DECOMMISSIONING PLAN

FOR

REVERE, PENNSYLVANIA SITE

Prepared for:

Cabot Corporation
County Line Road
Boyertown, PA 19512

Prepared by:

ST Environmental Professionals, Inc.
114 Lutz Road
Boyertown, PA 19512

Revision 1
February 28, 2001

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1.0 INTRODUCTION AND GENERAL INFORMATION

Cabot Corporation (Cabot) located at County Line Road, Boyertown, Pennsylvania holds US Nuclear Regulatory Commission (NRC) License SMC-1562 for source materials associated with former ore processing activities at their Revere, Pennsylvania facility (Site). The license also covers materials located at a site in Reading, Pennsylvania. This Decommissioning Plan applies only to the Revere Site.

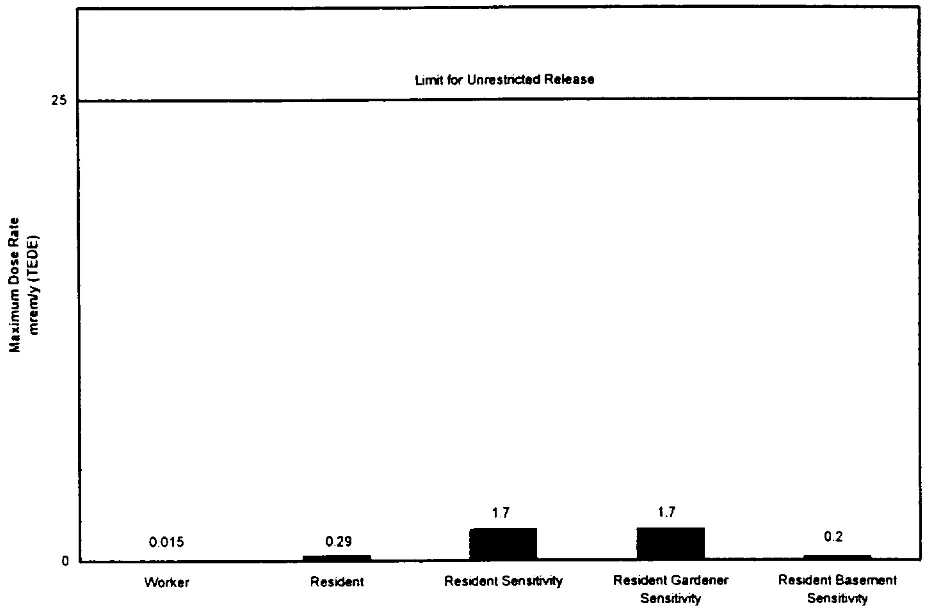
NRC's new rule (10 CFR Part 20 et al., Radiological Criteria for License Termination; Final Rule) became effective on August 20, 1997. This Decommissioning Plan (DP) is being submitted to meet the requirements of the new rule.

The objective of the decommissioning process is to terminate the license and remove the site from the Site Decommissioning Management Plan (SDMP) list. During the decommissioning process Cabot performed comprehensive site characterization and analysis including: surface gamma measurements at 1cm and 1m above the surface, test pits, radiological analysis of surface and subsurface samples, characterization of the site topography, climate, physiography, geology, and surface water hydrology, measurement of the RAU leach rate of uranium from the slag, determination of the leach rates of thorium and radium, evaluation of the weathering rate of the slag, preparation of a Radiological Assessment (STEP, 1997a, Rev.0) and preparation of a Decommissioning Plan (STEP, 1997b, Rev.0). This Decommissioning Plan (Rev. 1) and a Radiological Assessment (STEP, 2001, Rev.1), were prepared in response to the NRC's request for additional information.

The characterization information was used to develop input parameters for RESRAD modeling of maximum doses. Two reasonable base case scenarios (worker and resident) and three sensitivity scenarios were modeled. Detailed descriptions of the modeling input parameters and results are contained in the Radiological Assessment (STEP, 2001, Rev. 1) and are summarized in Section 1.5.2 of this report. The maximum calculated dose for each scenario are summarized below.

EXPOSURE SCENARIO	MAXIMUM ANNUAL TOTAL DOSE (mrem/y TEDE)
Worker	0.015
Resident	0.29
Resident sensitivity	1.7
Resident gardener sensitivity	1.7
Resident basement sensitivity	0.2
The 10 CFR Part 20 dose criterion for license termination with no restrictions on use is 25 mrem/y.	

These results are graphically depicted below and compared to the 25 mrem/y limit (10 CFR 20 Subpart E) for unrestricted release. As shown, they are all at least one order of magnitude less than the limit for unrestricted release.



* Unrestricted Release = Less Than 25 mrem/year (10 CFR 20 Subpart E)

The three sensitivity scenarios included one resident sensitivity scenario (RS), resident gardener sensitivity scenario (RG), and a resident basement scenario (RB). Exposure assumptions for these scenarios are not reasonable for the Revere site, but more closely match NRC assumptions for scenarios used for generic screening purposes. These assumptions are described fully in the Radiological Assessment (STEP, 2001, Rev.1). The results of all the screening scenarios were below the 25 mrem/y limit for unrestricted release. An ALARA analysis, contained in the Radiological Assessment (RA) concluded that release without restrictions was ALARA.

In summary, the potential exposure levels for the current conditions and any reasonable future conditions are all well below the 25 mrem/y criteria for unrestricted release and unrestricted release is ALARA. As a result no decommissioning activities are required.

1.1 GENERAL INFORMATION

The Cabot site is located in Revere, Bucks County, and Pennsylvania. Figure 1-1 shows the location of the Revere Site. Slag materials from metal processing activities performed in the early 1970's were deposited in four areas on the site. The four areas include the Parking Area, the Former Container Storage Area, the Building 4 & 5 Area, and the Old Pit Area. The locations of the areas of slag deposition are shown on Figure 1-2.

Kawecki Chemical (a predecessor to Cabot) used a thermite reduction process that included pyrochlore or columbite ore and powdered aluminum to produce a steel-grade (low purity) niobium (also known as columbium) metal alloy. The natural uranium and thorium in the ore remained in a waste silica slag, with concentrations that in some cases equaled source material levels. The slag was separated and deposited at the four locations described above.

1.2 FACILITY RADIOLOGICAL HISTORY INFORMATION

1.2.1 Radiological Material Used at Revere

In the early 1970's, Cabot's predecessor obtained a source materials license from the United States Nuclear Regulatory Commission (USNRC) in order to process ores containing niobium. The license was required because the ores contained naturally-occurring uranium and thorium at levels equaling those defined as source materials under the Atomic Energy Act of 1954. Source materials are defined as natural materials (such as soil, rock and ores) that contain greater than 0.05 percent by weight uranium or thorium individually or in any combination. For a short period after the USNRC license was obtained, the Revere plant processed pyrochlore and columbite (ores containing niobium) using powdered aluminum in a thermite reduction process, to produce a steel-grade (low purity) niobium metal alloy. This process resulted in a silica slag that contained uranium and thorium originally contained in the pyrochlore. The processing of radiological ore was discontinued in 1976. No source material is currently used on the site. Cabot holds license SMC-1562 which authorizes the company to possess the slag material resulting from the niobium processing that occurred in the early 1970's.

In 1990, 1992, and 1993 Cabot performed decommissioning activities (slag removal) at the Revere site. The Oak Ridge Institute for Science and Education (ORISE, 1993) performed a confirmatory survey and found that although average concentrations satisfied the existing NRC guidelines, individual fragments of slag at and below the surface exceed guidelines for natural uranium and thorium. In the spring of 1994, Enserch Environmental Corporation (Enserch) performed a radiological characterization survey of the Revere facility (Enserch, 1994). In the summer of 1994, NES, Inc. (NES), performed radiological subsurface sampling (NES, 1994) to determine the depth and extent of the slag deposits and to confirm the findings of Enserch. The survey showed that some slag remained on-site. NES also determined that the radioactivity is limited to the slag and that no detectable contamination had leached into the soil.

There are four areas at the Revere Facility where radiological levels are elevated above background due to the presence of silica slag containing natural uranium and thorium. The four areas are illustrated on Figure 1-2 and are described as follows:

> **Parking Area** - This area is located to the west of the principal manufacturing buildings and encompasses approximately 35,500 square feet. The material of interest consists of building rubble mixed with slag and some soil to a depth of approximately six feet.

Former Container Storage Area - This area encompasses approximately 19,900 square feet in the central portion of the property. It consists of a slag and soil mixture to a depth of approximately four feet.

Building 4 & 5 Area - This area is an approximately 16,000 square feet area behind Building 4 & 5 which consists of slag and rock mixed with some soil to a depth of approximately two feet.

Old Pit Area - This area is located at the western-most portion of the property away from the manufacturing facilities. It encompasses approximately 54,900 square feet and consists of building debris mixed with slag and some soil to a depth of approximately nine feet.

No activities are currently conducted in any of the slag areas described above.

1.2.2 Operating Occurrences Affecting Decommissioning Safety

Currently there are no licensed materials used on site. There are no known radiological operating occurrences that would affect the safety of the personnel during decommissioning.

1.3 SITE DESCRIPTION

As shown on Figure 1-1 the site is located approximately ½ mile southeast of Revere on the west side of Beaver Run Road. Rapp Creek passes along the northern and western sides of the site and drains to the south. The area surrounding the site is generally rural with land uses including industrial, commercial, residential, and agricultural. Much of the surrounding area consists of woodlands, especially along Rapp Creek and northeast of Beaver Run Road according to the United States Geological Survey (USGS) topographic map (USGS, 1973).

The site encompasses approximately 100 acres that slope generally westward and northwestward toward Rapp Creek. The site is bounded by Rapp Creek to the west and northwest, Beaver Run Road to the northeast and east, and by various properties to the south.

1.3.1 Topography

Figures 1-1 and 1-2 depict the regional and site topography as ground surface elevation contours. The ground surface elevation rises from approximately 420 feet above mean sea level (MSL) at Rapp Creek to somewhat above elevation 510 feet MSL at the edge of the site along Beaver Run Road. The slope is steepest at the western side of the site near Rapp Creek.

1.3.2 Climate

Bucks County has a temperate humid, maritime-type climate. Average temperature in the Revere area is approximately 51° F and average annual precipitation is approximately 45 inches. Approximately one half of the precipitation (20.7 inches) is returned to the atmosphere through evapotranspiration with the remainder entering streams as direct runoff and groundwater discharge. Precipitation is fairly evenly distributed throughout the year with the monthly average ranging from approximately 3.3 inches in February to 4.9 inches in August (Greenman, 1955). Despite the higher precipitation in the summer months the runoff is lower due to higher rates of evapotranspiration.

1.3.3 Physiography and Geology

The Site is located in the Piedmont physiographic province near the boundary with the New Jersey Highlands province. Bedrock beneath the site is mapped as the Triassic age Lockatong Formation in the eastern portion of the site and the Triassic age Brunswick Formation in the western portion of the site. Both of these units are part of the Newark Group. The Lockatong Formation at the site was metamorphosed by the intrusive diabase that occurs near the eastern edge of the site.

The Lockatong Formation consists of a gray to black argillite which grades laterally into the red shales and sandstones of the Brunswick Formation (Greenman, 1955). In areas such as the site, where the Lockatong has been metamorphosed, it changes gradually from the argillite to a black hornfels. The metamorphosed zones around the diabase intrusives commonly contain secondary mineralization such as azurite and malachite which are common copper-bearing minerals.

The Lockatong Formation is generally a poor source of water since its ability to store and transmit water is very low. Reported yields of wells in the Lockatong Formation ranged from 2 to 25 gpm with an average of 10 gpm (Greenman, 1955). Water quality is typically moderately to highly mineralized and hard. Reported yields in the Brunswick Formation ranged from 2 to 260 gpm with an average of 40 gpm. Water in the Brunswick Formation is typically moderately mineralized and moderately hard to hard.

The site characterization effort and visual observations indicate that in some areas of the site, the geologic formations are covered with fill associated with past operations.

The Lockatong and Brunswick Formations result in low hills and rolling terrain that is largely dependent on the occurrence of the argillite and sandstone that are more resistant to weathering. The highest topographic features in this area are typically associated with the diabase that is the most resistant to weathering of these units.

1.3.4 Surface Water Hydrology

The primary surface water body in the vicinity of the site is Rapp Creek that flows through the northwestern portion of the site. Rapp Creek originates in the vicinity of Lake Warren, approximately 2 miles north of the site, and flows southward to the confluence with Beaver Creek where it becomes Tinicum Creek. The site is located just west of the divide between the Rapp Creek and Beaver Creek drainage basins. The Delaware River is located approximately 3.5 miles north of the site where it passes eastward and eventually southward in its overall southerly course.

Based on United States Geological Survey stream gauge data (USGS, 1997), the flow on Tinicum Creek near Ottsville, approximately 2.5 miles south of the site, has averaged 15.96 cubic feet per second (cfs) during the period of record. Based on the relative areas of the Tinicum basin above the gauging station (14.7 mi^2) and the Rapp creek sub-basin above the Site (2.93 mi^2) the average flow at the Site during the same period was approximately 3.2 cfs.

1.4 PREVIOUS DECOMMISSIONING AND CHARACTERIZATION ACTIVITIES

Cabot has performed characterization and decommissioning activities at the Revere Site. Detailed descriptions of those activities are contained in the Confirmatory Radiological Survey (ORISE, 1993), Radiological Characterization Survey Report (Enserch, 1994), Radiological Subsurface Sampling Report (NES, 1994), and evaluation of the leaching rate of uranium and thorium from the slag (ERM, 1996b). Slag removal activities were conducted in 1990, 1992, and 1993 and are described in Appendix A of the Radiological Assessment (STEP, 2001, Rev. 1).

The Enserch Survey consisted of a comprehensive gamma survey conducted at 1 m and 1 cm above the ground surface, establishment of background levels, and collection and analysis of surface samples. That effort provided measured gamma data which has been used in the Radiological Assessment Report (STEP, 2001, Rev 1). The Radiological Subsurface Sampling (NES, 1994) activities included the excavation of test pits and trenches into the slag and collection and analysis of subsurface slag, soil, and water samples. Subsurface slag samples were used to measure the readily available uranium (RAU) leach rate of uranium from slag. Detailed production records were used to calculate the total inventory of radionuclides processed at the facility and the overall average radiological concentration of the slag mixture.

1.5 SUMMARY OF CURRENT RADIOLOGICAL CONDITIONS

1.5.1 Summary of Site Characterization Results

The nature and extent of the slag disposal areas have been characterized by review of detailed production records, test pits, radiological analysis of surface and subsurface samples, and surface gamma measurements at 1cm and 1m above the surface. The NES Radiological Subsurface

Characterization (NES, 1994) analyzed groundwater seep samples collected from the slag areas. Based on the NES Subsurface Characterization report, the areas containing radiological slag were found to consist primarily of non-radiological material (primarily slag and debris) with isolated fragments of radiological slag (NES, 1994).

Slag Characterization

The slag was formed by processing of silicate ores containing niobium in a thermite reaction. The thermite process utilized an extremely energetic exothermic chemical reaction to quickly melt the ore mixture. The desired metals separated out and accumulated in the bottom of a reaction vessel. After cooling, the niobium alloy was separated from the slag that typically had a glass-like texture. The texture and composition of the slag is comparable to an extrusive (volcanic) igneous silicate rock.

Leach Rate of Radionuclides From Slag

The slag is not weathered; it's elemental constituents (including uranium and other radionuclides) are locked in the silicate matrix and are not available to the environment. The low expected leach rate for uranium was confirmed by leach tests run by Environmental Science & Engineering, Inc. (ESE) on representative radiological slag samples (NES, 1996, Appendix A). The total available uranium (TAU) and readily available uranium (RAU) measurements for those samples were very low. Because it involves grinding up the sample and utilizing an acidic leach solution, the RAU conservatively overestimates the maximum leachate concentration for water in contact with the slag. Environmental Resources Management, Inc. (ERM) developed a methodology for calculating the leach rate of uranium and thorium for the Reading slag pile site based on the RAU test results (ERM, 1996a). To determine the leach rate of thorium, the leachability of thorium relative to uranium, based on K_d values reported in the literature, was used to extrapolate the RAU values to determine the thorium leach rates. The ERM leach methodology was approved by the NRC for the Reading, PA slag pile site (NRC, 1996). ERM proposed the same methodology for calculating the leach rate of uranium and thorium from the Revere site (ERM, 1996b). The NRC also approved the methodology for use at the Revere site (NRC, 1997).

The NRC requested that any dose assessment take into account the leach rates of other important radionuclides from the slag (NRC, 1997). The RAU leach rate was used as a basis to calculate the leach rate for other important radionuclides. The RESRAD modeling results contained in the Radiological Assessment report (STEP, 2001) indicate that other than uranium and thorium only radium isotopes have a significant contribution to the total radiological dose.

In response to the NRC request, a geochemist from GCX, Inc. provided an assessment of the relative leach rates of other important radionuclides for the Revere slag (Attachment 1). Based on this assessment, radium would be expected to leach at a slower rate than uranium. Even though the NRC approved the use of a thorium leach rate lower than the leach rate of uranium and GCX concluded that radium would also leach slower than uranium, the Radiologic Assessment (STEP, 2001) has assumed that the leach rate of thorium, radium, and all other radionuclides are equal to the leach rate of uranium. This approach is conservative in that it overestimates the calculated dose.

Weathering Rate of Slag

NRC requested information regarding the rate of soil formation from the slag that could lead to development of a growing media. ERM estimated the weathering rate of the slag by performing a review of available literature regarding the weathering rate of natural materials analogous to the Revere slag. ERM concluded that the weathering rate of the slag would be inconsequential; likely in the range of 0.002 to 0.015 mm of surface thickness over 1,000 years (ERM, 1996b). GCX also evaluated the weathering rate of the slag and estimated that *in situ* soil formation in the Revere slag would be in the range of hundreds of thousands of years or more (Attachment 1).

1.5.2 Radiological Assessment

The NRC radiological criteria for license termination are expressed in terms of radiation dose that might reasonably be expected from residual radioactive material after decommissioning. As used here, the term "dose" is intended to be interpreted as total effective dose equivalent (TEDE), which is the quantity expressed in the NRC regulation. At the Revere site this dose would depend upon concentrations of residual radioactive materials in soils and other remaining materials. The dose would also depend on site-specific factors that might control potential resource use, potential migration of radioactive materials, and potential access to radioactive materials. Finally, this dose would also depend on potential activities of future users of the site.

The radiation dose assessment process, as applied herein, includes the estimation of the maximum radiation dose (TEDE) that might be received by a typical member of a small group of people that could be expected to receive the highest doses from use of the site as far as 1,000 years into the future, as required in the radiological criteria for license termination. Thus, the assessment considers not only the expected conditions at the site, soon after remediation, but conditions projected for the distant future, as well. The assessment evaluates potential uses of the site and potential migration of radioactive materials through the environment over time, taking account of both natural processes and human activities that could be expected to alter the patterns or rates of constituent movement.

In general, the dose assessment process consists of two steps: 1) development of representations of site physical conditions and potentially exposed populations, and expression of these representations in mathematical terms; and 2) use of a mathematical model with input from the representations and/or technical literature to estimate future exposures and radiation doses (TEDE) as a function of time. The dual objective in the development of simplified representations is that the representations be realistic and not result in underestimation of exposures and doses.

Based on the foregoing, two groups of scenarios have been developed and analyzed. The first (base case) group represents those scenarios that are considered reasonably likely. Development of assumptions for these scenarios begins with the generic screening scenarios as a point of departure and makes changes as necessary to develop most likely exposure scenarios. The second (sensitivity) group, more similar to screening scenarios described above, is included for purposes of sensitivity interpretations.

The most likely exposure scenarios consist of a worker scenario, designated "W," and a resident scenario, designated "R." The worker scenario recognizes that the Site is an industrial site and areas bearing slag materials are not used for any purpose. Consequently, the time a worker might spend in any or all areas would be very small, and it is quite likely that a worker might spend no time in the areas. In the event that a worker might have occasion to visit the areas of interest, the only potential exposure pathways would be external exposure and inhalation of resuspended dust that might occur during walking over the areas. For purposes of conservative analysis, the worker is assumed to be exposed outdoors in an area containing residual radioactive material for a period of 40 hours per year. No indoor exposure is assumed because there are no buildings on the areas of interest. If, as is likely, the areas of interest continue not to be used in the future, the W scenario can also serve as representative scenarios for exposure of workers on the Site in the future.

The resident scenario, R, considers the possible, but unlikely, future use of the Site for residences. In the resident scenario, it is assumed that residences are constructed entirely on an area containing residual radioactive materials, and that the resident spends 78% of his time on the area—85% of that indoors and 15% outdoors. Exposure through the ground, inhalation, and soil ingestion pathways is assumed. Only limited structural reduction in dose rate for the external and inhalation pathways is assumed. It is also assumed that water is obtained from a shallow well. These assumptions are consistent with screening scenarios (NRC, 2000). This scenario departs from the screening scenarios in assuming no garden in keeping with the form of the residual radioactive materials, as explained above. A 6-inch layer of topsoil is assumed to be maintained over the slag over the period of assessment. This layer of topsoil would support grass, but would not be deep enough to support edible vegetation.

The first of three sensitivity scenarios analyzed, resident sensitivity (RS) is identical to the base case R scenario, except that no covering of slag is assumed. The exposure pathways evaluated again include ground exposure, dust inhalation, and soil and water ingestion.

The second of three sensitivity scenarios (RG) is identical to RS, except that the vegetable ingestion pathway is added to represent a garden in the slag. Radionuclide transport through three routes is assessed. They include deposition of airborne dust, deposition of irrigation water, and uptake from soil. To account for the limited environmental availability of radionuclides in slag, plant/soil transfer factors for radionuclides of interest were adjusted by multiplying them by the fraction environmentally available (percent TAU), as calculated from solubility test data.

The last sensitivity scenario (RB) examines the potential impact from using the slag as excavation and as foundation fill in the construction of a house. Because there are no screening scenarios quite like this scenario, cautious judgment was used in defining the scenario and in selecting parameter values. It was assumed that a person spends half his time in the basement in a room 36 square meters in floor area. Slag is assumed to be used as fill to the extent that slabs one meter thick lie against the outside basement walls up to a height of 3 meters and a 1-meter thick slab underlies the floor. Because the slag is not likely to be good for making concrete, it was assumed that the concrete walls and floor, constituting a shielding equivalent to 6" of concrete were slag-free. It was also assumed that the concrete walls and floor would preclude exposure to radionuclides of interest from pathways other than direct radiation.

The key assumptions for each of the base case and sensitivity exposure scenarios developed for the Revere Site are summarized in the Table 1-1 The dose assessment results are summarized in Table 1-2 and depicted graphically in Figure 1-3.

In summary, the maximum doses (TEDE) calculated for the base case scenarios (worker and resident) are all below 0.30 mrem/y. Results from the base case analysis show that the maximum radiation dose that might be expected from unrestricted use of the site is far below the 10 CFR Part 20 limit of 25 millirem per year (TEDE) for release with unrestricted use. The maximum dose calculated for the resident base case was nearly a factor of 100 below the limit, and the maximum dose calculated for the worker base case was more than a factor of 1000 below the limit for release with unrestricted use.

Results for the three sensitivity scenarios ("RS", "RG", and "RB") are provided in the Radiological Assessment (STEP, 2001). The maximum doses calculated for the RS and RG sensitivity scenarios were both 1.7 mrem/y. The maximum calculated dose for the RB scenario was 0.2 mrem/y. The results from the sensitivity analysis show that even unrealistically conservative calculated doses are also below the limit for release with unrestricted use.

The radiological assessment also included an analysis to determine whether concentrations of radioactive material at the site are ALARA (As Low As Reasonably Achievable). In the context of slag remediation, ALARA analysis is fundamentally a balancing of the value of remedial action against its cost. If the expected value of the dose reduction exceeds the cost of remediation required to achieve the dose reduction, the action is warranted. The test is applied successively in a way that implements the most cost-effective actions first. When no further remedial actions are warranted by the ALARA test, remediation has reached the ALARA condition.

The ALARA assessment for the Revere site demonstrates that a limit of 25 millirem per year for land released for unrestricted use is as low as reasonably achievable (ALARA) by a substantial margin. Any lower level would be achieved only at a cost that far exceeds the value of any resulting dose savings.

Detailed results of the radiological assessment show that the maximum radiation dose that might reasonably be expected from unrestricted use of the site is far below 25 millirem per year and is ALARA. The site qualifies for license termination with no restrictions on use. The results from sensitivity studies also support the conclusion that the site qualifies for release with unrestricted use.

TABLE 1-1
SCENARIO PATHWAYS AND KEY PARAMETER VALUES FOR SCENARIOS

	SCENARIO				
	W Worker	R Resident	RS Resident Sensitivity	RSG Resident Gardener Sensitivity	RB Resident Basement Sensitivity
PATHWAY					
Water-Independent					
External					
Indoor exposure time (h/y)	0	5760	5760	5760	4380 bsmt
Structural shielding factor	0	0.59	0.59	0.59	Calculated
Outdoor exposure time (h/y)	40	1030	1030	1030	0
Other		6" topsoil			
Inhalation (dust)					
Indoor exposure time (h/y)	0	5760	5760	5760	4380
Structural shielding factor	0	0.5	0.5	0.5	0
Outdoor exposure time (h/y)	40	1030	1030	1030	0
Dust loading (g/m3)	3.40E-05	3.40E-05	3.40E-05	3.40E-05	3.40E-05
Other		6" topsoil			
Inhalation (radon)	No	No	No	No	No
Ingestion of vegetables	No	No garden	No garden	Yes	No
Ingestion of meat	No	No	No	No	No
Ingestion of milk	No	No	No	No	No
Ingestion of soil	No	Yes--6" topsoil	Yes	Yes	No
Water-dependent					
Ingestion of water	No	Shallow well	Shallow well	Shallow well	No
Ingestion of aquatic food	No	No	No	No	No
Ingestion of vegetables (irrigated)	No	No	No	Yes	No
Ingestion of meat (irrigated)	No	No	No	No	No
Ingestion of milk (irrigated)	No	No	No	No	No
Inhalation (radon from water)	No	No	No	No	No

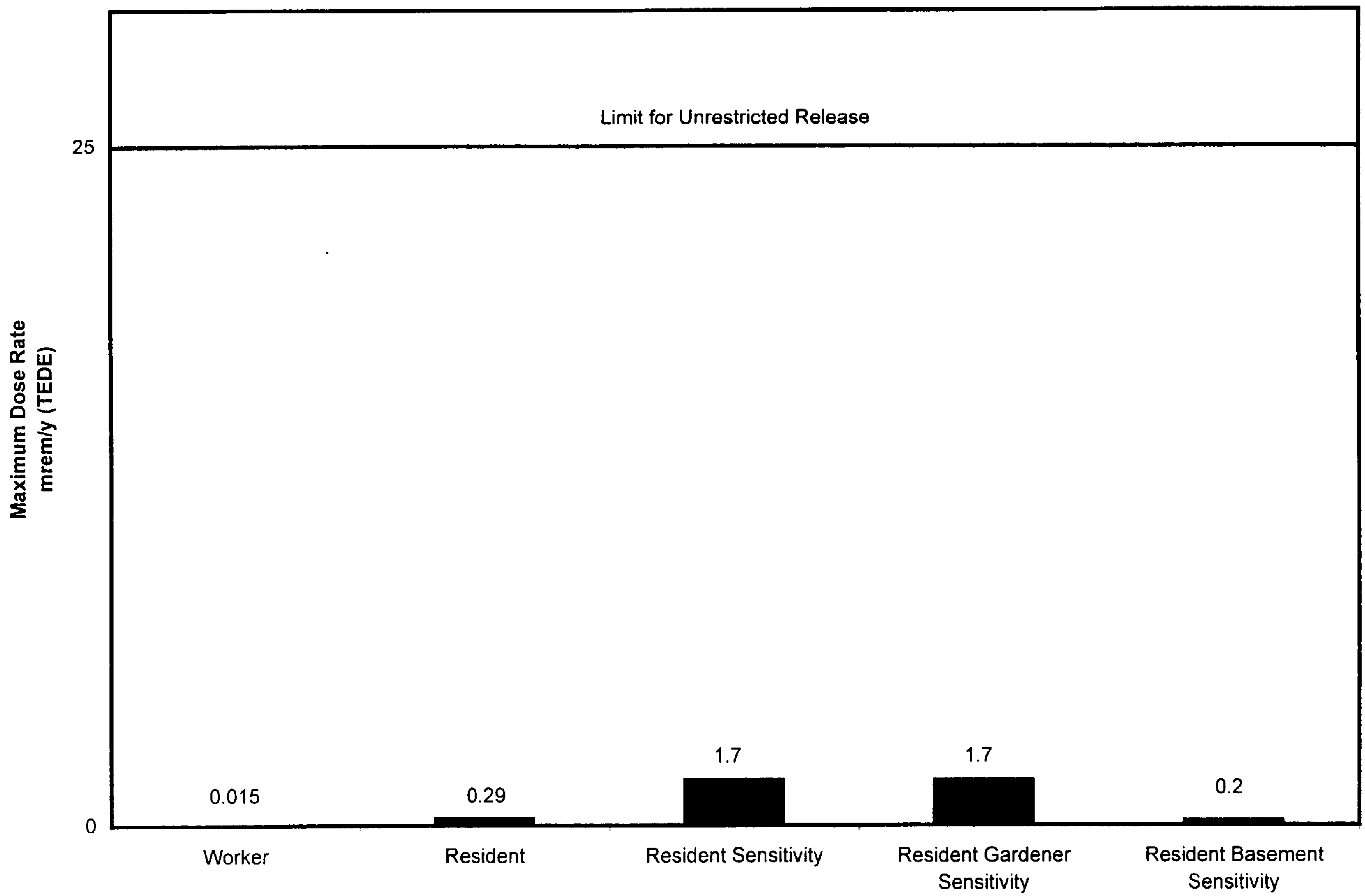
Resident exposure times, and structural dose reduction factors are mean values from Beyeler, 1998.
Dust loading for inhalation is the 90%-tile value from Biwer, 2000.

TABLE 1-2
WORKER, RESIDENT, AND SENSITIVITY SCENARIOS - RESULTS SUMMARY

EXPOSURE SCENARIO	MAXIMUM ANNUAL TOTAL DOSEmrem/y TEDE
Worker	0.015
Resident	0.29
Resident Sensitivity	1.7
Resident Gardener Sensitivity	1.7
Resident Basement Sensitivity	0.20

The 10 CFR Part 20 dose criterion for license termination with no restrictions on use is 25 mrem/y.

FIGURE 1-3
MAXIMUM ANNUAL RADIATION DOSE (TEDE) SUMMARY



*** Unrestricted Release = Less Than 25 mrem/y (10 CFR 20 Subpart E)**

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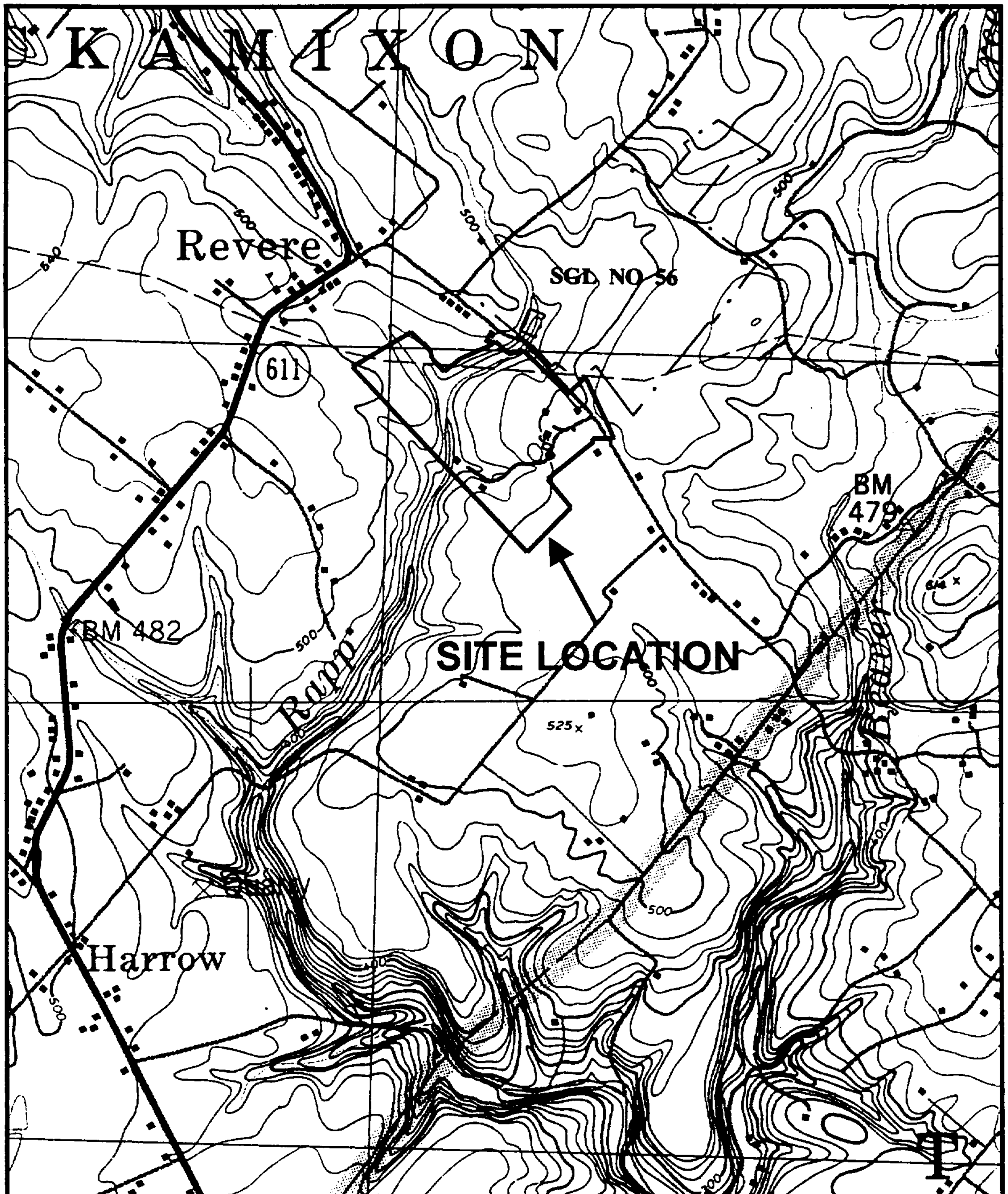

SCALE FEET

0 2,000 4,000

NORTH

SOURCE: USGS, County Map Series, Bucks County, Pennsylvania, 1:50,000 Scale

FIGURE 1-1
Site Location Map

Revere, Pennsylvania, Site
Cabot Corporation

ST Environmental Professionals, Inc.
STEP Project Number 97C048
Revision 1, February 28, 2001

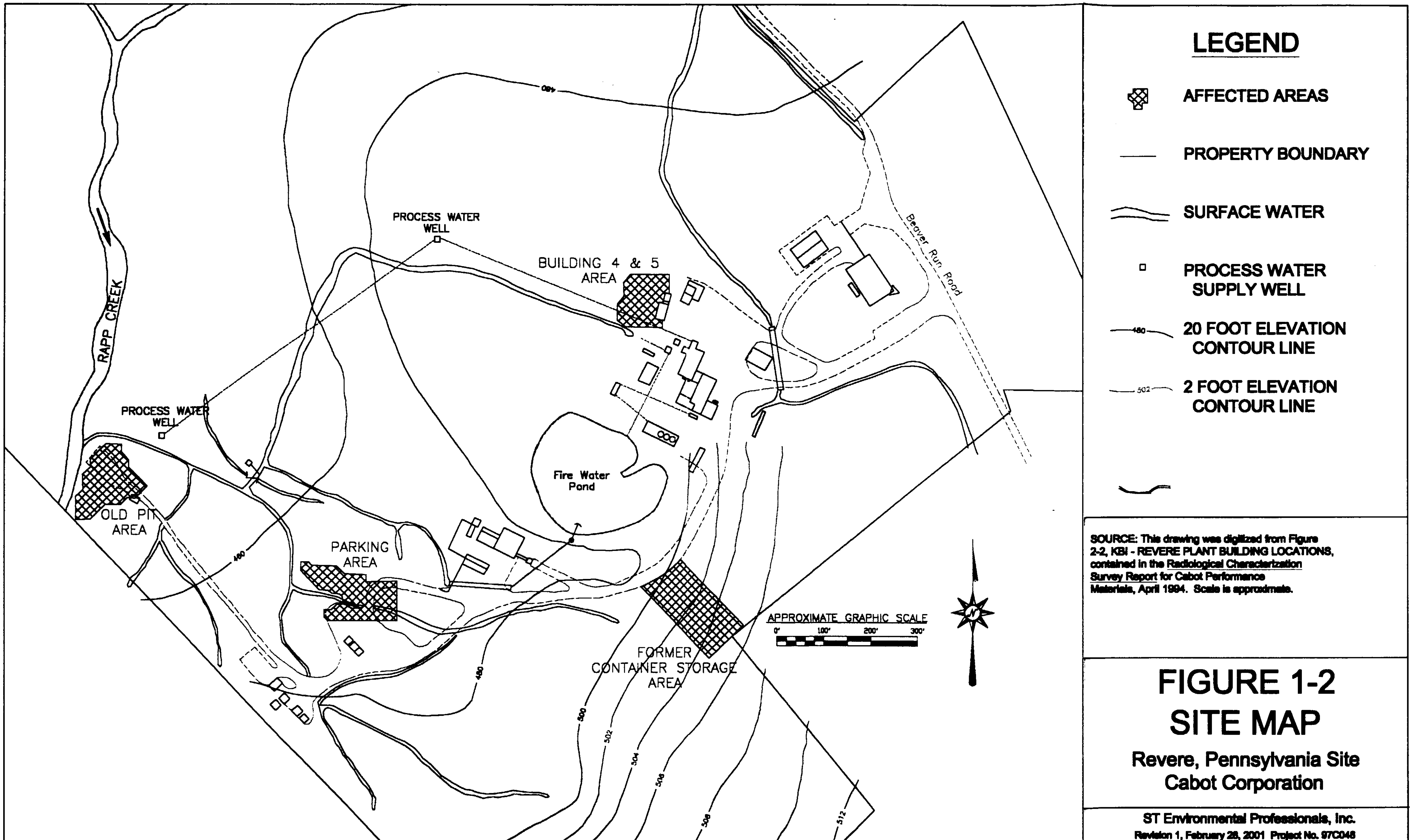

FIGURE 1-2
SITE MAP
Revere, Pennsylvania Site
Cabot Corporation

ST Environmental Professionals, Inc.
Revision 1, February 28, 2001 Project No. 97C048

2.0 PLANNED DECOMMISSIONING ACTIVITIES

The objective of the decommissioning process is to terminate the license and remove the site from the Site Decommissioning Management Plan (SDMP) list. During the decommissioning process Cabot performed comprehensive site characterization and analysis including:

- Review of detailed production records
- Surface gamma measurements at 1cm and 1m above the surface
- Test pits
- Radiological analysis of surface and subsurface samples
- Characterization of the site topography, climate, physiography, geology, and surface water hydrology
- Measurement of the RAU leach rate of uranium from the slag
- Determination of the leach rates of thorium and radium
- Evaluation of the weathering rate of the slag
- Performance of a Radiological Assessment
- Preparation of this Decommissioning Plan

Using the characterization information, the Radiological Assessment Report (STEP, 1997) concludes that the potential exposure levels for the current conditions and any reasonable future conditions are all well below the 25 mrem/y criteria for unrestricted release. The Radiological Assessment also concludes that release without restrictions is ALARA. As a result no decommissioning activities are required.

3.0 METHOD USED FOR PROTECTION OF OCCUPATIONAL AND PUBLIC HEALTH AND SAFETY DURING DECOMMISSIONING ACTIVITIES

Because there will be no onsite decommissioning activities, and the site meets the criteria for unrestricted release, this section is not applicable.

4.0 PLANNED FINAL RADIATION SURVEY

Because there will be no onsite decommissioning activities, and the site meets the criteria for unrestricted release, this section is not applicable.

5.0 FUNDING

Because there will be no onsite decommissioning activities, and the site meets the criteria for unrestricted release, this section is not applicable.

6.0 PHYSICAL SECURITY PLAN AND MATERIAL CONTROL AND ACCOUNTING PLAN PROVISIONS IN PLACE DURING DECOMMISSIONING

Because there will be no onsite decommissioning activities, and the site meets the criteria for unrestricted release, this section is not applicable.

7.0 REFERENCES

Ensearch, 1994, Enserch Environmental Corporation, *"Radiological Characterization Survey Report for the Cabot Performance Materials Revere Plant;"* April 1994.

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ATTACHMENT 1

LEACHING BEHAVIOR OF RADIONUCLIDES FROM GLASS AND SLAG AT THE REVERE AND READING, PENNSYLVANIA SITES

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November 9, 1997

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Subject: LEACHING BEHAVIOR OF RADIONUCLIDES FROM GLASS AND SLAG AT THE REVERE AND READING SITES

Dear Mr. Helbig,

GCX, Inc. (GCX) was requested by ST Environmental Professionals, Inc. (STEP) to assess the relative leach rates of radionuclides from the slag materials at the Revere, Pennsylvania site and the Reading, Pennsylvania slag pile site. Previous characterization testing measured the readily available uranium (RAU) leach rate from the slag for the Revere and Reading sites (NES, 1996a and NES, 1996b). Environmental Resources Management (ERM) developed a methodology to calculate the leach rates of uranium and thorium from the Revere slag based on the RAU values (ERM, 1996). The NRC approved the ERM methodology to calculate leach rates used to perform radiological dose assessment calculations for Revere and Reading (NRC, 1996 and NRC, 1997). This report assesses the leach rate of other important nuclides relative to the RAU rate of uranium.

The leaching behavior of radioactive daughter products in the uranium and thorium decay series from glass or other forms of slag produced in high temperature processes is of importance to calculation of the potential radiation dose. There are basically two potential mechanisms for leaching of these daughter products depending on their individual chemical behavior. One mechanism assumes the slag leaches radionuclides congruently whereas the other mechanism involves incongruent behavior. In the first mechanism, the slag leaches/dissolves layer by layer much like the peeling of an onion. This mechanism would produce daughter product concentrations in solution that are proportional to the concentrations of uranium in solution, the proportionality constant being the ratio of the parent concentration in the solid to the daughter product concentration in the solid. The incongruent dissolution mechanism could result in daughter product concentrations in solution that are <u>not</u> proportional to the uranium concentration in solution. In this case, the dissolution rates of each daughter product may be greater than or less than the dissolution rate of the uranium. This requires that the dissolution rates of the individual daughter products be determined independently.

With this background, the first question to be answered is "Does the glass-like slag leach congruently or incongruently?" Based on studies of the dissolution behavior of natural and nuclear waste glasses (e.g., Clark et al., 1994), the answer to this question appears to be that these glasses leach/dissolve incongruently. Analyses of the near-surface layers of natural and nuclear waste glasses and minerals show that some elements (e.g., sodium, lithium,) are readily leached from these layers in aqueous solutions. The leaching process is actually an ion exchange process in which hydrogen ions (and other ions) replace the ions of alkali elements such as sodium. When only hydrogen ions are involved, this process is also referred to as the hydrolysis of the aluminosilicate framework.

The aluminosilicate framework of the glass or mineral dissolves or leaches at a much slower rate than the rate of the ion exchange processes. This results in surface layers that are enriched in silicon, aluminum and hydrogen and depleted in the light alkali elements and to a lesser extent other elements depending on the chemistry of the aqueous solution. The aluminosilicate surface layers are generally amorphous in structure. That is, they lack a well defined crystallographic structure. Assuming that the slags at the Revere and Reading sites have dissolution/leaching behaviors similar to the natural and nuclear waste glasses, the main question now becomes "What are the relative leaching rates of uranium, thorium and their daughter products"?

Before proceeding on this question it is important to note that not all daughter products of the uranium and thorium decay series are of equal significance from the point of view of potential doses to the public. The daughter products of primary concern are radium isotopes. Therefore, the question is "what are the relative leaching/dissolution rates of uranium, thorium and radium?" There are three useful sources of information that bear on this question. The first source involves experiments with nuclear waste glass. These experiments suggest that thorium and radium leach more slowly than uranium in typical groundwater compositions (Bibler, 1986). As discussed further below, the likely reason for this behavior is that the amorphous nature of the leached surface layers provides favorable sites for the sorption or binding of elements such as thorium and radium.

The second source involves measurements on weathered igneous rocks. Rosholt et al. (1971) and many others have found that, relative to uranium, thorium is leached very slowly from glassy and crystallized silicic volcanic rocks. Because the slags are chemically similar to such volcanic rocks, it is to be expected that thorium will also leach more slowly from the slags. Although specific data on radium leaching from silicic volcanic rocks was not uncovered in the literature, data on the leaching behavior of barium was found in Zielinski et al. (1977). Barium and radium behave similarly in surficial geochemical processes, with radium generally being less mobile due to lower solubilities of radium compounds and higher sorption affinities of radium relative to barium (Langmuir and Riese, 1985). The data presented by Zielinski et al. (1977) indicate that, during weathering, barium actually becomes enriched in weathered volcanic rocks while uranium either is leached or is unchanged. These authors attribute this behavior to ion exchange processes that replace alkali elements such as lithium and sodium in the rocks with alkaline earth elements such as barium and radium. These data suggest that thorium and radium will be leached slower than uranium from the slags at Revere and Reading. As noted above, this behavior likely reflects the high affinity of the leached surface layers on glasses and minerals for the larger alkali (e.g., cesium) and alkaline earth ions (e.g., barium and radium).

A third source of information on the leaching and transport behavior of uranium, thorium and radium involves studies of the uranium and thorium decay series in groundwaters. Krishnaswami et al. (1982) studied the uranium and thorium decay series in various groundwaters in Connecticut. These authors came to the conclusion that "sorption removes radium and thorium from these groundwaters on a time scale of 3 minutes or less." Further, they calculated retardation factors for radium in the range of 4800 to 120,000. Calculated retardation factors for thorium were in the range of 14000 to 200,000. Retardation factors reflect the rate of movement of the radionuclides relative to the rate of water movement through an aquifer. The very large retardation factors reported for radium and thorium indicate these elements migrate very slowly in the investigated aquifer.

Krishnaswami et al., (1982) did not report a retardation factor for uranium. However, relative leaching/migration behavior can be estimated with their data. The retardation factor (RF) is related to K_d by the formula $RF = 1 \div (D_b/n)(K_d)$, where D_b equals bulk density and n equals porosity (Freeze and Cherry, 1979). Using typical soil values for bulk density (2.0 gm/cm) and porosity (0.4), the ratio of the median calculated radium K_d to the median calculated thorium K_d is 0.58. ERM cited an average ratio of thorium K_d to uranium K_d of 6.06. Applying the ERM ratios to Krishnaswami's ratios results in a radium K_d to uranium K_d of approximately 3.5. This suggests that radium is much less mobile than uranium and would be expected to leach from the slag at a much slower rate.

Latham and Schwartcz (1987) reached similar conclusions regarding the migration behavior of uranium, thorium and radium in weathered igneous rocks in Ontario, Canada. These authors found that uranium was generally leached from the rocks they studied whereas radium and thorium were largely retained within the rock units. These observations strongly suggest that the leaching rates of radium and thorium from the Revere and Reading slags will be much slower than the leaching rate of uranium.

Variations in the water compositions can affect the behavior of radium in rock/ water systems. For example, radium concentration are often found to be elevated in highly saline waters such as oil field brines (Kolb and Wojcik, 1985). The cause for the high radium concentration in these brines are ion exchange reactions. That is, the saline brines contain high concentrations of sodium and other cations that compete with radium for ion exchange sites in the aquifers from which the brines are produced (Havlik, et al., 1968). Because the waters that could leach the slags at the Revere and Reading sites will be dilute (i.e., essentially precipitation waters), such competitive ion exchange effects will not be important at these sites.

In summary, data from a variety of sources and a variety of rock/water systems point to the conclusion that radium and thorium will be leached more slowly than uranium from the slags at the Revere and Reading sites.

Weathering Rates

The overall weathering rates of the slags at the Revere and Reading sites are also of interest because they will influence the rate of *in-situ* soil formation on the slags. Soils formed *in-situ* on the slags could contain radionuclides that could be available to plants grown on the soils. The rate of soil formation at a given site is a function of many factors including the nature of the parent materials, climate, biota, topography and time (Brady and Weil, 1996). The *in situ* rate of soil formation is here defined as the rate at which slag is converted into soil. This rate is proportional to the weathering rate of the slag. Unfortunately, the proportionality constant is a rather complex function of the soil formation factors listed above.

The weathering rate is here defined as the rate at which primary phases in parent materials (e.g., slags) are altered. Because the alteration processes are likely to involve incongruent dissolution, weathering will generally result in a dissolved component and a residual component. It is the residual component that eventually leads to the formation of *in situ* soils. Studies of the rates of *in situ* weathering of igneous rocks provide bounds on the soil formation rates to be expected at the Revere and Reading sites.

The initial stage of weathering of volcanic glass involves simple hydration and not clay formation (Clark et al., 1994). In fact, the hydration rate of volcanic glass is used as a chronometer for archeological studies. The hydration rind thickness is found to be on the order of 1-3 microns after one thousand years at ambient conditions (Friedman and Long, 1976). Hydration rind thicknesses of 10-20 microns are commonly observed and reflect ages of several hundred thousand years (Friedman and Long, 1976). Note that the relationship between rind thickness and age is not linear but logarithmic. These hydration rinds do not contain significant amounts of secondary minerals (e.g., clays). This suggests the time required for the *in situ* formation of sufficient secondary minerals to form soils is greater than several thousand years and probably greater than several hundred thousand years..

A study by Dorn (1995) of the rate of weathering of well dated (2,000-3,000 year old) volcanic flows on the island of Hawaii corroborates this conclusion. Because Hawaii has a tropical climate with high rainfall and high temperatures, the rates of weathering of volcanic rocks on this island are likely higher than the rates applicable in a cooler climate such as that found at the Revere and Reading sites. Dorn (1995) found that the weathering processes on the volcanic flows on Hawaii produced little if any *in situ* clay.

On the basis of these observations, we would expect *in situ* soil formation ages at ambient surface conditions at the Revere and Reading sites to be in the range of hundreds of thousands of years or more.

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If I can provide any additional information, please call.

Yours truly,

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