Rocks of the Bottle Lake Complex are typically massive. Foliation occurs primarily in cataclastic zones and near the granite country rock contact. In the core facies of the Passadumkeag River Pluton, foliation trends northeast. Foliation in the core facies of the Whitney Cove Pluton is randomly oriented (Ayuso, 1984).

Joints and fractures exhibiting a wide range of orientations are common throughout the complex. Ayuso (1984) did not identify regional joint trends in the granite but indicates a significant increase in jointing with proximity to the areas of intense cataclastic deformation.

Felsic dikes are found throughout the complex but are more common in the Whitney Cove Pluton than in the candidate area (Ayuso and Wones, 1980). These dikes exhibit diffuse contact with the granites and extreme variations in attitude (Ayuso, 1984).

Vertical crustal motion in the region is influenced by several factors, including continental glaciation and active tectonic processes, as well as by sea level changes which occur in response to these factors. Uplift rates in the vicinity of the Bottle Lake Pluton are less than 1 mm (0.04 in) per century (Gable and Hatton, 1983). Studies along coastal Maine suggest the possibility of a tectonic component of vertical movement (Anderson et al., 1984).

Estimates of vertical motion (from all probable sources) inferred from geodetic data suggest possible subsidence at a rate of approximately 1 mm (0.04 in) per year in the vicinity of the Bottle Lake Pluton. If such activity continued at the present inferred rate for the next 10,000 years, net subsidence would be approximately 10 m (33 ft). This amount of vertical motion is probably insignificant with respect to repository performance. There are no in situ stress data available for the vicinity of the preliminary candidate area.

The preliminary candidate area is located in an intraplate tectonic setting. There is no evidence of igneous activity or tectonic deformation during the Quaternary Period. Additionally, no correlation is known to exist between seismicity and known geologic structures. Vertical crustal motions have been inferred in the vicinity of the preliminary candidate area, but the rates and magnitude of these processes are low. There appears to be no significant potential for tectonic deformation that could affect the regional ground-water flow system.

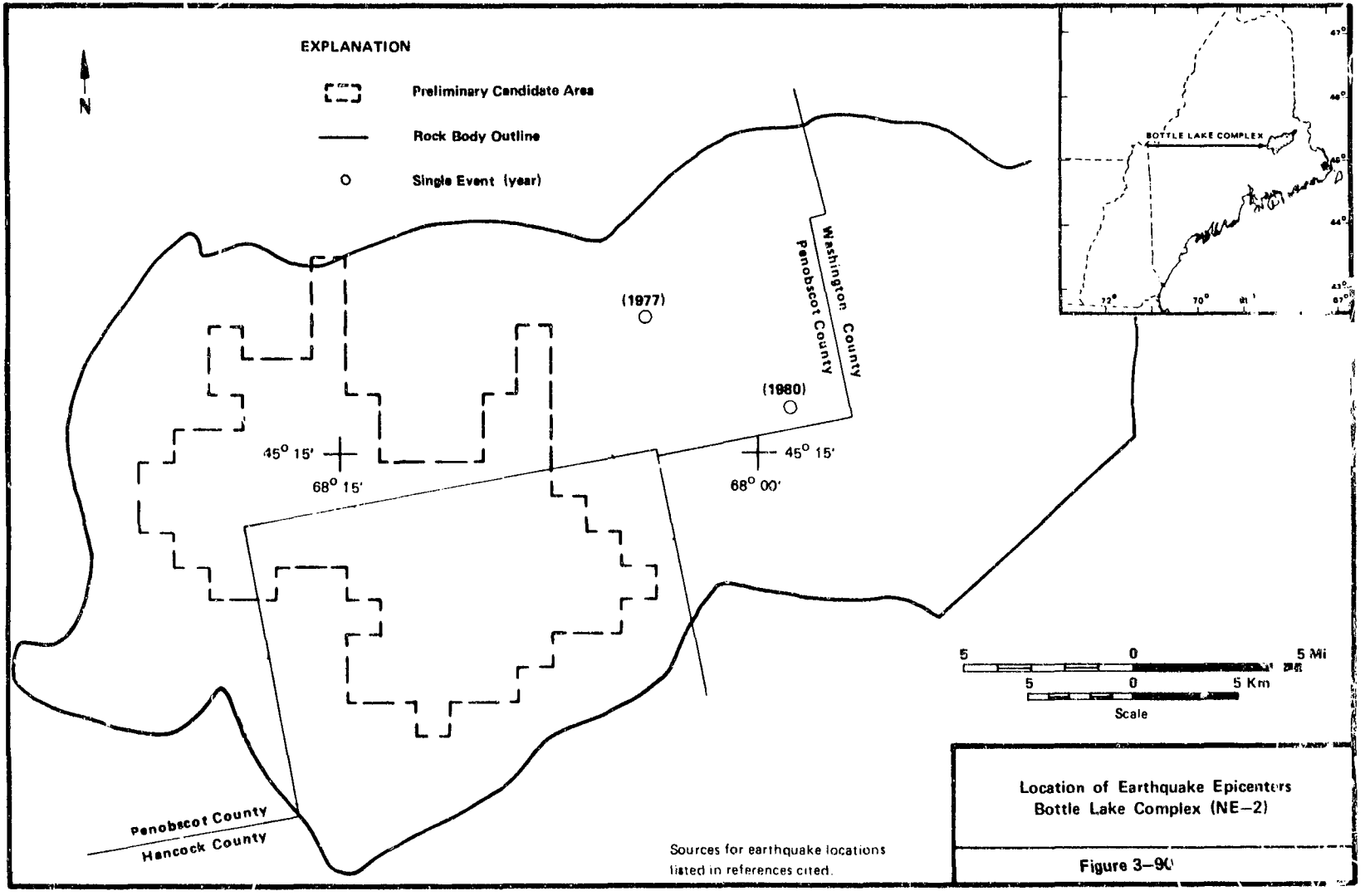
3.2.2.2.3 Seismicity. Regional aspects of seismology and neotectonics are discussed in Section 3.2.2.1.1.3. The evidence presented in that discussion indicates that large uncertainties associated with the location and size of earthquakes in the eastern United States make it necessary to discuss their distribution with respect to geologic features, in a broad rather than specific sense.

All earthquake epicenters lying within 16 km (10 mi) of the Bottle Lake Complex preliminary candidate area are shown on Figure 3-90. The accuracy of the location of these earthquakes, which is drawn from both instrumental and historical records, is discussed in Section 3.2.2.1.1.3 No data are available regarding the intensity of the earthquakes located in the vicinity of the candidate area.

There is no evidence for Quaternary surface displacements in the geologic setting. No correlations are known between earthquakes and documented geologic structure or tectonic processes in the geologic setting. Earthquake foci in the regional setting occur at depths that far exceed repository horizons. Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity could produce ground motion in excess of reasonable design limits.

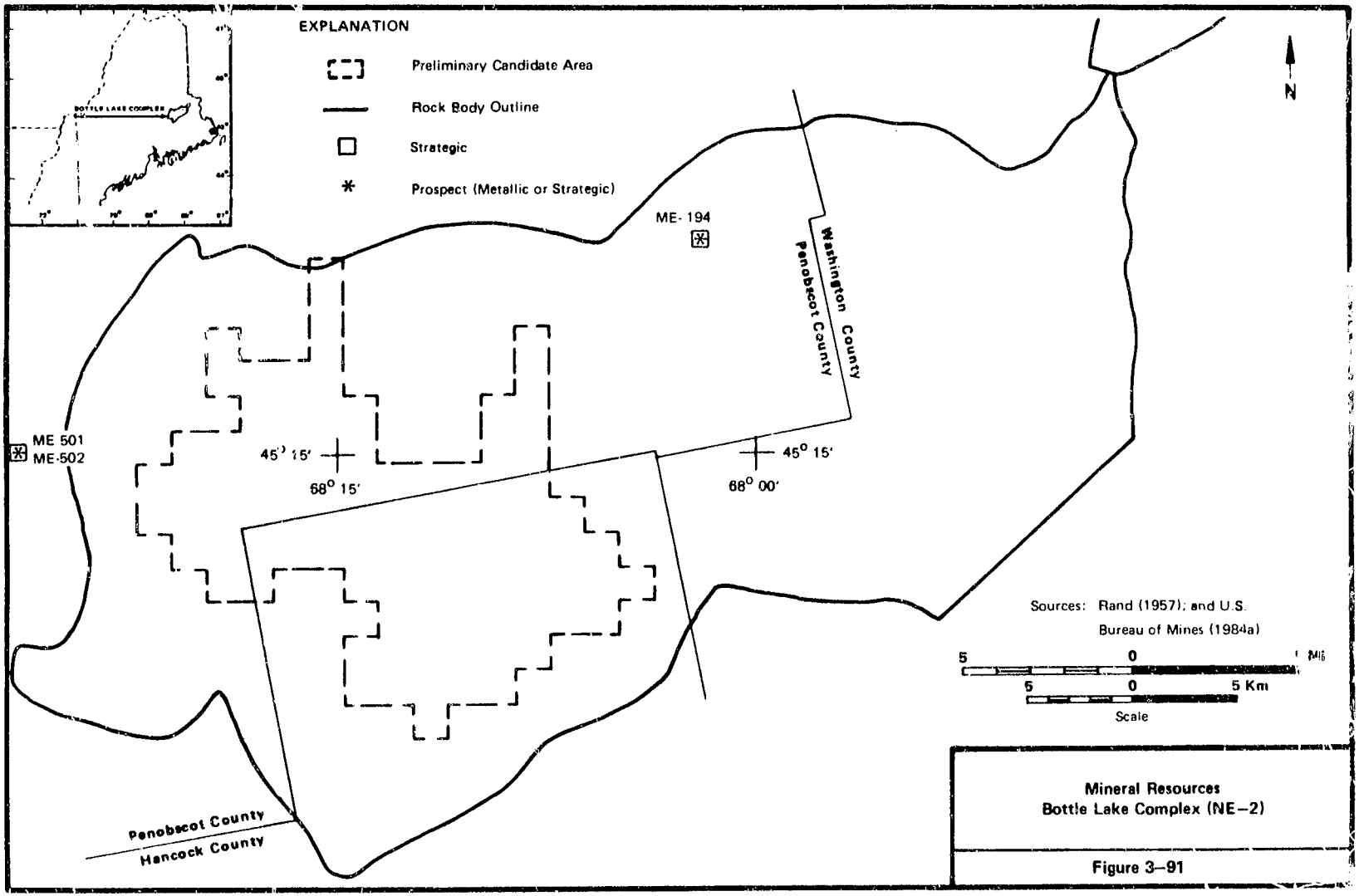
3.2.2.2.4 Mineral Resources. Strategic, metallic, and energy-related resources located within 10 km (6 mi) of the preliminary candidate area are shown on Figure 3-91. The three prospects identified occur beyond the limits of the preliminary candidate area. Locations 501 and 502 (Figure 3-91) are considered strategic resource prospects based on their potential for containing copper and iron, and silver and gold, respectively (USBM, 1985). The third prospect, location 194, is a potential metallic resource based on the occurrence of magnetite (Rand, 1957).

The nearest deep mine or quarry is an inactive mine (Black Hawk Mine) approximately 89 km (55 mi) southwest of the preliminary candidate area. The area is 215 m (705 ft) in depth and contains zinc, copper, and lead (Slack, 1980; Shields, 1967; MAS).



Location of Earthquake Epicenters
Bottle Lake Complex (NE–2)

Figure 3–90



Mineral Resources
Bottle Lake Complex (NE–2)

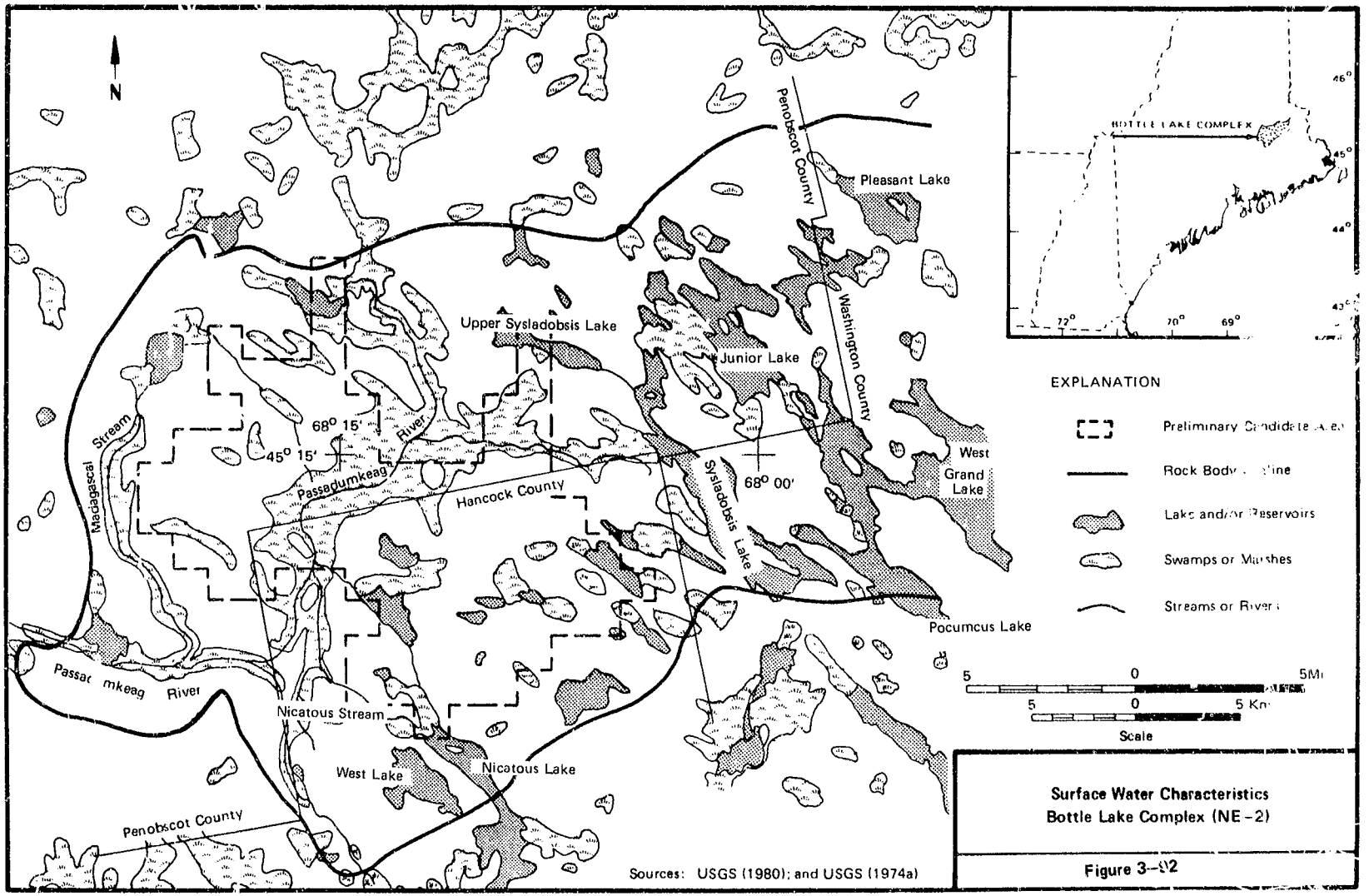
Figure 3–91

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources within the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation, and no information is available to indicate that deep drillholes are present in the preliminary candidate area.

3.2.2.2.5 Topography and Surface Water Characteristics. Topographic relief within the preliminary candidate area is low to moderate, with elevations ranging between 91 and 356 m (300 and 1,169 ft) (USGS, 1957; 1967). The majority of the area is generally flat with scattered hills and marshlands. Most of the preliminary candidate area lies within the Penobscot River drainage basin. The Passadumkeag River, a major tributary to the Penobscot River, drains the area to the southwest. The easternmost portion of the preliminary candidate area lies within the St. Croix River basin. A series of northwest-trending lakes drain southeastward into the St. Croix River which eventually forms the boundary between Maine and New Brunswick. Both the St. Croix River and the Penobscot River drain to the southwest. The locations of surface water features contained within and adjacent to the preliminary candidate area are shown on Figure 3-92.

As represented by the region-to-area screening data base, the preliminary candidate area is covered by less than 6% surface water and 18% wetlands. The location of lakes, rivers, and wetlands in the preliminary candidate area on Figure 3-92 are based on surface water features shown on USGS Land Use Maps.

The majority of the wetlands contained within this region correspond to the floodplains of the Passadumkeag River. The "1,000-Acre Heath", a concentration of wetlands, occupies the area between the eastern and western portions of the preliminary candidate area. Despite the occurrence of these wetlands, a significant portion of the preliminary candidate area is well drained and appears not to lie in flood prone areas.


N
Penobscot County
Pleasant Lake
Upper Sysladobsis Lake
Junior Lake
Washington County
Stream
Madagascal
68° 15'
River
45° 15'
Passadumkeag
Hancock County
Sysladobsis Lake
68° 00'
West
Grand
Lake
Pocumcus Lake
Passadumkeag River
Nicatous Stream
West Lake
Nicatous Lake
Penobscot County
Sources: USGS (1980); and USGS (1974a)
BOTTLE LAKE COMPLEX
46°
45°
44°
72°
70°
69°
EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Lakes and/or Reservoirs
Swamps or Marshes
Streams or Rivers
5 0 5Mi
5 0 5 Km
Scale
Surface Water Characteristics
Bottle Lake Complex (NE-2)
Figure 3-52

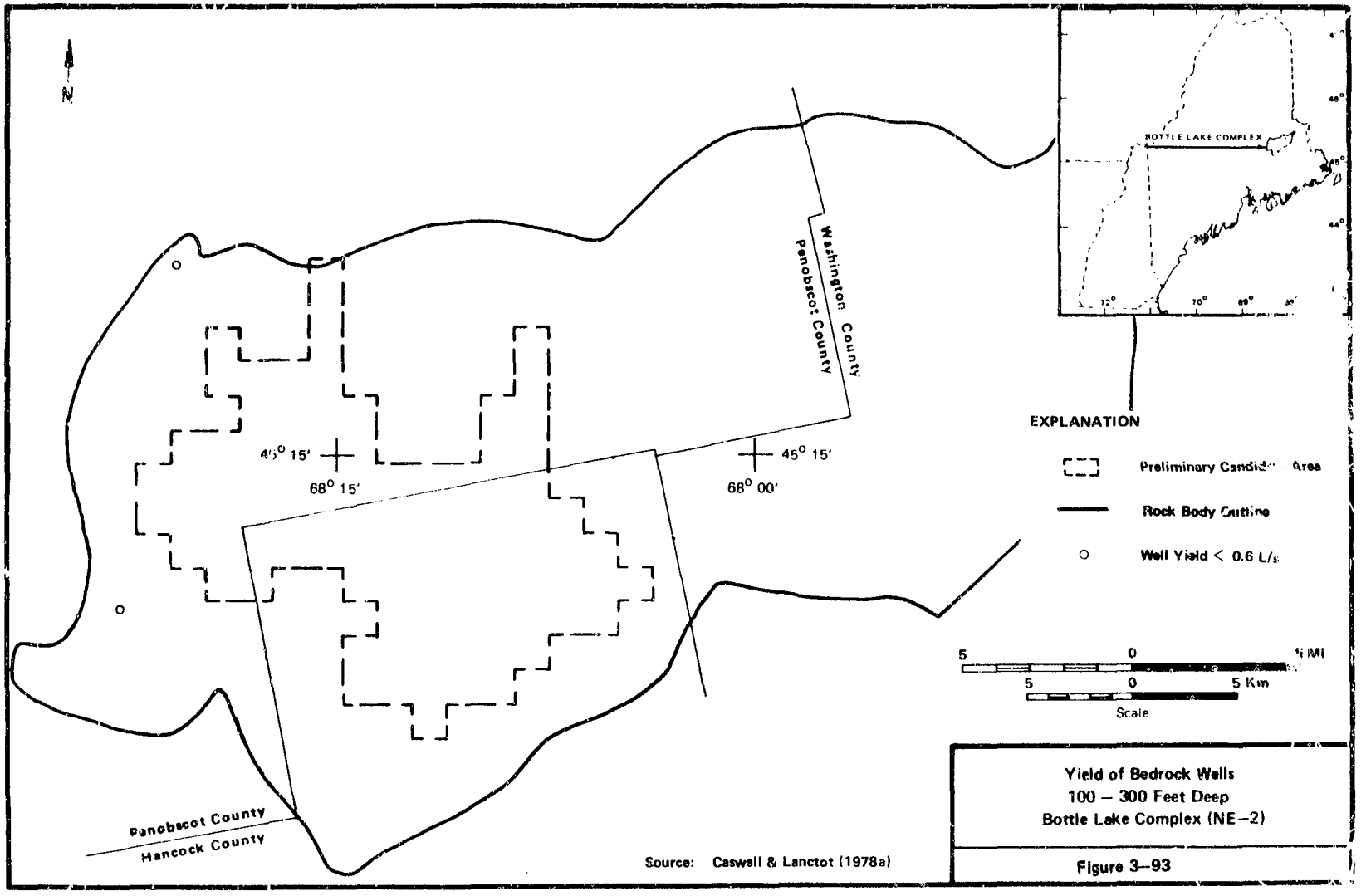
The majority of the wetlands contained within this region correspond to the floodplains of the Passadumkeag River. The "1,000-Acre Heath", a concentration of wetlands, occupies the area between the eastern and western portions of the preliminary candidate area. Despite the occurrence of these wetlands, a significant portion of the preliminary candidate area is well drained and appears not to lie in flood prone areas.

The preliminary candidate area is of sufficient size (see Section 3.2.2.2.1) to allow significant flexibility in siting a repository.

3.2.2.2.6 Ground-Water Resources. The regional hydrology is discussed in section 3.2.2.1.1.5. Ground-water resource maps compiled by Caswell and Lanctot (1978c) provide hydrologic data for approximately 15% of the Bottle Lake Complex. These maps supply information concerning location, depths, and yields of bedrock wells for the extreme western portion of the rock body. Published information is available only for the northwestern portion of the preliminary candidate area. Two wells are located adjacent to the western boundary of the rock body (Caswell and Lanctot, 1978c), outside the limits of the preliminary candidate area (Figure 3-93).

The available data (Caswell and Lanctot, 1978c) indicate that both wells have yields of less than 0.63 L/s (10 gpm) and total depths (the depth of a well drilled through overburden and into the underlying bedrock) of between 30 and 90 m (100 and 300 ft).

Sand and gravel aquifer maps, published by the Maine Geological Survey (Tolman and Lanctot, 1981c; 1981d) provide data for approximately



Yield of Bedrock Wells
100 – 300 Feet Deep
Bottle Lake Complex (NE–2)

Figure 3–93

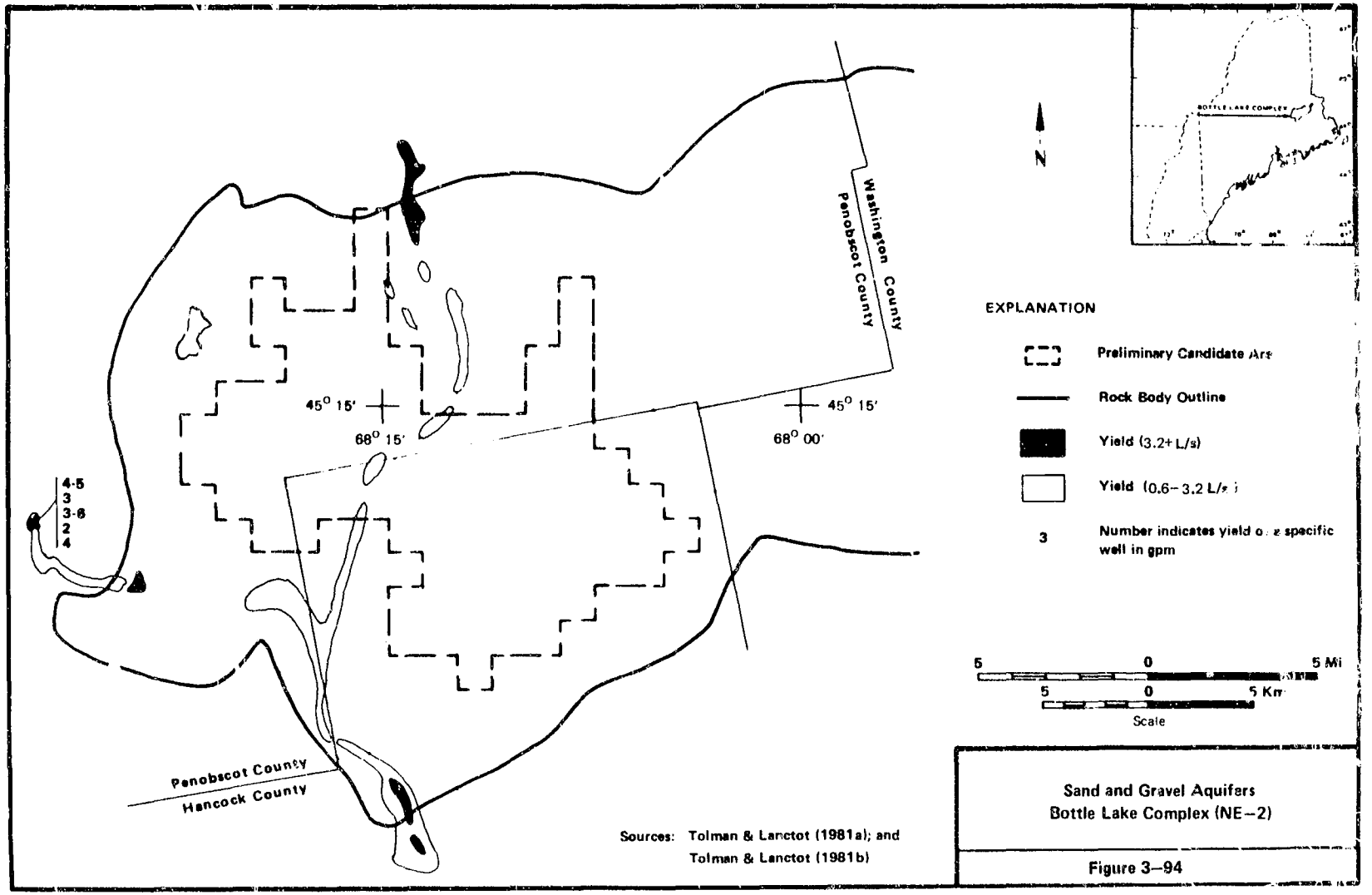
The preliminary candidate area is of sufficient size (see Section 3.2.2.2.1) to allow significant flexibility in siting a repository.

3.2.2.2.6 Ground-Water Resources. The regional hydrology is discussed in section 3.2.2.1.1.5. Ground-water resource maps compiled by Caswell and Lanctot (1978c) provide hydrologic data for approximately 15% of the Bottle Lake Complex. These maps supply information concerning location, depths, and yields of bedrock wells for the extreme western portion of the rock body. Published information is available only for the northwestern portion of the preliminary candidate area. Two wells are located adjacent to the western boundary of the rock body (Caswell and Lanctot, 1978c), outside the limits of the preliminary candidate area (Figure 3-93).

The available data (Caswell and Lanctot, 1978c) indicate that both wells have yields of less than 0.63 L/s (10 gpm) and total depths (the depth of a well drilled through overburden and into the underlying bedrock) of between 30 and 90 m (100 and 300 ft).

Sand and gravel aquifer maps, published by the Maine Geological Survey (Tolman and Lanctot, 1981c; 1981d) provide data for approximately 50% of the Bottle Lake Complex (80% of the preliminary candidate area). The distribution of surficial aquifers within and adjacent to the preliminary candidate area is shown on Figure 3-94.

Within the Bottle Lake Complex surficial aquifers have been reported in the western portion of the rock body (published data are not available for the eastern portion of the rock body). Surficial aquifers (Figure 3-94) are narrow, elongate north- to northeast-trending features, and are generally associated with rivers, streams, lakes, ponds, and swamps. Yields associated with surficial aquifers in the Bottle Lake Complex are reported as 0.63 to 3.2 L/s (10 to 50 gpm) and greater than 3.2 L/s (50 gpm). The data, as shown on Figure 3-94, indicate yields ranging from 0.63 to 3.2 L/s (10 to 50 gpm) for the majority of the sand



Sand and Gravel Aquifers
Bottle Lake Complex (NE–2)

Figure 3–94

and gravel aquifers in the vicinity of the Bottle Lake Complex. Individual well yields from five shallow wells located several kilometers west of the rock body boundary (Figure 3-94) are, however, generally less than 0.63 L/s (10 gpm). The surficial aquifers reported in the Bottle Lake Complex are restricted to the boundaries of the preliminary candidate area. No "high" yield zones (greater than 6.3 L/s or 100 gpm), as evidenced by individual well yield data, are observed within or adjacent to the Bottle Lake Complex.

Based on preliminary interpretations regarding regional ground-water movement, the preliminary candidate area is located away from major discharge zones. The data indicate that aquifers are present and that ground-water sources suitable for irrigation or human consumption are present.

3.2.2.2.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition, vertical crustal movements, denudation rates, and changes in sea level, are discussed in Section 3.2.2.1.1.1.

3.2.2.2.8 Federal Lands. There are no Federal lands greater than 130 ha (230 ac) in size located in or within 10 km (6 mi) of the preliminary candidate area. Federal lands which do occur in Maine are depicted in Plate 2A of the Northeastern RECR (DOE, 1985f) or are listed in Appendix A of that report. In addition, there is no evidence in the data base that Federal lands less than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.

3.2.2.2.9 State Lands. There are no disqualified State lands located within the preliminary candidate area. However, portions of three unnamed State forests lie within the preliminary candidate area. These forests lie near the northwest, southwest, and southeast boundaries of the preliminary candidate area, totalling approximately 2,000 ha (5,000 ac), or about 9% of the area. Four unnamed State forests are within 1.6 km (1 mi) of the preliminary candidate area (three to the

north and one to the south. Two segments of the Machias Outstanding Wild and Scenic River pass within 10 km (6 mi) to the southeast of the preliminary candidate area. All features described above are greater than 130 ha (320 ac) in size and are depicted on Plates 3A or 4A of the Northeastern RECR (DOE, 1985f) (see also Figure 3-95). There is no evidence in the data base that State lands less than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.

3.2.2.2.10 Environmental Compliance. Parts of the preliminary candidate area lie near current air quality nonattainment areas. Specifically, parts of Penobscot County are nonattainment for total suspended particulates (TSP) and sulfur dioxide. However, the nonattainment areas are not believed to include the preliminary candidate area (40 CFR 81.320, 1985). There are no Prevention of Significant Deterioration (PSD) Class I Areas within 40 km (25 mi) of the preliminary candidate area. No existing or proposed National Register of Historic Places (NRHP) exist within the preliminary candidate area. There is one potential archaeological site (Maine Archaeological Survey Site) at an undisclosed location in Penobscot County (50 FR 8866, 1985); it is not known whether or not this site is located within the preliminary candidate area. No National Trails are located within 40 km (25 mi) of the preliminary candidate area.

3.2.2.2.11 Population Density and Distribution. The preliminary candidate area contains no highly populated areas. There is one highly populated area, Lincoln, which is located 13 km (8 mi) northwest of the preliminary candidate area; Lincoln has a population of 3,524 (see Figure 3-95). The preliminary candidate area contains no areas with population densities greater than or equal to 1,000 persons per square mile. There are also no areas with population densities greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area. Bangor is located approximately 48 km (30 mi) southwest of the preliminary candidate area. Areas with population densities greater than or equal to 1,000 persons per square

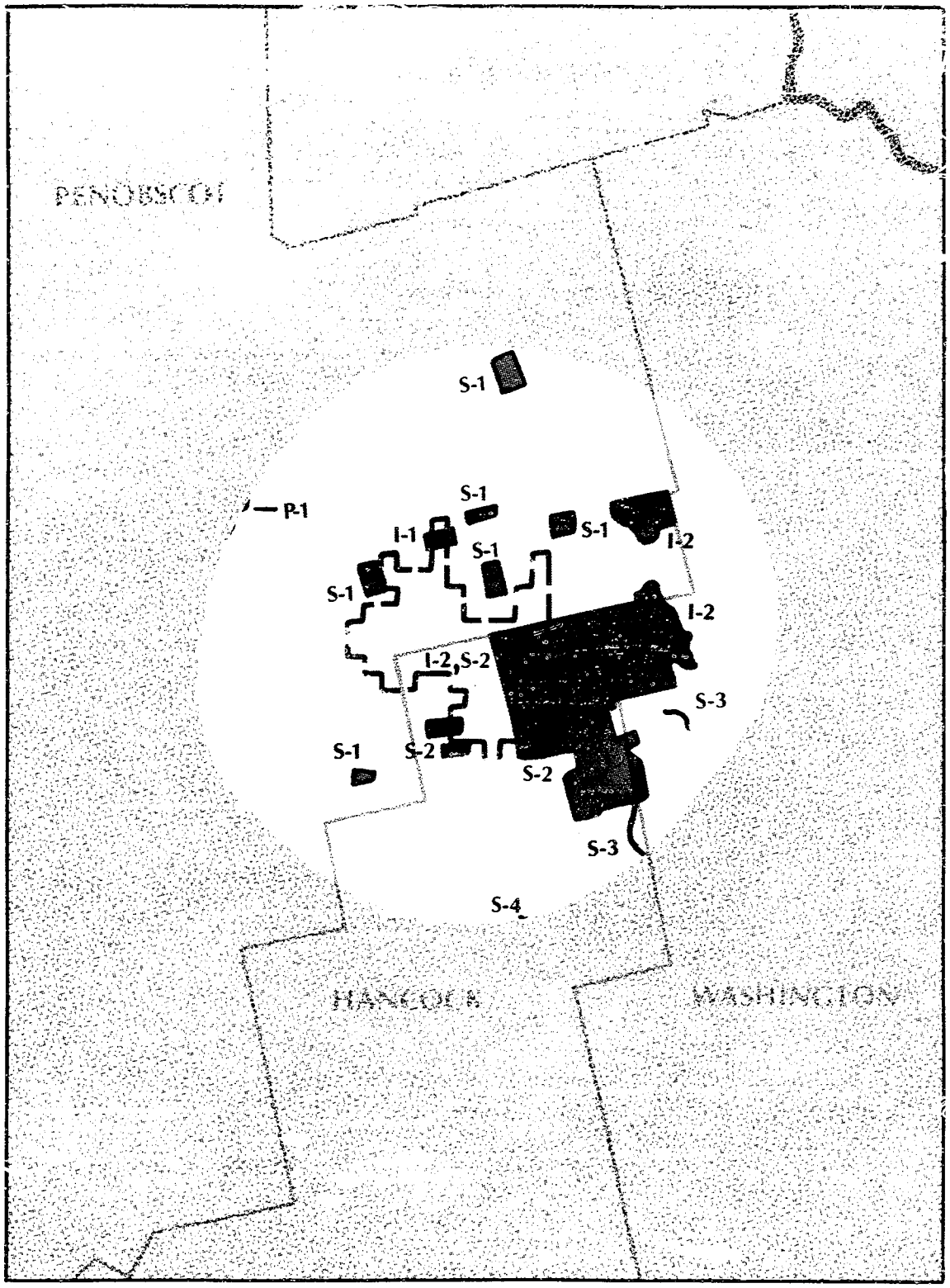


Figure 3–95 Sheet 1

Environmental Features
Bottle Lake Complex (NE-2)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3–95 Sheet 2

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI)
OF PRELIMINARY CANDIDATE AREA NE-2*

Code	Feature
Population Features	
P-1	Lincoln Highly Populated Area (HPA)
Federal Lands	
None	
State Lands	
S-1	Unnamed State Forests in Penobscot County
S-2	Unnamed State Forests in Hancock County
S-3	Machias Outstanding (Wild and Scenic) River
S-4	Narraguagus Outstanding (Wild and Scenic) River
Indian Reservations	
I-1	Penobscot
I-2	Passamaquoddy

* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

Figure 3-95, sheet 3

mile in Maine are depicted on Plate 6A of the Northeastern RECR (DOE, 1985f). The average population density of the preliminary candidate area is less than 1 person per square mile. The average population density within 80 km* (50 mi) of the preliminary candidate area is approximately 23 persons per square mile. Low population density is defined as a density in the general region of the preliminary candidate area less than the average population density of the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.2.2.12 Site Ownership. There are no Federal or DOE-owned lands located within the preliminary candidate area. There are two Federally recognized Indian Reservations located within the preliminary candidate area. The Penobscot Reservation occupies approximately 250 ha (600 ac) in the northeastern portion of the preliminary candidate area. The Passamaquoddy Reservation lies in the eastern half of the preliminary candidate area, covering approximately 6,100 ha (15,000 ac). Together, Federal Indian Reservations occupy approximately 27% of the preliminary candidate area. The remainder of the Passamaquoddy Reservation segment adjoins the eastern boundary of the preliminary candidate area; another segment lies approximately 6 km (4 mi) to the northeast (see Figure 3-95).

3.2.2.2.13 Offsite Installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Maine Yankee which is approximately 177 km (110 mi) to the southwest (Wamsley, 1985; Electrical World Directory of Electric Utilities, n.d.). The nearest commercial nuclear reactor under

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* The density calculation does not include the portion of the 80 km (50 mi) area that passes into Canada.

construction is the Seabrook Nuclear Plant which is approximately 322 km (200 mi) to the south-southwest (Wamsley, 1985; New Hampshire Department of Resources and Economic Development, 1981). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.2.2.14 Transportation. The nearest interstate highway (I95) is located about 24 km (15 mi) to the west of the preliminary candidate area. The closest U.S. highway to the preliminary candidate area is U.S. 2, which is located 13 to 21 km (8 to 13 mi) west of the preliminary candidate area. U.S. 1 circles the area at a distance of 32 to 64 km (20 to 40 mi). State Route 6 is located about 32 km (20 mi) north of the preliminary candidate area; this is a major State highway in the region connecting Lincoln (at the junction of U.S. 2) and Topsfield, Maine (where it crosses U.S. 2). State Route 9, another principal highway, is over 32 km (20 mi) to the south of the preliminary candidate area, but truck traffic is prohibited on this road. State Route 188 (which is not shown on the plot) terminates at Saponac, Maine, and is within a couple of kilometers (miles) of the western edge of the preliminary candidate area.

The nearest mainline railroad is the Canadian Pacific Railroad's mainline which runs east and west through central Maine. This line is about 19 to 27 km (12 to 17 mi) north of the preliminary candidate area. The Bangor and Aroostook Railroads' mainline is located approximately 35 m (22 mi) west of the preliminary candidate area. The nearest branchline railroad is the Main Central Railroad which parallels U.S. 2 north of Bangor. This line is about 14 km (9 mi) west of the preliminary candidate area. This branchline connects with the Canadian Pacific mainline at Mattawamkeag, Maine.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.2.2.15 [illegible] Additional Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NE-2 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggests that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]

- absence of [illegible] earthquakes that, if they recurred, could produce ground motion [illegible] levels of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)]
- absence of State lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- a majority of the preliminary candidate area is beyond 16 km (10 mi) from highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(b)(2) and (c)(2)].
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]

- no prob[illegible]nership conflicts that cannot be successfully re[illegible]ved thro[illegible] voluntary purchase-sell agreements, nondisputed agency-to-agency transfer of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2), 960.5-2-7(b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NE-2 at this time.

3.2.2.3 Preliminary Candidate Area Description - Sebago Lake Batholith (NE-4)

The Sebago Lake batholith is located in both the Central Highlands and the Coastal Lowlands physiographic provinces and lies in Androscoggin, Cumberland, and Oxford Counties in southern Maine, and in Carroll County in eastern New Hampshire. The preliminary candidate area identified in the Sebago Lake batholith is located entirely within Maine at approximately 44°02' N latitude and 70°34' W longitude.

3.2.2.3.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area shown on Figure 3-96 has an area of approximately 1,000 km^2 (385 mi^2). Gravity models of the Sebago Lake batholith suggest that it is a subhorizontal, broadly arched sheet on the order of 1 km (0.62 mi) thick (Hodge et al., 1982; Hayward and Gaudette, 1984). Geologic cross-sections suggest an east-northeast dip for the Sebago Lake batholith (Moench and Zartman, 1976; Creasy, 1979; Osberg et al., 1984) and introduce the possibility that the body may reach a thickness of up to 5 km (3 mi) (Creasy, 1979). Gravity models of two small, felsic intrusives that lie within 15 km (9 mi) of the eastern border of the batholith reveal similar, east-dipping, sheet-like geometry (Figure 3-97). These small bodies are thought to be cupolas of a larger sheet-like mass of granitic material and are interpreted to thicken to 2 km (1.2 mi) with depth (Hodge et al., 1982).

Approximately 7% of the Sebago Lake batholith either has exposed bedrock or is covered by less than 3 m (10 ft) of surficial deposits (Thompson and Borns, 1984). Much of this area lies within or adjacent to the southern portion of the preliminary candidate area (Figure 3-98).

Contours of overburden thickness (Figure 3-99) for the eastern half of the Sebago Lake batholith indicate that the majority of this area has less than 6 m (20 ft) of overburden (Caswell and Lanctot, 1978a, b). These areas generally have moderate bedrock relief (greater than 90 m [300 ft]). Overburden thickness in areas of low bedrock relief (less

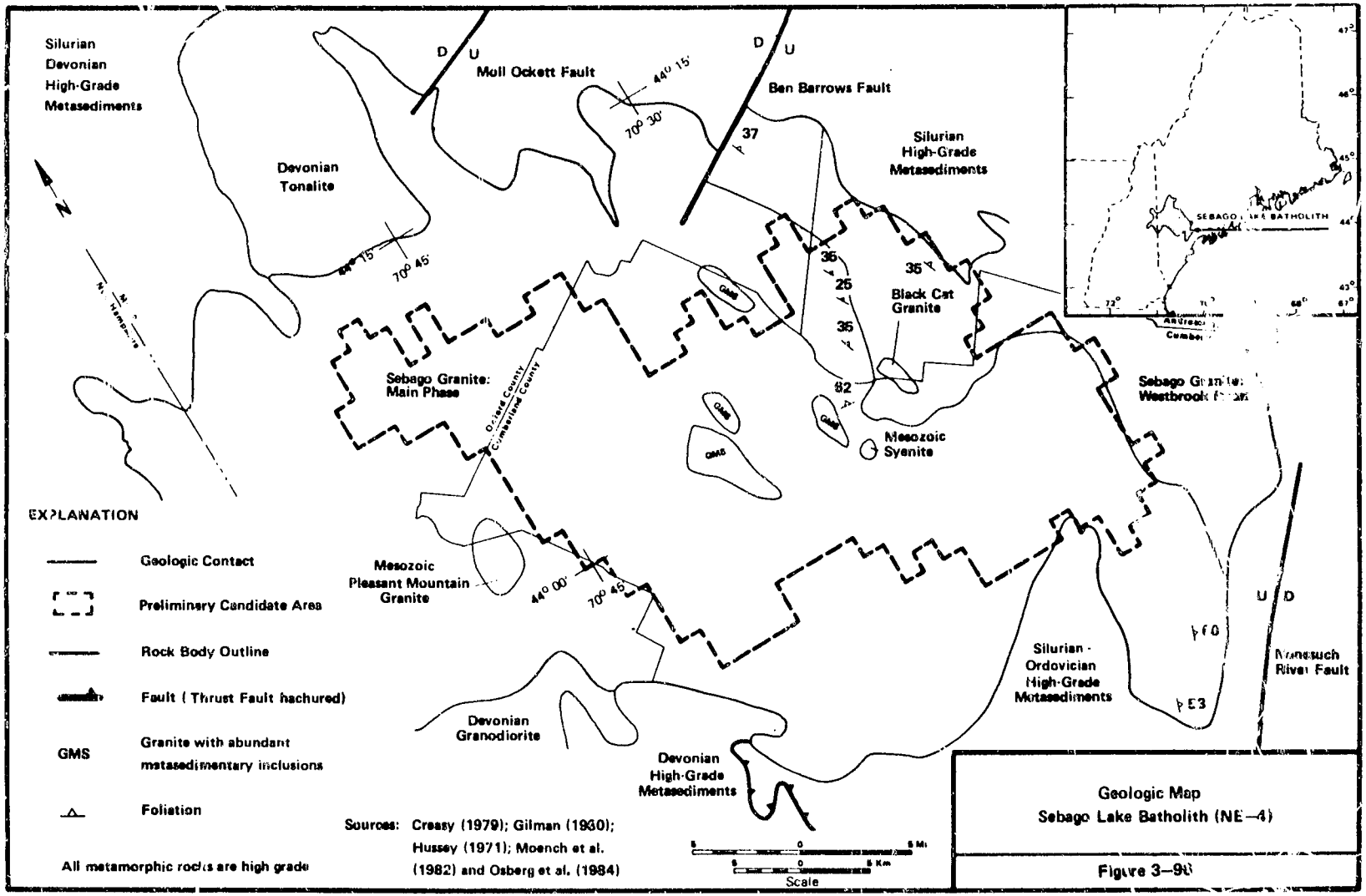
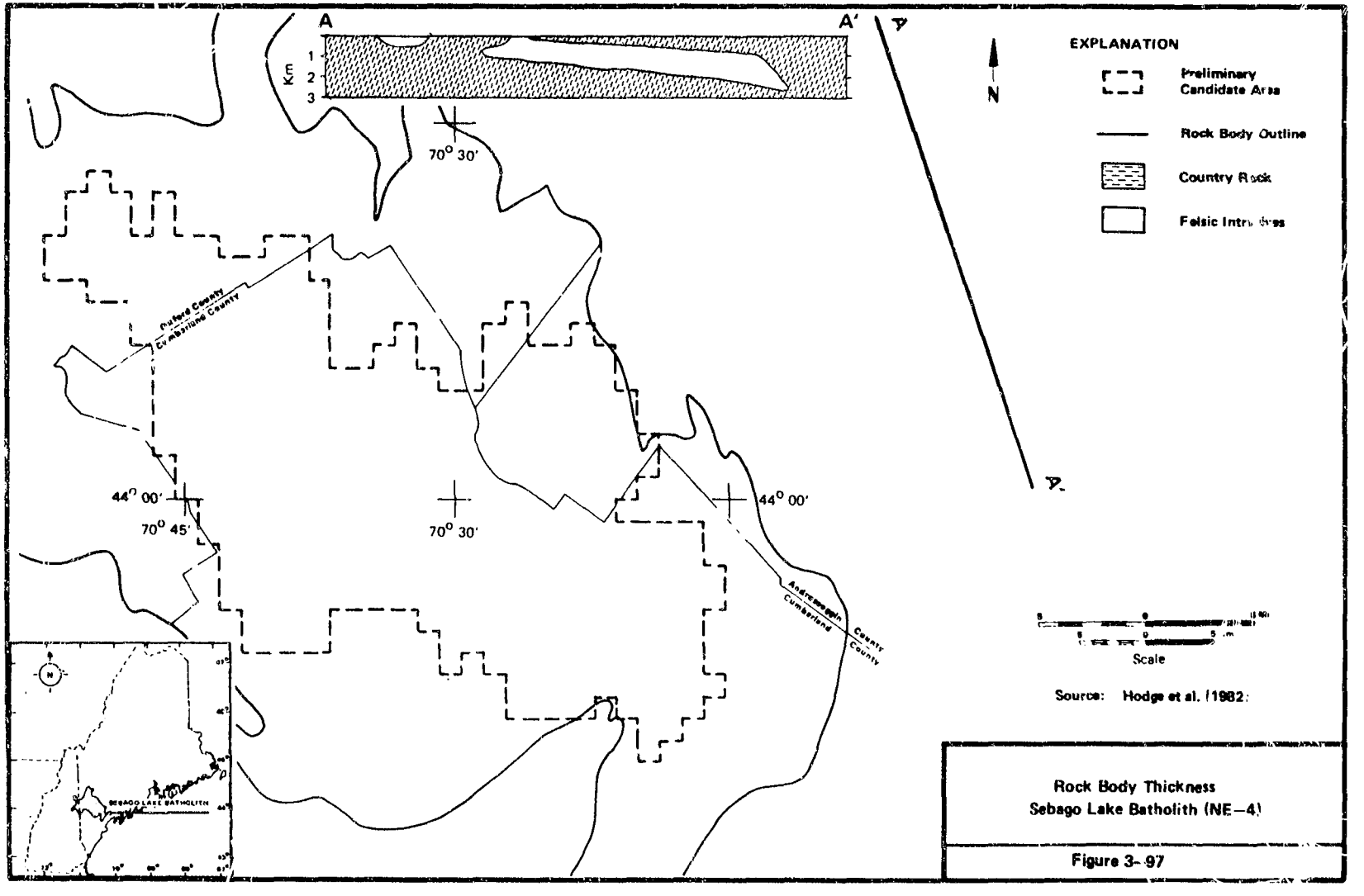
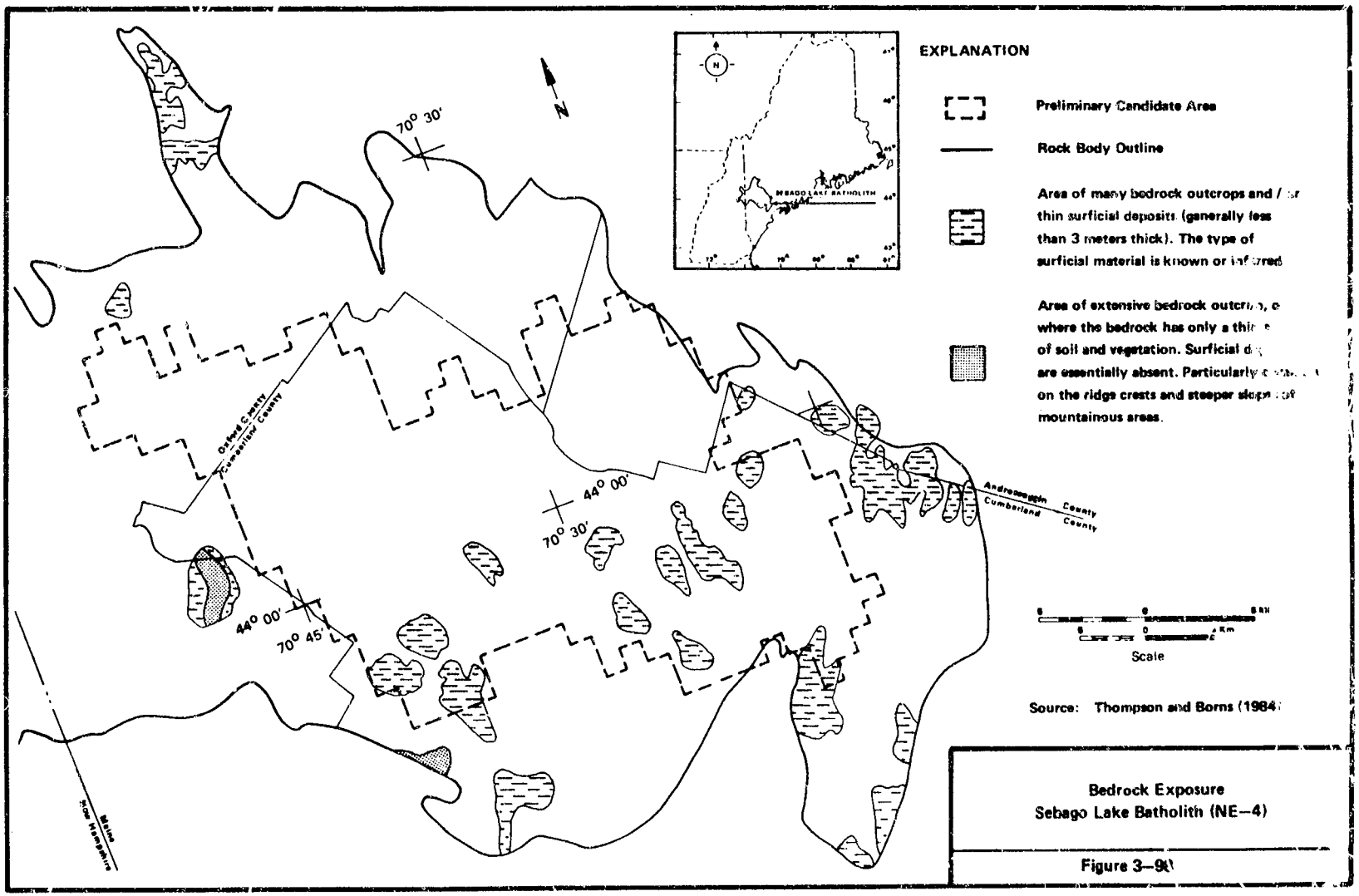

Silurian
Devonian
High-Grade
Metasediments
Devonian
Tonalite
Moll Ockett Fault
Ben Barrows Fault
Silurian
High-Grade
Metasediments
Black Cat
Granite
Sebago Granite:
Main Phase
Mesozoic
Syenite
Mesozoic
Pleasant Mountain
Granite
Devonian
Granodiorite
Devonian
High-Grade
Metasediments
Silurian -
Ordovician
High-Grade
Metasediments
Ransuch
River Fault
Oxford County
Cumberland County
44° 15'
70° 30'
44° 15'
70° 45'
44° 00'
70° 45'
37
35
25
35
35
82
EXPLANATION
Geologic Contact
Preliminary Candidate Area
Rock Body Outline
Fault (Thrust Fault hachured)
GMS
Granite with abundant
metasedimentary inclusions
Foliation
All metamorphic rocks are high grade
Sources: Creasy (1979); Gilman (1980);
Hussey (1971); Moench et al.
(1982) and Osberg et al. (1984)
Scale
Geologic Map
Sebago Lake Batholith (NE—4)

Figure 3–98



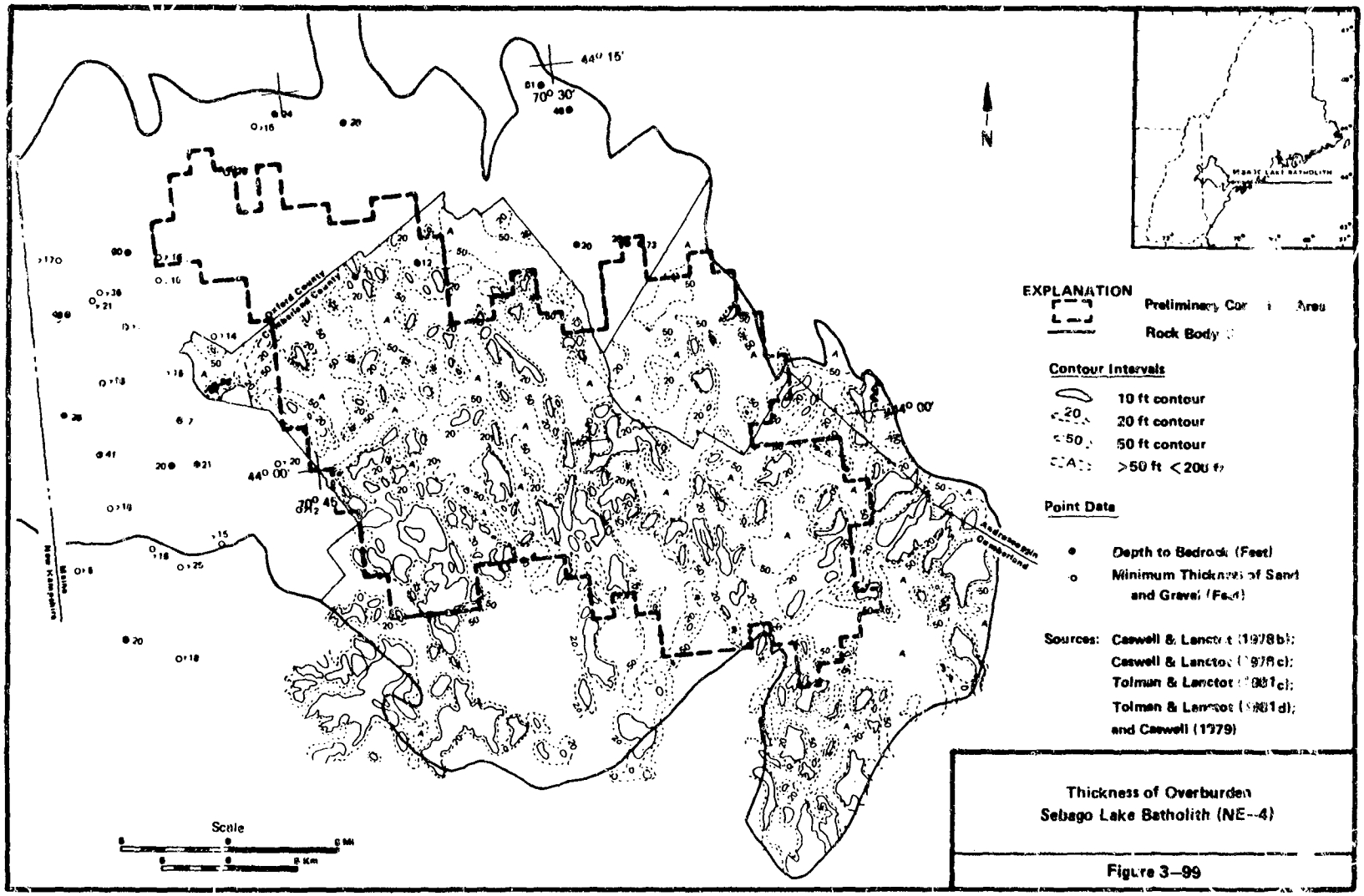
Rock Body Thickness
Sebago Lake Batholith (NE–4)

Figure 3-97



Bedrock Exposure
Sebago Lake Batholith (NE–4)

Figure 3–9



Thickness of Overburden
Sebago Lake Batholith (NE--4)

Figure 3–99

than 90 m [300 ft]) commonly ranges from 15 to 60 m (50 to 200 ft). The data for the western half of the batholith are limited to point source information of either depth to bedrock or minimum thickness of sand and gravel. Depth to bedrock exceeds 8 m (26 ft) in only seven of 16 locations where data are available, and the maximum depth is 25 m (81 ft) (Tolman and Lanctot, 1981a, 1981b; Caswell, 1979). Of 16 minimum thickness data points, only three have values greater than 8 m (26 ft) and the greatest thickness is 52 m (170 ft) (Figure 3-97). Most of the surficial deposits in the eastern half of the batholith consist of till, with the exception of a large, north-northeast-trending arc of glacial outwash. To the west, the surficial deposits are much more complex and include both till and ice-contact deposits, as well as paludal deposits and alluvium (Thompson and Borns, 1984).

On the basis of the data presented above, and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the rock of the preliminary candidate area is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

3.2.2.3.2 Lithology and Tectonics. The Sebago Lake batholith is a medium-grained, equigranular, gray, biotite-muscovite granite to quartz monzonite granodiorite (Hussey, 1971; Creasy, 1979) composed of plagioclase, quartz, microcline, biotite, muscovite and minor amounts of garnet, sillimanite, zircon, apatite and opaques (Gilman, 1977). The batholith consists of two mineralogically similar facies, the main phase of the Sebago granite and the Westbrook phase. The Westbrook phase is distinguished from the main phase on the basis of textural variations, and abundance of metasedimentary inclusions. The majority of the preliminary candidate area (Figure 3-96) is underlain by the main phase of the Sebago granite which is generally homogeneous in texture. The Westbrook phase, which forms the eastern boundary of the batholith, exhibits greater textural variation, ranging from medium grained to

pegmatitic in outcrop. Metasedimentary inclusions that may exceed 100 m (328 ft) in diameter and account for up to 40% of a given outcrop characterize the Westbrook Phase (Creasy, 1979). Metasedimentary inclusions are also locally abundant in the main phase granite but generally account for less than 2 to 4% of a given outcrop (Creasy, 1979). Contact relations between the main phase and the Westbrook phase are irregular and gradational (Hussey, 1981).

The origin of the Sebago Lake batholith is attributed to anatectic melting of country rock at deep crustal levels; an interpretation based on the presence of the abundant metasedimentary inclusions found in the Westbrook phase (Creasy, 1979). The magma appears to have been emplaced diapirically, displacing and deforming overlying metasediments as it migrated upward. Along the eastern margin of the batholith, this deformation caused asymmetric refolding of pre-existing, northeast-trending folds about northwest-trending axes (Creasy, 1979). Both the Sebago Lake batholith and the country rock are cut by pegmatites. In the country rock, pegmatites are generally tabular bodies which lie parallel to the lithologic banding of the host rock. Cross-cutting relationships have been observed in some outcrops northwest of the Bon Barrows fault where northwest-trending folds are cross-cut by pegmatites (Creasy, 1979).

The Sebago Lake batholith intruded the rocks of the Merrimack synclinorium during the Carboniferous Period, apparently after the peak of Acadian deformation. A radiometric age determination (U-Pb method on zircon) fixes the age of intrusion 325 million years (Aleinikoff, 1984). The Merrimack synclinorium, a large-scale structure formed during the Acadian orogeny, is underlain by a suite of Ordovician- to Devonian-aged metasedimentary rocks. The metasedimentary units consist of calc-silicate granulites, micas, schists, gneisses, granofels, and migmatites (Guidotti, 1965; Osberg et al., 1984; Creasy, 1979), which were regionally metamorphosed to sillimanite or sillimanite + K-feldspar grade during the Acadian orogeny (Creasy, 1979). Acadian-aged

deformation resulted in the development of a regional pattern of northeast-trending, large-scale anticlines and synclines (Guidotti, 1965; Creasy, 1979). On a small scale, the deformation is characterized by gently plunging upright isoclinal folds. Although the structural pattern in the country rock surrounding the pluton is complex, most folds south of the Sebago Lake batholith trend northeast, parallel to the regional trend (Hussey, 1971).

The preliminary candidate area is not affected by any known faults. Beyond the boundary of the preliminary candidate area, the northeastern edge of the batholith is partly cut by the Ben Barrows and Moll Ockett faults (Figure 3-96). These northeast trending faults lie approximately 12 km (7 mi) apart and may have resulted from localized stresses imparted to the country rock by the forceful emplacement of the batholith (Creasy, 1979). A preintrusive, east-dipping thrust fault (Figure 3-96) is truncated by the southern boundary of the pluton (Osberg et al., 1984). The Ben Barrows fault partly bounds the batholith for approximately 3 km (2 mi) and extends 7 km (4.3 mi) into the granite (Figure 3-96) (Osberg et al., 1984). The fault is documented as the basis of offset lithologic contacts and silicified zones (Creasy, 1979). The fault is interpreted to be a high-angle structure, and has 1 to 2 km (0.6 to 1.2 mi) of vertical displacement (Creasy, 1979). The Moll Ockett fault cuts the batholith for a distance of less than 3 km (2 mi) and is interpreted to be a normal fault, dipping 60 to 80 degrees to the northwest, and down-dropped to the south (Guidotti, 1965). Evidence for this fault includes sharp topographic and lithologic breaks, brecciated zones, a break in structural style, and strong retrograde metamorphic effects in a 1- to 2-km (0.6- to 1.2-mi) wide zone running the length of the fault (Hussey, 1981; Guidotti, 1965). These effects include the alteration of biotite to chlorite, and feldspar to sericite (Guidotti, 1965).

The Nonesuch River fault, about 10 km (6 mi) from the eastern boundary of the preliminary candidate area, is a postmetamorphic

(Hussey, 1981), north- ...g fault which parallels the southeastern border of the Sebago Lake ...olith (Figure 3-96). Osberg et al. (1984) suggest that the batholith dips to the southeast beneath the overlying country rock, where it may be cut by this fault. Evidence for the Nonesuch River fault includes the juxtaposition of garnet grade rocks to the west with chlorite and biotite grade rocks to the east, the presence of silicified and sheared zones, the gentle dip of the strata to the west as opposed to the steep dip of the strata to the east, and the straight course of the Nonesuch River (Hussey, 1971). Osberg et al. (1984) indicate that the northern extension of the Nonesuch River fault is a normal fault with the south side down-dropped.

The Sebago Lake batholith is moderately foliated to massive. The foliation generally strikes northeast, parallel to contacts with adjacent metasediments and dips 25 to 40 degrees to the east (Creasy, 1979; Hussey, 1971; Guidotti, 1965)). Commonly, the development of the foliation is intensified near joints (Hussey, 1971). Well developed joints are present in both phases of the Sebago Lake batholith (Creasy, 1979; Hussey, 1971.) Major sets trend east-west, N40°60'W, and N15°30'E, and commonly are filled with vein quartz (Hussey, 1971; Gilman, 1977). Triassic aged diabasic and basaltic dikes, ranging up to 5 m (16 ft) in width, intrude both the pluton and country rock (Creasy, 1979; Gilman, 1965). These steeply dipping, northeast-trending dikes are traceable for hundreds of meters (Creasy, 1979; Gilman, 1977; Guidotti, 1965).

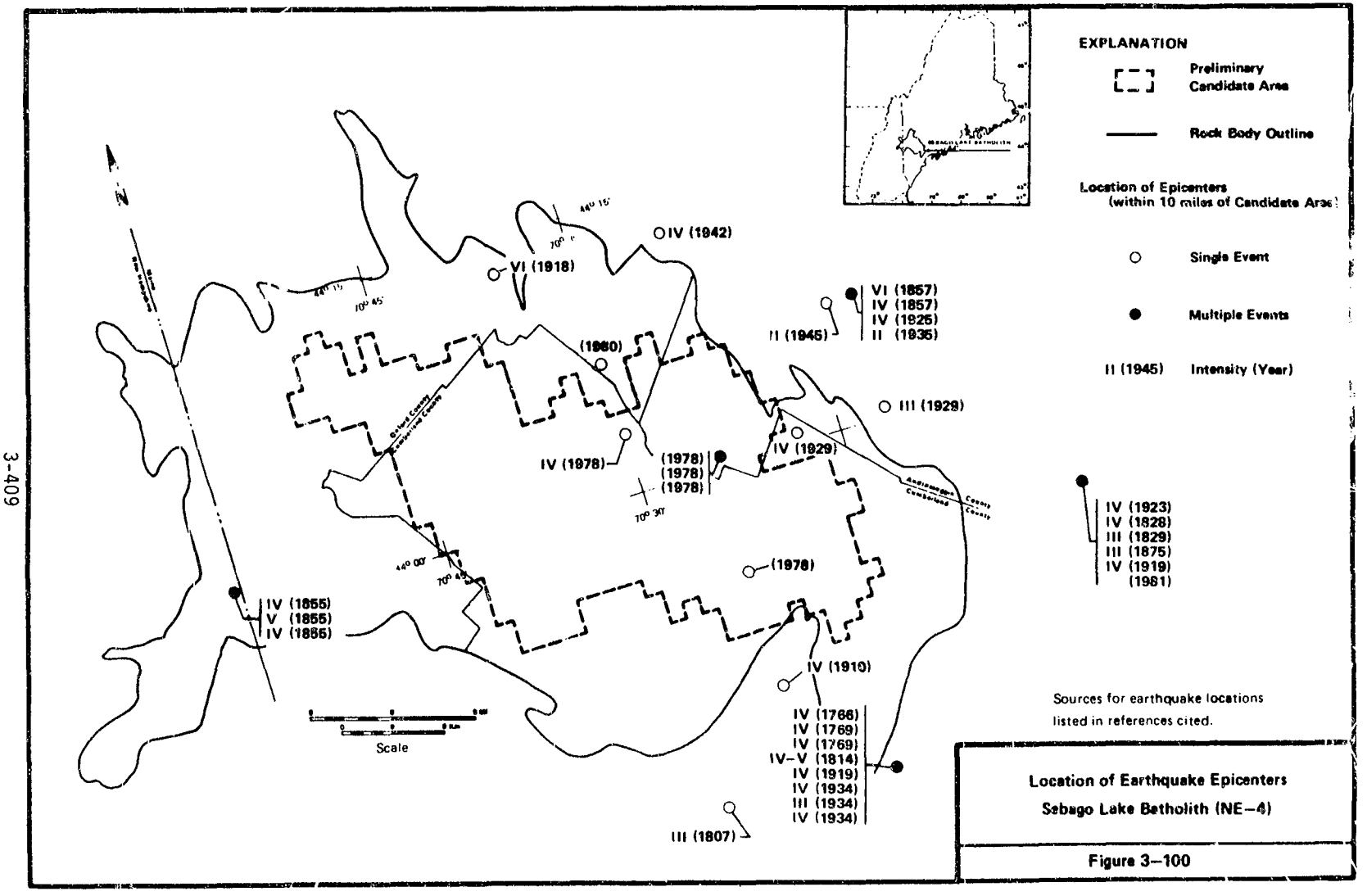
Vertical crustal movement in the region is influenced by several factors, including continental glaciation and active tectonic processes, as well as by sea level changes which occur in response to these factors. Uplift rates in the vicinity of the Sebago Lake batholith (Figure 3-84) are less than 1 mm (0.04 in) per century (Gable and Hatton, 1983). Studies along coastal Maine suggest the possibility of a tectonic component of vertical movement (Anderson et al., 1984). Estimates of vertical movement (from all probable sources) inferred from geodetic data

suggest possible subsidence at a rate of less than 1 mm (0.04 in) per year in the vicinity of the Sebago Lake batholith (Figure 3-85). If such activity were to continue at the inferred rate, net subsidence over the next 10,000 years would be less than 10 m (33 ft). This amount of vertical movement is probably insignificant with respect to repository performance. There are no in situ stress data available for the vicinity of the preliminary candidate area.

The preliminary candidate area is located in an intraplate tectonic setting. There is no evidence of igneous activity or tectonic deformation during the Quaternary Period. Additionally, no correlation is known to exist between seismicity and known geologic structures (see Section 3.2.2.1.1.3). Vertical crustal motions have been inferred in the vicinity of the preliminary candidate area, but the rates and magnitude of these processes are low. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.2.3.3 Seismicity. Regional aspects of seismicity and neotectonics are discussed in Section 3.2.2.1.1.3. The evidence presented indicates that large uncertainties associated with the location and size of earthquakes in the eastern United States make it necessary to discuss their distribution with respect to geologic features, in a broad rather than specific sense.

Earthquake epicenters identified within the vicinity of the preliminary candidate area are shown on Figure 3-100. The locations of the epicenters, which are drawn from both instrumental and historical records, are poorly known. The accuracy and reliability of earthquake locations documented in the historical record are strongly influenced by population distribution. As population increases, so does the ability to accurately locate epicenters. The apparent spatial coincidence of repeated earthquake activity, shown on Figure 3-100, is probably a result



Location of Earthquake Epicenters
Sebago Lake Batholith (NE–4)

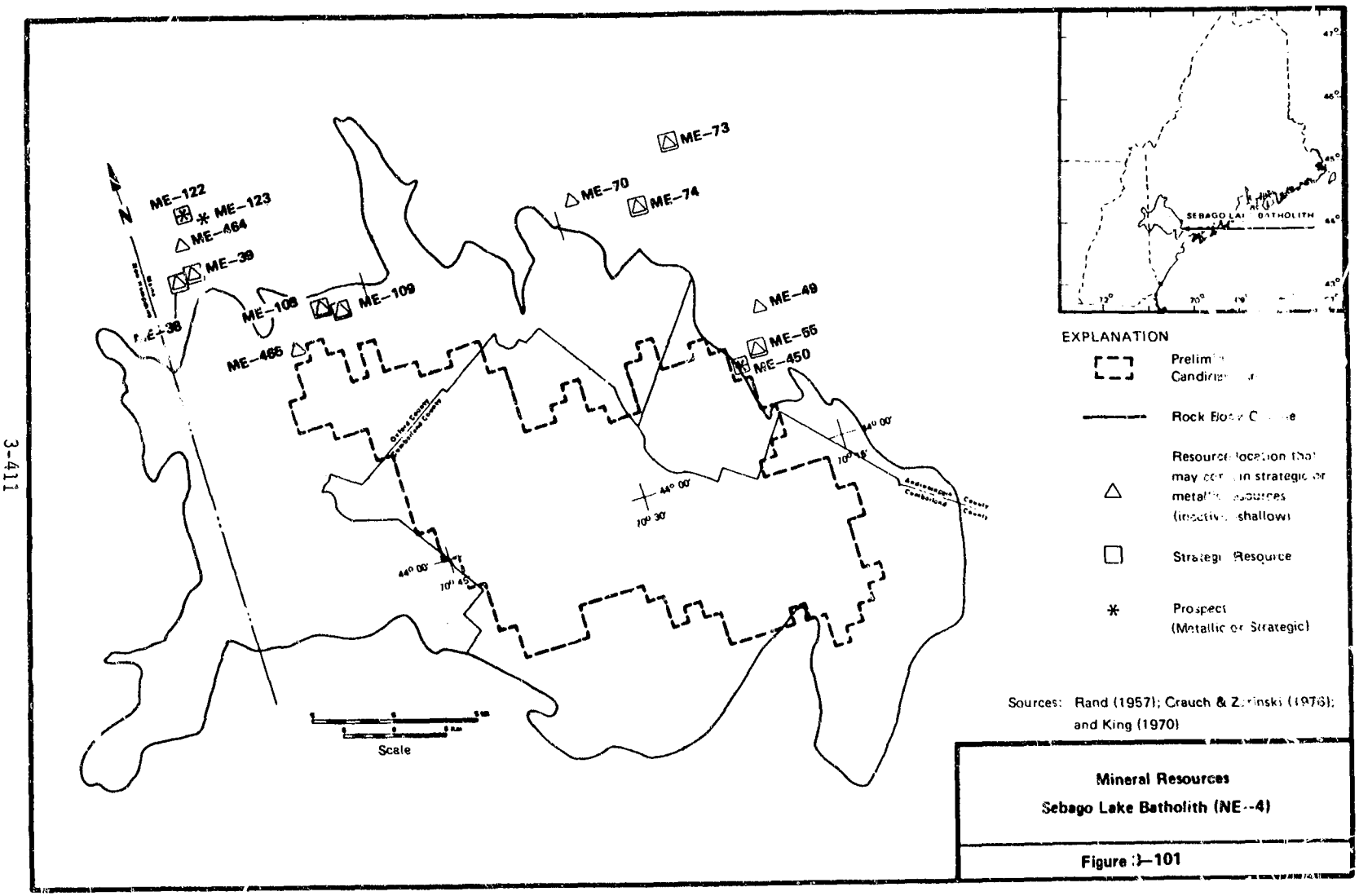
Figure 3–100

of population patterns. [illegible] of the earthquakes located within 16 km (10 mi) of the preliminary candidate area are interpreted to have intensities of MM IV.

There is no evidence for Quaternary surface displacements in the geologic setting. No correlations are known between earthquakes and documented geologic structures or tectonic processes in the geologic setting. Earthquake foci in the regional setting occur at depths that far exceed repository horizons. Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity could produce ground motion in excess of reasonable design limits.

3.2.2.3.4 Mineral Resources. All potential strategic, metallic, and energy-related resources known to occur within 10 km (6 mi) of the preliminary candidate area are shown on Figure 3-101. These consist of three prospects and 11 inactive operations, all of which are less than 100 m (328 ft) in depth (Rand, 1957; Grauch and Zarinski, 1976; King, 1970). No disqualified mines or quarries are located within the preliminary candidate area. The nearest deep mine or quarry is 86 km (55 mi) east of the preliminary candidate area.

ME 465 (Figure 3-101) is the potential resource site located adjacent to the boundary of the preliminary candidate area and consists of an uranium-bearing pegmatite (Grauch & Sarinski, 1976). The 13 remaining potential resource locations, which consist of nine strategic minerals (ME 38, 39, 55, 73, 74, 108, 109, 122, and 450) and four uranium occurrences (ME 49, 70, 123, and 464), are within 10 km (6 mi) of the preliminary candidate area boundary (Figure 3-101). The strategic resources have been identified based on their potential for containing either pyrite, columbite, molybdenum, chalcopyrite, cassiterite, magnetite and/or pyrrhotite. None of the potential resource locations reported in the vicinity of this preliminary candidate area is unique to



Mineral Resources

Sebago Lake Batholith (NE--4)

Figure 3-101

the Northeastern Region. One 300-m (984-ft) deep exploratory borehole is located in the preliminary candidate area adjacent to the north central portion of its northern boundary (Roseboom et al., 1985). The location of this borehole is 44°3' N latitude and 70°31' W longitude.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources within the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation.

3.2.2.3.5 Topography and Surface Water Characteristics. Topographic relief within the preliminary candidate area is low to moderate, with elevations ranging between 62 and 394 m (200 and 1,280 ft). Low hills are common in the northwest section of the preliminary candidate area, where elevations range between 122 and 389 m (400 and 1,280 ft). The central, southeast, and northeast portions are generally low-lying; elevations range from 62 to 308 m (200 and 1,000 ft), but tend to be less than 152 m (500 ft).

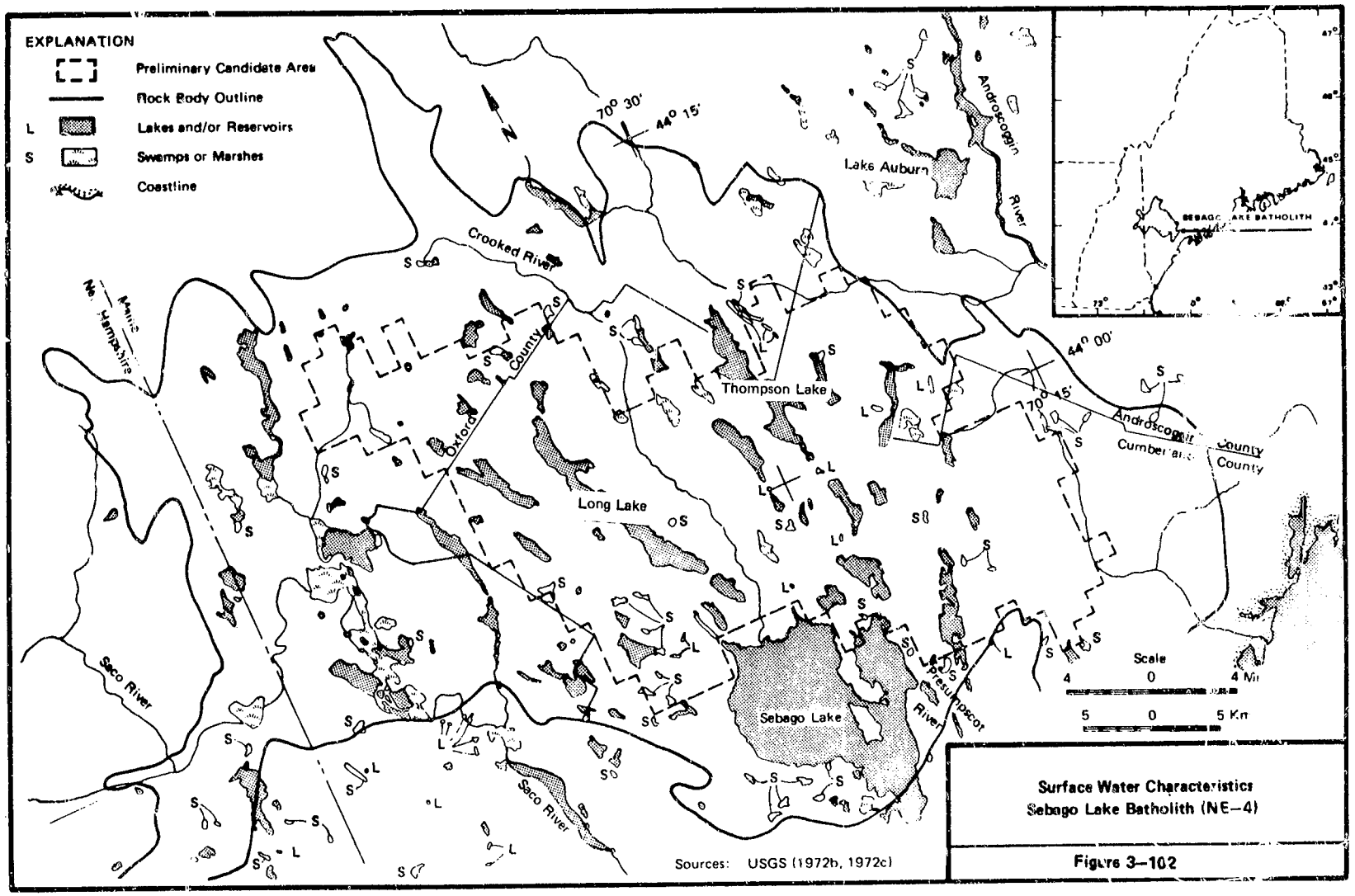
The Sebago Lake batholith is drained by the Androscoggin, Presumpscot, and Saco Rivers. Approximately 25% of the preliminary candidate area comprising the northwest portion is drained by a series of southwest-flowing streams and lakes which exhibit a dendritic drainage pattern. These streams drain into the Saco River. Stream valleys are moderately steep-sided and "V" shaped. Relief is sufficient to provide extensive areas that are in no danger of flooding by minor streams. The preliminary candidate area is well drained, contains few swamps, and no major floodplains. The remaining 75% consists of the low-lying southeast, northeast and central portions of the preliminary candidate area which drain south-southeast. These areas of low relief are characterized by broad, flat stream valleys which contain many lakes and scattered swamps. Drainage patterns are typically dendritic.

As represented by [illegible] area screening data base, the preliminary candidate area [illegible] less than 1% surface water and 0% wetland. The location of lakes, rivers, and wetlands in the preliminary candidate area on Figure 3-102 are based on surface water features shown on USGS land use maps.

Most of the wetlands are concentrated in the northeast and central portions of the preliminary candidate area (Figure 3-102). These areas of low topographic relief may be subject to flooding by minor streams. However, the data presented in this section indicate that the terrain of the preliminary candidate area is generally well drained and the preliminary candidate area is of sufficient size to allow significant flexibility in siting a repository.

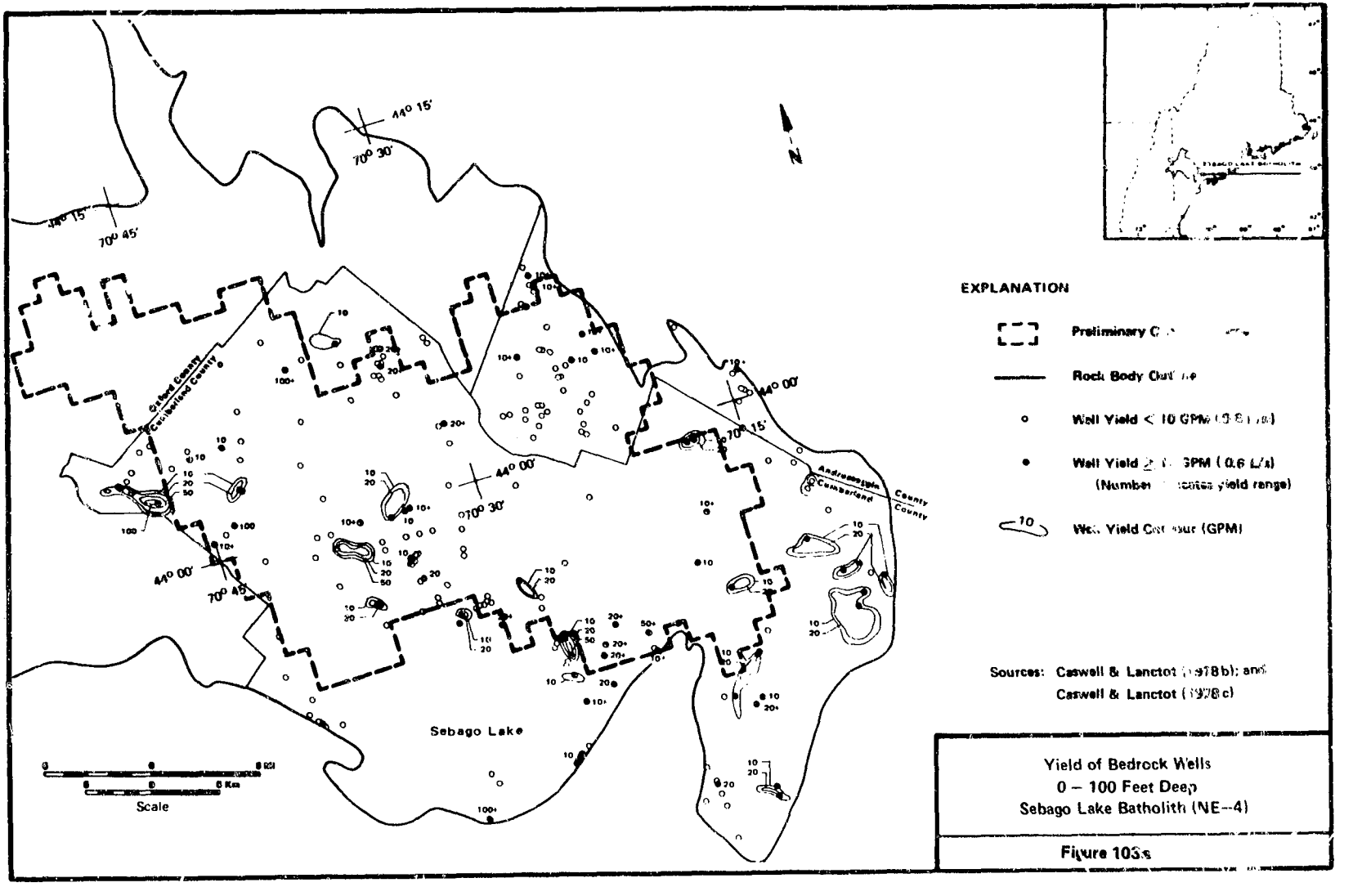
3.2.2.3.6 Ground-Water Resources. The regional hydrology is discussed in section 3.2.1.1.1.5. Ground-water resource maps, compiled by Caswell and Lanctot (1978a; 1978b) provide hydrologic information including location, depth, and yield of bedrock wells, as well as bedrock surface topography and overburden thickness data for approximately 75% of the Sebago Lake batholith. Data are available for approximately 1,000 wells completed in bedrock within the Sebago Lake batholith. Of these, 484 are located within the preliminary candidate area. Figures 3-103a, 3-103b, and 3-103c, show yields of wells drilled through overburden into underlying bedrock at depths ranging to greater than 90 m (300 ft). Within the Sebago Lake batholith as a whole, as well as in the portion identified as the preliminary candidate area, wells most commonly have a depth of 30 to 90 m (100 to 300 ft). Those which exceed 90 m (300 ft) in depth comprise 18% of the wells completed in the entire rock body, and 15% within the preliminary candidate area.

Ground-water yields from wells completed in bedrock indicate that greater than 70% of all wells located within the preliminary candidate area have yields of less than 0.63 L/s (10 gpm). Within the preliminary candidate area, well yields may reach as high as 12.6 L/s (200 gpm). The



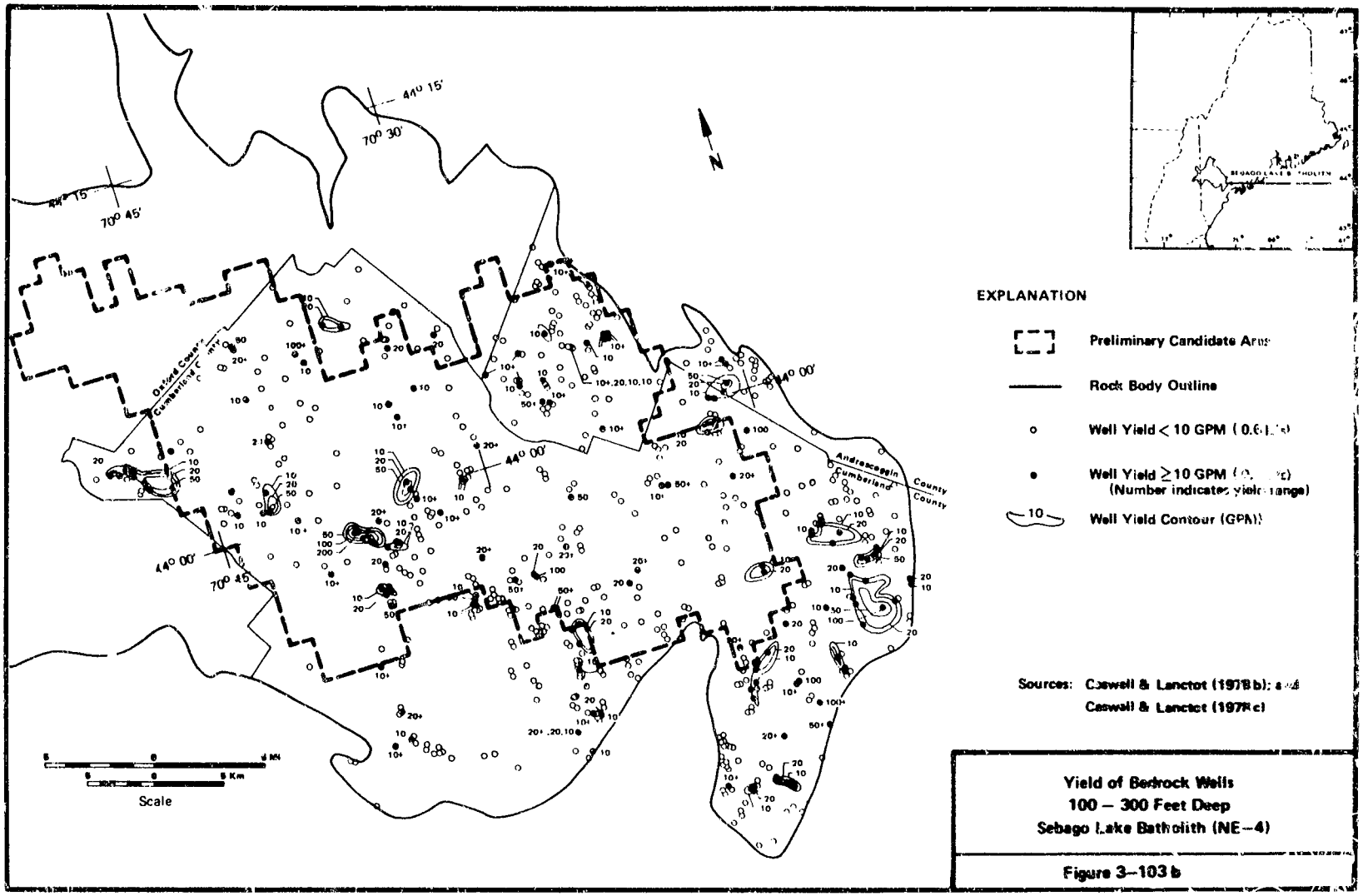
Surface Water Characteristics
Sebago Lake Batholith (NE–4)

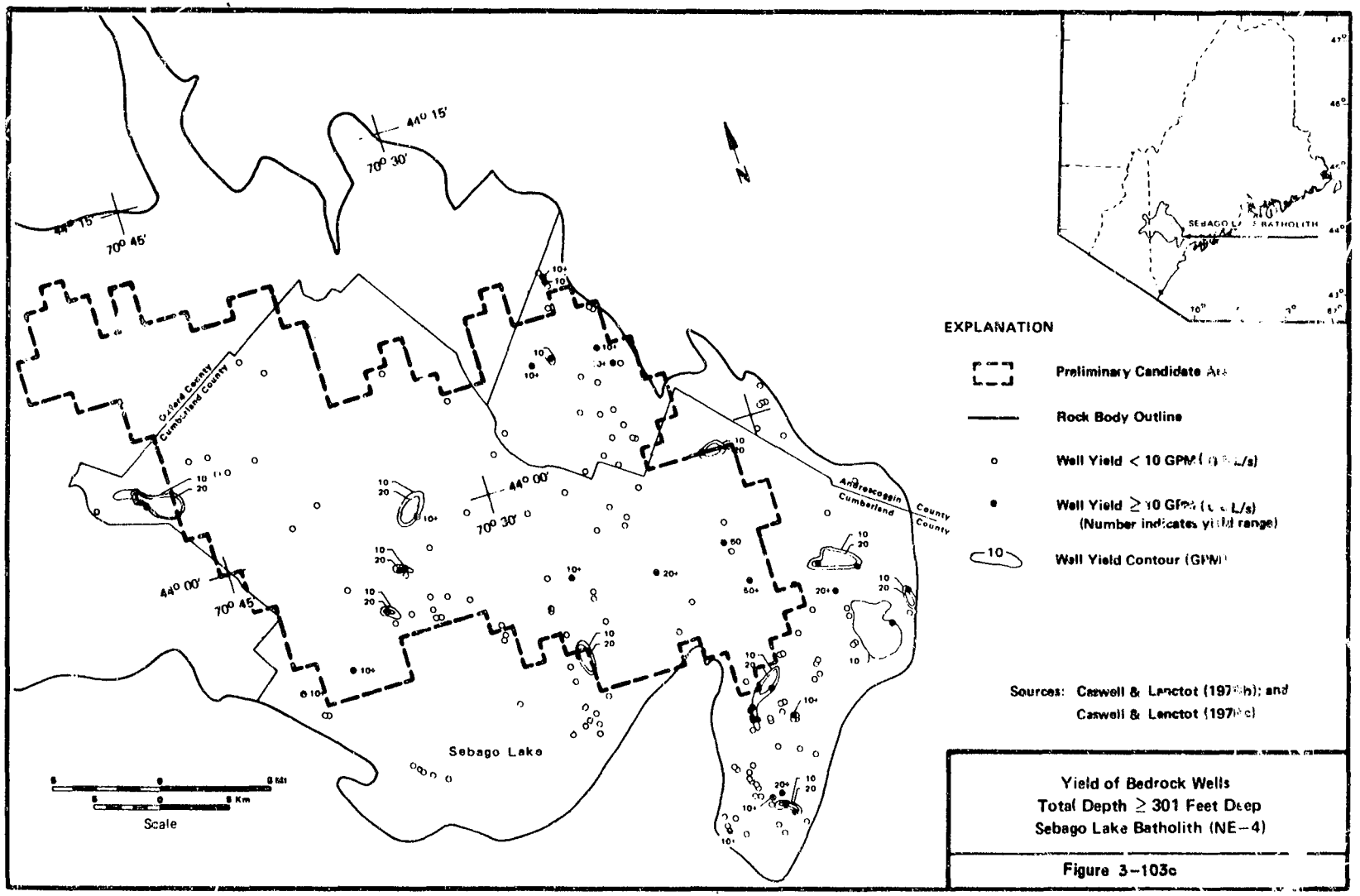
Figure 3–102



Yield of Bedrock Wells
0 – 100 Feet Deep
Sebago Lake Batholith (NE--4)

Figure 103


44° 15'
70° 30'
44° 15'
70° 45'
44° 00'
44° 00'
70° 45'
N
Androscoggin County
Cumberland County
Oxford County
EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Well Yield < 10 GPM (0.6 L/s)
Well Yield ≥ 10 GPM
(Number indicates yield range)
10
Well Yield Contour (GPM)
Sources: Caswell & Lanctot (1978b); and
Caswell & Lanctot (1978c)
Scale
Yield of Bedrock Wells
100 – 300 Feet Deep
Sebago Lake Batholith (NE–4)
Figure 3–103 b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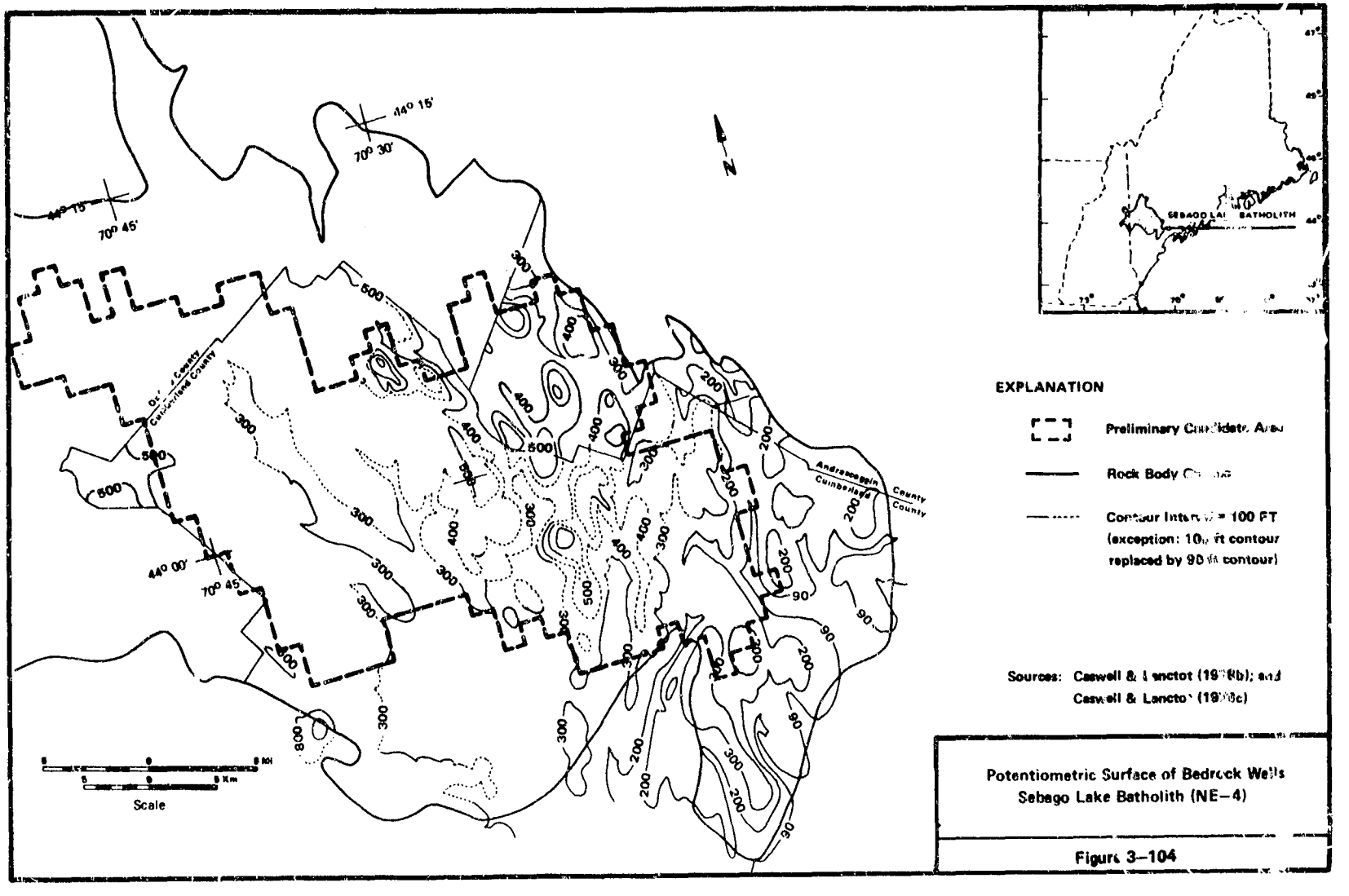
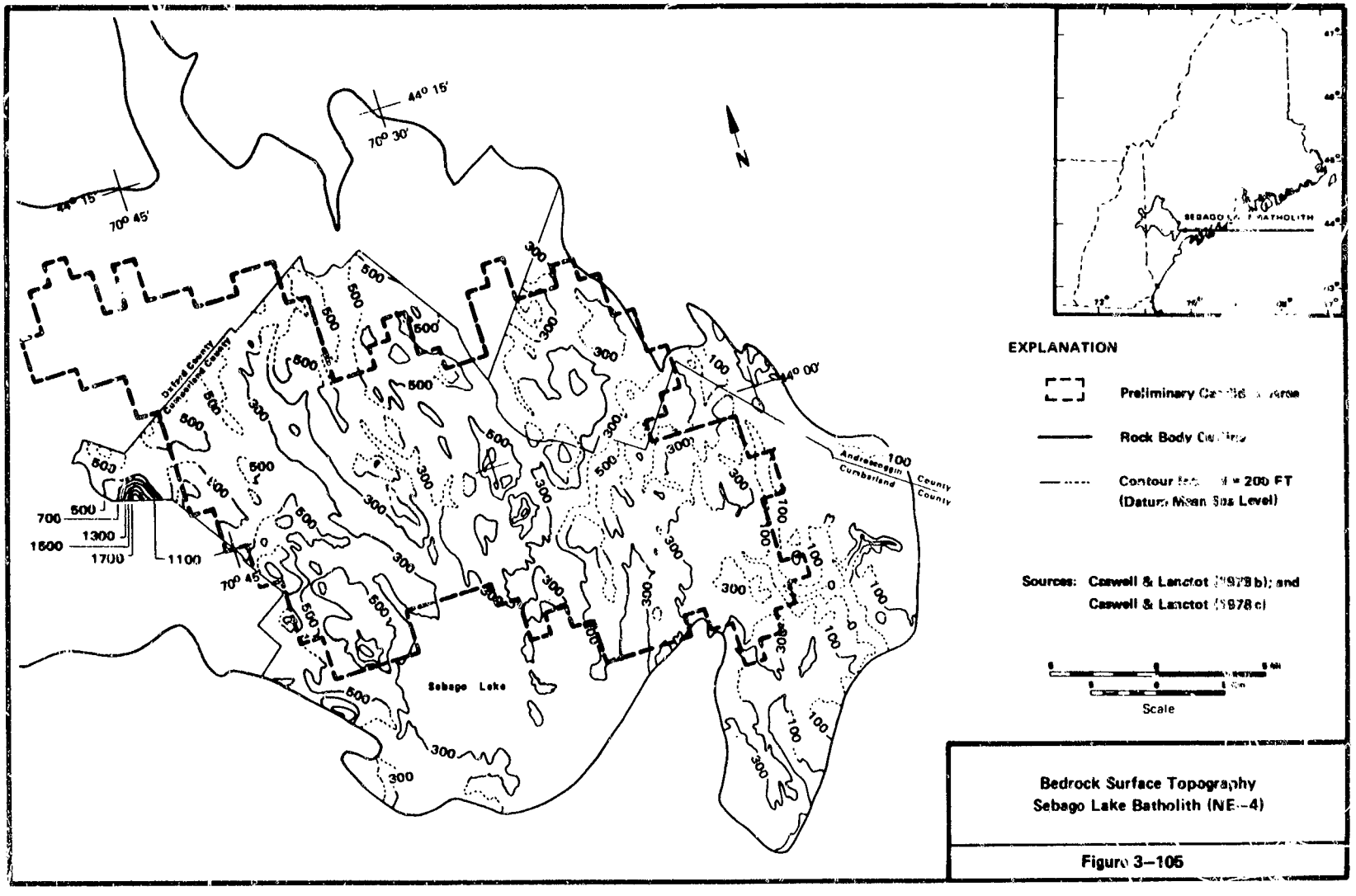
70° 30'
44° 00'
70° 45'
N
Oxford County
Cumberland County
Androscoggin County
Cumberland County
Sebago Lake
Scale
EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Well Yield < 10 GPM
Well Yield ≥ 10 GPM
(Number indicates yield range)
10
Well Yield Contour (GPM)
Sources: Caswell & Lanctot (1978b); and
Caswell & Lanctot (1978c)
Yield of Bedrock Wells
Total Depth ≥ 301 Feet Deep
Sebago Lake Batholith (NE–4)
Figure 3–103c

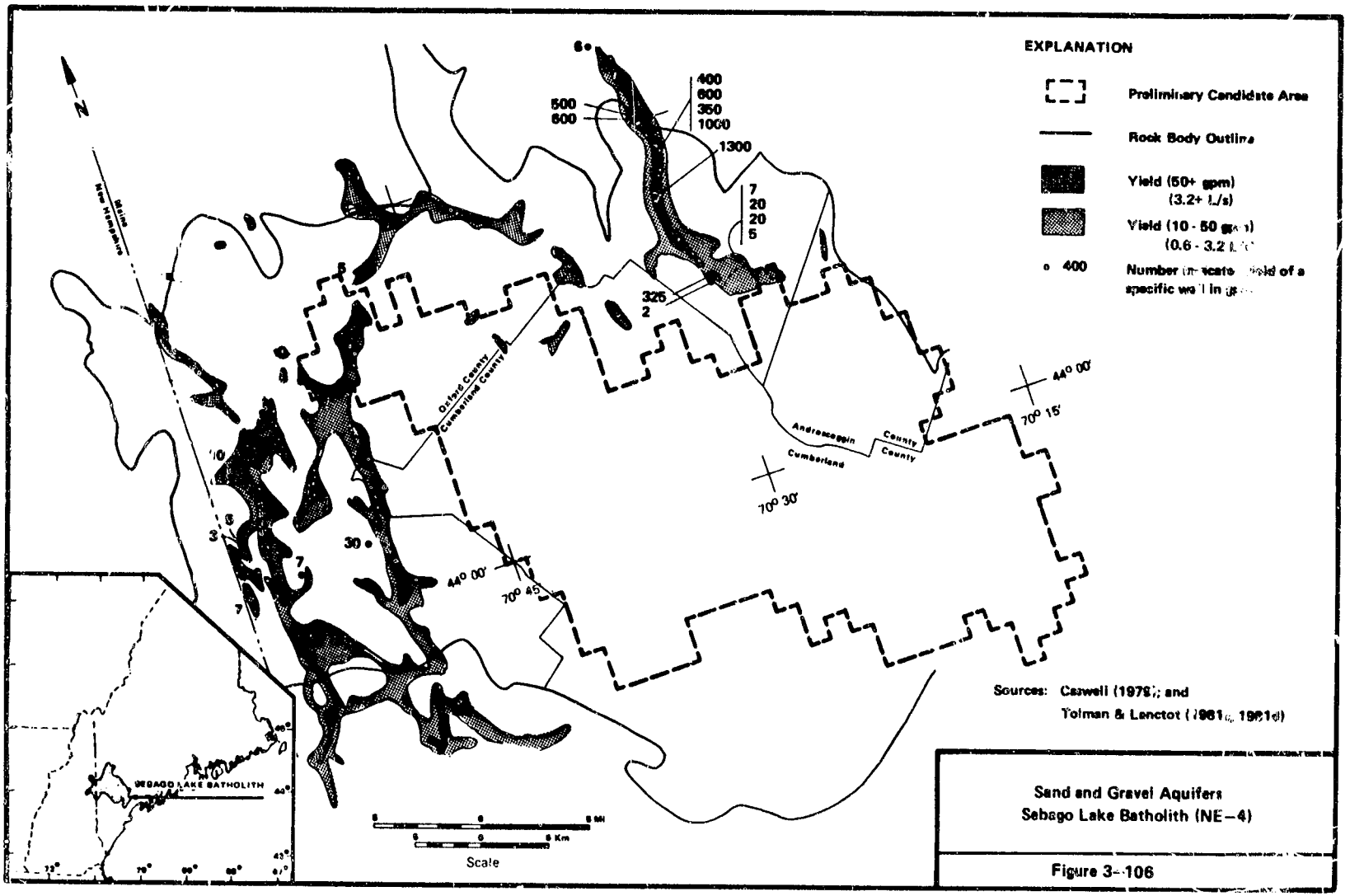
available information indicates that yields from bedrock wells vary with location and depth. The distribution of "high" yield zones, as shown by yield contours on Figure 3-103a through 3-103c, do not suggest the existence of major water-bearing fractures within the preliminary candidate area. Analysis of yield versus depth indicates that yields generally decrease with increasing depth. This implies that the abundance of interconnected fracture systems (and their ability to transmit water) decreases with depth. Figure 3-104 shows the potentiometric surface of shallow bedrock wells drilled in the Sebago Lake batholith and indicates that the near-surface ground-water flow direction is toward the Atlantic Ocean. This is in agreement with flow directions inferred from bedrock surface topography. Regional analogies of deeper ground-water flow also suggest a low hydraulic gradient toward the Atlantic Ocean (see Section 3.2.2.3.5 above and Figure 3-105).

Sand and gravel aquifer maps (Caswell, 1979; Tolman and Lanctot, 1981a; 1981b) are available for the northern and western portions of the Sebago Lake batholith. The surficial aquifers are elongate features that are localized and restricted in extent, generally coinciding with rivers and streams. Most of the reported surficial aquifers which overlie the Sebago Lake batholith occur outside the preliminary candidate area boundary. The data indicate yields ranging from 0.63 to 3.2 L/s (10 to 50 gpm) for the majority of sand and gravel aquifers (Figure 3-106). Data for 22 shallow wells indicate that greater than 40% have yields of less than 0.6 L/s (10 gpm). A zone with yields in excess of 6.4 L/s (100 gpm), is restricted to the north central portion of the rock body and does not transect the preliminary candidate area.

Based on preliminary interpretation regarding regional ground-water movement, the preliminary candidate area is located away from major discharge zones. Ground-water resources are present in the preliminary candidate area. These resources include a small area of surficial aquifers in the preliminary candidate area. Wells in bedrock indicate that near-surface fractures can yield water. The data also suggest that


44° 15'
70° 30'
44° 15'
70° 45'
44° 00'
70° 45'
N
SEBAGO LAKE BATHOLITH
EXPLANATION
Preliminary Candidate Area
Rock Body Contact
Contour Interval = 100 FT
(exception: 100 ft contour
replaced by 90 ft contour)
Sources: Caswell & Lanctot (1978b); and
Caswell & Lanctot (1978c)
Scale
Potentiometric Surface of Bedrock Wells
Sebago Lake Batholith (NE–4)
Figure 3–104


44° 15'
70° 30'
44° 15'
70° 45'
N
44° 00'
70° 45'
Androscoggin County
Cumberland County
Sebago Lake
700
500
1300
1500
1700
1100
100
0
300
500
EXPLANATION
Preliminary Caswell & Lanctot (1978a) Rock Body Outline
Rock Body Outline
Contour Interval = 200 FT (Datum: Mean Sea Level)
Sources: Caswell & Lanctot (1978b); and Caswell & Lanctot (1978c)
Scale
Bedrock Surface Topography
Sebago Lake Batholith (NE-4)
Figure 3-105


EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Yield (50+ gpm)
(3.2+ L/s)
Yield (10 - 50 gpm)
(0.6 - 3.2 L/s)
400
Number indicates yield of a specific well in gpm
Sources: Caswell (1978); and
Tolman & Lanctot (1981c, 1981d)
Sebago Lake Batholith (NE-4)
Scale
Figure 3-106

ground-water conditions in the vicinity of the preliminary candidate area will not pose significant problems during construction.

3.2.2.3.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition, vertical crustal movements, denudation rates and changes in sea level is in Section 3.2.2.1.1.1.

3.2.2.3.8 Federal Lands. There are no Federal lands located within the preliminary candidate area. The closest Federal land is the White Mountain National Forest which is located 5 km (3 mi) to the northwest of the preliminary candidate area. This feature is greater than 130 ha (320 ac) in size and is depicted on Plate 2A of the Northeastern RECR (DOE 1985f) (see also Figure 3-107). There is no evidence in the data base that Federal lands less than 130 ha (320 ac) in size are located in or within 10 km (6 mi) of the preliminary candidate area.

3.2.2.3.9 State Lands. Several State lands lie within the boundary of the preliminary candidate area. Middle Pond, Range Ponds, and Sebago Lake State Parks overlap approximately 930 ha (2290 ac), or approximately 1% of the preliminary candidate area, in the southwest, eastern, and south central portions, respectively. The Crooked Outstanding (Wild and Scenic) River traverses approximately 18 km (11 mi) through the center of the preliminary candidate area.

In addition, six State lands, each less than 130 ha (320 ac) in size, lie within the preliminary candidate area. Black Pond Island Heronry Critical Area (northwest edge), Sebago Rare Plant Stand Critical Area (southwest edge), Sebago Lake White Oak Forest Critical Area (southern edge), Poland Spring Esker Segment Critical Area (northeast) and New Gloucester Tupelo Stand Critical Area (east edge) are all located within the preliminary candidate area. In addition, Northwest River Wildlife Management Area lies on the southwest edge of the preliminary candidate area. These six State lands all lie just inside the boundary and occupy

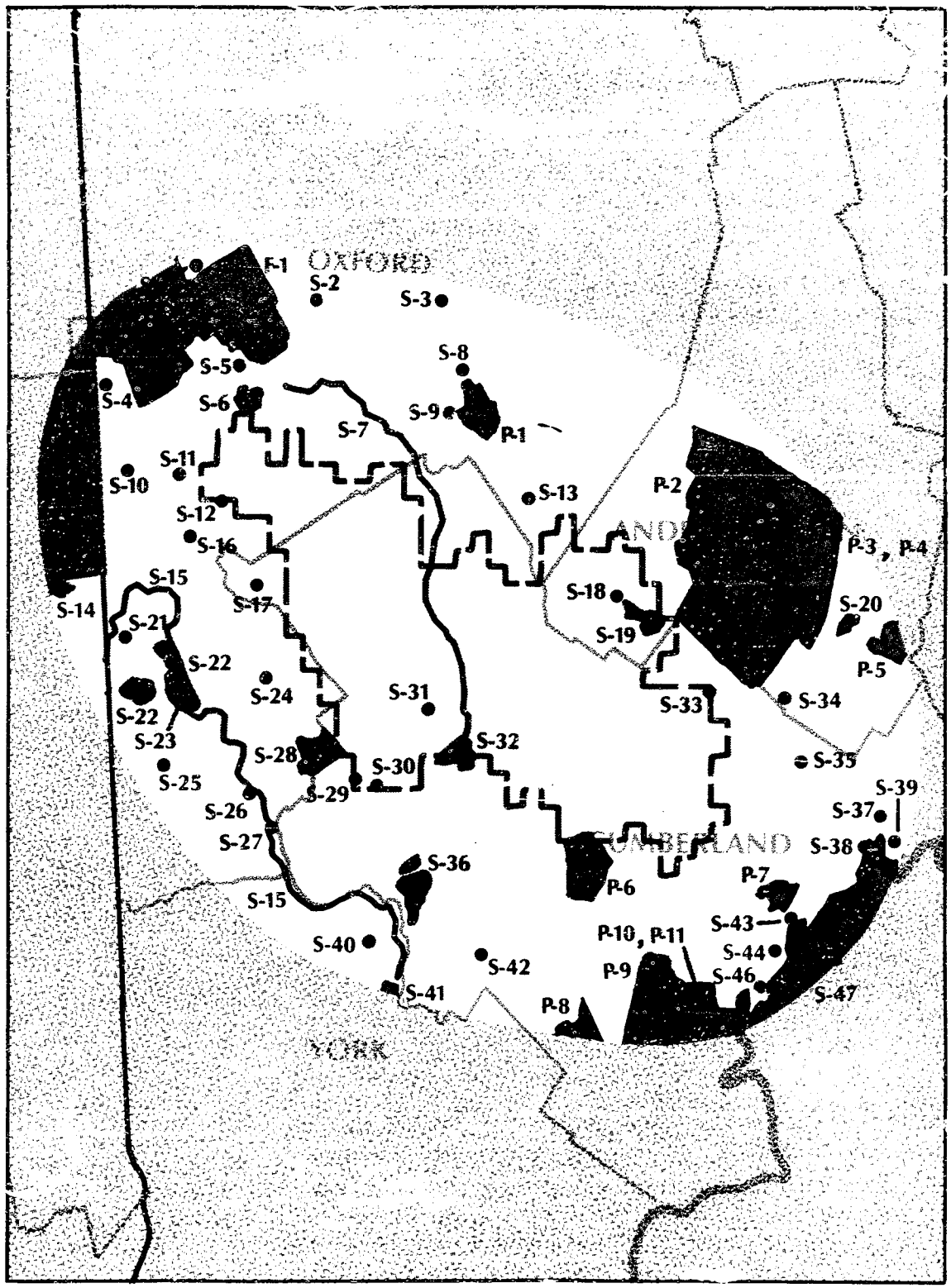


Figure 3—107 Sheet 1

Environmental Features
Sebago Lake Batholith (NE-4)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

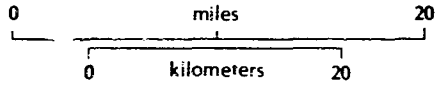


Figure 3-107 Sheet 2

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI)
OF PRELIMINARY CANDIDATE AREA NE-4A

Code	Feature
Population Features	
P-1	Norway Highly Populated Area (HPA)
P-2	Auburn HPA
P-3	Lewiston HPA
P-4	Lewiston Minor Civil Division (MCD)
P-5	Lisbon Falls HPA
P-6	North Windham HPA
P-7	Yarmouth HPA
P-8	Gorham HPA
P-9	Westbrook HPA
P-10	Portland HPA
P-11	Portland MCD
Federal Lands	
F-1	White Mountain National Forest
State Lands	
S-1	Haystack Notch Rare Plant Station Critical Area (CA)
S-2	Albany Basin Gorge CA
S-2	Albany Mountain Laurel Stand CA
S-3	Snows Falls Gorge CA
S-3	West Paris Slender Cliff Brake CA
S-4	Evans Notch Rare Plant Station CA
S-5	Miles Notch Nodding Pogonia Station CA
S-6	Trout Pond State Park (SP)
S-7	Crooked Outstanding (Wild and Scenic) River
S-8	Norway, North Pond Arethusa Station CA
S-8	Ordway Grove Old Growth White Pine CA
S-9	Lake Pennessewassee SP
S-10	Deer Hill Nodding Pogonia Stand CA
S-10	Bickford Trout Brook Nodding Pogonia Stand CA
S-10	Rattlesnake Brook Falls CA
S-11	Five Kezar Pond Esker Segment CA
S-12	Black Pond Island Heronry CA
S-13	Welchville Island Heronry CA
S-13	Oxford New Jersey Tea Stand CA
S-13	Whitney Hogan Pond Esker Segment CA
S-14	Conway Common Land State Forest (SF)

Figure 3-107, Sheet 3

ENVIRONMENTAL FEATURES WITHIN 16 KM (10 MI)
OF PRELIMINARY CANDIDATE AREA NE-4*

Code	Feature
State Lands - Continued	
S-15	Saco Outstanding (Wild and Scenic) River
S-16	Kezar Pond Lot Wildlife Management Area (WMA)
S-17	Sabatis Island SP
S-18	Poland Spring Esker Segment CA
S-19	Range Ponds SP
S-20	Beaver SP
S-21	Highland Park White Oak and Tupelo Station CA
S-21	Lovewell Pond Rare Plant Station CA
S-21	Lower Kimball Pond Rare Plant Station CA
S-22	Brownfield WMA
S-23	Saco River SP
S-24	Denmark Sassafras Stand CA
S-25	Frost Mountain Rare Plant Station CA
S-26	Gould Mountain Rare Plant Station Ca
S-27	Hiram Falls (Great Falls) CA
S-28	Middle Pond SP
S-29	Sebago Rare Plant Stand CA
S-30	Northwest River WMA
S-31	Sebago Lake White Oak Forest CA
S-32	Sebago Lake SP
S-33	New Gloucester Tupelo Stand CA
S-34	Runaround Pond SP
S-35	Bradbury Mountain SP
S-36	Steep Falls WMA
S-37	Freeport Fuchsite Locality CA
S-37	Sister Island Ledge Seabird Nesting CA
S-38	Mere Point SP
S-39	Wolf Neck Woods SP
S-40	Pequawket Pond SP
S-41	Little Ossipee River SP
S-42	Chandler Rhododendron Stand (No. 1) CA
S-42	Chandler Rhododendron Stand (No. 2) CA
S-42	Standish Mountain Laurel Stand CA
S-42	Frye Island Tupelo Stand CA
S-43	Stockman Island Eider Nesting CA

Figure 3-107, Sheet 4

ENVIR[illegible] FEATURES WITHIN 16 KM (10 MI)
OF [illegible] CANDIDATE AREA NE-4*

Code	Feature
State Lands - Continued	
S-44	Falmouth Old Growth White Pine CA
S-44	Presumpscot River Old Growth White Pine CA
S-45	Bangs Island SP
S-46	Andrews Island Sand Beach CA
S-47	Little Chebeague Island SP
Indian Reservations	
None	

* The accompanying text identifies only these environmental features within 10 km (6 mi) of the preliminary candidate area.

Figure 3-107, Sheet 5

an approximate total area of 71 ha (176 ac) or less than 0.1% of the preliminary candidate area.

Trout Pond State Park lies approximately 1.6 km (1 mi) to the north and Steep Falls Wildlife Management Area lies 6 km (4 mi) to the south of the preliminary candidate area. The Saco Outstanding (Wild and Scenic) River passes within 8 km (5 mi) to the southwest of the preliminary candidate area. In addition, 16 State lands, each less than 130 ha (320 ac) in size, lie within 10 km (6 mi) of the preliminary candidate area. These lands consist of 11 critical areas, four state parks, and the Kezar Pond Lot Wildlife Management Area. All the features described above are either depicted on Plates 3A or 4A of the Northeastern RECR (DOE, 1985f) or are listed in Appendix B of that report.

In summary, nine State lands (three are greater than and six are less than 130 ha or 320 ac) totaling approximately 1,000 ha (2,470 ac), or less than 2% of the preliminary candidate area lie within the preliminary candidate area. A wild and scenic river (greater than 130 ha or 320 ac) traverses the preliminary candidate area (occupying approximately 3% of the preliminary candidate area). An additional 19 State lands (three are greater than and 16 are less than 130 ha or 320 ac) are located within 10 km (6 mi) of the preliminary candidate area (See Figure 3-107).

3.2.2.3.10 Environmental Compliance. Parts of the preliminary candidate area lie within current air quality nonattainment areas. Androscoggin and Cumberland Counties are nonattainment areas for ozone and together cover approximately 84% of the preliminary candidate area (EPA, 1984). A portion of Oxford County is also a nonattainment area for ozone, though it is not known whether this includes the preliminary candidate area. Mobile sources such as automobiles, trucks, and buses are the primary contributors to the nonattainment status for ozone. The closest Prevention of Significant Deterioration (PSD) Class I Areas are the Presidential/Dry Range and Great Gulf National Wildernesses, which lie approximately 32 km (20 mi) to the west and northwest, respectively,

of the preliminary candidate area (42 FR 7486, 1977). Sixteen sites on the National Register of Historic Places (NRHP) are located within the preliminary candidate area boundary (see Table 3-12).

Table 3-12. NRHP Sites Located within NE-4

Name	Location	Reference
Shaker Village	Sabbathday Lake	44 FR 7486, 1979
Barrow-Scribner Mill	Harrison	44 FR 7487, 1979
William F. Perry House	Bridgton	44 FR 7486, 1979
Farnsworth House	North Bridgton	47 FR 4940, 1982
Walker Memorial Hall	Bridgton	50 FR 8866, 1985
Stone House	Bridgton	50 FR 8866, 1985
Maine State Building	Poland	44 FR 7486, 1979
Poland Springs Bottling Plant	Poland	50 FR 8866, 1985
Manor House	Naples	44 FR 7487, 1979
Songo Lock	Naples	44 FR 7487, 1979
Sam Perly Farm	Naples	45 FR 17459, 1980
New Gloucester Historic District	New Gloucester	44 FR 7487, 1979
Nutting Homestead	Otisfield	44 FR 7487, 1979
Nathaniel Hawthorne Boyhood Home	South Casco	44 FR 7487, 1979
Pennell Institute	Gray	48 FR 8641, 1983
All Soul's Chapel	Mechanic Falls	44 FR 7486, 1979

One proposed NRHP site (George Seaverns House in Mechanic Falls) exists within the preliminary candidate area (50 FR 34767, 1985). In the regional data base there are no known existing archaeological sites or districts or any proposed for designation within the preliminary candidate area boundary. No National Trails are located within the preliminary candidate area. The Appalachian Trail is 24 km (15 mi) to the northwest of the preliminary candidate area at its closest approach in New Hampshire (New Hampshire Department of Resources and Economic Development, 1982).

3.2.2.3.11 Population Density and Distribution. The preliminary candidate area contains no highly populated areas. There are nine highly

populated areas within [illegible] (10 mi) of the preliminary candidate area (Auburn, Gorham, Lewiston, Lisbon Falls, North Windham, Norway, Portland, Westbrook, Yarmouth) (see Figure 3-107). North Windham lies just outside the southern boundary of the preliminary candidate area and has a population of 5,492. Auburn, with a population of 23,128, is located adjacent to the northeast corner of the preliminary candidate area. Westbrook, Portland, and Gorham are located 8 km (5 mi), 10 km (6 mi), and 11 km (8 mi) south of the preliminary candidate area, respectively. Westbrook has a population of 14,976, while the populations of Portland and Gorham are 61,572 and 4,052, respectively. Yarmouth and Norway are located 6.4 km (4 mi) southeast and north of the preliminary candidate area, respectively. Yarmouth has a population of 2,981 and Norway has a population of 2,653. Lewiston, with a population of 40,481, lies 10 km (6 mi) northeast of the preliminary candidate area; and Lisbon Falls lies 14 km (9 mi) east of the preliminary candidate area. The population of Lisbon Falls is 4,370. The preliminary candidate area contains no areas with population densities greater than or equal to 1,000 persons per square mile. There are two areas with population densities greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area. These are Portland and Lewiston, which are also highly populated areas (see Figure 3-107). The average population density of the preliminary candidate area is approximately 62 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area is approximately 66 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.2.3.12 Site Ownership. There are no Federal or DOE-owned lands located within the preliminary candidate area. The Penobscot Indian Reservation is located approximately 110 km (68 mi) north of the preliminary candidate area (see Plate NE-1A).

3.2.2.3.13 Offsite [illegible]. No commercial nuclear reactors are located within the [illegible] candidate area. The nearest operating commercial nuclear reactor is Maine Yankee which is approximately 39 km (24 mi) to the east (Wamsley, 1985; Electrical World Directory of Electric Utilities, n.d.). The nearest commercial nuclear reactor under construction is Seabrook Nuclear Plant which is approximately 112 km (70 mi) to the south (Wamsley, 1985; New Hampshire Department of Resources and Economic Development, 1981). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.2.3.14 Transportation. I95 is the nearest interstate highway and is just over 8 km (5 mi) southeast of the preliminary candidate area. The Maine Turnpike (which is shown as a State highway on the plot) crosses over the eastern portion of the preliminary candidate area. Two U.S. highways traverse this preliminary candidate area. U.S. 202 crosses the southeastern part of the preliminary candidate area and intersects the Maine Turnpike at the town of Gray, Maine, which is within the boundaries of the preliminary candidate area. U.S. 302 runs diagonally across the preliminary candidate area between Portland, Maine, where it intersects I95 and the New Hampshire State line. While only two State highways (other than the Maine Turnpike) are shown on the plot, there are numerous State highways which cross over this preliminary candidate area. The following State Routes cross portions of the preliminary candidate area: 5, 11, 26, 35, 37, 85, 107, 117, 121, and 231. State Routes 16 and 117 are also principal highways in the area.

The Maine Central has a rail line which crosses the eastern portion of the preliminary candidate area. Currently, this line is no longer classified as a mainline due to changes in the Maine Central Railroad System. However, the preliminary candidate area is only 8 km (5 mi) north of another Maine Central mainline. The Maine Central also has a branchline which is about 6.4 km (4 mi) from the southwestern edge of the

preliminary candidate area. On the northern and eastern portions of the preliminary candidate area, the Canadian National's line between Montreal and Portland passes within 3.2 km (2 mi) of the preliminary candidate area.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.2.3.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NE-4 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations that suggest the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]

- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could produce ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)]

- limited presence of State lands less than 130 ha (320 ac) within (i.e. six) and in proximity to (i.e., 16 within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- low population density within its boundaries and within 80 km (50 mi) of the preliminary candidate area [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfer of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2), 960.5-2-7(b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]
- a majority of the preliminary candidate area is within 16 km (10 mi) of highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(c)(2)].

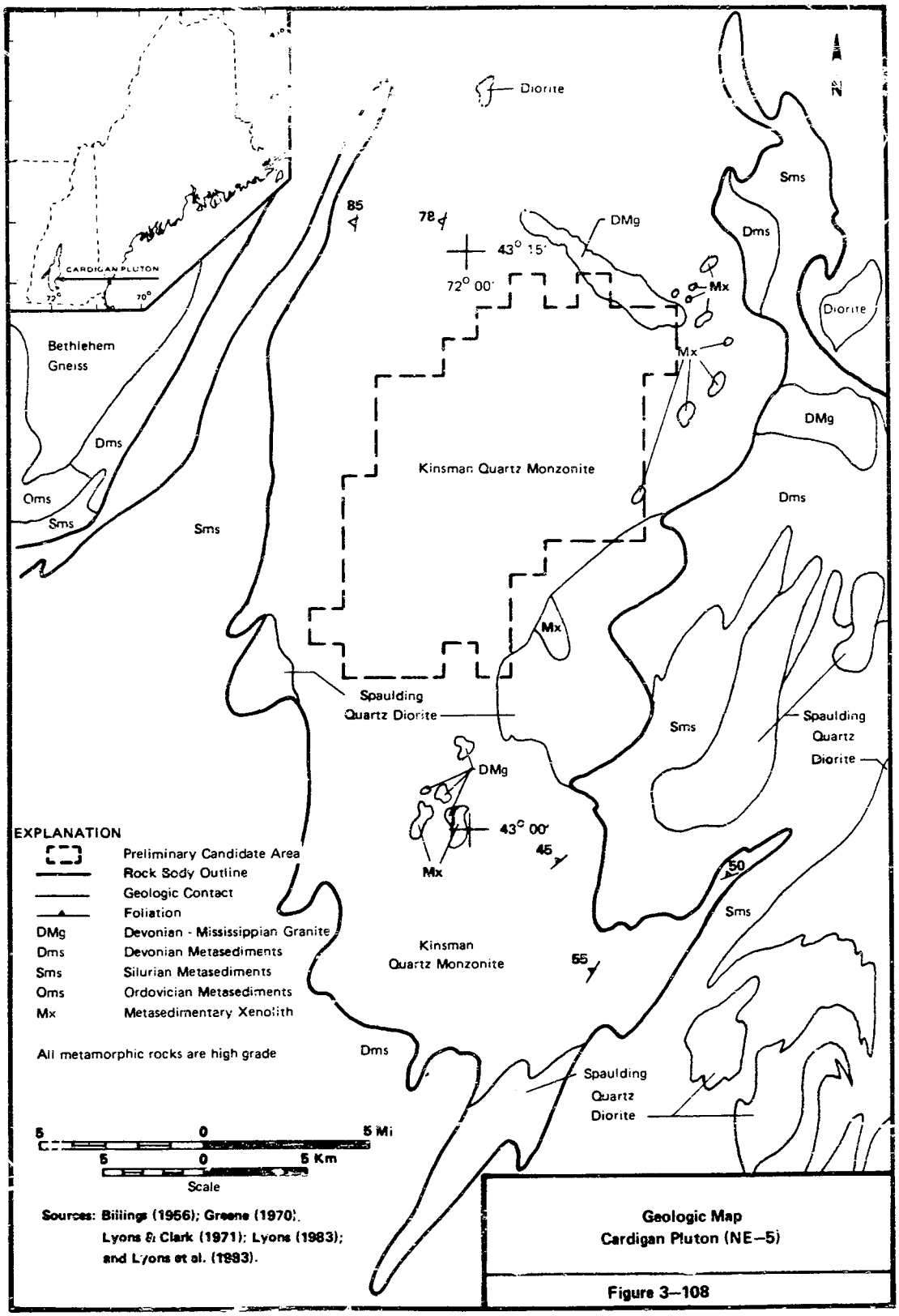
The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NE-4 at this time.

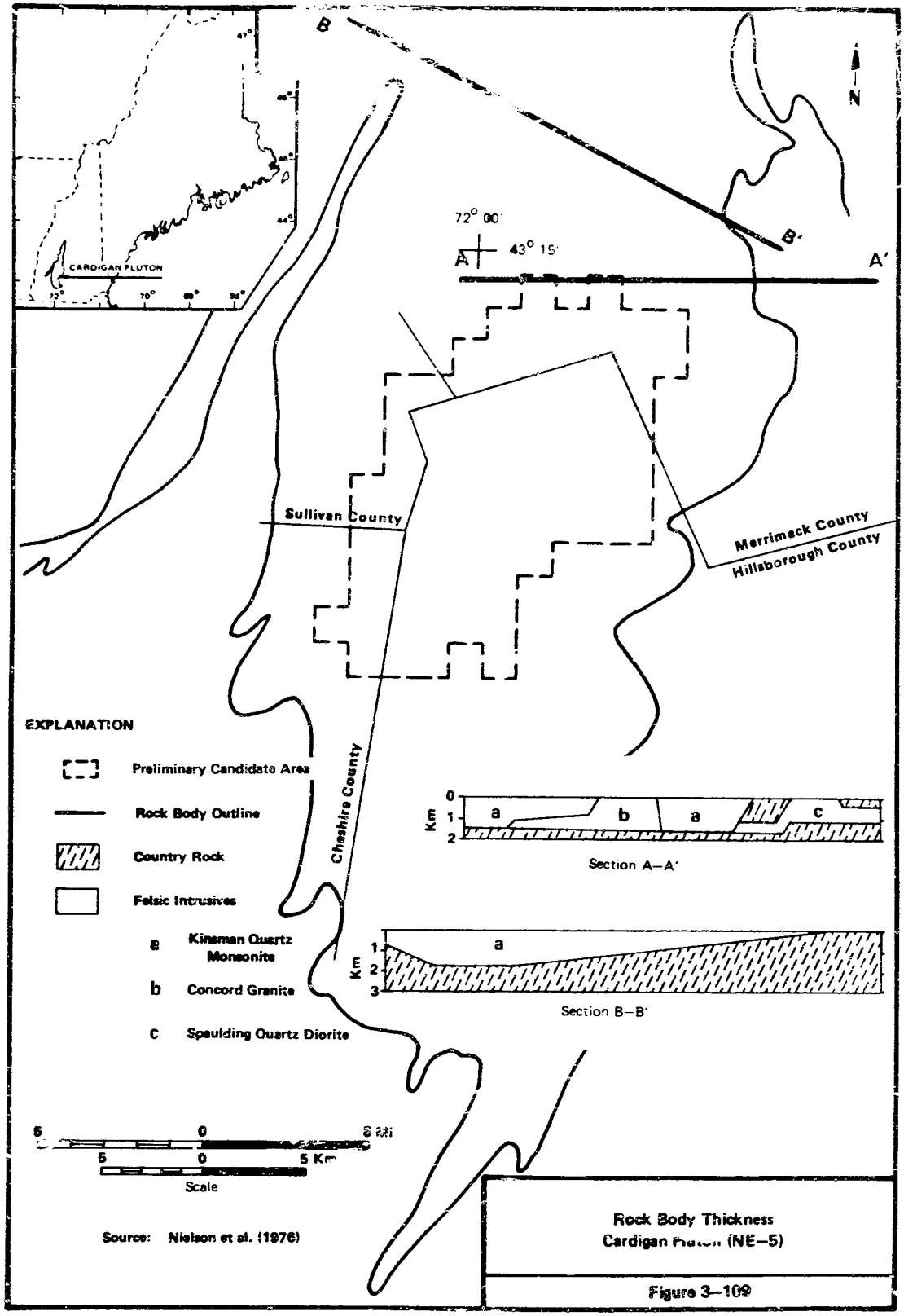
3.2.2.4 Preliminary Candidate Area Description - Cardigan Pluton (NE-5)

The Cardigan pluton is located in the Central Highlands physiographic province in south-central New Hampshire. The preliminary candidate area identified in the Cardigan pluton lies entirely in New Hampshire in parts of Sullivan, Merrimack, Cheshire, and Hillsborough Counties. The center of the preliminary candidate area is located at approximately 43°09' N latitude and 71°58' W longitude.

3.2.2.4.1 Host Rock Extent Geometry and Overburden Thickness. The size of the preliminary candidate area within the Cardigan pluton (Figure 3-108) is approximately 203 km^2 (78 mi^2). Multiple gravity profiles across the Cardigan pluton show that it consists of a subhorizontal sheet that ranges in thickness from 1 to 2 km (0.6 to 1.2 mi), with a maximum of 2.5 km (1.5 mi) at the center of the pluton (Nielson et al., 1976). This is consistent with other members of the New Hampshire magma series that are interpreted to have intruded the cores of large nappes during or after deformation (Nielson et al., 1976; Wones, 1980). Of the six gravity profiles that traverse the Cardigan pluton, two are of particular interest because of their location. The first, located north of the preliminary candidate area, shows the pluton with shallow, inward-dipping contacts that reach a maximum depth of approximately 2 km (1.2 mi) near the western limit of the body. The second profile to the south intersects the preliminary candidate area (Figure 3-109). It shows the preliminary candidate area to be underlain by an approximately 2 km (1.2 mi) thick, sheet-like mass of quartz monzonite.

No quantitative information on bedrock exposure is available for the Cardigan pluton. Geologic mapping in a portion of the Cardigan pluton suggest the existence of reasonable amounts of outcrop, based on the number of structural measurements reported in the Sunapee, Lovewell, and Peterborough Quadrangles (Weald, 1950; Chapman, 1953; Green, 1970). Overburden thickness information within the Cardigan pluton is available only as average depth to bedrock within a township (Figure 3-110). Of 12


CARDIGAN PLUTON
Diorite
N
Sms
Dms
DMg
43° 15'
72° 00'
Mx
Diorite
Bethlehem
Gneiss
Dms
Oms
Sms
Kinsman Quartz Monzonite
DMg
Dms
Sms
Mx
Spaulding
Quartz Diorite
Sms
Spaulding
Quartz
Diorite
DMg
43° 00'
Mx
Sms
Kinsman
Quartz Monzonite
Dms
Spaulding
Quartz
Diorite
EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Geologic Contact
Foliation
DMg Devonian - Mississippian Granite
Dms Devonian Metasediments
Sms Silurian Metasediments
Oms Ordovician Metasediments
Mx Metasedimentary Xenolith
All metamorphic rocks are high grade
5 0 5 Mi
5 0 5 Km
Scale
Sources: Billings (1956); Greene (1970); Lyons & Clark (1971); Lyons (1983); and Lyons et al. (1993).
Geologic Map
Cardigan Pluton (NE–5)
Figure 3–108


B
B'
N
72° 00'
43° 15'
A
A'
CARDIGAN PLUTON
Sullivan County
Merrimack County
Hillsborough County
Cheshire County
EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Country Rock
Felsic Intrusives
a Kinsman Quartz Monzonite
b Concord Granite
c Spaulding Quartz Diorite
Km
0
1
2
a
b
a
c
Section A–A'
Km
1
2
3
a
Section B–B'
5 0 5 Miles
5 0 5 Km
Scale
Source: Nielson et al. (1976)
Rock Body Thickness
Cardigan Pluton (NE–5)
Figure 3–109

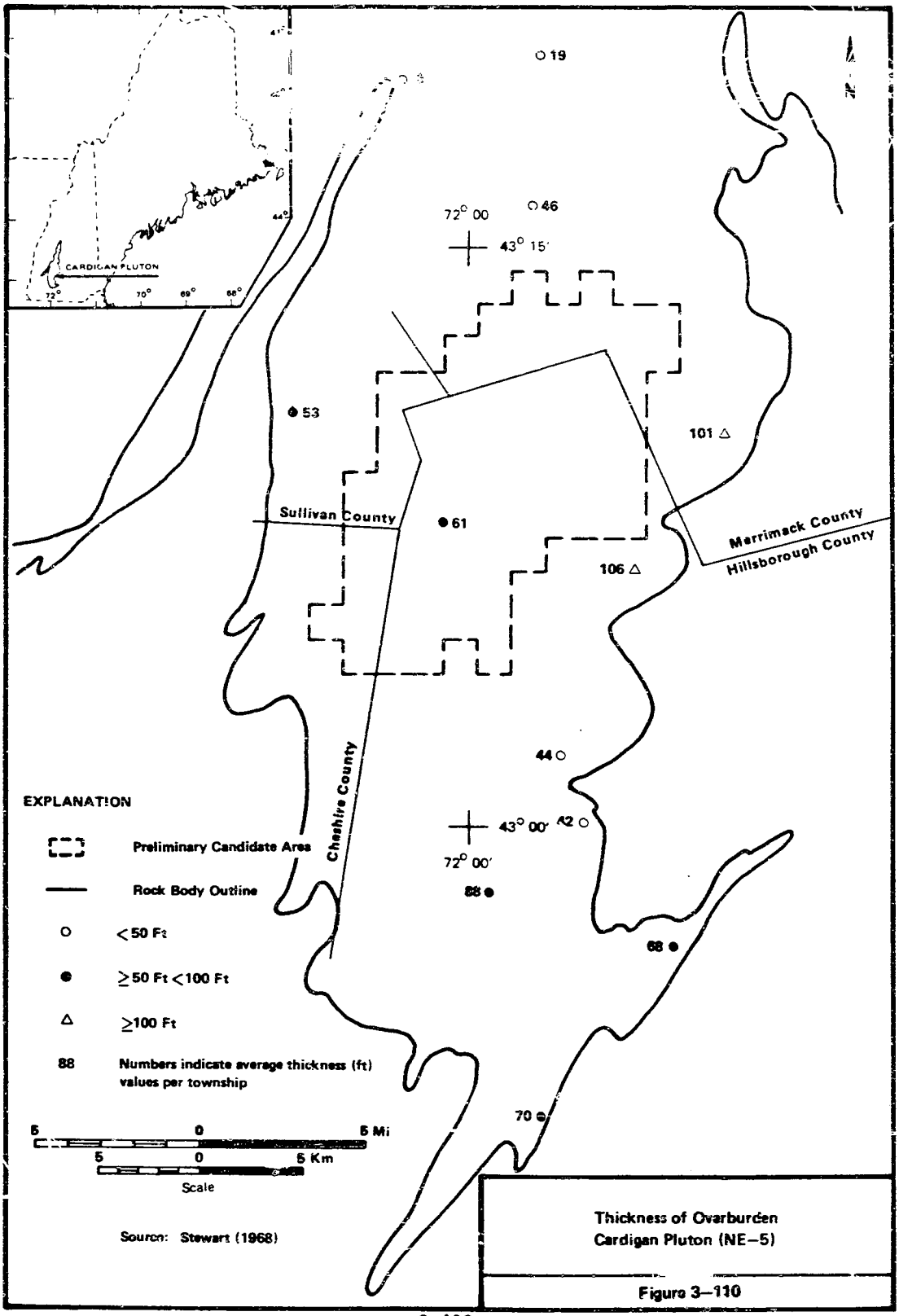

CARDIGAN PLUTON
72°
70°
69°
68°
19
46
72° 00
43° 15'
53
101
Sullivan County
61
Merrimack County
Hillsborough County
106
Cheshire County
44
43° 00'
42
72° 00'
88
68
70
EXPLANATION
Preliminary Candidate Area
Rock Body Outline
<50 Ft
≥50 Ft <100 Ft
≥100 Ft
88 Numbers indicate average thickness (ft) values per township
5 0 5 Mi
5 0 5 Km
Scale
Source: Stewart (1968)
Thickness of Overburden
Cardigan Pluton (NE–5)

Figure 3–110

townships surveyed [illegible] averages greater than 30 m (100 ft) (Stewart, 1968). Average [illegible] to bedrock from wells drilled elsewhere in New Hampshire are consistent with the above figures. Only 6% yielded depths greater than 30 m (100 ft) and 79% were less than 15 m (50 ft) (Goldthwait et al., 1949). The vast majority of the overburden is mapped as glacial till (unstratified drift) (Goldthwait et al., 1950). The only major exception lies outside the preliminary candidate area in the southeastern corner of the pluton where large concentrations of stratified sand and sandy gravel deposits (kames, eskers, etc.), or stratified sand and silt (outwash), and recent stream deposits occur.

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the rock of the preliminary candidate area is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

3.2.2.4.2 Lithology and Tectonics. The Cardigan pluton is a member of the Devonian-Permain-aged New Hampshire plutonic series. It is composed primarily of the syntectonic Kinsman quartz monzonite, but includes the slightly younger, Spaulding quartz diorite and Concord granite (Lyons et al., 1983; Billings, 1956). The pluton is intruded by several stages of pegmatites and aplites which appear as both dikes and sills. The earliest of these intrusions probably occurred when the Kinsman quartz monzonite was only semisolidified as evidenced by crystal alignments and boundins. Later stages intruded during and after the emplacement of the Spaulding quartz diorite and the Concord granite (Lyons and Clark, 1971; Greene, 1970). The Kinsman quartz monzonite is a medium- to coarse-grained rock ranging in composition from tonalite to granite (Lyons et al., 1983; Billings, 1956). Typically, it contains large phenocrysts of K-feldspar up to 12 cm (4.8 in) in length and an abundance of garnet (1 to 3 cm) [0.4 to 1.2 in] in a matrix of

plagioclase, microcline, quartz, biotite, and muscovite (Billings, 1956; Green, 1970; Lyons and Clark, 1971). The matrix commonly displays a hypidiomorphic granular texture but can range to granoblastic (Billings, 1956).

The Kinsman quartz monzonite contains ubiquitous, often partially resorbed, slab-like, metasedimentary inclusions generally ranging in size from a few centimeters to tens of meters , occasionally reaching several hundred meters (Billings, 1956). Similarly, Lyons and Clark (1971) report areas of garnet-plagioclase-quartz granofels which are often associated with large xenoliths of aluminous schists in the Kinsman.

Locally, the Kinsman quartz monzonite is intruded by the Devonian-aged Spaulding quartz diorite and the Mississippian-aged Concord granite. The Spaulding is a dark gray, medium-grained rock composed of plagioclase, quartz and biotite (Green, 1970). The Concord is light gray, fine- to coarse-grained to subporphyritic rock, and is composed of quartz microcline, plagioclase, biotite and muscovite (Vernon, 1971). Nielson et al. (1976) postulate that the Kinsman magma moved "into a zone of active tectonic transport (nappe formation) where they were channeled into or between the still forming recumbent folds" (Nielson et al., 1976, p. 314). After a period of relative inactivity, the Spaulding quartz diorite was similarly emplaced into a ductile crust following pre-existing pathways and using earlier sheets of Kinsman quartz monzonite and Bethlehem gneiss as guides. The post-tectonic Concord granite intruded into a more brittle crust by using pre-existing areas of crustal weakness or multiple forcible intrusions (Nielson et al., 1976; Vernon, 1971).

Three folding episodes associated with the Acadian orogeny are reported by Englund (1971). First to develop were large isoclinal recumbent folds overturned to the west. The Cardigan pluton intruded syndeformationally with the first folding episode (Nielson et al., 1976; Lyons and Clark, 1971). These were followed by gentle, open folding

about northwest-trending [illegible]. Finally, folding about northeast-trending axes produced regional north-to-northeast-trending axial plane cleavage, and a moderate to strongly developed foliation (Lyons and Clark, 1971; Billings, 1956). The preliminary candidate area and its surrounding terrain are not affected by any mapped faults.

The Kinsman quartz monzonite contains two prominent foliations. The initial foliation is defined by north-south-trending, subhorizontal alignment of large microcline phenocrysts which developed during syntectonic emplacement of a crystal mush (Nielson et al., 1976; Lyons and Clark, 1971). The Kinsman also contains a pervasive, steeply dipping, northeast-trending foliation associated with the third episode of folding described by Englund (1971). This late foliation is sometimes accompanied by shearing, typically in areas with a low concentration of garnet (Greene, 1970; Billings 1956). In the southeast portion of the pluton, Greene (1970) reports the presence of two sets of vertical joints oriented at N 30° E and N 60° W. The extent of these joints throughout the pluton is unknown.

Vertical crustal movement in the region is influenced by several factors, including continental glaciation and active tectonic processes, as well as by sea level changes which occur in response to these factors. Uplift rates in the vicinity of the Cardigan pluton are less than 1 mm (0.04 in) per century (Gable and Hatton, 1983). There are no in situ stress data available for the vicinity of the preliminary candidate area.

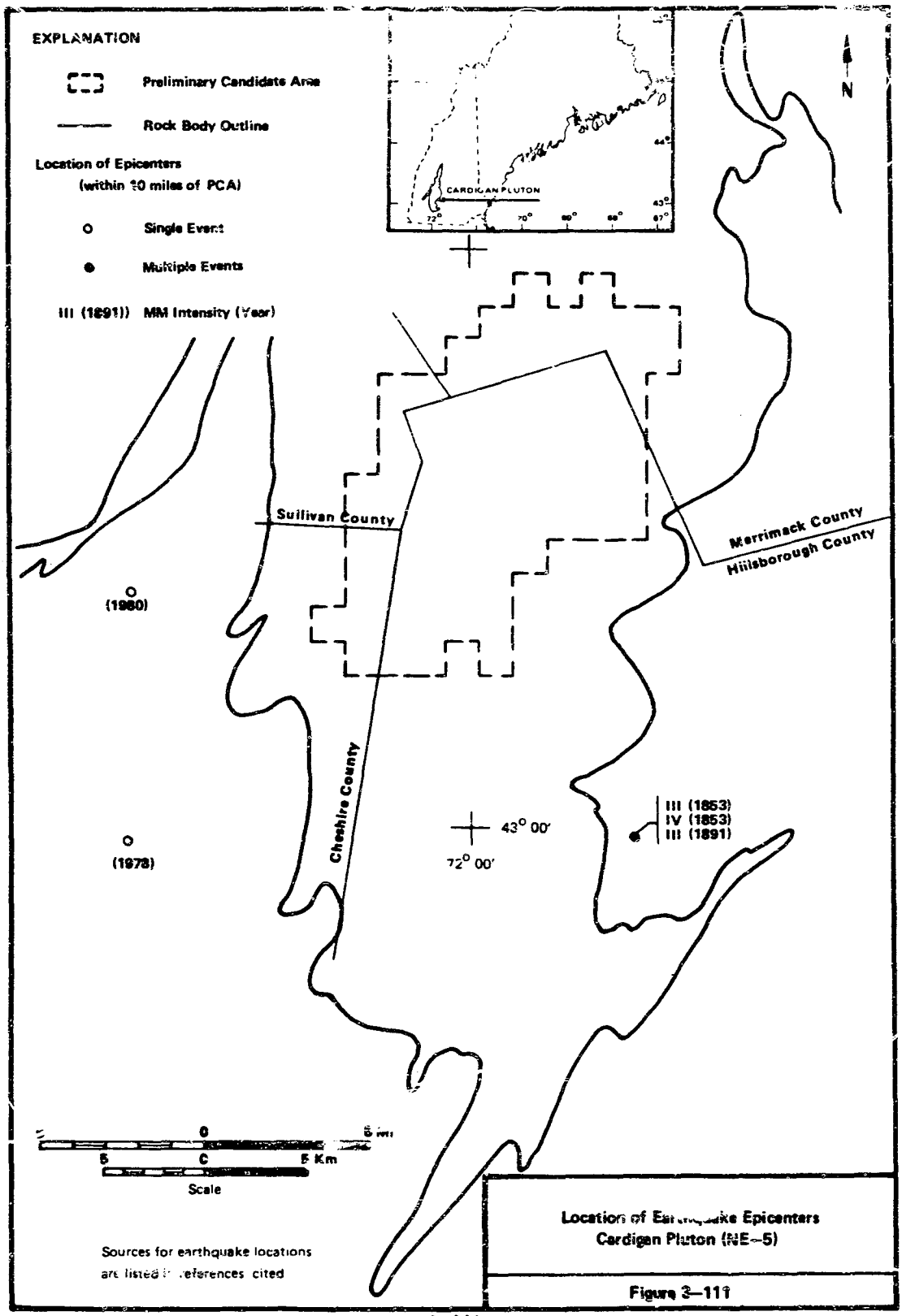
The preliminary candidate area is located in an intraplate tectonic setting. There is no evidence of igneous activity or tectonic deformation during the Quarternary Period. Additionally, no correlation is known to exist between seismicity and known geologic structures (see Section 3.2.2.1.1.3). The rates and magnitude of movements in the region are low. There appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

3.2.2.4.3 Seismicity. Regional aspects of seismology and neotectonics are discussed in Section 3.2.2.1.1.3. The evidence presented in that discussion indicates that large uncertainties associated with the location and size of earthquakes in the eastern United States make it necessary to discuss their distribution with respect to geologic features, in a broad rather than specific sense.

Earthquake epicenters lying in the vicinity of the Cardigan pluton preliminary candidate area are shown in Figure 3-111. Most of the earthquakes located in the vicinity of the candidate area are interpreted to have intensities of MM III.

There is no evidence for Quaternary surface displacement in the geologic setting. No correlations are known between earthquakes and documented geologic structures or tectonic processes in the geologic setting. Earthquake foci in the regional setting occur at depths that far exceed repository horizons. Considering the low level and magnitude of seismic activity in the region and the absence of active tectonic processes within the geologic setting during the Quaternary Period, it is unlikely that seismic activity could produce ground motion in excess of reasonable design limits.

3.2.2.4.4 Mineral Resources. There are no potential strategic, metallic or energy-related resources located within 10 km (6 mi) of the preliminary candidate area. A single potential metallic resource located within the Cardigan pluton is a shallow, inactive gold mine more than 15 km (9 mi) south of the preliminary candidate area (Fowler & Billings, 1949). Seven potential resources have been reported within 10 km (6 mi) of the preliminary candidate area, but these are either shallow and inactive, or prospects containing feldspar or graphite (Heald, 1950; Fowler & Billings, 1949; Meyers and Stewart, 1977; Pearre and Calkins, 1957a; Clark, 1977). One exploration borehole (depth unavailable) is located outside of the preliminary candidate area adjacent to its


EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Location of Epicenters
(within 10 miles of PCA)
Single Event
Multiple Events
III (1891)) MM Intensity (Year)
CARDIGAN PLUTON
N
Sullivan County
Merrimack County
Hillsborough County
Cheshire County
(1980)
(1978)
43° 00'
72° 00'
III (1853)
IV (1853)
III (1891)
0
5 mi
5
0
5 Km
Scale
Sources for earthquake locations
are listed in references cited
Location of Earthquake Epicenters
Cardigan Pluton (NE-5)
Figure 3-111

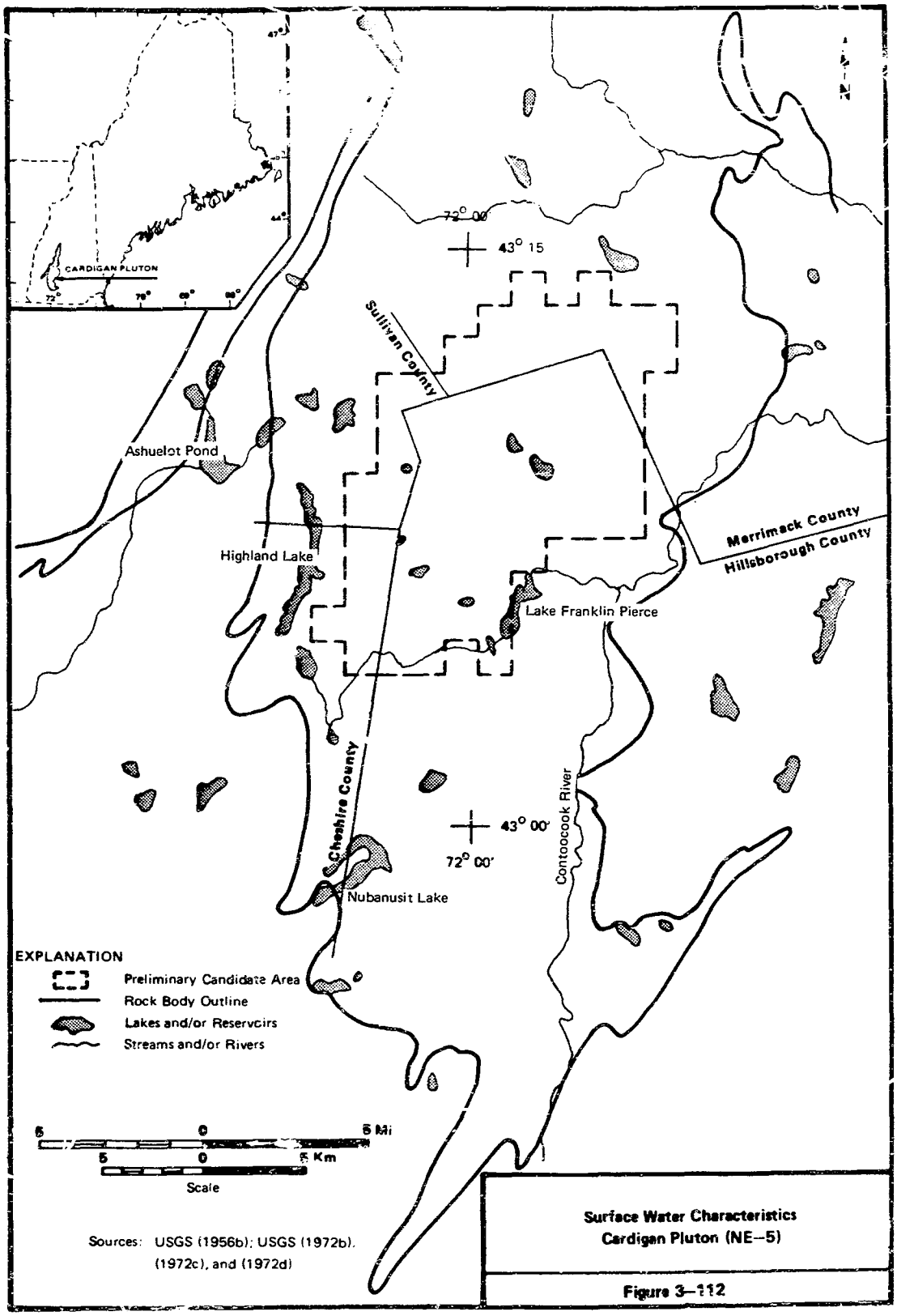
northern boundary [illegible] latitude and 71°59' W longitude (Birch et al., 1968). No deep mines or quarries (greater than 100 m [328 ft] in depth) are located within the preliminary candidate area. The nearest deep mine or quarry is an inactive talc mine in Vermont, located approximately 52 km (32 mi) northeast of the preliminary candidate area.

Based on the data presented in this section, there are no metallic, strategic, or energy-related resources in the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation, and no information is available to indicate that deep drillholes are present in the preliminary candidate area.

3.2.2.4.5 Topographic and Surface Water Characteristics. The relief of the preliminary candidate area is moderate with elevations ranging from approximately 274 to 456 m (approximately 900 to 1,500 ft). The highest elevation and steepest gradients are in the northernmost and southernmost portions of the preliminary candidate area. The bulk of the area consists of rolling hills with total elevation change of approximately 152 to 213 m (500 to 700 ft).

The preliminary candidate area lies in the western portion of the Merrimack River drainage basin. It is drained almost exclusively by tributaries of the northeast-flowing Contoocook River (Figure 3-112). The drainage pattern of the area is dendritic, and most stream valleys are V-shaped with relatively steep sides. As represented by the region-to-area data base, the preliminary candidate area contains no surface water or wetlands. The locations of major lakes, reservoirs, and rivers contained within the preliminary candidate area are shown on Figure 3-112. There are essentially no swamps or marshy areas and the preliminary candidate area appears to be very well drained. No major floodplains appear to be present within the preliminary candidate area.

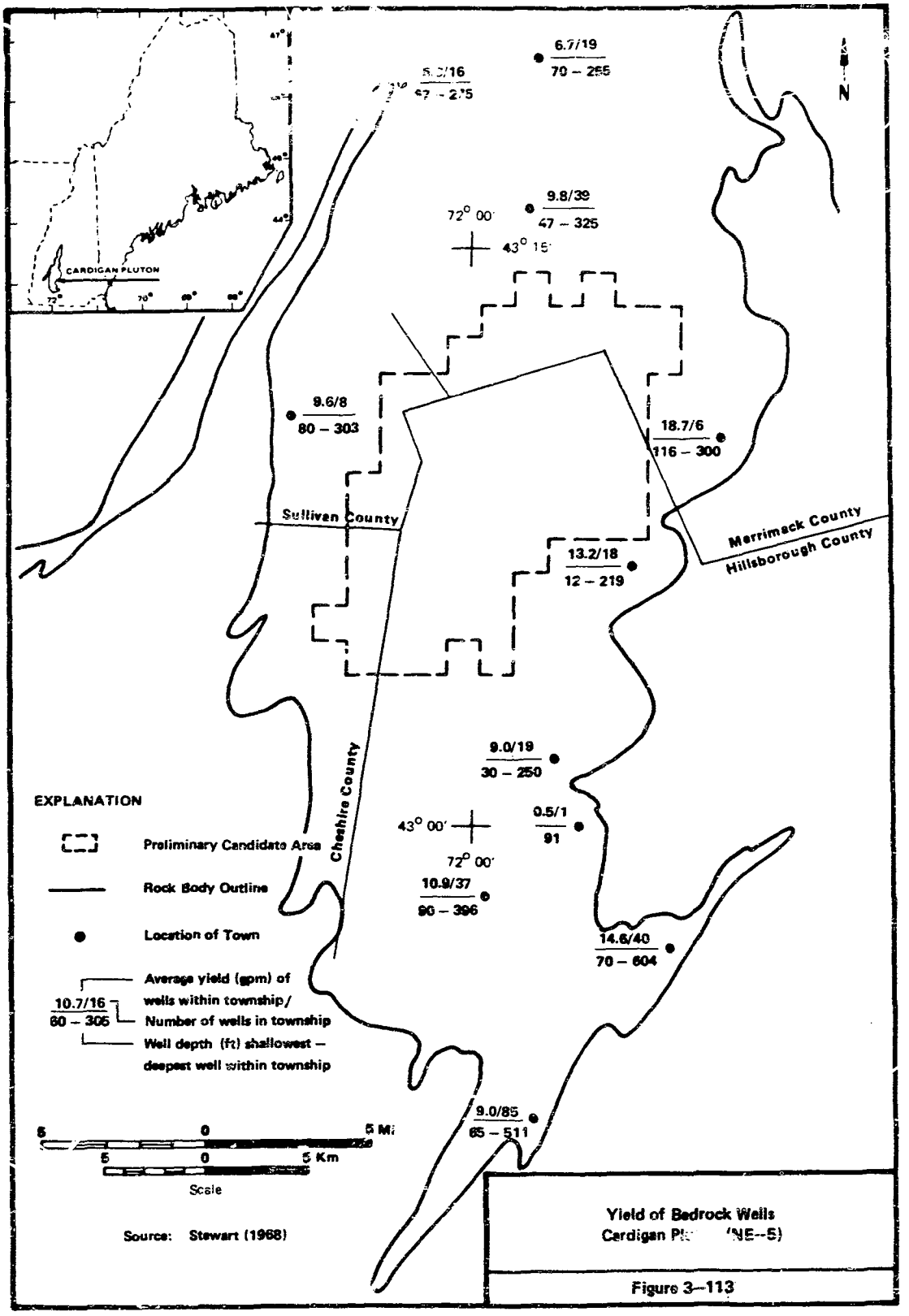
The data presented above indicate the terrain of the preliminary candidate area is generally well drained and the preliminary candidate


CARDIGAN PLUTON
72° 00'
43° 15'
Sullivan County
Ashuelot Pond
Highland Lake
Merrimack County
Hillsborough County
Lake Franklin Pierce
Cheshire County
Contoocook River
43° 00'
72° 00'
Nubanusit Lake
EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Lakes and/or Reservoirs
Streams and/or Rivers
5 0 5 Mi
5 0 5 Km
Scale
Sources: USGS (1956b); USGS (1972b), (1972c), and (1972d)
Surface Water Characteristics
Cardigan Pluton (NE-5)
Figure 3-112

area is of sufficient size (see Section 3.2.2.4.1) to allow significant flexibility in siting a repository.

3.2.2.4.6 Ground-Water Resources. The regional hydrology is discussed in Section 3.2.2.1.1.5. Information concerning ground-water resources in the preliminary candidate area is limited. Stewart (1968) reported the existence of over 288 bedrock wells within the southern portion of the Cardigan pluton. The data presented by Stewart (1968) incorporate all wells in a particular township and are given as "average yields" and "minimum/maximum depths". No site-specific well yields, locations, or depths are given. A summary of the available data is presented in Figure 3-113. The well location points are plotted at the location of the town for which the township is named. The minimum and maximum well depths observed within the southern portion of the Cardigan pluton are 3.7 m (12 ft) and 184 m (604 ft), respectively. Considering only the four location points adjacent to the preliminary candidate area, the maximum and minimum well depths are 4 m (12 ft) and 99 m (325 ft). Average yields range from 0.612 to 1.18 L/s (9.6 to 18.7 gpm). Based on 1,938 wells throughout the state, the average depth is 59 m (192 ft) and average yield is 0.79 L/s (12.6 gpm) Stewart (1968). Within Merrimack and Sullivan Counties, the data are 52 m (169 ft) and 0.71 L/s (11.3 gpm) and 68 m (222 ft) and 0.71 L/s (11.5 gpm), respectively.

Surficial aquifers are scattered throughout the southern portion of the preliminary candidate area. The locations, yields, and descriptions of these aquifers are reported in USGS water resources investigations maps. Ground-water availability in the preliminary candidate area can be found in a study of the Merrimack River Basin by Cotton (1976). The extent, location, and yield of surficial aquifers within and around the preliminary candidate area are shown on Figure 3-114. These relatively thin, elongate aquifers are located, for the most part, in areas underlain by coarse sand and gravel. In general, stratified deposits of silts, sands, and gravels which have the potential to yield water, occur


CARDIGAN PLUTON
6.7/19
70 – 255
9.8/39
47 – 325
72° 00'
43° 15'
9.6/8
80 – 303
18.7/6
116 – 300
Sullivan County
Merrimack County
Hillsborough County
13.2/18
12 – 219
Cheshire County
9.0/19
30 – 250
43° 00'
72° 00'
0.5/1
91
10.9/37
90 – 396
14.6/40
70 – 604
9.0/85
65 – 511
N
EXPLANATION
Preliminary Candidate Area
Rock Body Outline
Location of Town
Average yield (gpm) of wells within township/ Number of wells in township
Well depth (ft) shallowest – deepest well within township
10.7/16
60 – 306
5 0 5 Mi
5 0 5 Km
Scale
Source: Stewart (1968)
Yield of Bedrock Wells
Cardigan Pl (NE--5)
Figure 3--113

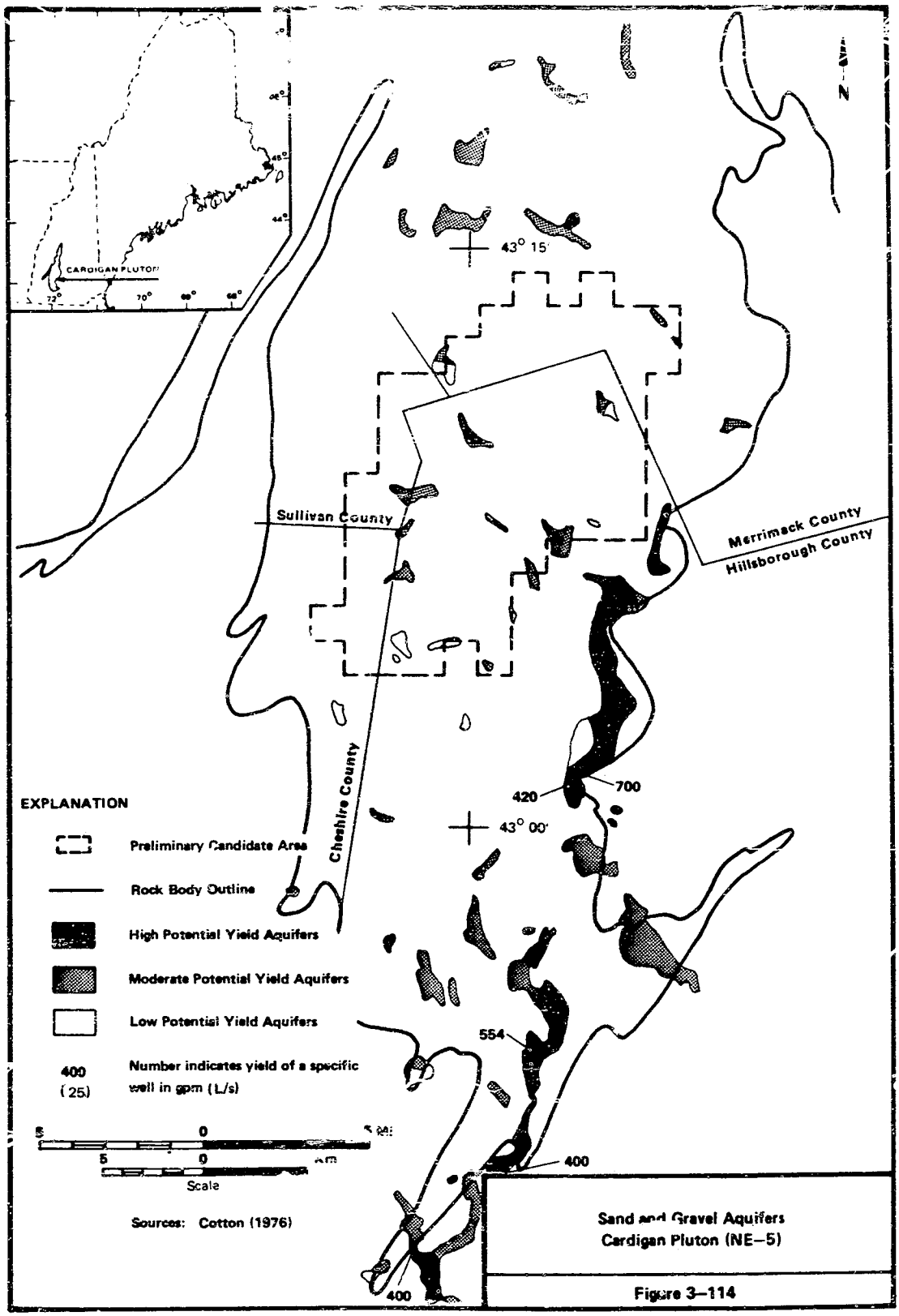

CARDIGAN PLUTON
N
43° 15'
43° 00'
Sullivan County
Cheshire County
Merrimack County
Hillsborough County
420
700
554
400
400
EXPLANATION
Preliminary Candidate Area
Rock Body Outline
High Potential Yield Aquifers
Moderate Potential Yield Aquifers
Low Potential Yield Aquifers
400 (25)
Number indicates yield of a specific well in gpm (L/s)
5 0
5 0
Scale
Sources: Cotton (1976)
Sand and Gravel Aquifers
Cardigan Pluton (NE–5)

Figure 3–114

in valley bottoms [illegible] sand and gravel aquifers within the preliminary candidate area [illegible] been [illegible] into low, moderate, and high potential yield aquifers (Cotton, 1976). The terms "low, moderate, and high potential yield" were not quantitatively defined by Cotton (1976) but the sparse individual well yield data indicate that high potential yield aquifers can produce 25 L/s (400 gpm) or more. Most of the surficial aquifers in the preliminary candidate area are characterized by moderate potential yields.

Based on preliminary interpretations regarding regional ground-water movement, the preliminary candidate area is located away from major discharge zones. The data also indicate that aquifers are present and that ground-water sources suitable for irrigation or human consumption are present.

3.2.2.4.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including erosion and deposition, vertical crustal movement, denudation rates, and changes in sea level is in Section 3.2.2.1.1.1.

3.2.2.4.8 Federal Lands. There are no Federal lands greater than 130 ha (320 ac) in size located in or within 10 km (6 mi) of the preliminary candidate area. Federal lands which do occur in New Hampshire are depicted on Plate 2A of the Northeastern RECR (DOE, 1985f). In addition, there is no evidence in the data base of Federal lands less than 130 ha (320 ac) in size located in or within 10 km (6 mi) of the preliminary candidate area.

3.2.2.4.9 State Lands. Three State lands lie within the boundary of the preliminary candidate area. Low State Forest covers approximately 364 ha (900 ac) or approximately 2% of the preliminary candidate area in the northern portion. Fox State Forest covers approximately 585 ha (1,445 ac) or approximately 3% of the preliminary candidate area in the southeast portion. In addition, Sand Brook Marsh (Farrar's Marsh)

Wildlife Management [illegible] which is less than 130 ha (320 ac) in size, covers 118 ha (291 ac) or less than [illegible] the eastern edge of the preliminary candidate area.

Pillsbury and Mt. Sunapee State Parks lie approximately 3 km (2 mi) and 6 km (4 mi) northwest, respectively, of the preliminary candidate area. Two State forests, Harriman-Chandler, and Vincent, are 2 km (1 mi) northeast and 5 km (3 mi) east, respectively. In addition, nine State lands less than 130 ha (320 ac) in size lie within 10 km (6 mi) of the preliminary candidate area. These lands consist of five wildlife management areas and four State forests. All the features described above are either depicted on Plates 3A or 4A of the Northeastern RECR (DOE, 1985f) or are listed in Appendix B of that report.

In summary, three State lands (two are greater than and one is less than 130 ha or 320 ac) cover approximately 1,067 ha (2,636 ac), or less than 6% of the preliminary candidate area. A total of two State parks (each of which is greater than 130 ha or 320 ac), six State forests (two are greater than and four are less than 130 ha or 320 ac), and five wildlife management areas (each of which is less than 130 ha or 320 ac) are located within 10 km (6 mi) of the preliminary candidate area (Figure 3-115).

3.2.2.4.10 Environmental Compliance. The entire preliminary candidate area lies within current air quality nonattainment areas. Cheshire, Merrimack, Sullivan, and Hillsborough Counties are nonattainment areas for ozone; together, these counties include all of the preliminary candidate area (EPA, 1984). Parts of Hillsborough County are also nonattainment for carbon monoxide and total suspended particulates (TSP), but these areas are believed to exclude the preliminary candidate area (40 CFR 81.330, 1985). Mobile sources such as automobiles, trucks, and buses are the primary contributors to the nonattainment status for ozone. There are no Prevention of Significant Deterioration (PSD) Class I Areas within 40 km (25 mi) of the preliminary

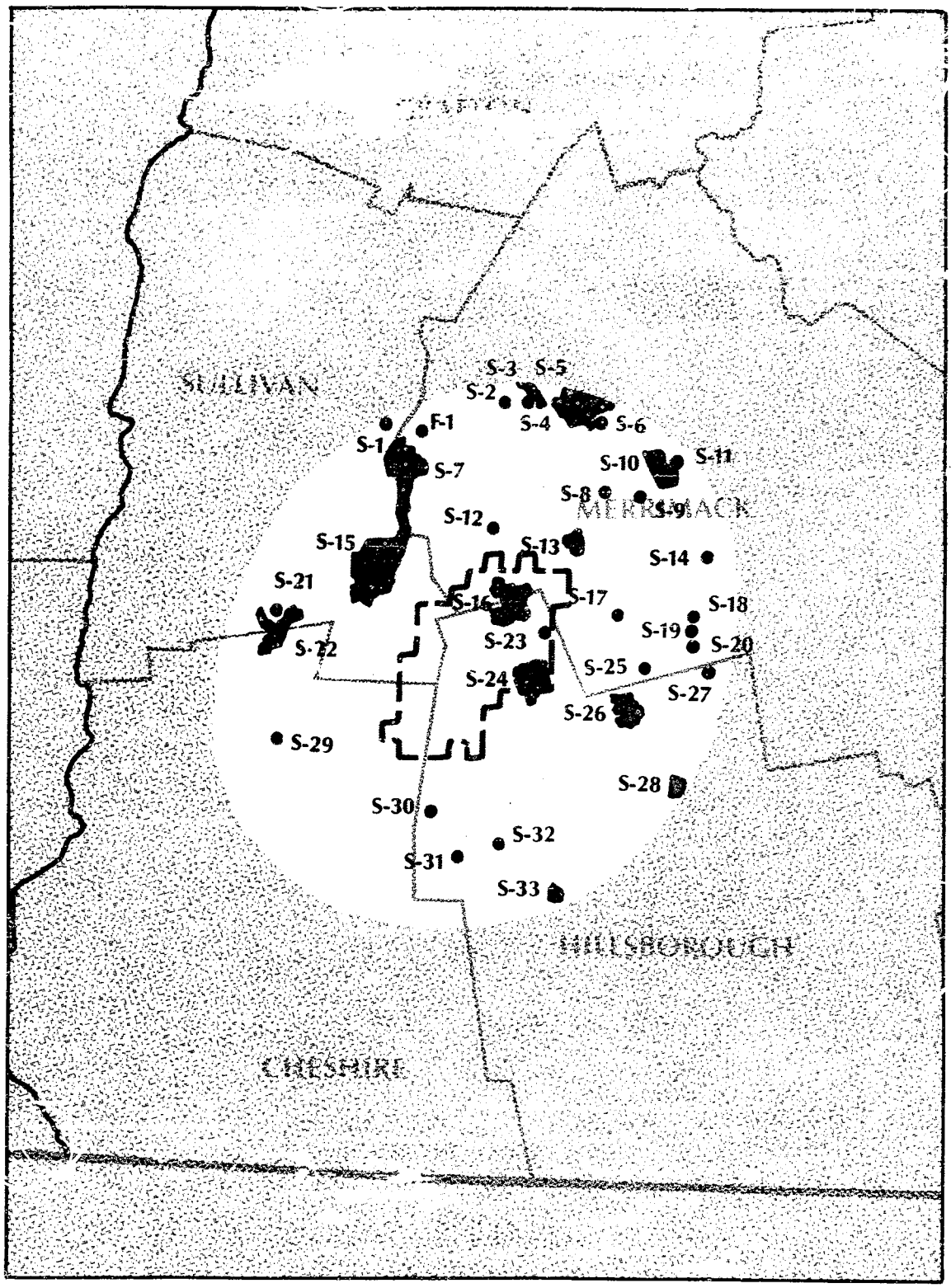


Figure 3—115 Sheet 1

Environmental Features
Cardigan Pluton (NE-5)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

0 miles 20

0 kilometers 20

Figure 3–115 Sheet 2

[illegible] FEATURES WITHIN 16 KM (10 MI)
OF [illegible] PRIMARY CANDIDATE AREA NR-5

Code	Feature
Population Features	
None	
Federal Lands	
F-1	John Hay National Wildlife Refuge
State Lands	
S-1	Wendell Marsh Wildlife Management Area (WMA)
S-2	Wadliegh State Park (SP)
S-3	Cascade Marsh WMA
S-4	Shadow Hill State Forest (SF)
S-5	Monadnock SP
S-6	Rollins SP
S-7	Mt. Sunapee SP
S-8	Gillmore SF
S-9	Carroll SF
S-10	Leonard WMA
S-11	Knight's Meadow Marsh WMA
S-12	Bradford Pines SF
S-13	Harriman Chandler SF
S-14	Davisville SF
S-15	Pillsbury SP
S-16	Low SF
S-17	Grassy Pond WMA
S-18	Contoocook SF
S-19	Crancy Hill SF
S-20	Ames SF
S-21	Dodge Brook SF
S-22	Honey Brook SF
S-23	Sand Brook Marsh (Farrah's Marsh) WMA
S-24	Fox SF
S-25	Totten Trails SF
S-26	Vincent SF
S-27	Stumpfield Marsh WMA
S-28	Perkins Pond Marsh WMA

Figure 3-115, Sheet 3

FEATURES WITHIN 16 KM (10 MI)
OF PRELIMINARY CANDIDATE AREA No. 56

Code	Feature
State Lands - Continued	
S-29	Kinson Lot WMA
S-30	Hosmer Lot WMA
S-31	Carpenter's Marsh WMA
S-32	Eva's Marsh WMA
S-33	Greenfield SP
Indian Reservations	
None	

* The accompanying text indicates only those environmental features within 10 km (6 mi) of the preliminary candidate area.

Figure 3-115, Sheet 4

candidate area. There are [illegible] sites on the National Register of Historic Places (NRHP) located in the city of Hillsborough within the southeast part of the preliminary candidate area. These sites are the Jonathon Barnes House (48 CFR 8651, 1983) and the Franklin Pierce Homestead (44 FR 7525, 1979). There are also two unnamed NRHP sites in Hillsborough County. There are no proposed NRHP sites within the preliminary candidate area. In the regional data base there are no known existing archaeological sites or districts or any proposed for designation within the preliminary candidate area. No National Trails are located within the preliminary candidate area or within 40 km (25 mi) of the area boundary.

3.2.2.4.11 Population Density and Distribution. The preliminary candidate area contains no highly populated areas. There are also no highly populated areas within 16 km (10 mi) of the preliminary candidate area, although Concord is located 17 km (10.5 mi) northeast of the preliminary candidate area. The preliminary candidate area contains no areas with population densities greater than or equal to 1,000 persons per square mile, nor are there areas with population densities greater than or equal to 1,000 persons per square mile within 16 km (10 mi) of the preliminary candidate area. The highly populated areas and areas with population densities greater than or equal to 1,000 persons per square mile in New Hampshire are depicted on Plates 5A and 6A of the Northeastern REGR (DOE, 1985f). The average population density of the preliminary candidate area is approximately 47 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area is approximately 158 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.2.4.12 Site Ownership. There are no Federal or DOE-owned lands located within the preliminary candidate area. The Mashantucket Indian Reservation is located approximately 176 km (110 mi) south of the

preliminary candidate area (Plate 1B of the Northeastern REGR) (DOE, 1985f).

3.2.2.4.13 Offsite Installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is Vermont Yankee which is approximately 48 km (30 mi) to the southwest near Brattleboro, Vermont (Wamsley, 1985; Electrical World Directory of Electric Utilities, n.d.). The nearest commercial nuclear reactor under construction is the Seabrook Nuclear Plant which is approximately 88 km (55 mi) to the east (Wamsley, 1985; New Hampshire Department of Resources and Economic Development, 1981). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.2.4.14 Transportation. The nearest interstate highway, I89, is about 8 km (5 mi) to the northeast of the preliminary candidate area. Further east, approximately 32 km (20 mi) away, is I93. I91, a third Interstate highway is located about 32 km (20 mi) west of the preliminary candidate area. U.S. 20 is the only U.S. highway in the vicinity of this preliminary candidate area. This highway passes along the eastern edge of the site at Hillsboro, New Hampshire. U.S. 202 is a four-lane, limited-access highway between Hillsboro, New Hampshire, and I89. State Route 9, a principal through highway, runs along the southern edge of the preliminary candidate area. State Route 9 intersects U.S. 202 at Hillsboro and eventually intersects I91 north of Brattleboro, Vermont. State Route 31 (not shown on the plot) runs directly through the middle of the preliminary candidate area. State Route 31 intersects State Route 9 near Hillsboro and State Route 10, another principal highway, about 8 km (5 mi) west of the area.

The nearest mainline railroad is Central Vermont which travels through the Connecticut River valley on the Vermont side of the river 32 km (20 mi) away. The Boston and Maine mainline between Boston,

Massachusetts, and Albany, New York, is about 48 km (30 mi) south of the preliminary candidate area in Massachusetts. Another mainline between Boston, Massachusetts, and Portland, Maine, is located approximately 80 km (50 mi) east of the preliminary candidate area. All the branchlines that are nearby are owned by the Boston and Maine Railroad. The nearest branchline ends at Bennington, New Hampshire, which is about 8 km (5 mi) southeast of the preliminary candidate area. Another branchline ends at Keene which is approximately 24 km (15 mi) southwest of the preliminary candidate area. To the north and east, another branchline which extends from the Boston area through Manchester and Concord, New Hampshire and White River Junction, Vermont, comes within 24 km (15 mi) of the preliminary candidate area. Construction of a spurline would most likely be an extension of the branchline that terminates at Bennington. This line at one time extended to Hillsboro and a route into the preliminary candidate area appears to be feasible since there is a small valley leading northwestern from Hillsboro. Along this route, the nearest mainline is at Lowell, Maine, (a distance of about 80 km [50 mi]).

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.2.4.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area NE-5 that could affect DOE's decision to defer further consideration of the area. Based on evaluation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground

facilities during construction [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(b)(1)]

- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- absence of Quaternary igneous activity and tectonism (faulting) [960.4-2-7(b)]
- absence of active folding, faulting, diapirism, uplift, subsidence or other tectonic processes or igneous activity [960.4-2-7(c)(1)]
- low potential for tectonic deformations suggests that the regional ground-water flow systems should be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could produce ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]
- absence of evidence, based on correlations of earthquakes with tectonic processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]

- no evidence of [illegible] mining or extraction for resources that could affect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)]
- limited presence of State lands less than 130 ha (320 ac) within (i.e., one) and in proximity to (i.e., nine within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- the preliminary candidate area is beyond 16 km (10 mi) from highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(b)(2) and (c)(2)]
- low population density within its boundaries [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfer of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)]
- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2), 960.5-2-7(b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)].

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area NE-5 at this time.

3.2.3 Southeastern Region

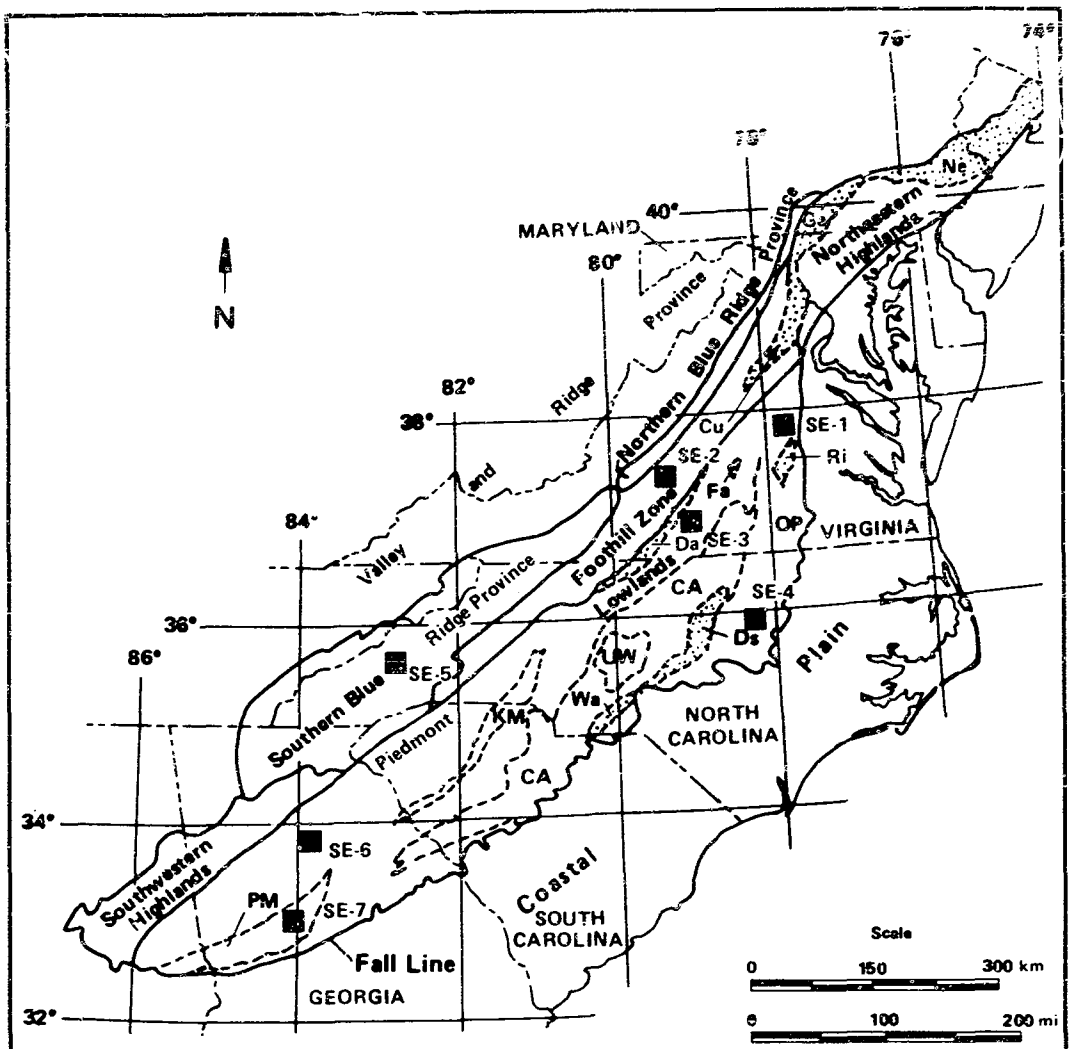
3.2.3.1 Regional Setting

3.2.3.1.1 Geological. The Southeastern Regional Geologic Characterization Report (RGCR) (DOE, 1985g) describes the regional geologic setting and related features. The regional setting and geologic setting for the seven preliminary candidate areas in this region are defined as the Southern Appalachians; and the Blue Ridge and Piedmont physiographic provinces, respectively.

3.2.3.1.1.1 Physiography, Geomorphology, and Quaternary Geology. Crystalline rocks of the southern Appalachians occur in both the Blue Ridge and Piedmont physiographic provinces. The Blue Ridge physiographic province (Fenneman, 1938; Hack, 1982) extends from Pennsylvania, southwestward to Pine Log Mountain, Georgia (Figure 3-116). The topography of the Blue Ridge ranges from steep hills and mountains to gently rolling hills and local relief ranges from 900 m (2,790 ft) to less than 10 m (33 ft) (Hack, 1982).

Lying east of the Blue Ridge, the Piedmont physiographic province is subdivided into the Northeastern Highlands, the Foothill zone, and the Piedmont Lowlands (Figure 3-116) (Hack, 1982). The broadly undulating rolling surface of the Piedmont Lowlands comprises most of the Piedmont province where local relief ranges from 15 to 183 m (49 to 602 ft) (Hack, 1982). The Foothill zone is an upland area of limited extent with greater relief (30 to 450 m [98 to 1,476 ft]) than the Piedmont Lowlands.

Surface cover in the southern Appalachians consists of saprolite, overbank/floodplain deposits (alluvium) along major streams, and colluvium. Saprolite is produced by in situ chemical weathering of rock resulting in clay-rich surficial cover that is characterized by preservation of structures present in the unweathered rock. The thickness of saprolite varies considerably as a function of numerous factors including rock type, structure, precipitation, and drainage



Explanation

Subdivisions of Piedmont Lowlands

- CA Carolina Slate Belt
- UW Uwharrie Mountains
- OP Outer Piedmont of North Carolina and Virginia
- KM Kings Mountain Belt
- PM Pine Mountain Belt

Triassic and Jurassic Basins (Dotted Areas)

- Ne Newark Basin
- Ge Gettysburg
- Cu Culpeper Basin
- Ri Richmond Basin
- Fa Farmville Basin
- Da Danville Basin
- Ds Durham–Sanford Basin
- Wa Wadesboro Basin

Province Boundary

Approximate location of preliminary candidate area

Map of Southeastern United States Showing Physiographic Units and Selected Geologic Features in the Blue Ridge and Piedmont Provinces

Source: Heck, 1982

Figure 3-116

characteristics. Mapping of lithologies and structures in saprolitic exposures is generally considered reliable (Hurst, 1978). However, in areas of intense weathering, structures may not be apparent and trenching or excavation to less weathered material may be necessary for reliable mapping.

Floodplain alluvium is relatively thin, rarely exceeding 10 m (33 ft) in thickness (Wolman and Leopold, 1957). Significant accumulations (several tens of meters [feet]) of colluvium are almost totally restricted to the higher elevations in narrow stream valleys and the bases of mountain slopes.

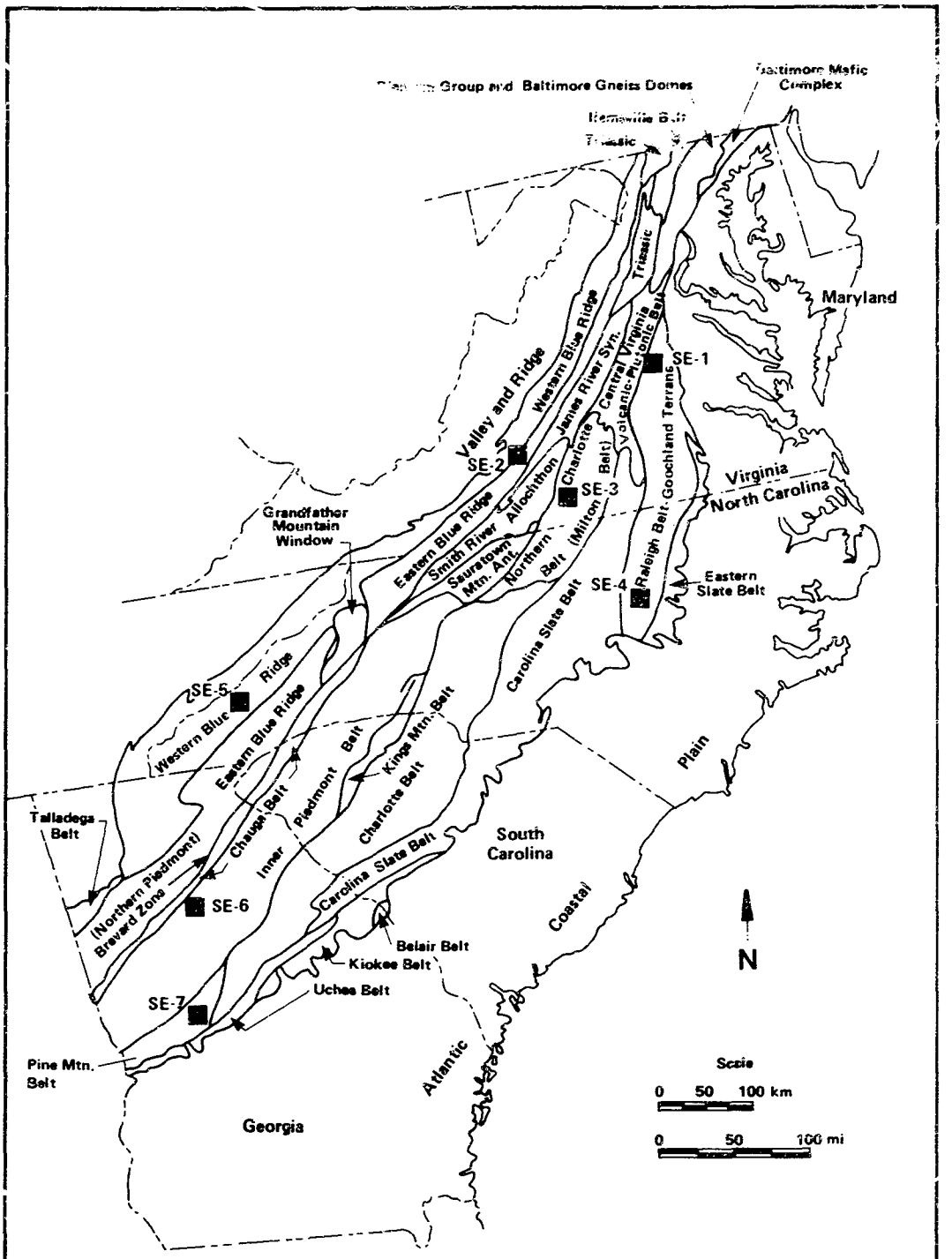
Water-well casing depth is the best available, although indirect, indicator of depth of overburden (soil and saprolite). Casing-depth data, where available in sufficient abundance, provides a rough estimate of depth to bedrock. However, these data are spatially restricted to zones of potentially high water-well yield. These zones usually do not coincide with areas of thin overburden or direct bedrock exposure, but rather with localized structures and lithologies (Hurst, 1978).

The Southeastern Region was not subject to glaciation during the Quaternary Period. However, the region was affected by climatic changes which resulted in increased runoff, weathering, and erosion. Climatic extremes during Pleistocene glaciation ranged from glacial maximum to interglacial climatic optimum conditions. On the basis of pollen assemblages, a warm, temperate-to-humid subtropical climate (similar to what exists today) existed in the region surrounding the preliminary candidate areas during the interglacial climatic optimum (Cronin et al., 1981). This was accompanied by a rise in sea level estimated to be +6 m (+20 ft) above its present level (Bloom, 1983). Projections based on the paleoclimatic record of the climatic optimum suggest that the surface water system would not be significantly affected and that the preliminary candidate areas would not be inundated. During glacial cycles, there was a wide annual temperature variation, and precipitation was increased in winter and decreased in the summer (Delcourt, 1979; Delcourt and

Delcourt, 1981; Watts, 1983; Barry, 1983). During a glacial maximum, sea level fell approximately 70 to 120 m (230 to 394 ft) (Bloom, 1983; McIntyre et al., 1976). If a glacial maximum were to recur, winters are expected to be cooler and wetter sea and levels would be lowered. On the other hand, summers are expected to be drier and the water table associated with the decrease in sea level would be lowered. The net effect on the hydrologic system is expected to be a slight increase in runoff and erosion during winter months but little change in ground-water flow direction or rates.

3.2.3.1.1.2 Geology and Tectonics. The lithotectonic belts of the Blue Ridge and Piedmont provinces (Figure 3-117) are each characterized by distinctive lithology and tectonic style. The Blue Ridge province is an anticlinorium cored by 1,000 to 1,500-million-year-old Grenville age basement rocks. It consists predominantly of metavolcanic and clastic metasedimentary rocks with widespread occurrences of mafic, ultramafic, and granitic rocks. The Blue Ridge can be subdivided into western and eastern belts that are structurally separated by the Hayesville-Fries fault system (Hatcher, 1978; Hatcher and Odom, 1980). The peak of regional metamorphism in the Blue Ridge occurred approximately 480 to 450 million years ago (Butler, 1972; Dallmeyer, 1975) and reached the upper amphibolite facies (Hatcher, 1978). A subsequent retrogressive, greenschist facies overprint (Acadian orogeny, 400 to 350 million years ago) is also apparent in the southern Blue Ridge (Hatcher, 1978).

The Piedmont province of the southern Appalachians can be subdivided into at least six large lithotectonic belts (King, 1955; Hatcher, 1972). From northwest to southeast, the belts are the Inner Piedmont, Kings Mountain, Charlotte, Carolina Slate, Kiokee/Raleigh, and Belair/Eastern Slate (Figure 3-117). The peak of regional metamorphism in the western and central Piedmont occurred approximately 450 to 430 million years ago (Butler, 1972). The Kiokee/Raleigh belt experienced the Alleghenian (330 to 250 million years ago) prograde, amphibolite facies event (Snoke et al., 1980), which is not apparent elsewhere in the Piedmont. Virtually all of the postkinematic, Alleghenian age (330 to



Explanation

■ Approximate location of preliminary candidate area

Source: DOE, 1985b

Simplified Map of Lithotectonic Belts in the Blue Ridge and Piedmont Provinces

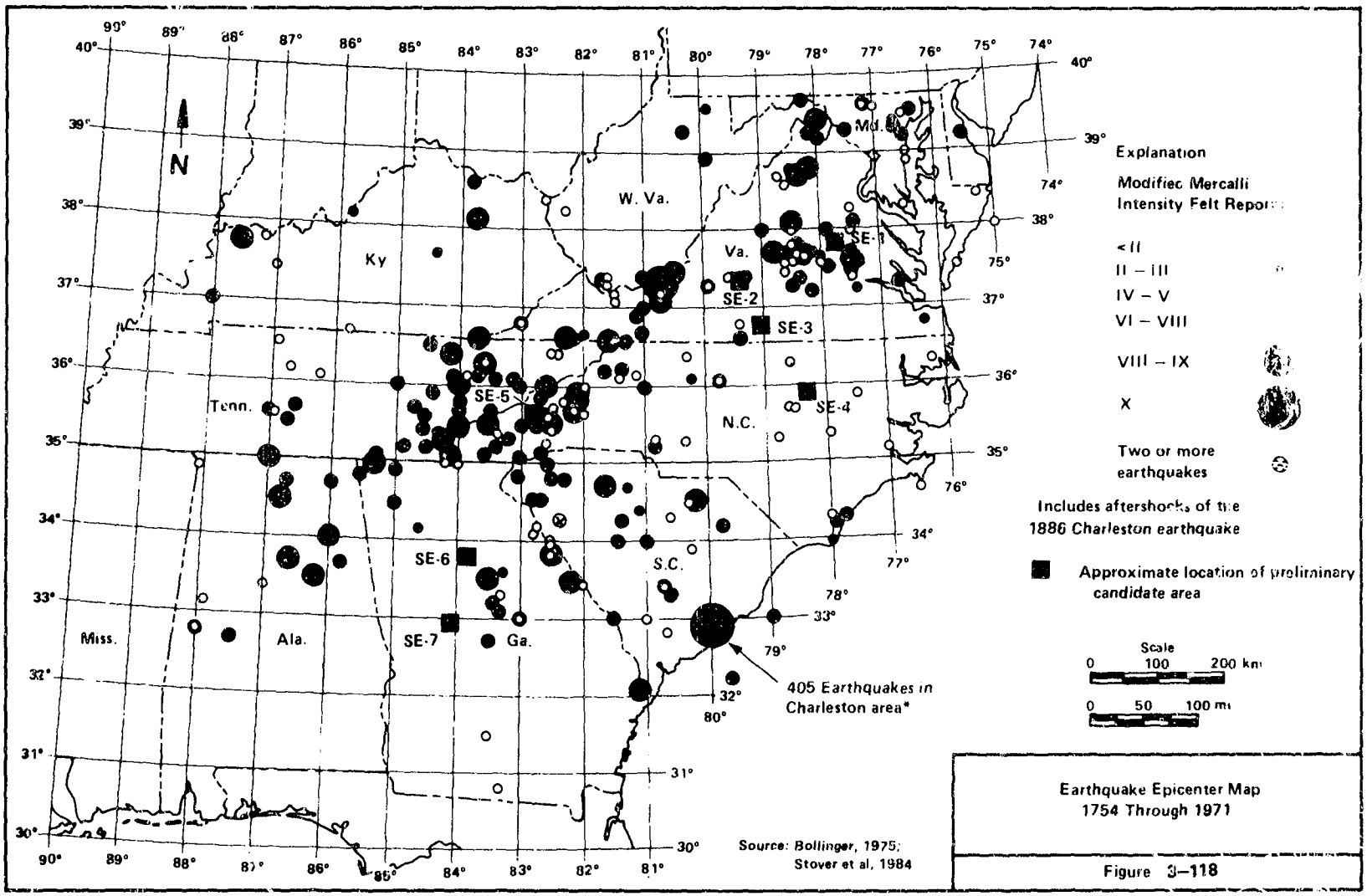
Figure 3–117

250-million-year [illegible] of the southern Appalachians occur within the Piedmont.

The first major period of thrust faulting in the southern Appalachians, although largely obscured by later deformation and metamorphism, began as early as Ordovician time (550 to 400 million years ago) (Hatcher and Odom, 1980). Regional faults in the Inner Piedmont and Blue Ridge, including the Brevard zone, were active (Hatcher and Odom, 1980) during the Taconic orogeny (480 to 450 million years ago) when most of the high-grade terranes were emplaced. A second major period of thrusting occurred during the late Devonian Acadian orogeny, during which most of the Blue Ridge thrust sheets were emplaced (Hatcher, 1978). The final period of thrusting occurred at the end of the Paleozoic Era during the Alleghenian orogeny between 330 to 250 million years ago (Hatcher, 1978).

3.2.3.1.1.3 Seismicity and Recent Crustal Movement. The seismicity in the southeastern United States is dominated by the 1886 Charleston, South Carolina earthquake, its aftershocks, and the ongoing seismicity in this area. Figure 3-118 shows historical earthquakes within the southeastern United States for the period of 1754 to 1971 (Bollinger, 1975; Stover et al., 1984). The interpretation of the regional seismicity in the Southeastern Region requires careful consideration in light of the present lack of consensus within the technical community regarding the causative mechanism(s) for the observed seismicity. Several models have been proposed to explain the seismicity at Charleston. These models can be divided into two broad classes: mechanistic and structural. In the former, a mechanism is suggested without specifying the geologic feature responsible. Taber's (1914) explanation by readjustments of the crystalline basement and Bollinger's (1973a) explanation by differential crustal uplift are mechanistic.

The structural models are divided into three categories. The first hypothesizes stress amplification near plutons based on the spatial association of seismicity near the location of intrusive igneous rock



Earthquake Epicenter Map
1754 Through 1971

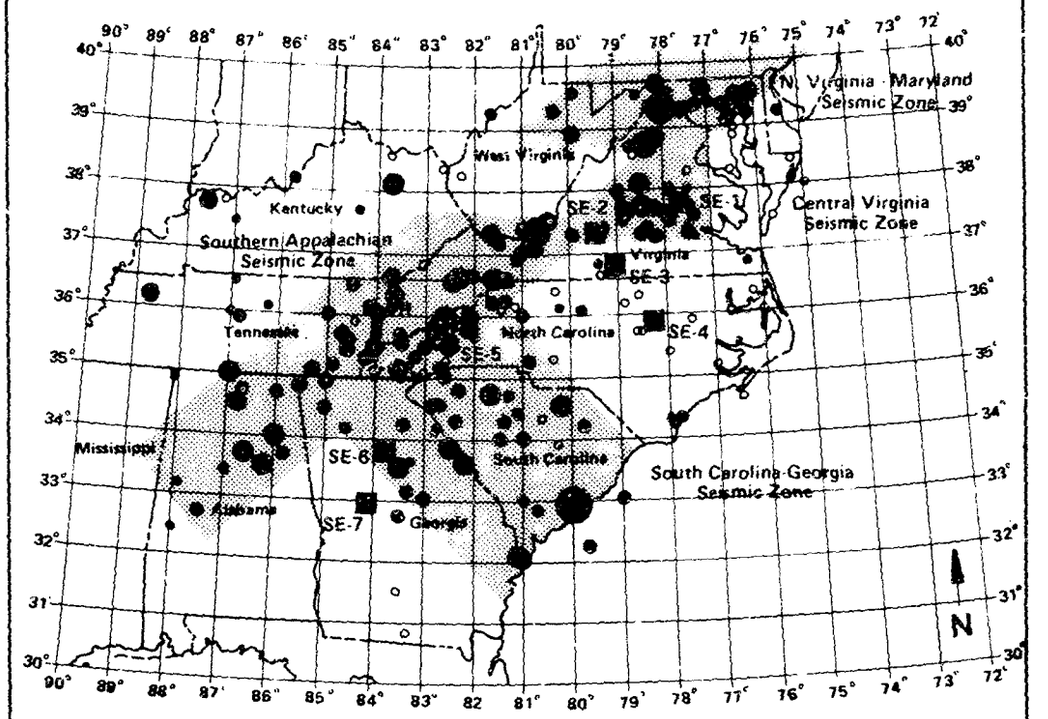
Figure 3–118

bodies (Kane, 1977 and Mc[illegible], 1978). In the second, earthquake activity is postulated to be directly or indirectly related to a near-horizontal decollement which is postulated to underlie most of the Blue Ridge and Piedmont provinces at a depth of about 10 to 12 km (6 to 7.5 mi) (Cook et al., 1979). In the third, movement is associated with essentially vertical faults (Talwani and Colouhaun, 1985).

Current seismic zone models for the southeastern United States are based primarily on the spatial pattern of observed earthquakes. Figure 3-119a shows the four seismic zones that Bollinger (1973b) established for the southeastern United States. However, this is only one of many seismic zonation models suggested for the region. For example, two separate panels of regional experts were recently brought together by the Electric Power Research Institute (EPRI, 1985) and the Lawrence Livermore National Laboratory (Bernreuter et al., 1984) to evaluate seismicity in the Southeastern Region. A comparison of the results of the evaluations from both studies indicates that opinions regarding seismic zonation models vary greatly and can only be resolved with additional data and analyses. However, all the EPRI and LLNL seismic zonation models isolate the Charleston area, suggesting the 1886 Charleston event is restricted to that area. One of the seismic source zones models developed for EPRI is shown in Figure 3-119b.

Because different technical opinions currently exist on which seismic zonation model is appropriate for the Southeastern Region, assignment of a maximum earthquake event for each preliminary candidate area is difficult at this time. However, regional geologic/seismologic studies have been completed for nuclear power plants in the southeastern United States and are available and could be used to provide some constraints and comparative estimates of seismic favorability for preliminary candidate areas during area phase studies. Discussions in the seismicity sections for each preliminary candidate area are based on the following:

- the relative number of earthquakes reported in the vicinity of the preliminary candidate area



Explanation

Modified Mercalli Intensity Felt Reports

- < II
- II–III
- IV–V
- VI–VII
- VIII–IX
- X

Seismic Zone

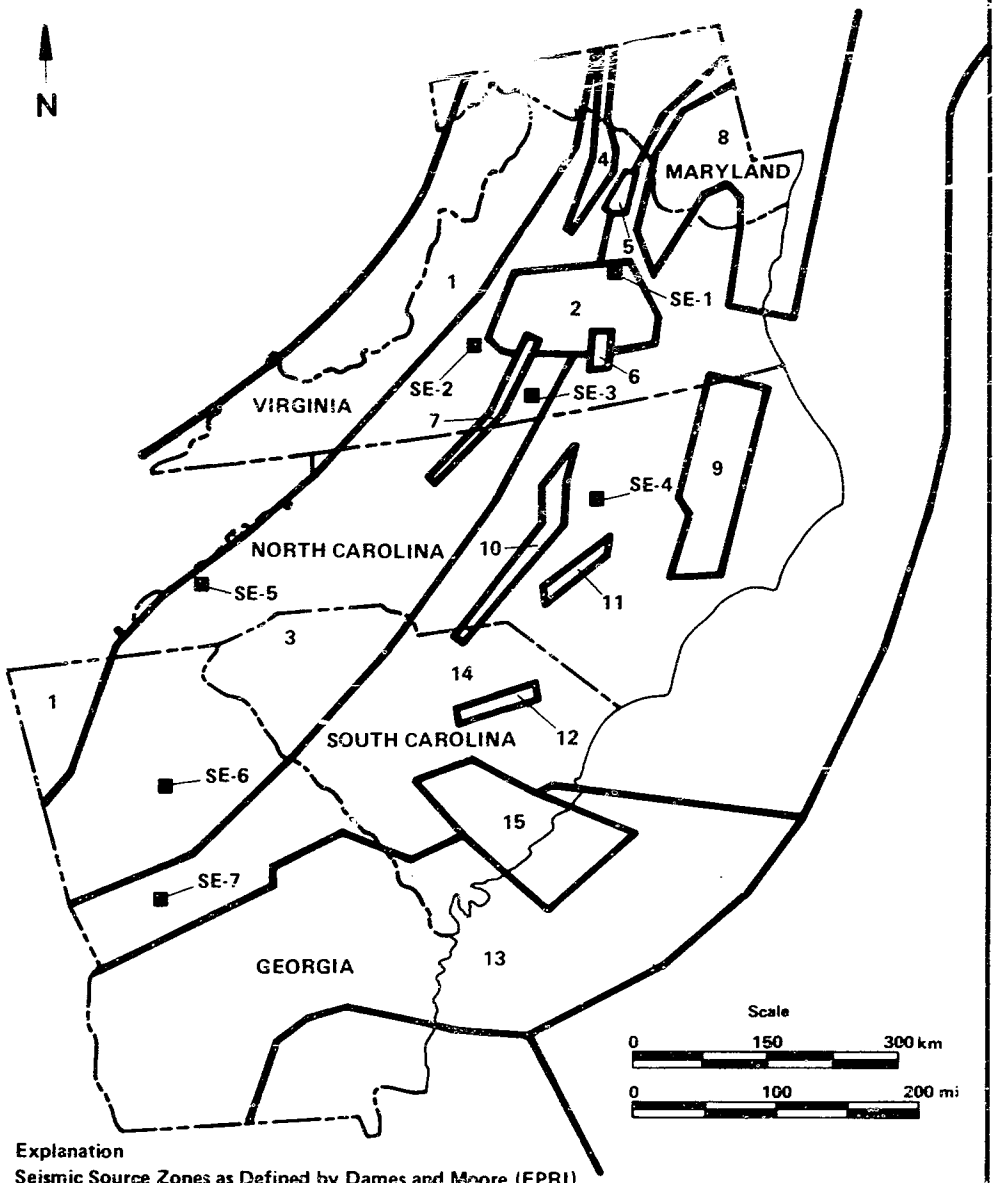
Approximate location of preliminary candidate area

Scale
0 100 200 km
0 100 200 mi

A Representative Seismic Zone Map of the Southeastern United States

Source: Bollinger, 1973b; Stover et al, 1984

Figure 3-118a



Explanation

Seismic Source Zones as Defined by Dames and Moore (EPRI)

1 Paleozoic Fold Belts
2 Central Virginia Seismic Zone
3 Southern Cratonic Margin (Default Source Zone)
4 Newark–Gettysburg Basin
5 Stafford Fault Zone
6 Hopewell Fault Zone
7 Dan River Basin
8 Connecticut Basin
9 Buried Triassic Basin
10 Jonesboro Basin
11 Buried Triassic Basin
12 Florence Basin
13 Charleston Mesozoic Rift
14 Southern Appalachian Mobile Belt (Default Source Zone)
15 Charleston Seismic Zone

■ Approximate location of preliminary candidate area

Source: Electric Power Research Institute (EPRI), 1985 (Draft)

Example of EPRI Seismic Source Zones for the Southeastern United States

Figure 3–119b

- preliminary ca[illegible] error location within the geologic setting and its relation to seismically active regions
- the largest historical earthquake that occurred within the seismically associated region
- known or possible correlations between the observed seismicity and geologic structure.

Locations determined for historical earthquake epicenters are, at best, only estimates. For noninstrumentally determined epicenters, locations are based on information from localities reporting the strongest shaking. Using the hypocenter quality codes from Stover et al. (1984), locational accuracy generally varies between 40 to 240 km (25 to 150 mi), with uncertainties being greater for the earlier events. For instrumentally determined epicenters, locational accuracies are generally less than 25 km (16 mi) (Bollinger, 1975), with uncertainties being less for the more recent events.

In situ stress measurements are limited in the Southeastern Region (DOE, 1985g) and none have been made in or near any of the preliminary candidate areas except for one principal stress direction measured just outside of the Rolesville batholith (Zoback and Zoback, 1980). The limited stress measurements made in the Southeastern Region suggest no evidence of high in situ stress differences.

Geodetic data in the Southeastern Region typically indicate much more rapid rates of uplift than the geologic evidence. Brown and Oliver (1976) reported rates of uplift of the Blue Ridge and Piedmont provinces of up to 6 mm (0.24 in) per year relative to the Atlantic coast based on geodetic first-order releveling data for profiles across the Appalachians. The geodetically derived uplift rate may be two orders of magnitude greater than the average uplift for the last 135 million years. The high uplift rate is thought to be episodic and temporary, with a periodicity possibly as low as 100 years (Brown and Oliver, 1976). Uncertainties arise from various types of error corrections that have been applied to the data, and resulting interpretations of

contemporary vertical movements vary widely. Whalen (1985) reports that leveling data collected after 1970 were obtained using a precise level susceptible to magnetically induced errors that can be larger than actual elevation changes measured between leveling stations. Citron and Brown (1979) studied uplift rates in the crystalline terranes of North Carolina and Georgia. Their data also indicate rapid neotectonic uplift (maximum uplift equals 4 ± 0.9 mm (0.16 ± 0.04 in) per year) and a correlation between uplift rate and topography. Other investigators have reported slower uplift rates.

Ahnert (1970) calculated uplift for the crystalline Appalachians of only 0.02 to 0.03 mm (0.0008 to 0.001 in) per year based on mean denudation rates of streams. Gable and Hatton (1983) synthesized data derived from geology, geomorphology, geophysics, paleobotany, radiocarbon dating, geodetic leveling, and sea level measurements (tide-gage data) to show average vertical crustal movements for the last 10 million years in the conterminous United States. This information, although highly interpretative, indicates an uplift rate between 0.01 and 0.1 mm (0.0004 and 0.004 in) per year in the southern Appalachian region.

3.2.3.1.1.4 Strategic, Metallic, and Energy-Related Resources. An overview of the rock and mineral resources in the Southeastern Region is presented in the Southeastern RGCR (DOE, 1985b). Current mineral production from Georgia, North Carolina, and Virginia is predominantly nonmetallic (U.S. Bureau of Mines, 1982). Prior to World War II, the Blue Ridge and Piedmont provinces produced significant quantities of gold, copper, manganese, iron ore, and tungsten. Exploration activity continues for metallic minerals. Economic deposits may yet be discovered, but it is likely that nonmetallic minerals will dominate the mineral economies of the three states.

Interpretation of geophysical data indicate that thrust-faulted crystalline rocks of the Piedmont and Blue Ridge may be underlain by sedimentary rocks (Cook et al., 1979). There is speculation that these

sedimentary rocks [illegible] potential sources of hydrocarbons (Harris et al., 1981; Hatcher, 1982). However, [illegible] resources have been proven to date.

3.2.3.1.1.5 Hydrology. The Blue Ridge and Piedmont physiographic provinces lie within the Piedmont ground-water province. The topography, geology, and climate of the region have a strong influence on the occurrence and movement of surface water and ground water. The crest of the Blue Ridge physiographic province forms a major drainage divide, with streams north of the divide generally flowing north-northwest and those south of the divide flowing south-southeast (Hack, 1982). In the crystalline terranes, the drainage pattern is typically dendritic.

Ground water throughout the Southeastern Regions occurs in four principal geohydrologic units: alluvium, saprolite, crystalline rocks, and sedimentary rocks of Triassic age. Ground water at all preliminary candidate areas can be discussed in terms of surficial aquifers (i.e., alluvium and saprolite), which can be characterized as porous flow media, and generally deeper crystalline bedrock aquifers which can be characterized as a fracture flow media, where flow is largely controlled by the geometry of secondary interstices (fractures, faults, etc.) apertures of fractures and interconnectedness of these features.

Although deep ground-water conditions are currently unknown for the preliminary candidate areas, studies by Toth (1962; 1963), Freeze and Witherspoon (1966; 1967; 1968), Stokes (1978), and Gale (1982) indicate that, in general, the water table and ground water at depth is a subdued replica of the topography. Therefore, ground water flows generally from topographically high areas to topographically low areas. The inherent assumption in such studies is that ground water at depth is, on a regional basis, in hydraulic connection with the shallow ground-water table. This assumption probably applies to the seven preliminary candidate areas described. Areas immediately adjacent to major water bodies and major through-flowing streams are potential locations of ground-water discharge. Specific directions and rates of ground-water

flow are influenced by spatial variations in permeability. Permeability variations are primarily controlled by geologic structures and lithology.

3.2.3.1.2 Environmental. The environmental setting of the Southeastern Region is described in detail in the Southeastern Regional Environmental Characterization Report (RECR) (DOE, 1985h).

3.2.3.1.2.1 Climate. Most of the Southeastern Region is characterized by warm, humid summers and short, relatively mild winters. In the mountainous terrain along the western part of the region, summer heat and humidity are less pronounced, but winters are harsher. Average annual temperature ranges from 11°C (53°F) in the northern part of the region to 18°C (65°F) in the southern part. Annual average precipitation generally ranges from 100 cm (40 in) in the northern part of the region to 130 cm (50 in) in the southern part of the region; however, in the high terrain areas of Georgia, South Carolina, and North Carolina, average annual precipitation is somewhat higher. All parts of the region have experienced severe weather events, including tornadoes, high wind speeds, and the direct or indirect effects of tropical storms.

3.2.3.1.2.2 Land Use. Land use patterns vary greatly within the region, but rural land uses are dominant. Urban areas, defined by the U.S. Bureau of the Census as places containing 2,500 or more persons, are found throughout the region. Heavy concentrations of urban areas occur along a belt of cities extending from Baltimore and Washington, D. C., southwest to Atlanta. There is an extensive rural area on either side of the belt of cities.

Private land ownership predominates within the region, but there are extensive tracts of public land administered by Federal, State, and local governments. National forests and national park units account for most of the Federal-protected lands, the largest of which are the Great Smoky Mountains National Park, the Jefferson National Forest and the Chattahoochee National Forest. Recreation and natural resource

management are the prevailing uses of these Federal lands. The national forests are primarily regional, rather than national, recreationresources. However, certain of the national park units, such as the Great Smoky Mountain National Park, are recreation resources of national significance. None of the preliminary candidate areas are located within a coastal zone of the Coastal Barrier Resource System.

All five states in the Southeastern Region maintain extensive and varied systems of State recreation areas and other protected lands. In addition to numerous State parks, the states in the Southeastern Region have designated lands comparable to Federal wildlife refuges, wilderness preservation areas, wild and scenic rivers, and forests.

3.2.3.1.2.3 Demography. The major population concentrations in the region form a belt of medium to large cities -- from Baltimore in the northern part of the region to Atlanta in the southern part. Baltimore, Washington, D.C. (adjacent to the region), Richmond, Raleigh-Durham, Greensboro-High Point, Winston-Salem, Charlotte, Greenville, and Atlanta are the main cities in this area of population concentration. Smaller cities such as Petersburg, Burlington, Concord, Gastonia, Spartanburg, and Athens fill in the belt, while Roanoke, Lynchburg, Asheville, Columbia, and Columbus form population centers on either side of the belt.

There are a greater proportion of rural residents in the region than in the United States as a whole. North Carolina has the highest percentage of rural population. The rural nonfarm population (persons who live in rural areas, but not on farms) constitutes most of the rural population and nowhere in the region is the population predominantly rural farm. The concentration of rural nonfarm population throughout the region may be due to the generally uniform distribution of small towns.

3.2.3.1.2.4 Ecological Systems. Six Federally listed threatened or endangered plant species occur in the Southeastern Region. Five plant species are listed as endangered and one plant species is listed as threatened. Each state within the region has, or is developing, a list

of State-protected plants. Currently, Virginia has no plants on its list while North Carolina and Georgia have 85 and 58 plant species listed for protection, respectively. One Federally designated critical habitat has been established for a protected plant population in North Carolina. This critical habitat is neither within any of the preliminary candidate areas in the Southeastern Region nor within 32 km (20 mi) of these preliminary candidate areas.

There are 32 Federally listed threatened and endangered animal species in the Southeastern Region. These include six species of mammals, seven species of birds, one species of reptile, six species of fish, and 12 species of invertebrates. Most of the invertebrates listed are bivalve molluscs, which occur in cold-water areas of Virginia. Federally designated critical habitats have been identified for two fish species in the Southeastern Region -- two areas in Virginia and one in North Carolina. Neither of these critical habitats are within any of the preliminary candidate areas in the Southeastern Region or within 10 km (6 m) of these preliminary candidate areas.

3.2.3.1.2.5 Federal Indian Reservations. There is one Federal Indian Reservation within the Southeastern Region (see Plate SE-1A). The tribe, the Eastern Band of Cherokee, does not have Federal off-reservation treaty rights.

3.2.3.1.3 Transportation. Transportation routes (highways and railroads) for the Southeastern Region are shown on Plates SE-6A and SE-6B.* Highway and railroad data bases used in generating the plates and the transportation analyses presented are derived from United States

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* Because the base map used to generate the transportation plates is a different projection than the base map used to generate the other plates in the accompanying portfolio, there will be some distortion if transporation plates are overlain on the other plates.

Geological Survey (USGS) data and are updated through 1985) by the Oak Ridge National Laboratory, Tennessee.* A brief description of highway andrailroad networks in the vicinity of the preliminary candidate areas in the Southeastern Region is presented in Sections 3.2.3.2.14 through 3.2.3.8.14. The highway network is broadly classified as interstate highways, U.S. highways, and State highways. The rail network is classified based on the volume of freight movements as mainline railroads and branchline railroads. It should be emphasized that all references to distances are approximate and measured from the edges of the preliminary candidate area, not the center. Furthermore, all distances are "straight line" since specific access routes and regional routes for waste transportation to the preliminary candidate area are yet to be defined.

* Although plates show only primary State highways, discussions provided in this report take into consideration additional State highways.

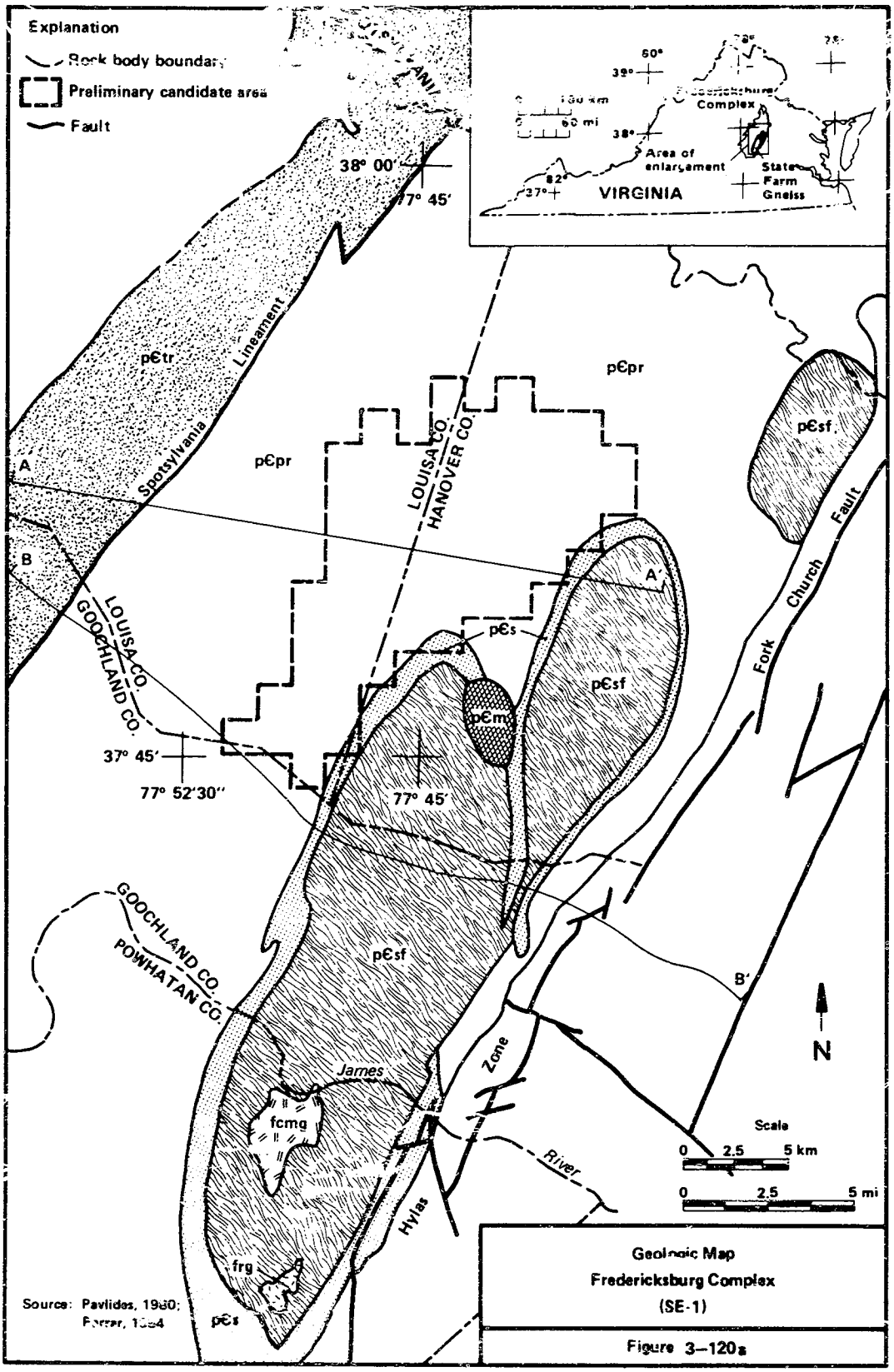
3 2.3.2 Preliminary Candidate Area Description - Fredericksburg Complex (SE-1)

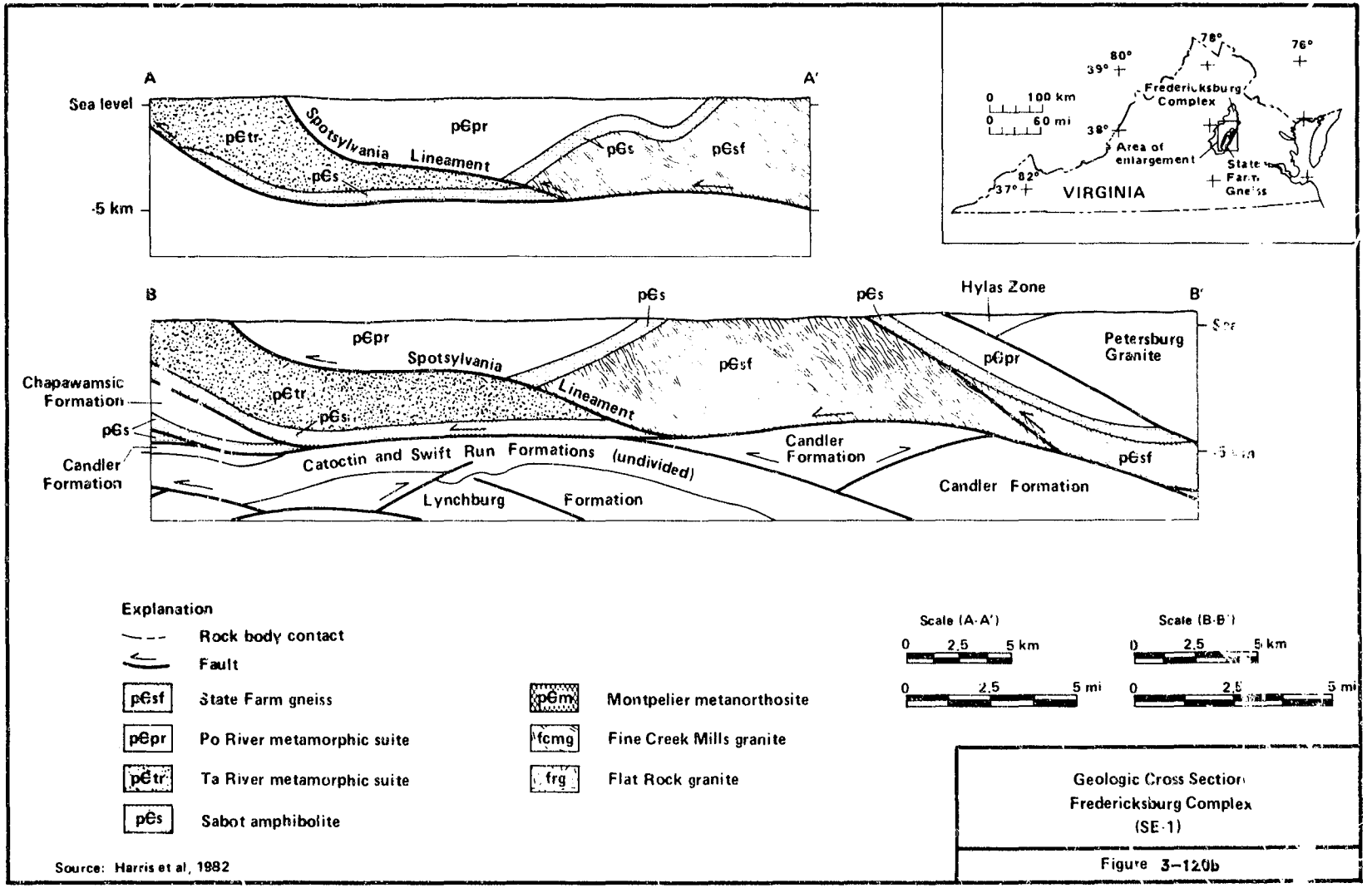
Preliminary candidate area SE-1 is located within the Piedmont physiographic province of east central Virginia in Goochland, Louisa, and Hanover Counties at approximately 37°50' N latitude, and 77°45' W longitude (Figure 3-117a).

3.2.3.2.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area has an area of 166 km^2 (64 mi^2) with a length of 19 km (12 mi), and a width of 12 km (7 mi); and overlies the Fredericksburg Complex (Figure 3-120a).

The Fredericksburg Complex and State Farm gneiss (outside the preliminary candidate area at the surface but underlies it at depth) are structurally separated by the Sabot amphibolite (Figures 3-120a and 3-120b), a lenticular to sheet-like unit about 0.7 to 1 km (0.4 to 0.6 mi) thick (Reilly, 1980; Farrar, 1984). Reilly (1980) studied magnetic and gravity data for this area and concluded that these data show no evidence of a structural discontinuity in the crust. Consequently, any sole fault in the preliminary candidate area is either very shallow (about 5 km or 3.1 mi) or very deep (more than 20 km or 12.4 mi), and the total thickness of crystalline rock within the preliminary candidate area appears to be at least 5 km (3.1 mi) (Goodwin, 1970; Reilly, 1980).

Available water well casing depth data in the vicinity of the preliminary candidate area are given on Figure 3-121. Based on nine data points, the average thickness of saprolite within the Fredericksburg Complex and State Farm gneiss is 14.9 m (49.1 ft). Additionally, based on 17 data points, the average thickness of saprolite overlying nearby surrounding units is 13.9 m (45.5 ft). No casing depth data are available for wells within the preliminary candidate area. Well data were supplied by the Bureau of Water Control Management of the Virginia State Water Control Board (1982). The location and distribution of areas

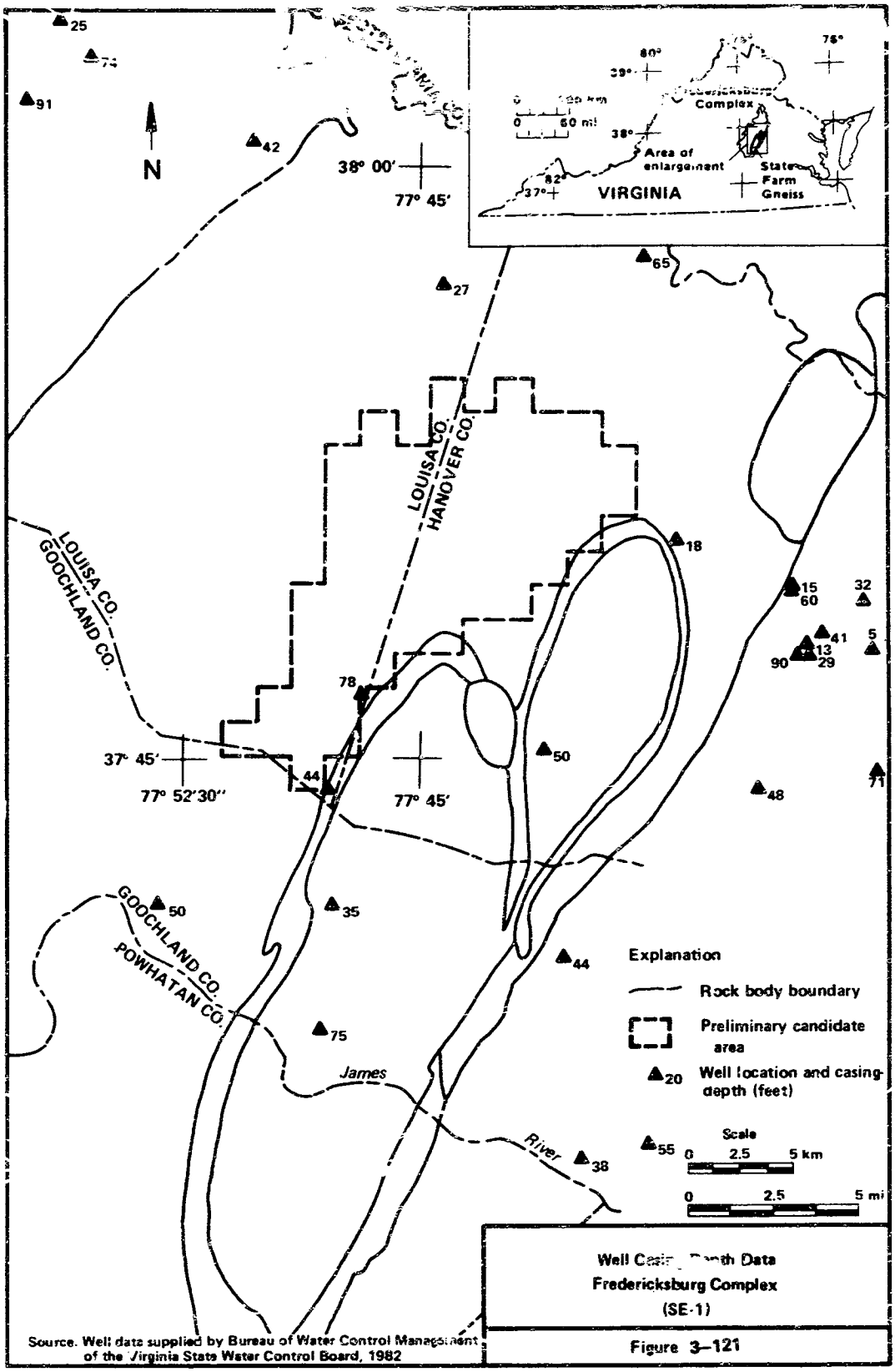

Explanation
Rock body boundary
Preliminary candidate area
Fault
38° 00'
77° 45'
pЄtr
Lineament
Spotsylvania
pЄpr
LOUISA CO.
HANOVER CO.
A
A'
B
B'
LOUISA CO.
GOOCHLAND CO.
37° 45'
77° 52'30"
pЄs
pЄsf
pЄm
fcmg
frg
GOOCHLAND CO.
POWHATAN CO.
James
River
Zone
Hylas
Fork
Church
Fault
N
Scale
0 2.5 5 km
0 2.5 5 mi
Source: Pavlides, 1980; Force, 1984
Geologic Map
Fredericksburg Complex
(SE-1)
Figure 3–120a
VIRGINIA
Area of enlargement
State Farm Gneiss
Spotsylvania Complex



Source: Harris et al, 1982

Geologic Cross Section
Fredericksburg Complex
(SE-1)

Figure 3-120b


25
74
91
42
N
38° 00'
77° 45'
65
27
LOUISA CO.
HANOVER CO.
LOUISA CO.
GOOCHLAND CO.
18
15
60
32
41
13
29
90
5
78
37° 45'
77° 52'30"
44
77° 45'
50
48
71
GOOCHLAND CO.
50
35
POWHATAN CO.
44
75
James
River
38
55
Explanation
Rock body boundary
Preliminary candidate area
20 Well location and casing depth (feet)
Scale
0 2.5 5 km
0 2.5 5 mi
Fredericksburg Complex
Area of enlargement
State Farm Gneiss
VIRGINIA
Well Casing Depth Data
Fredericksburg Complex
(SE-1)
Source. Well data supplied by Bureau of Water Control Management of the Virginia State Water Control Board, 1982
Figure 3-121

of rock exposure are presently unknown; however, mappable exposures are expected to be fairly

On the basis of the data presented above and the assumed depth and size of a repository in crystalline rock (see Section 1.5), the host rock underlying the preliminary candidate area is sufficiently thick and laterally extensive to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation.

3.2.3.2.2 Lithology and Tectonics. Preliminary candidate area SE-1 includes the Po River metamorphic suite portion of the Fredericksburg Complex and a very small part of the Sabot amphibolite (Pavlides, 1980; Farrar, 1984). The Po River metamorphic suite is the probable equivalent of the Maidens gneiss (Conley, 1982), and structurally overlies the Sabot amphibolite, which overlies the State Farm gneiss (Farrar, 1984; Poland, 1976). These relationships are depicted on Figure 3-120b.

The Po River metamorphic suite of the Fredericksburg Complex consists primarily of moderately well foliated, medium-grained biotite gneiss that includes concordant layers of medium- to coarse-grained garnetiferous quartizite of variable thickness (Poland, 1976). There are rare layers of potassium-feldspar-garnet-sillimanite gneiss (Poland, 1976) that are partially to nearly completely recrystallized to schist containing thin calc-silicate layers (Farrar, 1984). Lenses of intermediate to mafic gneiss are interbedded with the biotite gneiss (Farrar, 1984; Poland, 1976). Other minor interbedded lithologies include discontinuous layers of leucocratic garnet-plagioclase-quartz-potassium-feldspar gneiss and clinopyroxene-hornblende-plagioclase amphibolite (Farrar, 1984). All rock types are cut by stringers and veins of pegmatite (Poland, 1976).

The Sabot amphibolite consists of medium- to coarse-grained, weakly laminated amphibolite, with significant amounts of interlayered biotite gneiss and minor amounts of schist (Farrar, 1984; Poland, 1976). The

amphibolite appears to occur in lens-shaped bodies that are interbedded with the biotite gneiss and minor biotite schist (Poland, 1976). The upper and lower contacts of the Sabot are typically sharp, but locally may grade through a thin, transitional amphibolite gneiss phase (Poland, 1976).

The State Farm gneiss is exposed adjacent to the preliminary candidate area and consists of medium- to coarse-grained, massive to moderately layered biotite gneiss that is locally interbedded with or gradational into biotite gneiss, minor biotite schist, and granitic gneiss (less than 5% biotite) (Poland, 1976).

The State Farm gneiss, Sabot amphibolite, and Fredericksburg Complex were originally stratified sedimentary and volcanic rocks (Bobyarchick, 1976). All three occur in a refolded, northeast-plunging, antiformal structure; the State Farm gneiss forms the core of the structure (Farrar, 1984). During Grenville-time (about 1,000 million years ago), these rocks were subjected to a granulite-grade metamorphic event (Farrar, 1984). During Paleozoic time, the granulite terrane was remobilized under amphibolite-grade conditions and intensely deformed (Farrar, 1984). Low-angle, northwestward-directed thrust faulting developed during the late Paleozoic under greenschist-grade conditions and produced mylonite zones including the Hylas zone southeast of the preliminary candidate area (Bobyarchick, 1976). These episodes of metamorphism and deformation (orogenies) were primarily compressional and ductile in nature and produced folds and foliation. The Alleghenian orogeny, the youngest episode of deformation, differed from previous events in that it was partly extensional and brittle in nature and produced faults and fractures (Bobyarchick, 1976).

Two major faults lie within 10 km (6 mi) of preliminary candidate area SE-1: the Spotsylvania lineament and the Hylas zone-Fork Church fault (Figure 3-120a). The Spotsylvania lineament defines the contact between the Ta River metamorphic suite and the Po River metamorphic suite

of the Fredericksburg Comp... (Pavlides, 1980). The Spotsylvania lineament has been defined on the basis of a regional aeromagnetic anomaly and has not been studied in detail (Pavlides et al., 1982). Harris et al., (1982) interpret it to be a splay of a major thrust on the basis of COCORP seismic data.

The Hylas zone was formed by low-angle, northwestward-directed thrusting that occurred during late Paleozoic time and ranges in thickness from 0.5 to 2.4 km (0.3 to 1.5 mi) (Bobyarchick, 1976). High-angle faults and locally intense fracturing were superimposed on the Hylas zone about 220 million years ago (late Triassic) (Bobyarchick and Glover, 1979). The Fork Church fault probably formed during this same time period (Bobyarchick and Glover, 1979). No systematic studies of jointing have been undertaken in the preliminary candidate area.

Estimates of regional uplift and subsidence are not area-specific and are discussed in detail in Section 3.2.3.1.1.3. Regional data indicate a wide range of interpretation on uplift data. No data are available for the preliminary candidate area; therefore, until data are obtained, no conclusion can be drawn concerning affects of uplift. There are no in situ stress data available for the vicinity of the preliminary candidate area.

There is no evidence of Quaternary tectonic processes including igneous activity, folding, faulting, or subsidence within the geologic setting. Regional uplift data suggest the possibility of active tectonic processes; however, there appears to be no significant potential for tectonic deformations that could affect the regional ground-water flow system.

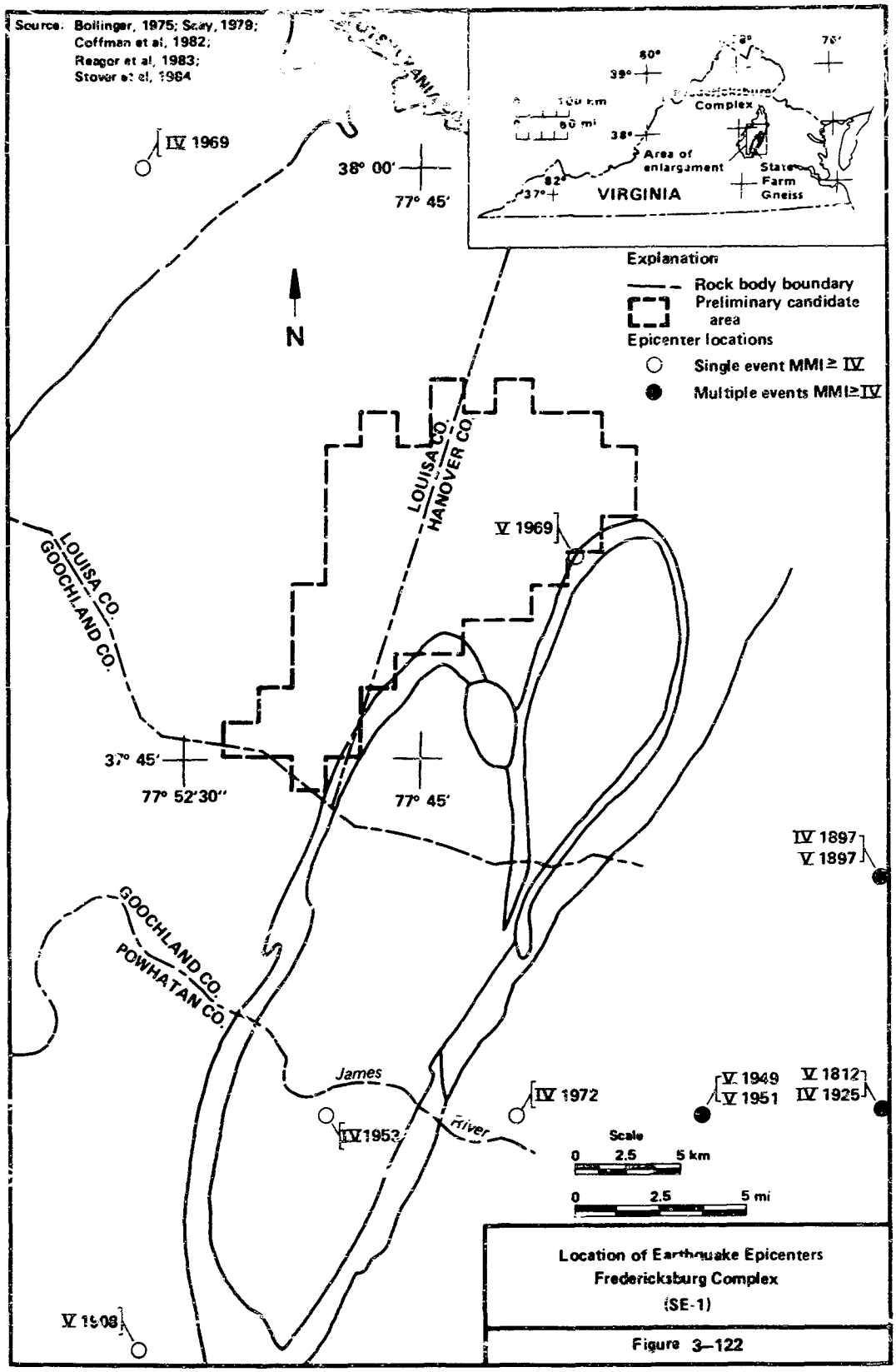
3.2.3.2.3 Seismicity. One earthquake epicenter with an intensity of MM V is located within 10 km (6 mi) of the preliminary candidate area (Reagor et al., 1980b; Stover et al., 1984). Other seismic events (from MM III to VI) in the vicinity of the preliminary candidate area are shown

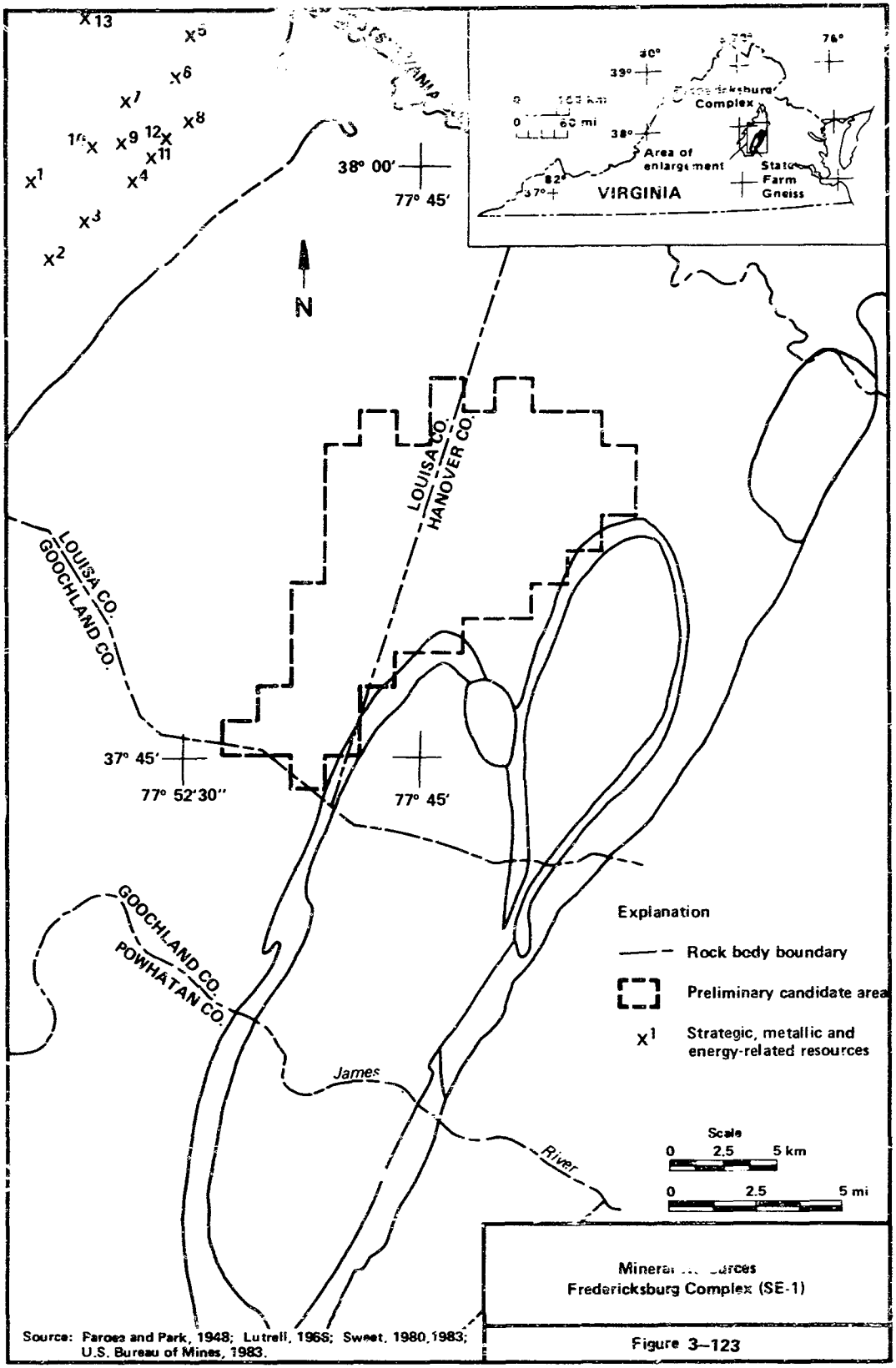
on Figure 3-122. The preliminary candidate area is located within a region of relatively high seismicity (see Figure 3.1.1-8 in Section 3.2.3.1.1.3) referred to by Bollinger (1973b) and others (EPRI, 1985) as the Central Virginia Seismic Zone. The largest historical earthquake associated with this zone is an MM VII which occurred on December 23, 1875, approximately 50 km (33 mi) southwest of the preliminary candidate area in Buckingham County, Virginia.

The major faults near the preliminary candidate area are discussed in Section 3.2.3.1.1.2. No definite correlation between seismicity and geologic structure has been made in the region encompassing the preliminary candidate area. However, Bollinger (1981) has suggested that there may be a correlation between microseismic events and the Hylas fault zone.

Although the level of seismic activity in the region is relatively high, it is unlikely that future seismic activity would produce ground motion in excess of reasonable design limits or could affect waste containment or isolation, and it is unlikely that the frequency of occurrence of earthquakes in the area will increase in the future.

3.2.3.2.4 Mineral Resources. No strategic, metallic, or energy-related resources are known to be present in the preliminary candidate area or within 10 km (6 mi). However, a base and precious metal mining district is located approximately 15 km (9.3 mi) northwest of the preliminary candidate area, outside of the Fredericksburg Complex (Figure 3-123 and Table 3-13) (Pavlides et al., 1982). Resources formerly extracted from this district include gold, iron, zinc, lead, silver, copper, and sulfur (Pardee and Park, 1948; Luttrell, 1966; Sweet, 1980, 1983; U.S. Bureau of Mines, 1983). The district occurs in rocks outside the Fredericksburg Complex and trends away from the preliminary candidate area. Therefore, the possibility of similar resources existing within the preliminary candidate area is very low. This concept is supported by the historical lack of mining activity for base and precious metal resources within the Fredericksburg Complex and the preliminary candidate area.


Source: Bollinger, 1975; Scay, 1979; Coffman et al, 1982; Reagor et al, 1983; Stover et al, 1984
IV 1969
38° 00'
77° 45'
VIRGINIA
Area of enlargement
Fredericksburg Complex
State Farm Gneiss
Explanation
Rock body boundary
Preliminary candidate area
Epicenter locations
Single event MMI ≥ IV
Multiple events MMI ≥ IV
N
LOUISA CO.
HANOVER CO.
V 1969
LOUISA CO.
GOOCHLAND CO.
37° 45'
77° 52'30"
77° 45'
IV 1897
V 1897
GOOCHLAND CO.
POWHATAN CO.
James
River
IV 1952
IV 1972
V 1949
V 1951
V 1812
IV 1925
Scale
0 2.5 5 km
0 2.5 5 mi
V 1908
Location of Earthquake Epicenters
Fredericksburg Complex
(SE-1)
Figure 3-122



Source: Farcas and Park, 1948; Lutrell, 1965; Sweet, 1980,1983; U.S. Bureau of Mines, 1983.

Figure 3–123

Table 3-13. Mineral Resources Near Preliminary Candidate Area SE-1

(Sheet 1 of 2)

Map Number (Figure 3-123)	Name	Commodity	Status
1	MacDonald Mine	Gold	Inactive
2	Walnut Grove Mine	Gold	Inactive
3	Louisa Mine	Gold	Inactive
4	Luce Mine	Gold	Inactive
*	New Luce Mine	Gold	Inactive
5	Cofer Mine	Zinc, Sulfur, Lead, Silver, Copper, Iron, Gold	Unknown
*	East Sulphur Mine	Sulfur, Zinc, Iron, Silver, Gold, Copper, Lead	Inactive
*	Piedmont Mineral Assoc.	Zinc, Lead, Copper, Silver, Sulfur	Inactive
*	Sulphur Mine	Sulfur, Iron, Cooper	Inactive
*	Tinder Mine	Gold, Zinc, Lead	Inactive
6	Boyd Smith Mine	Copper, Iron, Sulfur	Inactive
*	Old Dominion Mine	Sulfur, Iron	Inactive
7	Arminius Mine	Zinc, Copper, Iron, Sulfur, Lead, Silver	Unknown
*	Cooper Mine	Gold	Inactive
*	Sulphur Mine	Sulfur, Iron, Lead, Copper, Zinc	Inactive
*	Walton Mine	Gold, Copper, Zinc, Sulfur, Lead, Iron	Inactive

Table 3-13. Mineral Resources [illegible] Preliminary Candidate Area SE-1

(Sheet 2 of 2)

Map Number (Figure 3-123)	Name	Commodity	Status
6	Belden Mine	Gold	Inactive
*	Chick Mine	Gold	Inactive
*	Childs Mine	Iron	Inactive
*	Morriston Mine	Gold	Inactive
*	Simms Mines	Sulfur, Iron	Inactive
*	Stockton Mine	Gold	Inactive
9	Hemmer Mine	Sulfur, Lead, Zinc, Copper, Iron	Inactive
*	Kent Mine	Sulfur, Iron	Inactive
*	Lett Mine	Gold, Sulfur, Iron	Inactive
10	Julia Mine	Zinc, Sulfur, Lead, Silver, Copper, Iron, Gold	Unknown
11	Bibb Mine	Gold	Inactive
*	Harris Mine	Gold	Inactive
*	Jones Mine	Iron	Inactive
12	Unnamed Mine	Gold	Inactive
*	Hunter Mine	Gold	Inactive
13	Gunter Mine	Sulfur, Iron	Inactive

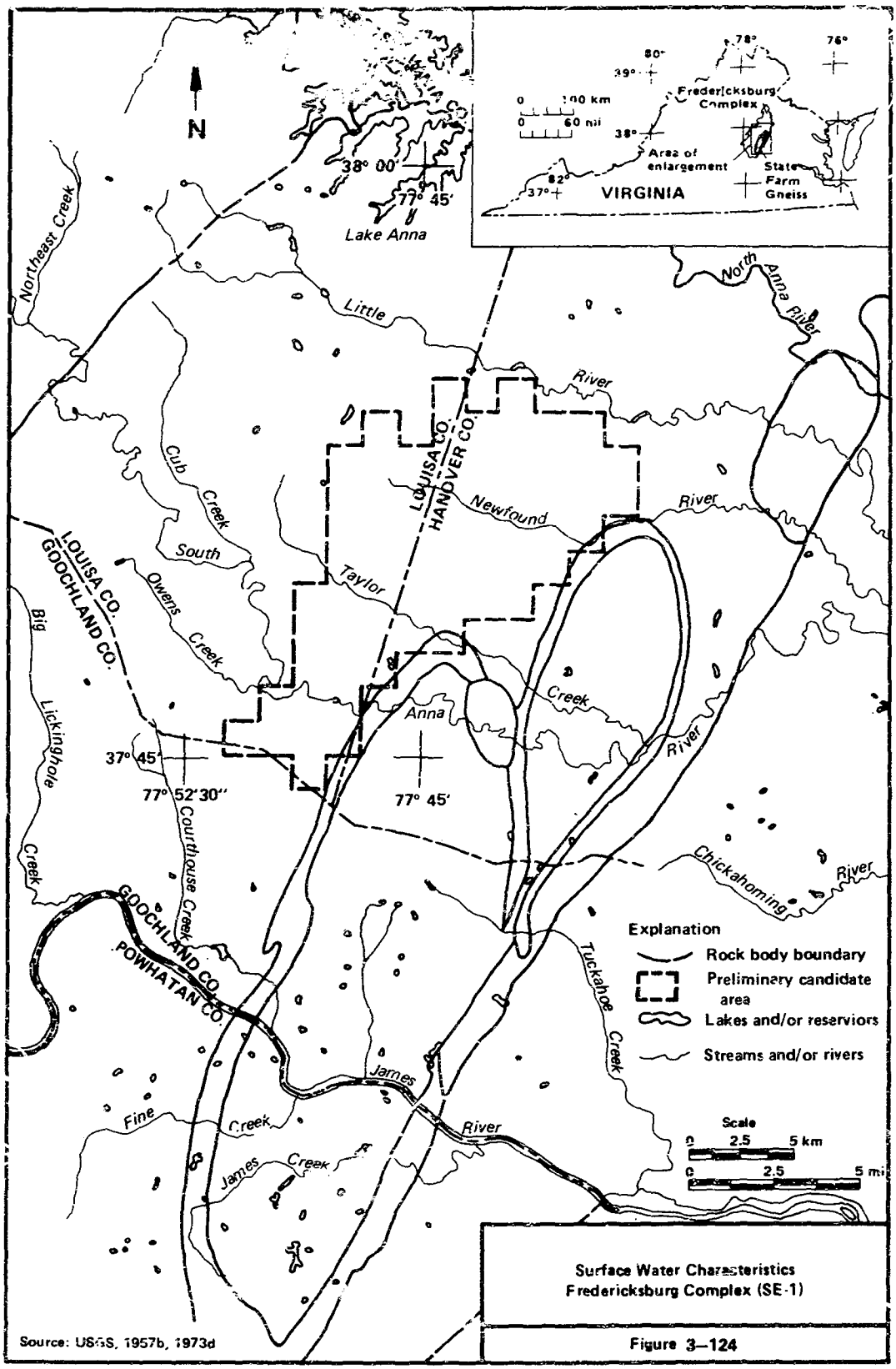
Source: Pardee and Park, 1948; Luttrell, 1966; Sweet, 1980, 1983; U.S. Bureau of Mines, 1983.

* Not shown on map, located off map.

Based on the data presented in this section, there are no known strategic, metallic, or energy-related mineral resources within the preliminary candidate area. There is no evidence for mining to a depth sufficient to affect waste isolation, and no information is available to indicate that deep drillholes (greater than 100 m [328 ft] in depth) are present in the preliminary candidate area.

3.2.3.2.5 Topography and Surface-Water Characteristics. The preliminary candidate area is characterized by a moderately dissected, relatively wide, gently sloping or rolling plain of low topographic relief. Elevations range from 61 to 122 m (200 to 400 ft) over the entire preliminary candidate area (USGS, 1968a; 1968d; 1968i; 1969a, 1969b). Floodplains are generally narrow (less than 31 m [100 ft]) to moderately wide (up to 244 m [800 ft]). Taylors Creek has a floodplain that is locally as much as 548 m (1,800 ft) wide, although it averages 244 m (800 ft) or less over most of its length. Local relief does not generally exceed 31 m (100 ft).

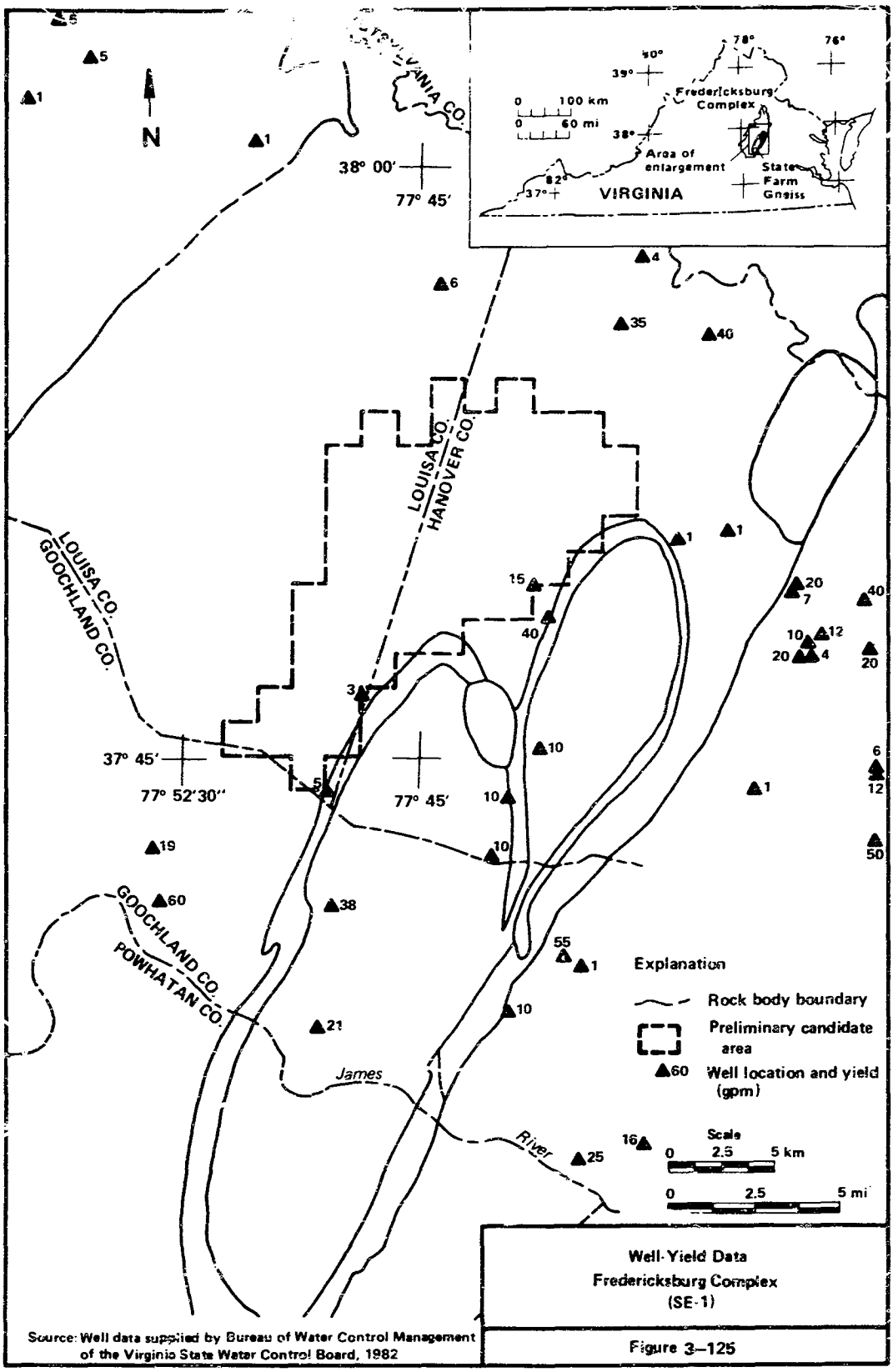
The surface-water system within the preliminary candidate area is characterized by a dendritic stream pattern that is dominated by the Newfound River, Taylors Creek, and their tributaries (Figure 3-124). These surface streams generally flow south-southeast across the preliminary candidate area. The Newfound River and Taylors Creek drain into the South Anna River approximately 14 and 9.5 km (8.4 and 5.7 mi), respectively, downstream from the preliminary candidate area (USGS, 1957b; 1973d). There are no large lakes or reservoirs within or near (within 8 km [4.8 mi]) of the preliminary candidate area, although numerous small (less than 4 ha [10 ac]) impoundments are scattered throughout. Marshes and swamps occur primarily along Taylors Creek and locally along Newfound River, but constitute less than 1% of the preliminary candidate area (USGS, 1968b; 1969a; 1969b).


N
38° 00'
77° 45'
Lake Anna
Northeast Creek
Little
River
North Anna River
LOUISA CO.
HANOVER CO.
Cub Creek
South
Newfound
River
Taylor
Owens Creek
LOUISA CO.
GOOCHLAND CO.
Big
Lickinghole
Creek
Anna
Creek
River
37° 45'
77° 52'30"
77° 45'
Courthouse Creek
Chickahominy
River
GOOCHLAND CO.
POWHATAN CO.
Tuckahoe Creek
James
River
Fine
Creek
James Creek
0 100 km
0 60 mi
80°
78°
76°
39°
38°
82°
37°
Fredericksburg Complex
Area of enlargement
State Farm Gneiss
VIRGINIA
Explanation
Rock body boundary
Preliminary candidate area
Lakes and/or reserviors
Streams and/or rivers
Scale
0 2.5 5 km
0 2.5 5 mi
Surface Water Characteristics
Fredericksburg Complex (SE-1)
Source: USGS, 1957b, 1973d
Figure 3–124

The presence of low [illegible] moderately wide floodplains, and local marshes and swamps indicate that the preliminary candidate area is moderately well drained to locally poorly drained. Consequently, there is a slight potential for small-scale, localized flooding along some streams. However, potential for localized flooding is limited to less than 1% of the entire preliminary candidate area.

3.2.3.2.6 Ground-Water Resources. Regional ground-water data are discussed in Section 3.2.3.1.1.5. Available data in the preliminary candidate area do not allow a differentiation between producing wells in saprolite and crystalline bedrock wells, nor are water level contour maps available for preliminary candidate area SE-1. Well data were provided by the Bureau of Water Control Management of the Virginia State Water Control Board (1982). Water well data in the vicinity of the preliminary candidate area are reported by county and expressed in terms of well yields. Figure 3-125 presents the available well-yield data in the vicinity of the preliminary candidate area. Seventeen wells located within the Fredericksburg Complex, the State Farm gneiss, and the Sabot amphibolite average 1.18 L/s (18.7 gpm). Of these, 11 yield less than 1.26 L/s (20 gpm), five yield from 1.26 to 3.15 L/s (20 to 50 gpm), and one yields 3.79 L/s (60 gpm). Only one well with a yield of 0.95 L/s (15 gpm) is located within the preliminary candidate area. Twenty-one additional wells located within the surrounding units average 1.08 L/s (17.2 gpm). Of these, 14 yield less than 1.26 L/s (20 gpm), six yield from 1.26 to 3.15 L/s (20 to 50 gpm), and one yields 3.47 L/s (55 gpm). The well yield information indicates the presence of potable ground water in the vicinity of the preliminary candidate area. The yields are generally very low [less than 1.26 L/s (20 gpm)] with a few wells producing around 3.15 L/s (50 gpm).

There are no data to suggest ground-water conditions in the preliminary candidate area differ from the surrounding area. Specific relationships between lithology, structure, and well yields are not currently available. There are no data on the deep ground-water system within the preliminary candidate area.


N
38° 00'
77° 45'
SPOTSYLVANIA CO.
LOUISA CO.
HANOVER CO.
LOUISA CO.
GOOCHLAND CO.
37° 45'
77° 52'30"
77° 45'
GOOCHLAND CO.
POWHATAN CO.
James
River
Fredericksburg Complex
Area of enlargement
VIRGINIA
State Farm Gneiss
0 100 km
0 60 mi
Explanation
Rock body boundary
Preliminary candidate area
▲60 Well location and yield (gpm)
Scale
0 2.5 5 km
0 2.5 5 mi
Well-Yield Data
Fredericksburg Complex
(SE-1)
Source: Well data supplied by Bureau of Water Control Management of the Virginia State Water Control Board, 1982
Figure 3–125

3.2.3.2.7 Quaternary Climate. A discussion of Quaternary climatic conditions, including paleoclimatic conditions, vertical crustal movements, and changes in sea level is in Section 3.2.3.1.1.1.

3.2.3.2.8 Federal Lands. There are no Federal lands greater than 130 ha (320 ac) in size located either in or within 10 km (6 mi) of the preliminary candidate area. Federal lands which do occur in Virginia are depicted on Plate 2A of the Southeastern RECR (DOE, 1985h) or are listed in Appendix A of that report. In addition, there is no evidence in the data base that Federal lands less than 130 ha (320 ac) in size are located either in or within 10 km (6 mi) of the preliminary candidate area.

3.2.3.2.9 State Lands. There are no State lands greater than 130 ha (320 ac) in size located either in or within 10 km (6 mi) of the preliminary candidate area. State lands which do occur in Virginia are depicted on Plates 3A or 4A of the Southeastern RECR (DOE, 1985h) or are listed in Appendix B of that report. In addition, there is no evidence in the data base that State lands less than 130 ha (320 ac) in size are located either in or within 10 km (6 mi) of the preliminary candidate area.

3.2.3.2.10 Environmental Compliance. No part of the preliminary candidate area lies within a current air quality nonattainment area. There are no Prevention of Significant Deterioration (PSD) Class I Areas within 40 km (25 mi) of the preliminary candidate area. Three sites on the National Register of Historic Places (NRHP) are located within the preliminary candidate area. These sites are Sycamore Tavern in Montpelier, Oakland near Montpelier (44 FR 7615, 1979), and the Anderson-Foster House in Holly Grove (44 FR 7616, 1979). No proposed NRHP sites exist within the preliminary candidate area. In the regional data base there are no known existing archaeological sites or districts or any proposed for designation within the preliminary candidate area. No National Trails are located within 40 km (25 mi) of the preliminary candidate area.

3.2.3.2.11 Population Density and Distribution. The preliminary candidate area contains no highly populated areas. There are two highly populated areas (Ashland and Tuckahoe) within 16 km (10 mi) of the preliminary candidate area (see Figure 3-126). Ashland is located 14 km (9 mi) east-southeast of the preliminary candidate area and has a population of 4,640. Tuckahoe, with a population of 39,868*, is located 14 km (9 mi) southeast of the preliminary candidate area. The preliminary candidate area contains no areas with population densities greater than or equal to 1,000 persons per square mile. However, there are three areas (Brookland, Three Chopt, and Tuckahoe) with population densities greater than or equal to 1,000 persons per square mile within 16 km (10 mi) from the preliminary candidate area (see Figure 3-126). Tuckahoe, with a population of 41,011*, is also a highly populated area. Brookland and Three Chopt are located 16 km (10 mi) and 11 km (7 mi) southeast of the preliminary candidate area, respectively. The population of Brookland is 35,127 while Three Chopt has a population of 30,443. The city of Richmond is located approximately 29 km (18 mi) southeast of the preliminary candidate area. The average population density of the preliminary candidate area is approximately 45 persons per square mile. The average population density within 80 km (50 mi) of the preliminary candidate area is approximately 123 persons per square mile. Low population density is defined as a density in the general region of the site less than the average population density for the conterminous United States (76 persons per square mile) based on the 1980 census.

3.2.3.2.12 Site Ownership. There are no Federal or DOE-owned lands located within the preliminary candidate area. The Cherokee Indian Reservation is located approximately 530 km (330 mi) southwest of the preliminary candidate area (see Plate SR-1A).

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* The difference in population figures is due to the fact that the geographic extent of the highly populated area of Tuckahoe is slightly different than the area defined by a density of 1,000 persons per square mile.

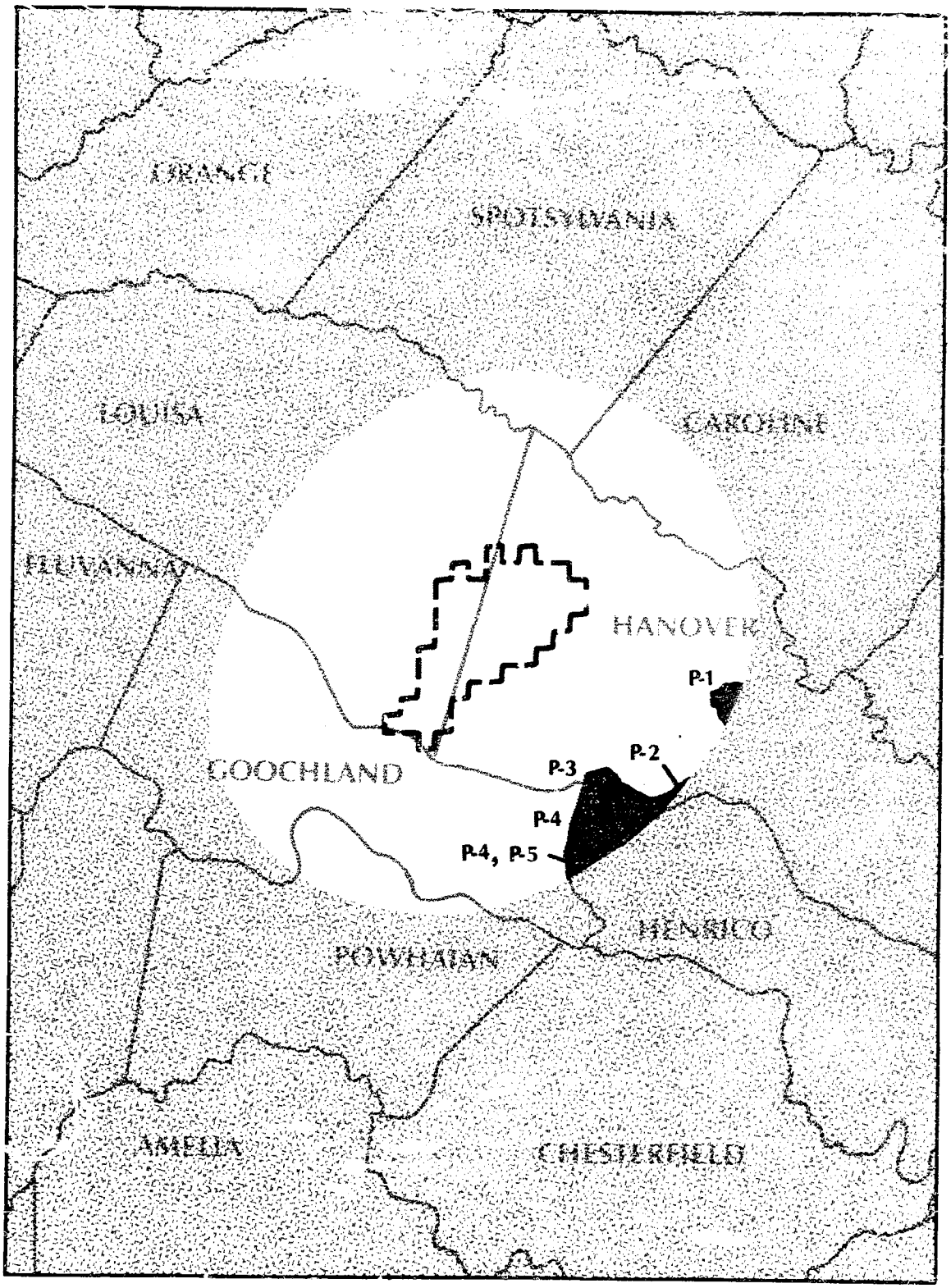


Figure 3–126 Sheet 1

Environmental Features
Fredericksburg Complex (SE-1)

Environmental Features Legend

Preliminary Candidate Area

Environmental Features

P Highly Populated Areas and Areas with Density Greater Than 1000 Persons per Square Mile

F Federal Lands Greater Than 320 Acres

S State Lands Greater Than 320 Acres

I Federal Indian Reservations

● Federal or State Lands Less Than 320 Acres

F-5 Map Alpha-numeric Codes are Keyed to Environmental Features

Rock Bodies

Beyond Ten Miles from Preliminary Candidate Area

State Boundary

County Lines

Scale 1:500,000

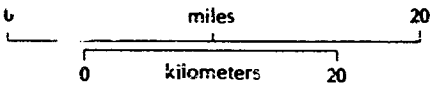


Figure 3-128 Sheet 2

[illegible] FEATURES WITHIN 16 KM (10 MI)
OF P[illegible] ARMA SE-1*

Code	Feature
Population Features	
P-1	Ashland Highly Populated Area (HPA)
P-2	Brookland Minor Civil Division (MCD)
P-3	Three Chopt MCD
P-4	Tuckahoe MCD
P-5	Tuckahoe HPA
Federal Lands	
None	
State Lands	
None	
Indian Reservations	
None	

* The accompanying text identifies only those environmental features within 10 km (6 mi) of the preliminary candidate area.

Figure 3-126, Sheet 3

3.2.3.2.13 Offsite Installations. No commercial nuclear reactors are located within the preliminary candidate area. The nearest operating commercial nuclear reactor is North Anna which is approximately 18 km (11 mi) to the north (Dames & Moore, 1972). The nearest commercial nuclear reactor under construction is the Shearon Harris Nuclear Plant which is approximately 250 km (155 mi) to the southwest (Wamsley, 1985). There are no other known nuclear installations or operations that must be considered under the requirements of 40 CFR 191, Subpart A, within or in proximity to the preliminary candidate area.

3.2.3.2.14 Transportation. Interstate highway I64 passes within 8 km (5 mi) of the southern edge of the preliminary candidate area. Other interstate highways in the vicinity are I95 about 10 km (6 mi) east of the preliminary candidate area and I295 about 13 km (8 mi) to the southeast. U.S. 33 passes through the middle of the preliminary candidate area. This highway intersects I295 northwest of Richmond and roughly parallels I64. U.S. 522 is located about 8 km (5 mi) west of the preliminary candidate area. There is only one State highway in the vicinity of the preliminary candidate area. This highway, State Route 54, runs east and west from I95 near Ashland, Virginia, to U.S. 33 at the eastern edge of the preliminary candidate area. There also are several county and local roads which traverse the area.

The nearest railroad is the Richmond-Fredericksburg and Potomac Railroad which is located about 8 km (5 mi) east of the preliminary candidate area. The Chesapeake and Ohio Railway, about 16 km (10 mi) south of the area, follows the James River valley through central Virginia. Both of these rail lines are important routes and are heavily traveled. The only branchline near this preliminary candidate area is a Chesapeake and Ohio Railway line about 4.8 km (3 mi) to the north. This is a connecting line between two Chesapeake and Ohio mainlines.

Based on the data presented above, access to the preliminary candidate area from both local and regional highway and railway systems appears to be available.

3.2.2.2.15 Preliminary Candidate Area Deferral Analysis. This section identifies significant additional information (specified in Section 3.2) not directly incorporated into Steps 1 through 3 on preliminary candidate area SE-1 that could affect DOE's decision to defer further considerations of the area. Based on evaulation of this additional available information, the area exhibits the following favorable characteristics:

- presence of host rock with sufficient thickness and lateral extent to allow significant flexibility in selecting the depth, configuration, and location of the underground facility to ensure isolation [960.4-2-3(b)(1), 960.5-2-9(b)(1), 960.5-2-9(c)(1)]
- presence of host rock that permits emplacement of waste at least 300 m (1,000 ft) below ground surface [960.4-2-5(b)(1)]
- low potential for tectonic deformations suggests that the regional ground-water flow systems should not be significantly affected [960.4-2-7(c)(6)]
- absence of active faulting within the geologic setting [960.5-2-11(c)(1)]
- absence of historical earthquakes of a magnitude and intensity that, if they recurred, could affect waste containment or isolation [960.4-2-7(c)(2)]
- no indications, based on correlations of earthquakes with tectonic processes and features, that the frequency of earthquake occurrence within the geologic setting may increase [960.4-2-7(c)(3)]
- the frequency of occurrence or magnitude of earthquakes within the geologic setting are no higher than within the region [960.4-2-7(c)(4)]
- absence of historical earthquakes that, if they recurred, could produce ground motion in excess of reasonable design limits [960.5-2-11(c)(2)]

- absence of [illegible], based on correlations of earthquakes with [illegible] processes and features within the geologic setting, that the magnitude of earthquakes during repository construction, operation, and closure may be larger than predicted from historical seismicity [960.5-2-11(c)(3)]
- no evidence of subsurface mining or extraction for resources that could effect waste containment or isolation [960.4-2-8-1(c)(2)]
- no evidence of drilling to a depth sufficient to affect waste containment or isolation [960.4-2-8-1(c)(3)]
- no evidence of significant concentrations of any naturally occurring material that is not widely available from other sources [960.4-2-8-1(c)(4)]
- presence of generally flat terrain [960.5-2-8(b)(1)]
- presence of generally well-drained terrain [960.5-2-8(b)(2)]
- general absence of surface characteristics or surface-water systems that could lead to flooding [960.5-2-8(c), 960.5-2-10(b)(2)]
- located within a geologic setting in which climatic changes have had little effect on the hydrologic system throughout the Quaternary Period [960.4-2-4(b)(2)]
- absence of Federal lands less than 130 ha (320 ac) within and in proximity to (i.e. within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(3)]
- absence of State lands less than 130 ha (320 ac) within and in proximity to (i.e., within 10 km [6 mi] of) the preliminary candidate area [960.5-2-5(c)(4)]
- low population density within its boundaries [960.5-2-1(b)(1)]
- absence of nuclear installations [960.5-2-4(b) and (c)(2)]
- no projected land ownership conflicts that cannot be successfully resolved through voluntary purchase-sell agreements, nondisputed agency-to-agency transfer of title, or Federal condemnation proceedings [960.4-2-8-2(c), 960.5-2-2(c)]

- available access to the national transportation system through regional highways and railroads and through local highways and railroads [960.5-2-7(b)(2), 960.5-2-7(b)(3)].

The preliminary candidate area also exhibits the following characteristics which could detract from repository siting and performance in the absence of further evaluation:

- evidence of active tectonic uplift [960.4-2-7(c)(1)]
- presence of shallow ground-water resources that could be economically extractable in the foreseeable future [960.4-2-8-1(c)(1)(i)]
- a majority (approximately 50%) of the preliminary candidate area is within 16 km (10 mi) of highly populated areas or areas containing more than 1,000 persons per square mile [960.5-2-1(c)(2)].

The results indicate that there are no significant adverse features identified to date that would preclude DOE from conducting further study of this area as a candidate for repository siting. In addition, many favorable characteristics have been identified in the area. Therefore, on balance, there is no basis for deferral of preliminary candidate area SE-1 at this time.

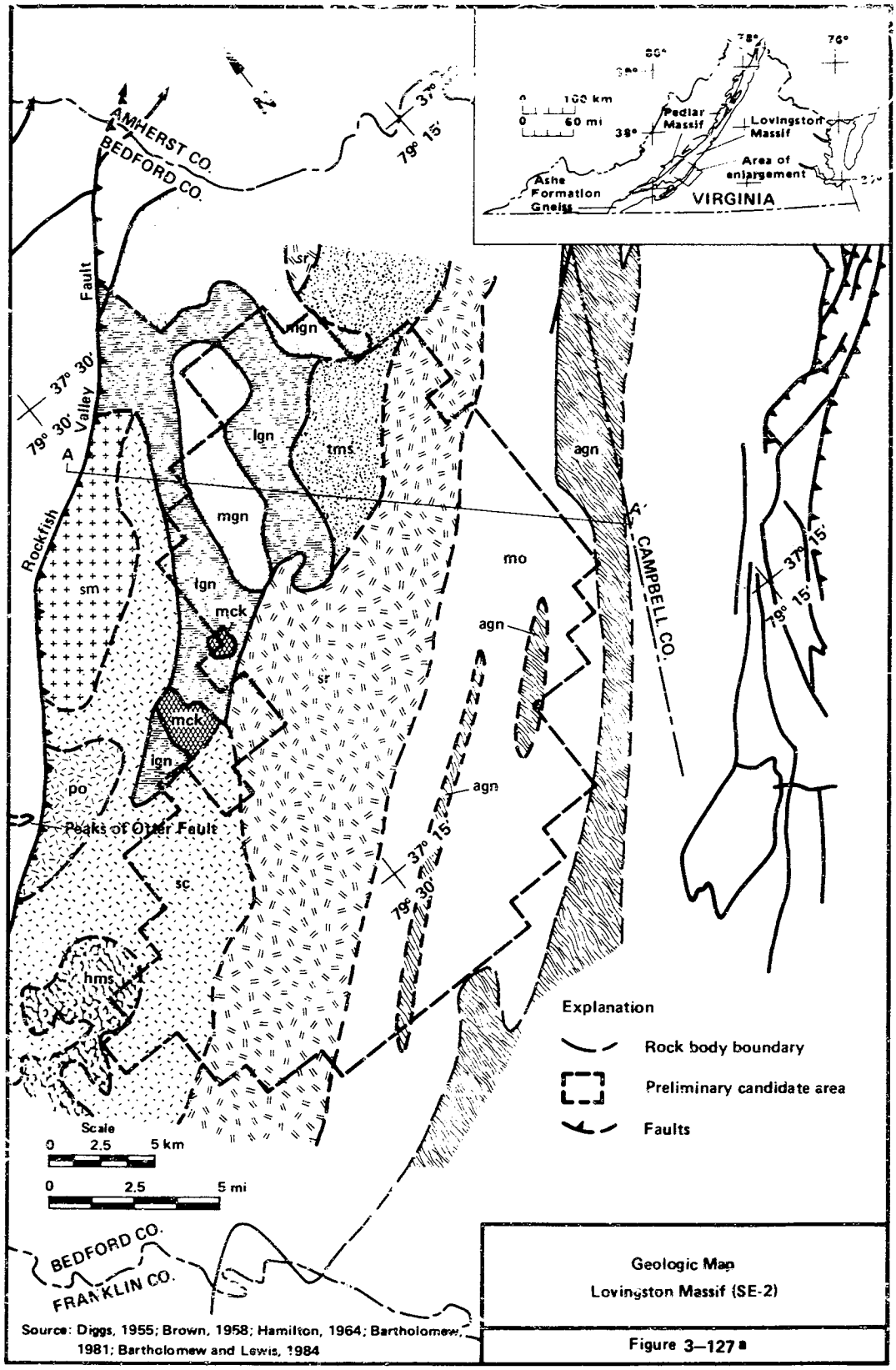
3.2.3.3 Preliminary Candidate Area Description - Lovingston Massif (SE-2)

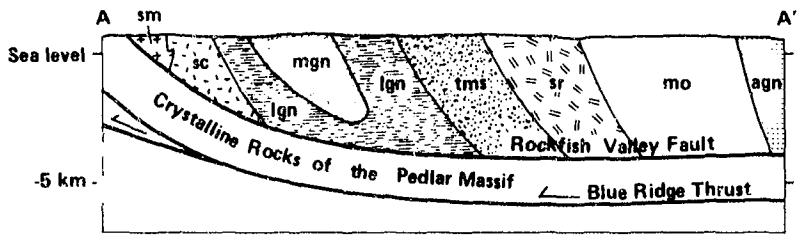
Preliminary candidate area SE-2 is located within the Blue Ridge physiographic province of Central Virginia in Bedford County, at approximately 37°15' N latitude and 79°30' W longitude (Figure 3-127a).

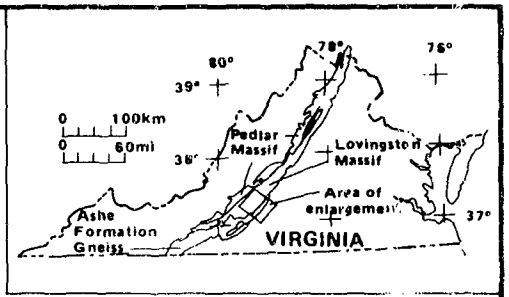
3.2.3.3.1 Host Rock Geometry and Overburden Thickness. The preliminary candidate area overlies the Lovingston massif and covers an area of 543 km^2 (209 mi^2), with a mapped length of 36 km (22 mi) and a width of 22 km (13 mi) (Figure 3-127b). Rock units within the Lovingston massif include the Sandy Creek granulite gneiss, Stage Road layered gneiss, Moneta gneiss, Turkey Mountain suite, Horsepen Mountain suite, Ashe Formation-gneiss (Lynchburg gneiss), and some unnamed rock bodies.

Herz et al. (1981) used gravity modeling to determine that the Turkey Mountain suite is about 7.2 km (4.5 mi) thick. More recently, a COCORP seismic traverse was run along I64, across the Stage Road layered gneiss, the Archer Mountain suite, and the Rockfish Valley fault zone about 100 km (62 mi) to the north of the preliminary candidate area. Harris et al. (1982) interpreted this line to indicate that the Rockfish Valley fault occurs from about 3 to 4 km (1.8 to 2.4 mi) below land surface in these rock bodies. There is no evidence of major structural discontinuities between these areas; therefore, extrapolation of these data should be valid for the preliminary candidate area. Below the Rockfish Valley fault, acceptable crystalline rock (Pedlar massif) persists to where it may be truncated at the Blue Ridge thrust at about 6 km (3.7 mi) below the land surface (Harris et al., 1982) (Figure 3-127b).

Available water well casing-depth data in the vicinity of the preliminary candidate area are given in Figure 3-128. Based on [illegible] data points, the average thickness of saprolite within the Lovingston [illegible] of


AMHERST CO.
BEDFORD CO.
37° 15'
79° 15'
Fault
37° 30'
79° 30'
Valley
Rockfish
A
A'
CAMPBELL CO.
sr
mgn
lgn
tms
agn
mgn
mo
lgn
sm
mck
agn
sr
mck
lgn
agn
po
Peaks of Otter Fault
sc
hms
37° 15'
79° 30'
37° 15'
79° 15'
Scale
0 2.5 5 km
0 2.5 5 mi
BEDFORD CO.
FRANKLIN CO.
Explanation
Rock body boundary
Preliminary candidate area
Faults
0 100 km
0 60 mi
Pedlar Massif
Lovingston Massif
Area of enlargement
Ashe Formation Gneiss
VIRGINIA
Source: Diggs, 1955; Brown, 1958; Hamilton, 1964; Bartholomew, 1981; Bartholomew and Lewis, 1984
Geologic Map
Lovingston Massif (SE-2)
Figure 3–127a





Explanation

- Lithologic contact
- Fault
- mck — Mesocratic charnockite
- lgn — Leucocratic granulite gneiss
- mgn — Mesocratic granulite gneiss
- sr — Stage Road layered gneiss
- sc — Sandy Creek granulite gneiss
- tms — Turkey Mountain suite
- hms — Horsepen Mountain suite
- agn — Ashe Formation-gneiss
- mo — Moneta gneiss
- sm — Suck Mountain pluton
- po — Peaks of Otter suite

Scale

0 2.5 5 km

0 2.5 5 mi

Source: Diggs, 1955; Hamilton, 1964; Harris et al, 1982

Geologic Cross Section
Lovingston Massif (SE-2)

Figure 3-127b