

7.0 Screening-Level Ecological Risk Assessment

7.1 Introduction

In order to determine the potential for ecological risks posed by site-related chemicals at the Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7), at FTMC, a screening-level ecological risk assessment (SLERA) was conducted. This SLERA consists of a description of the habitats in and around Parcel 94(7), a discussion of the constituents detected in site media, a discussion of the conceptual site model, an estimation of the screening-level risk, the identification of the constituents of potential ecological concern, an uncertainty analysis, a discussion of the different lines of evidence, and a summary of the results and conclusions.

7.2 Environmental Setting

Parcel 94(7) is approximately 5 acres in size. The site is bounded by Langley Avenue on the west and mixed deciduous/coniferous forest on the north, south, and east. The buildings that were reported to exist on this site have been removed, and the entire site is covered with asphalt pavement. The site slopes slightly to the north and east towards Ingram Creek, a tributary of Cane Creek. Elevation at the site ranges from approximately 800 to 825 feet above msl. There are two general types of ecological habitat in the near vicinity of the site: terrestrial and aquatic. These two habitat types are discussed in the following sections.

7.2.1 Terrestrial Habitat

The site is entirely paved with asphalt and, as such, ecological habitat at the site itself is insignificant. The area surrounding the asphalt paving at Parcel 94(7) is best described as mixed deciduous/coniferous forest. East of the site, the topography slopes to the east towards Ingram Creek. The forest type transitions to a lowland mixed deciduous forest community as the topography slopes to the floodplain of Ingram Creek.

The cover species typically found in the mixed deciduous/coniferous forested areas surrounding the site include scrub pine (*Pinus virginiana*), loblolly pine (*Pinus taeda*), white oak (*Quercus alba*), post oak (*Quercus stellata*), chestnut oak (*Quercus prinus*), southern red oak (*Quercus falcata*), wild black cherry (*Prunus serotina*), hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), and flowering dogwood (*Cornus stolonifera*). The shrub layer is dominated by southern low blueberry (*Vaccinium pallidum*), southern wild raisin (*Viburnum nudum*), and yellowroot (*Xanthorhiza simplicissima*). Numerous muscadine grape (*Vitis rotundifolia*) vines,

1 greenbriar (*Smilax rotundifolia*), and poison ivy (*Toxicodendron radicans*) are present in the
2 undergrowth.

3
4 The lowland mixed deciduous forest adjacent to Ingram Creek is characteristic of a ravine or
5 stream floodplain. This area may be inundated during periods of significant rainfall and contains
6 vegetative species indicative of moist soil conditions. Some of the plant species most commonly
7 found in this lowland mixed deciduous forest include American beech (*Fagus grandifolia*), tulip
8 tree (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), red maple (*Acer rubrum*), white
9 oak (*Quercus alba*), American holly (*Ilex opaca*), pignut hickory (*Carya glabra*), sweetgum
10 (*Liquidambar styraciflua*), common persimmon (*Diospyros virginiana*), and redbud (*Cercis*
11 *canadensis*).

12
13 Terrestrial species that may inhabit the vicinity of Parcel 94(7) include opossum, short-tailed
14 shrew, raccoon, white-tail deer, red fox, coyote, gray squirrel, striped skunk, a number of species
15 of mice and rats (e.g., white-footed mouse, eastern harvest mouse, cotton mouse, eastern
16 woodrat, and hispid cotton rat), and eastern cottontail. Approximately 200 avian species reside
17 at FTMC at least part of the year (USACE, 1998). Common species expected to occur in the
18 vicinity of Parcel 94(7) include northern cardinal (*Cardinalis cardinalis*), northern mockingbird
19 (*Mimus polyglottus*), warblers (*Dendroica spp.*), indigo bunting (*Passerina cyanea*), red-eyed
20 vireo (*Vireo olivaceus*), American crow (*Corvus brachyrhynchos*), bluejay (*Cyanocitta cristata*),
21 several species of woodpeckers (*Melanerpes spp.*, *Picoices spp.*), and Carolina chickadee (*Parus*
22 *carolinensis*). Game birds present in the vicinity of Parcel 94(7) may include northern bobwhite
23 (*Colinus virginianus*), mourning dove (*Zenaida macroura*), and eastern wild turkey (*Meleagris*
24 *gallopavo*). Woodland hawks (e.g., sharp-shinned hawk) were observed in this area during the
25 ecological investigation (September 2000) and are expected to use this area for a hunting ground.
26 A variety of other raptors (e.g., red-tailed hawk, barred owl, and great horned owl) could also use
27 portions of this area for a hunting ground, particularly the fringe area where the forested areas
28 abut roads and cleared areas. Due to the presence of Ingram Creek, piscivorous bird species may
29 also be present in the vicinity of Parcel 94(7). These piscivorous birds may include great blue
30 heron (*Ardea herodias*), green-backed heron (*Butorides striatus*), and belted kingfisher (*Ceryle*
31 *alcyon*).

32
33 In general, the terrain at FTMC supports large numbers of amphibians and reptiles. Jacksonville
34 State University has prepared a report titled *Amphibians and Reptiles of Fort McClellan,*
35 *Calhoun County, Alabama* (Cline and Adams, 1997). The report indicated that surveys in 1997

1 found 16 species of toads and frogs, 12 species of salamanders, 5 species of lizards, 7 species of
2 turtles, and 17 species of snakes. Typical inhabitants of the area surrounding Parcel 94(7) are
3 copperhead (*Agkistrodon contortix*), king snake (*Lampropeltis getulus*), black racer (*Coluber*
4 *constrictor*), fence lizard (*Sceloporous undulatus*), and six-lined racerunner (*Cnemidophorous*
5 *sexlineatus*).

7 **7.2.2 Ingram Creek Habitat**

8 Ingram Creek in the vicinity of Parcel 94(7) is a relatively small, ephemeral stream that flows
9 (when water is present) from southeast to northwest. The headwaters of Ingram Creek form
10 approximately 5,000 feet southeast of Parcel 94(7) near Reeves Hill near the center of Main Post.
11 From its headwaters, Ingram Creek flows northwest past Parcel 94(7) (approximately 200 to 500
12 feet east of the site) until its confluence with Cane Creek approximately 500 feet east-northeast
13 of the site. Cane Creek then flows in a west-northwesterly direction through the Main Post,
14 including the Cane Creek Golf Course, until it exits Main Post along the west-northwestern
15 boundary.

16
17 The headwaters of Ingram Creek are formed by runoff from Reeves Hill and the surrounding
18 watershed. There also appear to be localized contributions to creek flow from groundwater
19 where the potentiometric surface exceeds the creekbed surface. The flow contribution from
20 groundwater varies according to the amount of precipitation, with an increase when precipitation
21 raises the potentiometric surface. Ingram Creek is dry during significant portions of the year and
22 was dry during the on-site habitat evaluation conducted May 30 and 31, 2000. The presence of
23 water in Ingram Creek is highly dependent upon the volume of precipitation received by its
24 watershed. During dry periods, the creek may be entirely dry for significant portions of the year
25 (6 to 8 months). Under normal rainfall conditions, the creek most likely maintains flow for 6 to
26 8 months of the year. The land surrounding Ingram Creek adjacent to Parcel 94(7) and upstream
27 to its headwaters is mostly mixed deciduous forest. Downstream of the site, the land use is more
28 developed, as evidenced by the fact that a significant portion of Cane Creek downstream of
29 Ingram Creek runs through the Cane Creek Golf Course.

30
31 In general, the Ingram Creek channel is relatively wide (approximately 10 feet wide) with steep
32 erosional banks approximately 4 feet high. Ingram Creek exhibits a low gradient along its length
33 from its headwaters to its confluence with Cane Creek. The substrate of Ingram Creek in the
34 vicinity of Parcel 94(7) is mainly gravel and cobbles. There is very little evidence of organic
35 matter present as substrate in Ingram Creek near the site. In fact, large sections of the creek bed

1 near Parcel 94(7) are made up of exposed bedrock. As discussed previously, the vegetation
2 adjacent to Ingram Creek is characteristic of a lowland mixed deciduous forest. This area may be
3 inundated during periods of significant rainfall and contains vegetative species indicative of
4 moist soil conditions. The tree canopy is relatively high and continuous over the length of
5 Ingram Creek adjacent to Parcel 94(7).

6
7 Although ephemeral in nature and relatively shallow over most of its length in this area (less than
8 two feet deep when water is present), Ingram Creek has the potential to support a variety of
9 amphibious species and some small fish species. Bullfrog (*Rana catesbeiana*) and leopard frog
10 (*Rana sphenoccephala*) are examples of amphibians that may be found in Ingram Creek in the
11 vicinity of Parcel 94(7). Fish species that may be found in Ingram Creek in the vicinity of the
12 site include blacknose dace (*Rhinichthys atratulus*), creek chub (*Semotilus atromaculatus*),
13 stoneroller (*Campostoma anomalum*), striped shiner (*Luxilus chrysocephalus*), and various
14 darters (*Etheostoma spp.*). The ephemeral nature of Ingram Creek limits its ability to support
15 many aquatic organisms (e.g., large fish) and other organisms that rely on aquatic species for
16 food (e.g., piscivores). Larger fish species are not expected to inhabit Ingram Creek, due to its
17 ephemeral nature.

18
19 Ingram Creek in the area adjacent to Parcel 94(7) has been identified as a moderate quality
20 foraging area for the federally listed endangered gray bat (*Myotis grisescens*) (Garland, 1996).
21 Two major requirements for gray bat foraging habitat are contiguous forest cover and habitat for
22 aquatic insects (one of the gray bat's preferred dietary items). These two requirements are met
23 during certain times of the year by Ingram Creek in this area; therefore, gray bats could
24 potentially utilize this area for foraging.

25 26 **7.3 Constituents Detected On Site**

27 The sampling and analysis programs conducted at Parcel 94(7) were designed based on a number
28 of factors including:

- 29
- 30 • Site history
 - 31 • Results of the environmental baseline survey
 - 32 • Results of previous sampling and analysis programs.
- 33

34 The sampling and analysis programs at Parcel 94(7) are described in Chapter 2.0 of this report.
35 Constituents detected in surface soil at the site and in sediment and surface water in Ingram
36 Creek adjacent to the site are summarized in Chapter 4.0 of this report.

1
2 In general, inorganic constituents were commonly detected in soils, but organic compounds (i.e.,
3 SVOCs) were detected less frequently and at relatively low concentrations. Beryllium, cobalt,
4 copper, iron, lead, and manganese were detected in one or two samples at elevated concentrations
5 relative to ESVs and/or background concentrations. Mercury was detected in four samples,
6 selenium was detected in seven samples and zinc was detected in five samples at elevated
7 concentrations relative to ESVs. There was no apparent pattern to the elevated inorganic
8 constituent distributions in surface soil at the site.

9
10 A number of SVOCs were also detected in surface soil at elevated concentrations relative to
11 ESVs. This finding was not unexpected, since many of the surface soil samples were collected
12 from beneath the asphalt paving that is present throughout the site. The mean concentrations of
13 all of the SVOCs that were detected at elevated concentrations were less than the background
14 concentrations for soil beneath pavement as presented in the *Final Human Health and Ecological*
15 *Screening Values and PAH Background Summary Report* (IT, 2000c). Thus, the SVOCs in
16 surface soil at Parcel 94(7) are characteristic of soil beneath pavement at similar sites at FTMC
17 and may not be indicative of site-related Army activities.

18
19 None of the surface water samples collected from Ingram Creek adjacent to the site exhibited any
20 constituents with elevated concentrations relative to ESVs.

21
22 Only one inorganic constituent was detected in sediment samples from Ingram Creek at elevated
23 concentrations with respect to ESVs. Nickel was detected in both sediment samples from Ingram
24 Creek associated with Parcel 94(7). The maximum detected nickel concentration slightly
25 exceeded the ESV and naturally occurring background, while the minimum detected nickel value
26 was less than both the ESV and background. Beryllium and selenium do not have sediment
27 ESVs but were detected at concentrations that slightly exceeded their respective background
28 concentrations.

29
30 Several SVOCs were detected in a single sediment sample at concentrations that exceeded their
31 respective ESVs. It is important to note that the sediment sample that exhibited the slightly
32 elevated concentrations of SVOCs was located directly downgradient of a stormwater discharge
33 point for the former driving course associated with Parcel 200(7). The former driving course is a
34 large area, mostly covered by asphalt paving, used for driver training. The driving course is
35 located approximately 100 feet east of Ingram Creek (Figure 1-4). Several concrete-lined

1 drainage ditches that run throughout the driving course receive runoff from the driving course
2 and eventually discharge to Ingram Creek directly upstream of the sampling point that exhibited
3 elevated concentrations of SVOCs. It is probable that these SVOCs originated from the asphalt
4 paving at the driving course and not from Parcel 94(7).

6 **7.4 Site Conceptual Model**

7 The ecological site conceptual model (SCM) is a simplified, schematic diagram of possible
8 exposure pathways and the means by which contaminants are transported from the primary
9 contaminant source(s) to ecological receptors. The exposure scenarios include the sources,
10 environmental transport, partitioning of the contaminants amongst various environmental media,
11 potential chemical/biological transformation processes, and identification of potential routes of
12 exposure for the ecological receptors. In this chapter, the SCM will be described in relation to
13 constituent fate and transport properties, the ecotoxicity of the various constituents, potential
14 ecological receptors at Parcel 94(7), and the complete exposure pathways expected to exist at the
15 site.

17 **7.4.1 Constituent Fate and Transport**

18 The environmental fate and transport of contaminants in the various media at Parcel 94(7) will
19 govern the potential for exposures to ecological receptors. In general, contaminants in
20 environmental media may be available for direct exposure (e.g., plants exposed to surface soil),
21 and they may also have the potential to migrate to other environmental media or other areas of
22 the site. This section discusses the mechanisms by which contaminants can be transported and
23 the chemical properties that determine their transport.

25 **7.4.1.1 Fate and Transport in Soil**

26 The fate and transport of constituents in surface soil at Parcel 94(7) is highly dependent upon the
27 fact that the entire area of the parcel is currently covered with asphalt paving. As such, many of
28 these fate and transport pathways are not currently applicable. Therefore, fate and transport are
29 discussed in this section with the assumption that, although the site is currently paved, the
30 pavement may be removed or may deteriorate significantly at some time in the future.

31
32 Surface soil at Parcel 94(7) is currently completely paved; it is not subject to erosion or dust
33 generation, and water infiltration is significantly reduced. If the asphalt paving were to be
34 removed, constituents in surface soil at the site would have the potential to be transported from
35 their source area to other areas within the study area and to off-site locations by a number of

1 mechanisms, including volatilization, dust entrainment, surface runoff, and infiltration to
2 subsurface soil/groundwater.

3
4 Several VOCs were identified in the upper soil horizons at Parcel 94(7), albeit at very low
5 concentrations. These volatile constituents have a high potential to volatilize to the atmosphere
6 and be transported from their source area via air movement. The concentrations of VOCs
7 detected in surface soil at the site are low; therefore, this transport mechanism is expected to be
8 insignificant with respect to other transport mechanisms active at this site. Most of the metals
9 and SVOCs in the surface soil at the site are not expected to volatilize to any great extent, with
10 the exception of mercury, which would be expected to volatilize relatively rapidly. Most of the
11 metals and SVOCs in the surface soil at the site are closely associated with particulate matter and
12 could be transported from their source areas by fugitive dust generation and entrainment by the
13 wind. Subsequent dispersion by atmospheric mixing could transport particulate-associated
14 constituents to other parts of Parcel 94(7) and to off-site locations. The generation of fugitive
15 dust and subsequent transport by the wind is not expected to be a significant transport
16 mechanism at Parcel 94(7) because the entire site is covered with asphalt and the surrounding
17 area is forested. There are few, if any, areas devoid of asphalt or vegetation that could be
18 potential sources of fugitive dust.

19
20 The transport of surface soil-associated contaminants by surface runoff is another potential
21 transport mechanism. Surface soil contaminants could be solubilized by rainwater and
22 subsequently transported to drainage ditches, low-lying areas, and Ingram Creek via surface
23 runoff. The solubility of inorganics in rainwater is largely dependent upon the pH of the
24 rainwater. Because the rainwater in this region is most likely slightly acidic, the inorganic
25 constituents in surface soil may solubilize to some degree in the rainwater and be subject to
26 transport via runoff. Most of the SVOCs are strongly associated with soil particles and would
27 not solubilize to a large extent. Constituents that may be more strongly bound to particulate
28 matter in surface soil (i.e., SVOCs and some of the inorganics) may be entrained in surface water
29 runoff and transported to drainage ditches, low-lying areas, and Ingram Creek via surface runoff.
30 Many of the metals and SVOCs are strongly sorbed to soil particles and could be transported
31 from their source areas via this mechanism. However, the presence of asphalt over the entire
32 study area precludes the possibility of erosion of surface soil. Therefore, erosion and surface
33 runoff of soil are expected to be insignificant at Parcel 94(7).

34
35 Contaminants in surface soil may be transported vertically to subsurface soils and groundwater

1 via solubilization in rainwater and infiltration. Subsequent groundwater transport to surface
2 water in Ingram Creek could result in exposures of aquatic receptors to soil contaminants.
3 Migration in this manner is dependent upon contaminant solubility and frequency of rainfall and
4 infiltration rate. Although the soil types (sand, stone, and gravel) in the vicinity of Parcel 94(7)
5 are expected to promote relatively rapid infiltration of rainwater, the asphalt cover over the entire
6 study area greatly reduces the infiltration rate and the subsequent potential for vertical migration
7 of surface soil contaminants. Additionally, many of the constituents (i.e., SVOCs) detected in
8 surface soil at Parcel 94(7) exhibit low water solubilities and are not expected to migrate
9 vertically to any significant extent. Therefore, vertical migration of soil contaminants is
10 expected to be insignificant at the site.

11
12 The transfer of contaminants in surface soil to terrestrial plants through root uptake and transfer
13 to terrestrial animals through ingestion and other pathways are potential transfer mechanisms.
14 However, the presence of asphalt over the entire study area precludes the direct contact of surface
15 soil by plants and animals. Therefore, under current conditions, root uptake by plants and
16 ingestion by animals are expected to be insignificant transfer mechanisms at Parcel 94(7).

17
18 VOCs in the surface soil at Parcel 94(7) would volatilize and/or photolyze rapidly when exposed
19 to sunlight (half-lives of 3 hours to 5 days) (Burrows et al., 1989). However, the asphalt paving
20 will greatly reduce these fate processes. The other surface soil contaminants (metals and
21 SVOCs) are expected to remain in the soil relatively unchanged by physical and/or chemical
22 processes for much longer periods of time.

23 24 **7.4.1.2 Fate and Transport in Surface Water**

25 In general, constituents present in the surface water of Ingram Creek adjacent to Parcel 94(7) are
26 the result of natural weathering processes of rocks and soil in the area. As such, they are
27 indicative of naturally occurring background concentrations of minerals. Constituents in surface
28 water at Parcel 94(7) may be transported from their sources to other areas along Ingram Creek or
29 to off-site locations by the following mechanisms:

- 30
31
- 32 • Volatilization
 - 33 • Transfer to groundwater
 - 34 • Transfer to sediment
 - 35 • Flow downstream.

1 Volatile organic constituents in surface water would be expected to rapidly volatilize from the
2 water-air interface and be dispersed in the atmosphere. Therefore, based on the low levels of
3 VOCs detected in surface water and the fact that these compounds would be expected to
4 volatilize rapidly, the transport of volatile constituents in surface water is expected to be
5 insignificant.

6
7 Water in Ingram Creek originates mainly from overland flow from the surrounding watershed.
8 There also appears to be localized contribution to creek flow from groundwater where the
9 potentiometric surface exceeds the creek bed surface. The flow contribution in Ingram Creek
10 from groundwater varies according to the amount of precipitation, with an increase of
11 groundwater contribution when precipitation raises the potentiometric surface. Thus,
12 constituents in groundwater could migrate to surface water in Ingram Creek. This transport
13 mechanism appears to be relatively insignificant based on the fact that surface water samples
14 from Ingram Creek did not exhibit any elevated constituent concentrations relative to ESVs.

15
16 Constituent transfer to sediments represents another potential transfer mechanism, especially
17 where constituents are in the form of suspended solids or are hydrophobic substances (i.e.,
18 PAHs) that can become adsorbed to organic matter in the sediments.

19
20 Constituents in surface water could be transported to other areas along Ingram Creek or off-site
21 via Ingram Creek and Cane Creek. Transfer of contaminants in surface water to aquatic
22 organisms is also a potential transfer pathway. Because none of the constituent concentrations in
23 surface water were elevated with respect to ESVs, constituent transfer through the aquatic food
24 web is expected to be insignificant.

25 26 **7.4.1.3 Fate and Transport in Sediment**

27 Contaminant transfer between sediment and surface water potentially represents a significant
28 transfer mechanism, especially when contaminants are in the form of suspended solids.
29 Sediment/surface water transfer is reversible; sediments often act as temporary repositories for
30 contaminants and gradually release contaminants to surface waters. This is especially true in
31 surface water systems that are acidic, as is the case with Ingram Creek in the area adjacent to
32 Parcel 94(7). Sorbed or settled contaminants can be transported with the sediment to
33 downstream locations. Much of the substrate of Ingram Creek adjacent to the site is best
34 characterized as gravel or cobbles. Very few, if any, areas of high organic content sediment or
35 muck are present. The very low organic content of gravel and cobble create a substrate with very

1 low binding capacity; therefore, constituents released to Ingram Creek would most likely remain
2 suspended in the surface water and be transported downstream and would not be sequestered in
3 the stream substrate directly adjacent to Parcel 94(7).

4
5 Transfer of sediment-associated contaminants to bottom-dwelling biota also represents a
6 potentially significant transfer mechanism. Lower trophic level organisms may accumulate
7 metals and PAHs from the sediment; however, higher trophic level organisms have the ability to
8 metabolize PAHs and therefore reduce their accumulative properties. Most of the inorganics
9 detected in sediment are not bioaccumulative. However, several inorganic constituents (e.g.
10 nickel and selenium) may bioaccumulate and/or bioconcentrate to some extent due to exposures
11 to sediment in Ingram Creek.

12 13 **7.4.2 Ecotoxicity**

14 The ecotoxicological properties of the constituents detected in the various environmental media
15 at Parcel 94(7) are discussed in the following sections.

16 17 **7.4.2.1 Beryllium**

18 In environmental media, beryllium usually exists as beryllium oxide. Beryllium has limited
19 solubility and mobility in sediment and soil.

20
21 **Plants.** Beryllium uptake by plants occurs when beryllium is present in the soluble form. The
22 highest levels of beryllium are found in the roots, with lower levels in the stems and foliage
23 (EPA, 1985a).

24
25 Soluble forms of beryllium are easily taken up by plants, probably in a manner similar to calcium
26 and magnesium, but it is not readily translocated from roots to shoots (Peterson and Girling,
27 1981). Beryllium has been reported to inhibit seed germination, enzyme activation, and uptake
28 of calcium and magnesium by roots. Common symptoms of beryllium toxicity to plants are
29 brown, retarded roots and stunted foliage (Romney and Childress, 1965). The phytotoxicity
30 benchmark value for beryllium (10 mg/kg) is based on unspecified toxic effects on plants grown
31 in surface soil amended with 10 mg/kg beryllium (Kabata-Pendias and Pendias, 1992).

32
33 **Mammals.** The most important route of exposure for beryllium is inhalation, although
34 absorption by this route does not appear to be extensive. Beryllium is poorly absorbed from the
35 gastrointestinal tract, and is not absorbed through intact skin to any significant degree. Mammals

1 exposed via inhalation exhibit pulmonary effects, which may last long after exposure ceases.
2 Once beryllium is absorbed, it is circulated in the blood as an orthophosphate colloid and is then
3 distributed primarily to the bone, liver, and kidneys in both humans and animals. Beryllium and
4 its compounds are not biotransformed, but soluble beryllium compounds are partially converted
5 to more insoluble forms in the lungs (Reeves and Vorwald, 1967).

6
7 Following inhalation of soluble beryllium compounds in both humans and animals, the lung
8 appears to be the main target organ for toxicity. Acute exposure may cause chemical
9 pneumonitis; chronic exposure to insoluble forms may lead to chronic beryllium disease
10 (berylliosis), a fibrotic lung disease (Agency for Toxic Substances and Disease Registry
11 [ATSDR], 1993).

12
13 A variety of beryllium compounds have been demonstrated to cause pulmonary tumors in
14 animals following inhalation. However, it is thought that oral administration does not lead to
15 carcinogenesis due to poor absorption of the constituent from the gastrointestinal tract. The no-
16 observed-adverse-effects-level (NOAEL) for a rat lifetime chronic exposure to beryllium in
17 drinking water was 0.54 milligrams per kilogram of bodyweight per day (mg/kg/day) (Health
18 Effects Assessment Summary Tables [HEAST], 1997).

19
20 Based on laboratory rat toxicity data for beryllium sulfate, extrapolated NOAELs for chronic oral
21 exposure of various mammalian wildlife species to beryllium range from 1.73 mg/kg/day for the
22 little brown bat to 0.19 mg/kg/day for the whitetail deer (Sample et al., 1996). It should be noted
23 that these wildlife NOAEL values were estimated using a body-weight scaling relationship that is
24 not supported by EPA.

25
26 **Aquatic Life.** Exposure routes for aquatic organisms include ingestion and gill uptake.
27 Beryllium does not bioconcentrate in aquatic organisms. Beryllium uptake from water is low,
28 resulting in low bioconcentration rates. Biomagnification of beryllium in aquatic food chains
29 does not occur (Fishbein, 1981). Beryllium can be toxic to warm-water fish, especially in soft
30 water.

31
32 The Tier II secondary acute water quality value and secondary chronic water quality value for
33 beryllium, as calculated by the method described in the EPA's *Final Water Quality Guidance for*
34 *the Great Lakes System* (EPA, 1995b), are 35 and 0.66 micrograms per liter ($\mu\text{g/L}$), respectively.

1 The EC₂₀ for fish can be used as a benchmark indicative of reproduction within a population. It
2 is the highest tested concentration causing less than 20 percent reduction in either weight of
3 young fish per initial female fish in a life-cycle or partial life-cycle test, or the weight of young
4 per egg in an early life-stage test (Suter and Tsao, 1996). The EC₂₀ value for beryllium is 148
5 µg/L. A similar value can be determined for daphnids which reflects the highest tested
6 concentration causing less than 20 percent reduction in the product of growth, fecundity, and
7 survivorship in a chronic test with a daphnid species. The EC₂₀ for daphnids is 3.8 µg/L (Suter
8 and Tsao, 1996).

9 10 **7.4.2.2 Cobalt**

11 Cobalt is a natural element and is widely distributed in the Earth's crust at 0.001 to 0.002 percent
12 (Merck Index, 1983). Small amounts of cobalt are found in rocks, soil, surface water, and
13 groundwater. Natural cobalt can stay airborne for a few days but will stay for years in the soil.
14 In most soils, the transfer of cobalt from soils to plants is not significant, although higher transfer
15 rates have been observed in some higher plants and in acidic soils (Boikat et al., 1985; Francis et
16 al., 1980). Some cobalt may seep from acid soil into groundwater. It is present in trace
17 quantities in most foods and is readily absorbed by the gut in humans (International Commission
18 on Radiological Protection, 1979).

19
20 **Plants.** Although cobalt is essential to some blue-green algae, fungi, and microorganisms, it
21 apparently is not essential for the growth of higher plants (Kabata-Pendias and Pendias, 1992).
22 Several abiotic factors govern the availability of cobalt to plants. Soil factors include organic
23 matter and clay content, pH, leachability, and concentration of manganese and iron oxides.
24 Uptake of cobalt can occur via the roots or leaves of a plant (Kabata-Pendias and Pendias, 1992).

25
26 Concentrations of cobalt in leaf tissue that are excessive or toxic to various plant species range
27 from 15 to 50 mg/kg (dry weight) (Kabata-Pendias and Pendias, 1992). A soil concentration of
28 20 mg/kg (dry weight) has been proposed by Efroymson et al. (1997) as a benchmark screening
29 value for cobalt phytotoxicity. General symptoms of cobalt toxicity in plants include interveinal
30 chlorosis in new leaves followed by induced iron chlorosis and white leaf margins and damaged
31 root tips (Kabata-Pendias and Pendias, 1992).

32
33 **Mammals.** Cobalt is a component of vitamin B₁₂ and, therefore, is an essential micronutrient
34 for animal growth. No information has been located at this time on chronic toxic effects of

1 cobalt to terrestrial wildlife; however, some acute studies have been completed. Additionally,
2 there is little biomagnification of cobalt in animals of higher trophic levels (Jenkins, 1980).

3
4 Young rats are unable to survive repeated 30-mg doses of cobalt metal powder in their diet for a
5 month (total dosage about 900 mg), whereas they can tolerate 1,250 mg of the metal in a single
6 dose (Venugopal and Luckey, 1978). Cobalt was embryotoxic to rat fetuses when it was
7 administered during the entire gestation (dose of 0.05 mg/kg). A dose of 0.005 mg/kg was non-
8 toxic to the females, however the progeny of treated females had a reduced rate (Shepard, 1986).
9 At doses under 2 mg/kg/day, no adverse effects to sheep were noted. However, at 6 mg/kg/day,
10 sheep exhibited loss of appetite, loss of weight, and debilitation (National Research Council,
11 1977).

12
13 **Birds.** No information has been located at this time on chronic toxic effects of cobalt to birds;
14 however, some acute studies have been completed. Additionally, there is little biomagnification
15 of cobalt in animals of higher trophic levels (Jenkins, 1980).

16
17 Chickens were administered 50 mg/kg of diet/day with acute effects of loss of appetite, loss of
18 weight, and debilitation. At doses under 2 mg/kg/day, no adverse effects to chickens were noted
19 (National Research Council, 1977).

20
21 **Aquatic Life.** In most surface water bodies, cobalt is primarily associated with the sediment.
22 However, some mobilization may occur in acidic water and in the presence of chloride ions or
23 chelating agents. Bioaccumulation factors for freshwater fish range from 40 to 1,000 (Smith and
24 Carson, 1981).

25
26 Research by Evans et al. (1988) indicates that cobalt does not significantly bioaccumulate in
27 benthic bottom feeders.

28 29 **7.4.2.3 Copper**

30 Copper is ubiquitously distributed in nature in the free state and in sulfides, arsenides, chlorides,
31 and carbonates. Several copper-containing proteins have been identified in biological systems as
32 oxygen-binding hemomcyanin, cytochrome oxidase, tyrosinase, and laccase. Copper has also
33 been identified with the development of metalloproteins employed in the sequestering and
34 cellular detoxification of metals.

1 Copper has been known to sorb rapidly to sediment. The rate of sorption is, of course, dependent
2 upon factors such as the sediment grain size, organic fraction, pH, competing cations, and the
3 presence of ligands. In industrialized freshwater environments around the world, total copper
4 levels within sediments can range from 7 to 2,350 parts per million (ppm) (Moore and
5 Ramamoorthy, 1984).

6
7 **Plants.** Copper is an essential nutrient for the growth of plants. Background concentrations of
8 copper in grasses and clovers collected in the United States averaged 9.6 mg/kg and 16.2 mg/kg
9 (dry weight) (Kabata-Pendias and Pendias, 1992). Copper is one of the least mobile heavy
10 metals in soil, and its availability to plants is highly dependent on the molecular weight of
11 soluble copper complexes (Kabata-Pendias and Pendias, 1992).

12
13 According to Rhodes et al. (1989), copper concentrations in plant tissues do not serve as
14 conclusive evidence of copper toxicity in species of plants such as tomatoes, because some
15 species are able to tolerate higher concentrations of copper than others. The pH of soil may also
16 influence the availability and toxicity of copper in soils to plants (Rhodes et al., 1989). In a
17 study with tomato plants, Rhodes et al. (1989) found a reduction in plant growth when plants
18 were grown in soils containing greater than 150 mg/kg of copper at a pH of less than 6.5. At pH
19 values greater than 6.5, soil copper concentrations of greater than 330 mg/kg were required to
20 reduce plant growth.

21
22 Concentrations of copper in leaf tissue that are excessive or toxic to various plant species range
23 from 20 to 100 mg/kg (dry weight) (Kabata-Pendias and Pendias, 1992). A soil concentration of
24 100 mg/kg has been proposed by Efroymson et al., (1997) as a benchmark screening value for
25 copper phytotoxicity in soil. General symptoms of copper toxicity in plants include the presence
26 of dark green leaves followed by induced iron chlorosis; thick, short, or barbed-wire roots; and
27 depressed tillering (Kabata-Pendias and Pendias, 1992).

28
29 **Mammals.** Copper is an essential trace element to plants and animals (Callahan et al., 1979)
30 but becomes toxic at concentrations only slightly higher than essential levels (EPA, 1985b).
31 Copper is an essential element for hemoglobin synthesis and oxidative enzymes in animals.
32 Copper is absorbed by mammals following ingestion, inhalation, and dermal exposure. Once
33 absorbed, copper is distributed to the liver. Copper is not metabolized (Marceau et al., 1970).
34 No evidence of bioaccumulation was obtained in a study of pollutant concentrations in the
35 muscles and livers of ten species of herbivorous, omnivorous, and carnivorous animals in

1 Donana National Park in Spain (Hernandez et al., 1985). Copper concentrations in small
2 mammals collected from various uncontaminated sites ranged from 8.3 to 13.4 mg/kg (whole-
3 body concentrations) (Talmage and Walton, 1991). Highest concentrations of copper tend to be
4 in hair, followed in decreasing concentration by liver, kidney, and whole body (Hunter and
5 Johnson, 1982). Among the small mammals collected, Hunter and Johnson (1982) found shrews
6 (*Sorex araneus*) to contain the highest concentrations of copper. Mice were found to contain the
7 lowest copper concentrations. Increased fetal mortality was observed in fetuses of mice fed more
8 than 104 mg/kg/day of copper as copper sulfate (Lecyk, 1980). Increased mortality rates in mink
9 offspring have been observed at levels above 3.21 mg/kg/day (Aulerich et al., 1982).

10
11 Based on toxicity data specific to the mink, extrapolated NOAELs for chronic exposure of
12 various mammalian species to copper sulfate were estimated to be 30.4 mg/kg/day for the white-
13 footed mouse, 11.2 mg/kg/day for the cottontail rabbit, and 8.0 mg/kg/day for the red fox
14 (Sample et al., 1996). Examples of calculated chronic drinking water NOAELs for mammalian
15 wildlife were 101.3 mg/L for the white-footed mouse, 115.6 mg/L for the cottontail rabbit, and
16 95.1 mg/L for the red fox (Sample et al., 1996). It should be noted that these wildlife NOAEL
17 values were estimated using a body-weight scaling relationship that is not supported by EPA.
18 Symptoms of acute copper poisoning in mammals include vomiting, hypotension, melena, coma,
19 jaundice, and death (Klaassen et al., 1991). Selenium can act as an antidote for copper
20 poisoning.

21
22 **Birds.** Based on toxicity test data specific to the chicken, extrapolated NOAELs for chronic
23 exposure of avian species to copper oxide are 20.2 mg/kg/day for the great blue heron and 25.9
24 mg/kg/day for the red-tailed hawk (Sample et al., 1996). The calculated drinking water NOAEL
25 for these birds consuming water containing copper oxide is 457 mg/L (Sample et al., 1996).

26
27 **Aquatic Life.** Invertebrates inhabiting "polluted" freshwaters worldwide have been known to
28 have tissue residues of copper ranging from 5 to 200 ppm (Moore and Ramamoorthy, 1984).
29 Field studies have shown that there is virtually no accumulation of this metal through the food
30 chain (Fuller and Averett, 1975). Studies by Kosalwat and Knight (1987) indicated that copper
31 present in the substrate or sediment was significantly less toxic to chironomid species than
32 overlying water column levels. The substrate copper concentration at which chironomid larval
33 growth was reduced 50 percent (EC_{50}) was 1,602 mg/kg. These researchers found that
34 deformities in larval mouth parts were observed in elevated concentrations, and adult emergence
35 was inhibited when the sediment concentration exceeded 1,800 mg/kg. Carins et al. (1984)

1 reported copper toxicity in sediment for several chironomus midges and cladocerans with LC₅₀s
2 ranging from 681 to 2,296 mg/kg.

3 4 **7.4.2.4 Iron**

5 Iron is an essential trace element, required as a constituent of oxygen-carrying and oxidative-
6 reductive macro-molecules such as hemoglobin, myoglobin, and cytochrome P-450. As such,
7 most iron-related health concerns are induced by insufficient iron intake rather than excess iron
8 intake (Hayes, 1994).

9
10 **Plants.** Wallihan (1966) reported unspecified reductions in plant growth in a solution culture
11 with the addition of 10 ppm iron. Wallace et al., (1977) evaluated the effects of iron (as FeSO₄)
12 on leaf, stem, and root weights of bush bean seedlings grown for fifteen days in nutrient solution.
13 Iron at 28 ppm reduced all three measures 67, 52, and 67 percent, respectively, while 11.2 ppm
14 iron had no effect. After 55 days, cabbage seedling plant weight was reduced 45 percent by 50
15 ppm iron added as FeSO₄ to nutrient solution, while 10 ppm had no effect on growth (Hara et al.,
16 1976).

17
18 Iron is the key metal required for energy transformations needed for cellular function. It occurs
19 in heme and non-heme proteins and is concentrated in chloroplasts. Organic iron complexes are
20 involved in photosynthetic electron transfer. Plant symptoms of toxicity are not specific and
21 differ among plant species and growth stages (Foy et al., 1978).

22
23 **Mammals.** Iron is an essential nutrient for most wildlife species and is necessary to maintain
24 homeostasis; therefore, it is only toxic at very high concentrations. Bioaccumulation factors
25 have been calculated for several small mammal species. Small herbivorous mammals were
26 estimated to have an iron bioaccumulation factor of 0.0127, and small omnivorous mammals
27 were estimated to have an iron bioaccumulation factor of 0.01209. These bioaccumulation
28 factors indicate that iron is not accumulated in small mammal tissues (Sample et al., 1998a).
29 Additionally, the bioaccumulation factor for earthworms has been estimated to be 0.038,
30 indicating that iron is not accumulated in earthworm tissues (Sample et al., 1998b).

31
32 **Aquatic Life.** The National Recommended Water Quality Criteria for iron (1,000 µg/L) is
33 based on field study at a site receiving acid mine drainage. The lowest chronic value for
34 daphnids (158 µg/L) is a threshold for reproductive effects from a 21-day test using iron chloride
35 with *Daphnia magna* (Dave, 1984). It is considerably lower than the 4,380 µg/L concentration

1 causing 16 percent reproductive decrement in another test using iron chloride with *Daphnia*
2 *magna* (Biesinger and Christensen, 1972). The lowest chronic value for fish (1,300 µg/L) is a
3 concentration that caused 100 percent mortality in an embryo-larval test with rainbow trout
4 exposed to dissolved iron salts (Amelung, 1981).

5
6 The Ontario Ministry of the Environment has prepared provincial sediment quality guidelines
7 using the screening-level concentration approach, which estimates the highest concentration of a
8 particular contaminant in sediment that can be tolerated by approximately 95 percent of benthic
9 fauna (Neff et al., 1988). These values are based on Ontario sediments and benthic species from
10 a wide range of geographical areas within the province (Persaud et al., 1993). The lowest effect
11 level (Low) is the level at which actual ecotoxic effects become apparent. The severe effect level
12 (Severe) represents contaminant levels that could potentially eliminate most of the benthic
13 organisms (Persaud et al., 1993). The “Low” and “Severe” levels for iron in sediment are 2
14 percent (20,000 ppm) and 4 percent (40,000 ppm), respectively.

16 **7.4.2.5 Lead**

17 Global production of lead from both smelter and mining operations has been high throughout the
18 past 100 years. Lead is commonly used in storage batteries as well as in ammunition, solder, and
19 casting materials. In addition, tetraethyl lead was a principal additive to gasolines as an anti-
20 knock agent and was commonly used as an additive in paints. In short, lead is one of the most
21 ubiquitous pollutants in the civilized world.

22
23 Lead is strongly sorbed in sediments, and the rate is strongly correlated with grain size and
24 organic content. In the absence of soluble complexing species, lead is almost totally adsorbed to
25 clay particles at pHs greater than 6 (Moore and Ramamoorthy, 1984).

26
27 **Plants.** Although lead is not an essential nutrient for plant growth, it is detected in plant tissues
28 due to the prevalence of lead in the environment. The bioavailability of lead in soil to plants is
29 limited. Bioavailability may be enhanced by a reduction in soil pH, a reduction in the content of
30 organic matter and inorganic colloids in soil, a reduction in iron oxide and phosphorous content,
31 and by increased amounts of lead in soil (National Research Council of Canada, 1973). Plants
32 can absorb lead from soil and air. Aerial deposition of lead can also contribute significantly to
33 the concentration of lead in above-ground plant parts. Lead is believed to be the metal of least
34 bioavailability and the most highly accumulated metal in root tissue (Kabata-Pendias and
35 Pendias, 1992).

1
2 Mean background concentrations of lead in grasses and clovers have been reported to range from
3 2.1 to 2.5 mg/kg (dry weight) (Kabata-Pendias and Pendias, 1992). Adverse effects of lead on
4 terrestrial plants occur only at total concentrations of several hundred mg/kg of soil (Eisler,
5 1988). This is explained by the fact that, in most cases, lead is tightly bound to soils and
6 substantial amounts must accumulate before it can affect the growth of higher plants (Boggess,
7 1977).

8
9 **Mammals.** As with plants, lead is not considered an essential nutrient for mammalian life.
10 Ingestion is the major route of exposure for wildlife. Lead tends to accumulate in bone, hair, and
11 teeth. Biomagnification of lead is negligible (Eisler, 1988). Reduced survival was reported at
12 acute oral doses as low as 5 mg/kg body weight in rats, at a chronic dose of 0.3 mg/kg body
13 weight in dogs, and at a dietary level of 1.7 mg/kg body weight in horses (Eisler, 1988).
14 Examples of extrapolated NOAELs for chronic exposure of various mammalian wildlife species
15 to lead acetate are 15.98 mg/kg/day for the white-footed mouse, 5.88 mg/kg/day for the cottontail
16 rabbit, and 4.22 mg/kg/day for the red fox (Sample et al., 1996). It should be noted that these
17 wildlife NOAEL values were estimated using a body-weight scaling relationship that is not
18 supported by EPA. Symptoms of lead poisoning in mammals are diverse and depend on the
19 form of lead ingested, the concentration, and the mammal species and its age. These symptoms
20 may include reproductive impairment, decreased body weight, vomiting, uncoordinated body
21 movements, visual impairment, reduced life span, renal disorders, and abnormal social behavior
22 (Eisler, 1988).

23
24 In laboratory studies, breeding mice exposed to low doses of lead in drinking water (25 ppm)
25 resulted in loss of the strain in two generations with many abnormalities (Schroeder and
26 Mitchner, 1971). Exposure of rats in this same experiment resulted in many early deaths and
27 runts. Blood δ -aminolevulinic acid dehydratase (ALAD) activity associated with exposure to
28 lead was reduced in white-footed mice living near a metal smelter (Beyer et al., 1985). Amounts
29 of whole-body lead content and feeding habits of roadside rodents have been correlated with
30 highest body burdens in insectivores such as shrews, intermediate in herbivores, and lowest in
31 granivores (Boggess, 1977; Getz et al., 1977).

32
33 **Birds.** Most of the information on the effects of lead to terrestrial vertebrates is concerned with
34 the poisoning of waterfowl by lead shot. Apparent symptoms include loss of appetite and
35 mobility, avoidance of other birds, lethargy, weakness, emaciation, tremors, dropped wings,

1 green feces, impaired locomotion, loss of balance and depth perception, nervous system damage,
2 inhibition of heme synthesis, damage to kidneys and liver, and death (Eisler, 1988; Mudge,
3 1983). Anemia, kidney disease, testicular and liver lesions, and neurological disorders have been
4 associated with high brain lead concentrations in mourning doves (*Zenaida macroura*) (Kendall,
5 1992).

6
7 Toxicity of lead to birds is dependent upon the form of lead, the route of exposure and exposure
8 duration, and the species and age of the bird. Hatchlings of chickens, Japanese quail, mallards,
9 and pheasants are relatively more tolerant to moderate lead exposure, including no effect on
10 growth at dietary levels of 500 ppm and no effect on survival at 2,000 ppm (Hoffman et al.,
11 1985; Eisler, 1988). Based on toxicity data specific to American kestrels exposed orally to
12 metallic lead, Sample et al (1996) estimated NOAELs for the great blue heron and red-tailed
13 hawk to be 1.47 and 1.89 mg/kg/day, respectively. The drinking water NOAEL for these birds
14 was estimated to be 33 mg/L (Eisler, 1988).

15
16 **Aquatic Life.** All life stages are sensitive to the toxic effects of lead; however, embryos are
17 more sensitive to lead than are later juvenile stages (Davies et al., 1976). Lead uptake depends
18 on exposure time, aqueous concentration, pH, temperature, salinity, diet, and other factors. For
19 example, gill, liver, kidney, and erythrocytes accumulate lead from aqueous sources in
20 proportion to exposure time and concentration (Holcombe et al., 1976). Direct erythrocyte injury
21 is considered the first and most important sign of lead poisoning in catfish (Dawson, 1935).
22 Respiratory distress occurs in fish living in rivers receiving lead mining wastes in England
23 (Carpenter, 1924; 1925; 1926). Fish are thought to be asphyxiated as a result of a mucous
24 coating over the gills (National Academy of Sciences, 1972).

25
26 No significant biomagnification of lead occurs in aquatic ecosystems (Boggess, 1977).
27 Background concentrations of lead in fish tend to be less than 1 mg/kg (dry weight) L (Eisler,
28 1988). The EPA's National Recommended Water Quality Criteria for lead in freshwater is 65
29 µg/L for acute exposure and 2.5 µg/L for chronic exposure (EPA, 1999a). In general, dissolved
30 lead is more toxic than total lead, and organic forms of lead are more toxic than inorganic forms.
31 Soluble lead in the water column becomes less bioavailable as water hardness increases. Chronic
32 exposure of fish to lead may result in signs of lead poisoning such as spinal curvature, anemia,
33 darkening of the dorsal tail region, destruction of spinal neurons, difficulty in swimming, growth
34 inhibition, changes in blood chemistry, retarded sexual development, and death (Eisler, 1988).

1 The majority of benthic invertebrates do not bioconcentrate lead from water or abiotic sediment
2 particles. There is some evidence of bioaccumulation through the food web of organic forms of
3 lead, such as tetraethyl lead. Anderson et al. (1980) reported lead LC₅₀s of 258 ppm for the
4 chironomid and that growth of this amphipod was not reduced above this level in freshwater
5 sediments. In addition, Suter and Tsao (1996) reported effect levels in the water flea (*Daphnia*
6 *magna*) to be in the 12.26 ppb range, while Khangrot and Ray (1989) reported a *D. magna* LC₅₀
7 of 4.89 ppm.

9 **7.4.2.6 Manganese**

10 Manganese, a silver-colored metal with chemical properties similar to iron, is a naturally
11 occurring substance found in many minerals. Manganese is usually combined with oxygen,
12 sulfur, and/or chlorine. Manganese is present in all living organisms and is an essential element
13 for adequate nutritional needs in mammals and many other organisms. Manganese is poorly
14 absorbed from the intestinal tract; about 3 to 5 percent of the oral dose of manganese is absorbed.
15 Absorption efficiency is also related to dietary intake of iron and calcium. Sufficient body stores
16 of iron decrease absorption of manganese (ATSDR, 1992).

17
18 **Plants.** Manganese is an essential element for plant growth. Uptake of manganese may occur
19 via root or foliar uptake (Kabata-Pendias and Pendias, 1992). The concentration of manganese in
20 plants is dependent upon plant and soil characteristics. Plants grown on flooded or acid soils
21 tend to contain higher concentrations of manganese than plants grown in other, uncontaminated
22 soils. In addition, concentrations of manganese in plants are positively correlated with soil
23 organic matter (Kabata-Pendias and Pendias, 1992). Concentrations of manganese in leaf tissue
24 that are excessive or toxic to various plant species range from 400 to 1,000 mg/kg dry weight
25 (Kabata-Pendias and Pendias, 1992). A soil concentration of 500 mg/kg (dry weight) has been
26 proposed by Efroymson et al. (1997) as a benchmark screening value for manganese
27 phytotoxicity. General symptoms of manganese toxicity in plants include the presence of
28 chlorosis and necrotic lesions on old leaves, blackish brown or red necrotic spots, dried leaf tips,
29 and stunted root and plant growth (Kabata-Pendias and Pendias, 1992).

30
31 **Mammals.** Manganese is an essential nutrient that is homeostatically regulated in vertebrates
32 (Vanderploeg et al., 1975). Liver and kidney tissues generally contain the highest concentrations
33 of manganese in the body. Manganese is primarily excreted from the body in the feces (Gregus
34 and Klaassen, 1986).

1 Divalent manganese is more toxic than the trivalent form. Exposure to manganese dust via
2 inhalation is usually of greater toxicological concern than ingestion (Klaassen et al., 1991).
3 Based on an oral NOAEL of 88 mg/kg/day for rats exposed to manganese oxide, extrapolated
4 NOAELs for chronic oral exposure of various mammalian wildlife species to manganese were
5 estimated to be 176 mg/kg/day for the white-footed mouse, 65 mg/kg/day for the cottontail
6 rabbit, and 46 mg/kg/day for the red fox (Sample et al., 1996). Calculated chronic drinking water
7 NOAELs for wildlife were 586 mg/L for the white-footed mouse, 669 mg/L for the cottontail
8 rabbit, and 550 mg/L for the red fox (Sample et al., 1996). It should be noted that these wildlife
9 NOAEL values were estimated using a body-weight scaling relationship that is not supported by
10 EPA. Laboratory studies with rats have found no hematologic, behavioral, or histologic effects
11 in animals exposed to manganese dioxide at concentrations of 47 milligrams per cubic meter for
12 five hours per day, five days a week, for 100 days (Klaassen et al., 1991).

13
14 **Aquatic Life.** As discussed previously, manganese is a required nutrient for plant and animal
15 life. Manganese concentrations in most vertebrates are homeostatically controlled (Vanderploeg
16 et al., 1975). Bioconcentration factors for freshwater macrophytes have been reported to range
17 from 190 to approximately 25,000 (Vanderploeg et al., 1975). With regard to freshwater fish,
18 concentrations of manganese in fish muscle are generally less than 0.5 mg/kg and range from 3
19 to 10 mg/kg in whole fish (Vanderploeg et al., 1975). Bioconcentration factors from water to
20 whole fish range from 40 to 2,300. A bioconcentration factor of 10,000 was also suggested for
21 crustaceans (Vanderploeg et al., 1975).

22
23 No federal water quality criteria exist for the protection of freshwater biota from elevated
24 manganese concentrations. Suter and Tsao (1996) have estimated acute and chronic advisory
25 levels for manganese to be 1,470 and 80.3 µg/L, respectively. The EC₂₀ for fish can be used as a
26 benchmark indicative of production within a population. It is the highest tested concentration
27 causing less than 20 percent reduction in either weight of young fish per initial female fish in a
28 life-cycle or partial life-cycle test, or the weight of young per egg in an early life-stage test (Suter
29 and Tsao, 1996). The EC₂₀ value for manganese is 1,270 µg/L. A similar value can be
30 determined for daphnids which reflects the highest tested concentration causing less than 20
31 percent reduction in the product of growth, fecundity, and survivorship in a chronic test with a
32 daphnid species. The EC₂₀ for daphnids is less than 1,100 µg/L (Suter and Tsao, 1996).

33

1 **7.4.2.7 Mercury**

2 Mercury is a toxic compound with no known natural biological function. Mercury exists in three
3 valence states: mercuric (Hg^{2+}), mercurous (Hg^{1+}), and elemental (Hg^{0+}) mercury. It is present in
4 the environment in inorganic and organic forms. Inorganic mercury compounds are less toxic
5 than organomercury compounds; however, the inorganic forms are readily converted to organic
6 forms by bacteria commonly present in the environment. The organomercury compound of
7 greatest concern is methylmercury (EPA, 1999b).

8
9 Mercury sorbs strongly to soil and sediment. Elemental mercury is highly volatile. In aquatic
10 and terrestrial receptors, some forms of mercury, especially organomercury compounds,
11 bioaccumulate significantly and biomagnify in the food chain. In all receptors, the target organs
12 are the kidney and central nervous system. However, mercury causes numerous other effects,
13 including teratogenicity and mutagenicity (EPA, 1999b).

14
15 **Plants.** Mercury is not required for plant growth. Background concentrations of mercury in
16 plants usually range from 0.0026 to 0.086 mg/kg (dry weight) (Kabata-Pendias and Pendias,
17 1992). Pine needles have been reported to be good biomonitors of mercury-contaminated
18 environments (Kabata-Pendias and Pendias, 1992). In general, the concentration of mercury in
19 plants will be elevated when mercury concentrations in soils are high. Mercury concentrations in
20 plants, however, generally do not exceed those in associated soils (Lisk, 1972). Methyl mercury
21 is more available to plants than either phenyl- or sulfide-mercury. In addition to mercury uptake
22 from the soil, plants can also absorb mercury vapor (Browne and Fang, 1978).

23
24 Concentrations of mercury in leaf tissue that are excessive or toxic to various plant species range
25 from 1 to 3 mg/kg (dry weight) (Kabata-Pendias and Pendias, 1992). A soil concentration of 0.3
26 mg/kg has been proposed by Efrogmson et al. (1997) as a benchmark screening value for
27 mercury phytotoxicity. General symptoms of mercury toxicity in plants include severe stunting
28 of seedlings and roots, leaf chlorosis, and browning of leaf points (Kabata-Pendias and Pendias,
29 1992).

30
31 **Mammals.** Mercury is not an essential element for animal life. Background mercury
32 concentrations in wildlife tend to be less than 1.0 mg/kg (wet weight) (Eisler, 1987a).
33 Biomonitoring studies have shown that mercury concentrations in mammals are highest in hair,
34 followed by kidney and liver tissues (Bull et al., 1977; Klaassen et al., 1991; Wren, 1986).
35 Mercury is bioaccumulated and biomagnified in terrestrial food chains (Eisler, 1987a; Talmage

1 and Walton, 1993). Talmage (1989) has shown the insectivorous short-tailed shrew (*Blarina*
2 *brevicauda*) to be a better monitor of environmental mercury contamination than the granivorous
3 white-footed mouse (*Peromyscus leucopus*). Mink (*Mustela vison*) and river otter (*Lutra*
4 *canadensis*) have been shown to be good monitors of mercury contamination within river
5 environments due to their consumption of contaminated fish (Kucera, 1983).

6
7 Organic mercury compounds, especially methylmercury, are more toxic to mammals than
8 inorganic forms of mercury. Selenium has been shown to have a protective effect against
9 mercury poisoning (Ganter et al., 1972). Based on methylmercury toxicity data for rats and
10 mink, extrapolated NOAELs for chronic exposure of various mammalian wildlife species to
11 methylmercury have been estimated. The estimated NOAELs are the following: 0.084
12 mg/kg/day for the little brown bat, 0.07 mg/kg/day for the short-tailed shrew, 0.064 mg/kg/day
13 for the white-footed mouse, 0.054 mg/kg/day for the meadow vole, 0.015 mg/kg/day for the
14 mink, 0.024 mg/kg/day for the cottontail rabbit, 0.01 mg/kg/day for the red fox, 0.009 mg/kg/day
15 for the river otter, and 0.009 mg/kg/day for the whitetail deer (Sample et al., 1996). Calculated
16 chronic drinking water NOAELs for mammalian wildlife species are 0.523 mg/L for the little
17 brown bat, 0.32 mg/L for the short-tailed shrew, 0.213 mg/L for the white-footed mouse, 0.394
18 mg/L for the meadow vole, 0.152 mg/L for the mink, 0.243 mg/L for the cottontail rabbit, 0.122
19 mg/L for the red fox, 0.111 mg/L for the river otter, and 0.137 mg/L for the whitetail deer
20 (Sample et al., 1996). It should be noted that these wildlife NOAEL values were estimated using
21 a body-weight scaling relationship that is not supported by EPA.

22
23 Mercury has been shown to be teratogenic, mutagenic, and carcinogenic in animal studies
24 (Eisler, 1987a). Signs of mercury poisoning that have been observed in mink include anorexia,
25 weight loss, ataxia and splaying of hind legs, irregular vocalization, salivation, and convulsions
26 (Wren, 1986).

27
28 **Birds.** Concentrations of mercury that are acutely toxic to birds following oral exposure range
29 from 2.2 to 31 mg/kg body weight (Eisler, 1987a). Mercury concentrations in the livers of
30 methylmercury-poisoned birds ranged from 17 to 70 mg/kg (dry weight) (Solonen and Lodenius,
31 1984). Methylmercury is more toxic to avian species than inorganic mercury (Hill, 1981). In
32 addition to the form of mercury to which the bird is exposed, the species, gender, age, and health
33 of the individual may also influence the toxic response (Fimreite, 1979). Physical signs of
34 mercury poisoning in birds include muscular incoordination, falling, slowness, fluffed feathers,
35 calmness, withdrawal, hyporeactivity, and eyelid drooping (Eisler, 1987a).

1
2 **Aquatic Life.** Concentrations of mercury in freshwater fish collected from 12 monitoring
3 stations in the United States from 1978 to 1981 ranged from 0.1 to 1.1 mg/kg (wet weight), with
4 an average of 0.11 mg/kg (Lowe et al., 1985). Elevated concentrations of mercury in fish have
5 often been associated with low pH, low calcium concentrations in the water, and low water
6 hardness (Eisler, 1987a). Methylating bacteria in sediments actively convert inorganic mercury
7 into methylmercury. This results in an increase in the bioavailability of mercury. Fish absorb
8 methylmercury more easily than inorganic mercury from the water column (Huckabee et al.,
9 1979). Because exposure of fish to methylmercury can occur via ingestion of contaminated prey,
10 methylmercury concentrations are usually highest in organisms near the top of the food chain,
11 such as carnivorous fish (Huckabee et al., 1979).

12
13 Exposure of aquatic organisms to elevated mercury concentrations can result in reduced growth
14 and reproduction (Eisler, 1987a). The National Recommended Water Quality Criteria for acute
15 and chronic exposure to mercury in freshwater systems are 1.4 and 0.77 $\mu\text{g/L}$, respectively (EPA,
16 1999a). The test EC_{20} for fish can be used as a benchmark indicative of production within a
17 population. It is the highest tested concentration causing less than 20 percent reduction in either
18 the weight of young fish per initial female fish in a life-cycle or partial life-cycle test, or the
19 weight of young per egg in an early life-stage test. The EC_{20} value for methylmercury is less than
20 0.03 $\mu\text{g/L}$ (Suter and Tsao, 1996). A similar value can be determined for daphnids which
21 represents the highest tested concentration causing less than 20 percent reduction in the product
22 of growth, fecundity, and survivorship in a chronic test with a daphnid species. The EC_{20}
23 benchmark for daphnids has been determined to be 0.87 $\mu\text{g/L}$ (Suter and Tsao, 1996).

24
25 Physical signs of acute mercury poisoning in fish include the flaring of gills, an increase in the
26 frequency of respiratory movements, loss of equilibrium, and sluggishness (Armstrong, 1979).

27 28 **7.4.2.8 Nickel**

29 Nickel is a naturally occurring silvery metal that is found in the Earth's crust in the form of
30 various nickel minerals. Exposure of organisms to nickel and its compounds results from
31 breathing air, ingesting water and food that contain nickel and compounds, and skin contact with
32 a medium contaminated with nickel.

33
34 **Plants.** Nickel is not believed to be an essential element for plant growth; however, beneficial
35 effects of nickel have been reported on the growth of legumes. Background concentrations of

1 nickel in grasses and clovers collected in the United States averaged 0.13 and 1.5 mg/kg,
2 respectively (Kabata-Pendias and Pendias, 1992). The concentration of nickel in plants is
3 positively correlated with nickel concentrations in soil.

4
5 Concentrations of nickel in leaf tissue that are excessive or toxic to plant species range from 10
6 to 100 mg/kg (dry weight) (Kabata-Pendias and Pendias, 1992). A soil concentration of 30 mg/kg
7 has been proposed by Efroymson et al. (1997) as a benchmark screening value for nickel
8 phytotoxicity. General symptoms of nickel toxicity in plants include the presence of interveinal
9 chlorosis in new leaves, gray-green leaves, and brown and stunted root and plant growth. The
10 uptake of nutrients and minerals, especially iron, can be substantially reduced as a consequence
11 of nickel toxicity in plants (Kabata-Pendias and Pendias, 1992).

12
13 **Mammals.** Nickel is a non-essential element for animal life. Nickel concentrations within the
14 whole bodies of small mammals from uncontaminated sites were reported to range from 2.2 to
15 6.2 mg/kg (dry weight) (Talmage and Walton, 1991). Highest concentrations were measured in
16 the deer mouse (*Peromyscus maniculatus*). Highest tissue concentrations of nickel are usually
17 found in the liver of mammals (Schroeder et al., 1964). Because nickel is poorly absorbed by the
18 gastrointestinal tract, ingested nickel is generally not of great toxicological concern. Inhaled
19 nickel, however, is relatively toxic. Rats fed nickel in their diet as nickel sulfate hexahydrate
20 over three generations were studied for effects on reproduction. They were fed three dose levels
21 (250, 500, and 1,000 ppm nickel) in their diet, and only the highest dose level caused reduced
22 offspring body weights. No adverse effects were observed in the other dose levels. Because this
23 study considered exposures over multiple generations, the 500 ppm dose was considered to be
24 the chronic NOAEL, and the 1,000 ppm dose was considered to be the chronic lowest-observed-
25 adverse-effects-level (LOAEL) (EPA, 1999b).

26
27 Based on toxicity data for rats exposed to nickel sulfate hexahydrate, extrapolated NOAELs for
28 chronic exposure of various mammalian wildlife species were estimated to be 79.89 mg/kg/day
29 for the white-footed mouse, 29.4 mg/kg/day for the cottontail rabbit, and 21.12 mg/kg/day for the
30 red fox (Sample et al., 1996). Calculated chronic drinking water NOAELs for mammalian
31 wildlife were estimated to be 266.3 mg/L for the white-footed mouse, 304.1 mg/L for the
32 cottontail rabbit, and 250.2 mg/L for the red fox (Sample et al., 1996). It should be noted that
33 these wildlife NOAEL values were estimated using a body-weight scaling relationship that is not
34 supported by EPA.

1 **Birds.** Mallard ducklings were fed nickel as nickel sulfate in their diet for a duration of 90 days
2 to study the effects on mortality, growth, and behavior. They were fed three dose levels (176,
3 774, and 1,069 ppm nickel), and only the highest dose reduced growth and resulted in 70 percent
4 mortality. Because the study considered exposure over 90 days, the 774 ppm dose was
5 considered to be the chronic NOAEL, and the 1,069 dose was considered to be the chronic
6 LOAEL (Cain and Pafford, 1981).

7
8 **Aquatic Life.** The bioavailability and toxicity of nickel to aquatic biota is influenced by the pH
9 of the water (Schubauer-Berigan et al., 1993). The National Recommended Water Quality
10 Criteria for the protection of aquatic life for acute and chronic exposure are 470 and 52 µg/L,
11 respectively (EPA, 1999a). Background concentrations of nickel in adult anurans ranged
12 between 0.9 and 2.9 mg/kg (dry weight) (Hall and Mulhern, 1984).

13
14 The test EC₂₀ for fish can be used as a benchmark indicative of production within a population.
15 It is the highest tested concentration causing less than 20 percent reduction in either the weight of
16 young fish per initial female fish in a life-cycle or partial life-cycle test, or the weight of young
17 per egg in an early life-stage test. The EC₂₀ value for nickel is 62 µg/L (Suter and Tsao, 1996).
18 A similar value can be determined for daphnids which represents the highest tested concentration
19 causing less than 20 percent reduction in the product of growth, fecundity, and survivorship in a
20 chronic test with a daphnid species. The EC₂₀ benchmark for daphnids has been determined to be
21 45 µg/L (Suter and Tsao, 1996).

22 23 **7.4.2.9 Selenium**

24 Selenium is distributed widely in nature and is found in most rocks and soils at concentrations
25 between 0.1 and 2.0 mg/kg (Fishbein, 1981). The primary factor determining the fate of
26 selenium in the environment is its oxidation state. Selenium is stable in four valence states (-2,
27 0, +4, and +6) and forms chemical compounds similar to those of sulfur. The selenides (-2) are
28 insoluble in water, as is elemental selenium. The inorganic alkali selenites (+4) and the selenates
29 (+6) are soluble in water and are, therefore, more bioavailable.

30
31 Conditions such as pH, Eh, and the presence of metal oxides affect the partitioning of the various
32 compounds of selenium in the environment. In general, elemental selenium is stable in soils and
33 is found at low levels in water because of its ability to co-precipitate with sediments. The
34 soluble selenates are readily taken up by plants and converted to organic compounds such as

1 selenomethionine, selenocysteine, dimethyl selenide, and dimethyl diselenide. Selenium is
2 bioaccumulated by aquatic organisms and may also biomagnify in aquatic organisms.

3
4 **Plants.** The role of selenium in plant growth is not fully understood. It is generally not
5 considered essential in plant nutrition (Kabata-Pendias and Pendias, 1992). The concentration of
6 selenium in plants has been shown to be positively correlated with the concentration of selenium
7 in soil. Soil parameters such as pH, oxidation-reduction potential, and moisture content
8 determine the amount of selenium available for plant uptake. Concentrations of selenium in leaf
9 tissues that have been shown to be toxic to various plant species range from 5 to 30 mg/kg
10 (Kabata-Pendias and Pendias, 1992). General symptoms of selenium toxicity in plants include
11 signs of interveinal chlorosis or black spots in plants containing approximately 4 mg/kg
12 selenium, complete bleaching or yellowing of younger leaves at higher concentrations, and the
13 presence of pinkish spots on roots (Kabata-Pendias and Pendias, 1992).

14
15 **Mammals.** Selenium is an essential trace element for animal life. Concentrations that are
16 essential to animals are in the range of 0.05 to 0.1 mg/kg in the diet (Arthur et al., 1992).
17 According to Ganther (1974), selenium concentrations in healthy, unexposed, laboratory animals
18 and livestock range between 0.1 and 1 mg/kg. Selenium offers a protective effect against some
19 carcinogens such as benzo(a)pyrene and benzo(a)anthracene (Hammond and Beliles, 1980).
20 Selenium also functions as an antidote to the toxic effects of mercury, thallium, copper, arsenic
21 and cadmium (Frost and Lish, 1975).

22
23 Acute poisoning has been reported in livestock that consumed plant material containing 400 to
24 800 mg/kg selenium (Eisler, 1985). Signs of acute poisoning in livestock include abnormal
25 movements, lowered head, drooped ears, diarrhea, elevated temperature, rapid pulse, labored
26 breathing, bloating with abdominal pain, increased urination, and dilated pupils (Eisler, 1985).
27 Chronic poisoning may occur in animals exposed to dietary selenium concentrations between 1
28 and 44 mg/kg (Eisler, 1985). Based on an estimated oral NOAEL of 0.2 mg/kg/day for rats
29 exposed to selenate, Sample et al. (1996) calculated NOAELs for a number of wildlife species
30 including the little brown bat (0.523 mg/kg/day), short-tailed shrew (0.44 mg/kg/day), white-
31 footed mouse (0.399 mg/kg/day), meadow vole (0.336 mg/kg/day), mink (0.154 mg/kg/day),
32 cottontail rabbit (0.147 mg/kg/day), red fox (0.106 mg/kg/day), river otter (0.091 mg/kg/day),
33 and whitetail deer (0.056 mg/kg/day). Drinking water NOAELs for these species were estimated
34 to be 3.267 mg/L, 1.998 mg/L, 1.331 mg/L, 2.463 mg/L, 1.554 mg/L, 1.52 mg/L, 1.251 mg/L,
35 1.143 mg/L, and 0.857 mg/L, respectively (Sample et al., 1996). It should be noted that these

1 estimated wildlife NOAEL values were based on a body-weight scaling relationship that is not
2 supported by EPA.

3
4 **Birds.** Toxicity from selenium has also been documented in birds. The major toxic effect of
5 selenium on avian species is on reproductive success. Both sodium selenite and
6 selenomethionine have been reported to be embryotoxic and teratogenic (Heinz et al., 1987).
7 Reproductive impairment is likely to occur as concentrations of selenium approach 5 mg/kg.
8 Mortality in mallard ducklings does not occur until selenium concentrations in the diet reach 40
9 mg/kg. Extrapolated NOAELs for chronic exposure of various avian wildlife species to
10 selenomethionine, based on an estimated NOAEL for mallards of 0.4 mg/kg/day, are 0.3
11 mg/kg/day for the great blue heron and 0.385 mg/kg/day for the red-tailed hawk. The NOAEL
12 for selenomethionine consumed in drinking water has been estimated to be 6.8 mg/L for wild
13 birds (Sample et al., 1996).

14
15 **Aquatic Life.** Selenium is an essential micro-nutrient for fish. Dietary requirements of
16 selenium for fish range from 0.07 to 0.25 mg/kg, depending on the fish species (Gatlin and
17 Wilson, 1984). The bioconcentration of selenium from water is highly dependent on the species
18 of selenium present. Laboratory studies have shown bioconcentration factors for
19 selenomethionine to be greater than those for selenite and selenate. Bioconcentration factors for
20 aquatic biota exposed to 1 µg/L selenomethionine were approximately 16,000 for algae, 200,000
21 for daphnids, and 5,000 for bluegills (Besser et al., 1993).

22
23 The EPA's National Recommended Water Quality Criteria for Priority Toxic Pollutants for
24 selenium in freshwater is 5 µg/L for chronic exposure (EPA, 1999a). The toxicity of selenium to
25 freshwater fish appears to be correlated more closely with dietary than waterborne exposure
26 (Coyle et al., 1993). Sulfate concentrations in water may also influence the toxicity of selenium
27 to aquatic invertebrates (Maier et al., 1993).

28
29 The test EC₂₀ for fish can be used as a benchmark indicative of production within a population.
30 It is the highest tested concentration causing less than 20 percent reduction in the weight of
31 young fish per initial female fish in a life-cycle or partial life-cycle test, or the weight of young
32 per egg in an early life-stage test. The EC₂₀ for selenium is 40 µg/L (Suter and Tsao, 1996). A
33 similar value can be determined for daphnids which reflects the highest tested concentration
34 causing less than 20 percent reduction in the product of growth, fecundity, and survivorship in a

1 chronic test with a daphnid species. The EC₂₀ benchmark for daphnids is 25 µg/L selenium
2 (Suter and Tsao, 1996).

3 4 **7.4.2.10 Zinc**

5 Zinc is a naturally occurring element which may be found in both organic and inorganic forms
6 and, as such, is commonly found in the environment. In general, zinc is concentrated in the
7 sediments of water bodies. The National Academy of Sciences (1977) has reported that zinc will
8 probably be detected in 75 percent of all water bodies examined for the compound at various
9 locations. The fate of zinc in soils appears to have a pH basis. Studies have shown that a pH of
10 less than 7 often favors zinc desorption (EPA, 1984).

11
12 **Plants.** Background concentrations of zinc in terrestrial plants range from 25 to 150 mg/kg (dry
13 weight) (NAS, 1979). The deficiency content of zinc in plants is between 10 and 20 ppm (dry
14 weight). Roots often contain the highest concentrations of zinc (Kabata-Pendias and Pendias,
15 1992).

16
17 Certain species of plants, particularly those from the families *Caryophyllaceae*, *Cyperaceae*, and
18 *Plumbaginaceae*, and some tree species are extremely tolerant to elevated zinc concentrations
19 (Kabata-Pendias and Pendias, 1992). Concentrations of zinc in these plants may reach 1 percent
20 (dry weight) in the plant. Concentrations in leaf tissue that are excessive or toxic to various plant
21 species range from 100 to 400 mg/kg. Concentrations of 100 to 500 mg/kg are expected to result
22 in a 10 percent loss in crop yield (Kabata-Pendias and Pendias, 1992). General symptoms of zinc
23 toxicity in plants include the presence of chlorotic and necrotic leaf tips, interveinal chlorosis in
24 new leaves, retarded growth of the entire plant, and injured roots that resemble barbed wire
25 (Kabata-Pendias and Pendias, 1992).

26
27 **Mammals.** Zinc is an essential trace element for normal fetal growth and development.
28 However, exposure to high levels of zinc in the diet has been associated with reduced fetal
29 weights, altered concentrations of fetal iron and copper, and reduced growth in offspring (Cox et
30 al., 1969). Poisoning has been observed in ferrets and mink from chewing corroded galvanized
31 cages (Clark et al., 1981). Symptoms of zinc toxicity are lassitude, slower tendon reflexes,
32 bloody enteritis, diarrhea, lowered leukocyte count, depression of the central nervous system, and
33 paralysis of the extremities (Venugopal and Luckey, 1978). A study by Kinnamon (1963)
34 showed a NOAEL for oral exposure to a zinc compound over a period of 73 days to be 250
35 mg/kg body weight, and mice given 500 mg/L of zinc, as zinc sulfate, in drinking water have

1 shown hypertrophy of the adrenal cortex and pancreas. Young animals are much more
2 susceptible to poisoning by zinc than are mature animals (Clark et al., 1981).

3
4 Animals are quite tolerant to high concentrations of zinc in the diet. Levels 100 times that
5 required in the diet usually do not cause detectable symptoms of toxicosis (NAS, 1979).

6 Examples of extrapolated NOAELs for chronic exposure of various mammalian wildlife species
7 to zinc oxide based on an estimated rat NOAEL of 160 mg/kg/day were 319.5 mg/kg/day for the
8 white-footed mouse, 117.6 mg/kg/day for the cottontail rabbit, and 84.54 mg/kg/day for the red
9 fox (Sample et al., 1996). Drinking water NOAELs for these species were estimated to be 1,065,
10 1,216, and 1,001 mg/L. It should be noted that these wildlife NOAEL values were estimated
11 using a body-weight scaling relationship that is not supported by EPA. Symptoms of zinc
12 poisoning in mammals include lameness, acute diarrhea, and vomiting (Eisler, 1993).

13
14 **Birds.** Dietary zinc concentrations of greater than 2,000 mg/kg diet are known to result in
15 reduced growth of domestic poultry and wild birds (Eisler, 1993). Reduced survival has been
16 documented at zinc concentrations greater than 3,000 mg/kg diet or at a single dose of greater
17 than 742 mg/kg body weight (Eisler, 1993). Examples of extrapolated NOAELs for chronic
18 exposure of various avian wildlife species to zinc carbonate (based on an estimated NOAEL of 3
19 mg/kg/day for a mallard) are 2.25 mg/kg/day for the great blue heron and 2.89 mg/kg/day for the
20 red-tailed hawk. A value of 51 mg/L has been calculated as the NOAEL for chronic exposure of
21 birds to zinc carbonate in drinking water (Sample et al., 1996).

22
23 **Aquatic Life.** Zinc residues in freshwater and marine fish are generally much lower than those
24 found in algae and invertebrates. Thus there is little evidence for accumulation (Moore and
25 Ramamoorthy, 1984). Rainbow trout (*Oncorhynchus mykiss*) have the ability to detect and avoid
26 areas of water containing 5.6 ppb zinc (Sprague, 1968). Cairns and Scheier (1968) reported 96-
27 hour LC₅₀s ranging from 10.13 to 12.5 ppm in hard water for bluegills (*Lepomis macrochirus*),
28 and 96-hour LC₅₀s ranging from 2.86 to 3.78 ppm in soft water. These results demonstrate that
29 water hardness affects the toxicity of zinc to fish. Chronic toxicity tests have been conducted
30 with five species of freshwater fish. Chronic values ranged from 47 µg/L for flagfish (*Jordanella*
31 *floridae*) to 852 µg/L for brook trout (*Salvenius fontinalis*) (EPA, 1980).

32
33 Acute toxicity to freshwater invertebrates is relatively low and, as with other metals, increasing
34 water hardness decreases the toxicity of zinc (Moore and Ramamoorthy, 1984). As reported by
35 Baudouin and Scoppa (1974), the 48-hour LC₅₀ for the cladoceran *Daphnia hyalina* was 0.055

1 mg/L, and 5.5 mg/L for the copepod *Cyclops abyssorum*. Four chronic toxicity tests are reported
2 for *Daphnia magna*, with chronic values ranging from 47 µg/L to 136 µg/L (EPA, 1980).
3 Chronic testing with the saltwater species *Mysidopsis bahia* resulted in a chronic value of 166
4 µg/L (EPA, 1980).

6 **7.4.2.11 Polycyclic Aromatic Hydrocarbons**

7 PAHs are a diverse group of organic chemicals consisting of substituted and unsubstituted
8 polycyclic and heterocyclic aromatic rings in which interlinked rings have at least two carbon
9 atoms in common (Zander, 1983). They are formed as a result of incomplete combustion of
10 organic materials such as wood, coal, and oil and exist in the environment in quantity, both from
11 anthropogenic and natural sources. Activities associated with large releases of PAHs include
12 coke production; petroleum refining; the manufacture of carbon black, coal tar pitch and asphalt;
13 heating and power generation; and emissions from internal combustion engines. It is estimated
14 that approximately 270,000 metric tons of PAHs reach the environment yearly (Eisler, 1987b).

15
16 **Plants.** Some PAHs are synthesized by plants at very low concentrations (Sims and Overcash,
17 1983). Background concentrations of specific PAH compounds usually range from 22 to 88
18 µg/kg in tree leaves, 48 to 66 µg/kg in cereal crop plants, 0.05 to 50 µg/kg in leafy vegetables,
19 0.01 to 6 µg/kg in underground vegetables, and 0.02 to 0.04 µg/kg in fruits (Sims and Overcash,
20 1983). In general, PAH concentrations are usually greater in aboveground plant parts than in
21 belowground parts, and are greater on plant surfaces than within internal tissues (Eisler, 1987b).

22
23 Lower-molecular-weight PAHs are taken up from soil by plants more readily than higher-
24 molecular-weight PAHs (Eisler, 1987b). Soil-to-plant concentration ratios for total PAHs have
25 been reported to range from 0.001 to 0.183 (Talmage and Walton, 1990). Atmospheric
26 deposition is believed to be the usual source of PAHs in plants, not uptake from soil (Sims and
27 Overcash, 1983).

28
29 Limited data exist on the phytotoxicity of PAHs to plants. Benzo(b)fluoranthene concentrations
30 of 6,254 µg/kg in soil were reported to reduce stem growth in wheat but did not affect rye plants.
31 Benzo(a)pyrene and benzo(b)fluoranthene soil concentrations of up to 18,000 µg/kg do not
32 appear to be severely toxic to higher plants. There is some evidence that low concentrations of
33 some PAHs may actually stimulate plant growth (Sims and Overcash, 1983).

1 **Mammals.** Most of the PAHs taken into the body are not accumulated but are oxidized and the
2 metabolites excreted (National Library of Medicine, 1996). In fact, most PAH compounds are
3 detoxified and excreted from the body (Klaassen et al., 1991). PAHs are metabolized in
4 vertebrates by a group of enzymes known as mixed-function oxidases in the liver. A few
5 laboratory studies on rodents have revealed acute oral toxicities of PAHs are greatest for
6 benzo(a)pyrene, followed in decreasing order of toxicity by phenanthrene, naphthalene, and
7 fluoranthene (Sims and Overcash (1983). Based on an estimated laboratory mouse oral NOAEL
8 of 1.0 mg/kg/day for benzo(a)pyrene, Sample et al. (1996) estimated wildlife NOAELs for
9 benzo(a)pyrene of 1.08 mg/kg/day for the white-footed mouse, 0.4 mg/kg/day for the cottontail
10 rabbit, and 0.29 mg/kg/day for the red fox. Calculated chronic NOAELs for mammalian wildlife
11 exposed to benzo(a)pyrene in drinking water only ranged from 2.32 to 8.84 mg/L (Sample et al.,
12 1996). It should be noted that these wildlife NOAEL values were estimated using a body-weight
13 scaling relationship that is not supported by EPA.

14
15 Sims and Overcash (1983) have reported LC₅₀ values for rodents (*Rattus* spp. and *Mus* spp.) as
16 50 mg/kg-day benzo(a)pyrene, 700 mg/kg-day phenanthrene, and 2,000 mg/kg-day fluoranthene.
17 Sublethal effects manifested as decreased pup weight in mice has been reported at 10 mg/kg-day
18 benzo(a)pyrene (MacKenzie and Angevine, 1981). Subchronic and chronic effects of exposure
19 to PAHs in rats include liver and kidney damage, unspecified changes in peripheral blood
20 pattern, body weight loss, genetic aberrations, and increased serum aminotransferase activity
21 (Knobloch et al., 1969).

22
23 **Birds.** Hoffman and Gay (1981) measured embryotoxicity of various PAHs applied externally
24 to the surface of mallard duck eggs. Approximately 0.002 µg/egg of 7,12-
25 dimethylbenz(a)anthracene (DMBA) caused 26 percent mortality in 18 days and produced
26 significant reduction in embryonic growth among the survivors and a significant increase in the
27 percent of abnormalities, e.g., incomplete skeletal ossification, defects in eye, brain, liver,
28 feathers, and bill. At 0.1 µg DMBA/egg, only 10 percent survived to day 18.

29
30 **Aquatic Life.** In general, PAHs as a group are not appreciably acutely toxic (Eisler, 1987b;
31 Neff, 1985). The toxicity of PAH compounds to fish is related to the solubility of the compound
32 in water. The toxicity of PAHs to aquatic organisms is very species-specific and related to the
33 organisms' ability to metabolize and excrete the compound (Eisler, 1987b). For aquatic
34 organisms, only PAHs in the molecular weight range from naphthalene to pyrene are considered
35 acutely toxic. Toxicity in this group increases with increasing molecular weight. There is some

1 evidence to suggest that PAHs are responsible for reproductive and teratogenic effects in eggs of
2 the sand sole (*Psettichthys melanostictus*) exposed to 0.1 µg benzo(a)pyrene/L for five days. The
3 eggs showed reduced and delayed hatch and, when compared to controls, produced larvae with
4 high accumulations (2.1 mg/kg fresh weight) and gross abnormalities, such as tissue
5 overgrowths, in 50 percent of the test larvae (Hose et al., 1982).

6
7 Inhibited reproduction of daphnids and the delayed emergence of larval midges by fluorene was
8 reported by Finger et al. (1985). When sediment PAH levels are elevated, benthic organisms
9 obtain a majority of their PAHs from sediments through their ability to mobilize PAHs from the
10 sediment/pore water matrix. The elevated levels in the tissues of these organisms could provide
11 a significant source of PAHs to predatory fish. However, fish do have the ability to efficiently
12 metabolize and degrade PAHs.

13 14 **7.4.3 Potential Receptors**

15 Potential ecological receptors at Parcel 94(7) fall into two general categories: terrestrial and
16 aquatic. Within these two general categories, there are several major feeding guilds that could be
17 expected to occur at the site: herbivores, invertivores, omnivores, carnivores, and piscivores. All
18 of these feeding guilds have the potential to be directly exposed to various combinations of
19 surface soil at or near Parcel 94(7) and surface water and sediment in Ingram Creek near Parcel
20 94(7) via various activities (e.g., feeding, drinking, grooming, bathing). These feeding guilds
21 may also be exposed to site-related chemicals via food web transfers. It is important to note that
22 the entire area of Parcel 94(7) is covered with asphalt paving. This asphalt paving effectively
23 eliminates all of the surface soil exposure pathways for ecological receptors. Therefore,
24 ecological exposure pathways are discussed in the following sections under the assumption that
25 the asphalt paving will be removed or will deteriorate significantly in the future such that surface
26 soil will be exposed.

27
28 Dermal absorption of PAHs from soil would be a potential pathway for all feeding guilds at
29 Parcel 94(7) if the asphalt paving were removed; however, birds and mammals are less
30 susceptible to dermal exposures because their feathers or fur prevents skin from coming into
31 direct contact with the soil (EPA, 1993). Dermal absorption of inorganic compounds from direct
32 contact with soil is expected to be minimal, due to the low dermal permeability of these
33 compounds. Since there are no volatile organic constituents of potential ecological concern
34 (COPEC) in soil at Parcel 94(7), inhalation of VOCs is not a viable exposure pathway.

1 Inhalation of constituents sorbed to soil particles and inhaled as dust is a potential pathway for all
2 of the feeding guilds at Parcel 94(7) if the asphalt paving were removed.

3
4 Although terrestrial species could be exposed to constituents in surface water in Ingram Creek
5 through a number of pathways, these exposure pathways are insignificant, due to the fact that no
6 constituents have been detected at elevated concentrations relative to ESVs in surface water
7 samples from Ingram Creek

8
9 Aquatic and semi-aquatic (i.e., amphibian) species have a greater potential for exposure to
10 COPECs in surface water or sediment, as they spend a majority of their lifetime in close
11 proximity to water bodies. Although aquatic and semi-aquatic species may visit the area around
12 Parcel 94(7) when Ingram Creek has water, they would not be expected to live at the site because
13 of the ephemeral nature of Ingram Creek in this area. Aquatic and semi-aquatic species could
14 potentially be exposed to COPECs in sediment via direct contact, ingestion of sediment, and
15 ingestion of aquatic vegetation or aquatic invertebrates that may have accumulated site-related
16 constituents. Inorganic compounds and PAHs were the only constituents detected in sediment
17 samples at elevated concentrations relative to ESVs. However, the PAH compounds were
18 detected in only one sample and may not be site-related, as discussed in Chapter 4.0.

19 20 **7.4.3.1 Herbivorous Feeding Guild**

21 The major route of exposure for herbivores is through ingestion of plants that may have
22 accumulated contaminants from the soil, surface water, or sediment. Because the entire study
23 area at Parcel 94(7) is covered with asphalt, very little vegetation is present at the site itself. The
24 limited vegetation that does exist at the site consists of weed species that have grown through
25 cracks and other areas where the asphalt cover has been compromised. Since terrestrial
26 herbivores by definition are grazers and browsers, they could be exposed to chemicals that have
27 accumulated in the vegetative tissues of the weeds at the site, although this exposure is expected
28 to be minimal due to the asphalt cover over the vast majority of the site. Terrestrial herbivores
29 may also be exposed to site-related chemicals in soil through incidental ingestion of soil while
30 grazing, grooming, or other activities. However, the asphalt cover will minimize these potential
31 exposure routes. If the asphalt is removed, the potential for these exposures would increase.

32
33 Typical herbivorous species that could be expected to occur at Parcel 94(7) and are commonly
34 used as sentinel species in ecological risk assessment include eastern cottontail rabbit (*Sylvilagus*

1 *floridanus*), eastern gray squirrel (*Sciurus carolinensis*), pine vole (*Pitymys pinetorum*), whitetail
2 deer (*Odocoileus virginianus*), and wild turkey (*Meleagris gallopavo*).

3
4 Aquatic herbivores such as muskrat (*Ondatra zibethica*) and mallard (*Anas platyrhynchos*) could
5 be exposed to site-related constituents in sediment in Ingram Creek adjacent to Parcel 94(7).

7 **7.4.3.2 Invertivorous Feeding Guild**

8 Invertivores specialize in eating insects and other invertebrates. As such, they may be exposed to
9 site-related chemicals that have accumulated in insects and other invertebrates. Invertivores may
10 also be exposed to site-related chemicals in soil through incidental ingestion of soil while
11 probing for insects, grooming, or other activities. Ingestion of soil while feeding is a potential
12 exposure pathway for invertivores, since much of their food (e.g., earthworms and other
13 invertebrates) lives on or below the soil surface. These exposure pathways are expected to be
14 minimal because the site is currently covered with asphalt. If the asphalt were to be removed at
15 some time in the future, these exposures would be more significant.

16
17 Typical invertivorous species that could be expected to occur at Parcel 94(7) and are commonly
18 used as sentinel species in ecological risk assessment include American woodcock (*Philohela*
19 *minor*), carolina wren (*Thryothorus ludovicianus*), short-tailed shrew (*Blarina brevicauda*), and
20 eastern mole (*Scalopus aquaticus*). Aquatic invertivores could include the wood duck (*Aix*
21 *sponsa*) and blacknose dace (*Rhinichthys atratulus*).

23 **7.4.3.3 Omnivorous Feeding Guild**

24 Omnivores consume both plant and animal material in their diet, depending upon availability.
25 Therefore, they could be exposed to chemicals that have accumulated in the vegetative tissues of
26 plants at the site and also to chemicals that may have accumulated in smaller animal tissues that
27 the omnivores prey upon. These soil-related exposure pathways are expected to be minimal at
28 Parcel 94(7) because the entire site is covered with asphalt. If the asphalt were to be removed,
29 the potential for these exposure pathways to be complete would increase. Omnivores could be
30 exposed to surface water through ingestion of water in Ingram Creek adjacent to the site.
31 However, because no elevated concentrations of constituents were detected in surface water from
32 Ingram Creek, these exposures are expected to be insignificant. Omnivores may also be exposed
33 to site-related chemicals in soil through incidental ingestion of soil while feeding, grooming, or
34 other activities.

1 Typical omnivorous species expected to occur at Parcel 94(7) and commonly used as sentinel
2 species in ecological risk assessment include red fox (*Vulpes vulpes*), white-footed mouse
3 (*Peromyscus leucopus*), and American robin (*Turdus migratorius*). Aquatic omnivores such as
4 raccoon (*Procyon lotor*) and creek chub (*Semotilus atromaculatus*) could be exposed to COPECs
5 in surface water and sediment in Ingram Creek adjacent to Parcel 94(7).
6

7 **7.4.3.4 Carnivorous Feeding Guild**

8 Carnivores are meat-eating animals and are, therefore, potentially exposed to site-related
9 chemicals through consumption of prey animals that may have accumulated contaminants in
10 their tissues. Carnivores are quite often top predators in a local food web and are often subject to
11 exposure to contaminants that have bioaccumulated in lower trophic-level organisms or have
12 biomagnified through the food web. Food web exposures for carnivores are based on the
13 consumption of prey animals that have accumulated COPECs from various means. Smaller
14 herbivores, omnivores, invertivores, and other carnivores may consume soil, surface water,
15 sediment, and plant and animal material as food and accumulate COPECs in their tissues.
16 Subsequent ingestion of these prey animals by carnivorous animals would expose them to
17 COPECs. These soil-related exposure pathways are expected to be minimal at Parcel 94(7)
18 because the vast majority of the site is covered with asphalt. If the asphalt were to be removed,
19 the potential for these exposure pathways to be complete would increase. Most inorganic
20 compounds are not accumulated in animal tissues to any great extent (Shugart et al., 1991; U.S.
21 Army Environmental Hygiene Agency, 1994). Therefore, food web exposures to these
22 chemicals are expected to be minimal. PAHs have the potential to accumulate in lower trophic
23 level organisms but not in higher trophic level organisms because they have mechanisms for
24 metabolizing and excreting this class of compounds.
25

26 Carnivores may also be exposed to site-related chemicals in soil through incidental ingestion of
27 soil while feeding, grooming, or other activities. Typical carnivorous species expected to occur
28 at Parcel 94(7) and commonly used as sentinel species in ecological risk assessment include red-
29 tailed hawk (*Buteo jamaicensis*), black vulture (*Coragyps atratus*), and bobcat (*Lynx rufus*).
30

31 Because no COPECs have been identified in surface water in Ingram Creek adjacent to Parcel
32 94(7), surface water exposures are expected to be insignificant. Exposure to sediments, however,
33 is possible. Carnivorous fish such as largemouth bass (*Micropterus salmoides*) and spotted gar
34 (*Lepisosteus oculatus*) would not be expected to occur in Ingram Creek in the vicinity of Parcel
35 94(7), due to the habitat restrictions. Carnivorous mammals such as the mink (*Mustela vison*)

1 may feed along Ingram Creek during periods when water is present but most likely would not
2 live adjacent to Ingram Creek in the vicinity of Parcel 94(7), due to the ephemeral nature of the
3 creek.

5 **7.4.3.5 Piscivorous Feeding Guild**

6 Piscivores are specialists that feed mostly on fish. Therefore, they may be exposed to site-related
7 chemicals that have accumulated in small fish that may inhabit Ingram Creek adjacent to Parcel
8 94(7). They may also be exposed to surface water and sediment in the creek through ingestion of
9 drinking water and during feeding. Although Ingram Creek is dry during certain periods of the
10 year, it does hold flowing and/or standing water during portions of the year and could be utilized
11 for drinking purposes. Although piscivorous species could be expected to visit the areas around
12 Ingram Creek in the vicinity of Parcel 94(7) during periods of the year when the creek holds
13 water, they would not be expected to live near Parcel 94(7) due to the ephemeral nature of
14 Ingram Creek.

15
16 Food web exposures for piscivores are based on the consumption of fish that have accumulated
17 COPECs from surface water and sediment. Forage fish may consume surface water, sediment,
18 benthic invertebrates, aquatic plants, and planktonic material as food and accumulate COPECs in
19 their tissues. Subsequent ingestion of these forage fish by piscivorous animals would expose
20 them to COPECs. However, most PAHs and inorganics are not accumulated in fish tissues to
21 any great extent. Therefore, food web exposures to these chemicals are expected to be minimal.
22 SVOCs are readily metabolized by most fish species and are not accumulated to any extent.
23 Thus, the piscivorous feeding guild is not expected to be greatly exposed to COPECs at Parcel
24 94(7) through the food web.

25
26 Typical piscivorous species expected to occur near Parcel 94(7) and commonly used as sentinel
27 species in ecological risk assessment include great blue heron (*Ardea herodias*) and belted
28 kingfisher (*Megaceryle alcyon*). Larger piscivorous fish species (e.g., smallmouth bass, spotted
29 gar) and piscivorous mammals (e.g., mink) are not expected to occur in Ingram Creek, due to the
30 ephemeral nature of Ingram Creek in this area and its inability to support larger fish and other
31 aquatic species.

33 **7.4.3.6 Threatened and Endangered Species**

34 Four species listed as threatened or endangered by the U.S. Fish and Wildlife Service (USFWS)
35 have been recorded at FTMC. These threatened and endangered species are:

- Gray Bat (*Myotis grisescens*)
- Blue Shiner (*Cyprinella caerulea*)
- Mohr's Barbara Buttons (*Marshallia mohrii*)
- Tennessee Yellow-Eyed Grass (*Xyris tennesseensis*).

The only federally listed species that has the potential to occur in the vicinity of Parcel 94(7) is the gray bat (Garland, 1996). Ingram Creek adjacent to Parcel 94(7) has been designated as providing "moderate quality" foraging habitat for the gray bat (Garland, 1996). The other federally listed species occur at Pelham Range or Choccolocco Creek corridor.

The gray bat is almost entirely restricted to cave habitats and, with rare exceptions, roosts in caves year-round. Approximately 95 percent of the entire known population hibernates in only nine caves each winter, with more than half in a single cave. Gray bat summer foraging habitat is found primarily over open water of rivers and reservoirs. They apparently do not forage over sections of rivers or reservoirs that have lost their normal woody vegetation along the banks (USFWS, 1982). Gray bats usually follow wooded corridors from their summer caves to the open water areas used as foraging sites. Forested areas surrounding and between caves, as well as over feeding habitats, are clearly advantageous to gray bat survival, as the cover provides increased protection from predators such as screech owls. In addition, surveys have demonstrated that reservoirs and rivers that have been cleared of their adjacent forest canopy are avoided as foraging areas by gray bats (USFWS, 1982).

The gray bat is entirely insectivorous, and surveys have shown that gray bats feed almost exclusively on mayflies at certain times of the year (Mount, 1986). Therefore, gray bats could be exposed to site-related constituents that have accumulated in aquatic insects from Ingram Creek. Because gray bats are flying mammals and Parcel 94(7) does not provide roosting habitat, no other exposure pathways are potentially complete for the gray bat.

Most foraging occurs within 5 meters of the water's surface, usually near a shoreline or stream bank. Mist net surveys were conducted on and adjacent to FTMC in 1995. Gray bats were captured along both Choccolocco Creek (east of FTMC Main Post) and Cane Creek on Pelham Range (west of FTMC Main Post) during these mist net surveys (Garland, 1996). These preliminary data suggest that these major stream corridors at FTMC may provide at least a minimum foraging habitat for gray bats. However, gray bat surveys have not been conducted on Ingram Creek in the vicinity of Parcel 94(7).

7.4.4 Complete Exposure Pathways

For exposures to occur, a complete exposure pathway must exist between the contaminant and the receptor. A complete exposure pathway requires the following four components:

- A source mechanism for contaminant release
- A transport mechanism
- A point of environmental contact
- A route of uptake at the exposure point (EPA, 1989).

If any of these four components is absent, then a pathway is generally considered incomplete. Potentially complete exposure pathways are depicted in the SCM (Figure 7-1). It is important to note that the entire study area of Parcel 94(7) is currently covered by asphalt. The potential exposure pathways depicted in the SCM and discussed in this risk assessment assume that the asphalt will be removed or will degrade at some time in the future to a point where it no longer provides complete cover over the site.

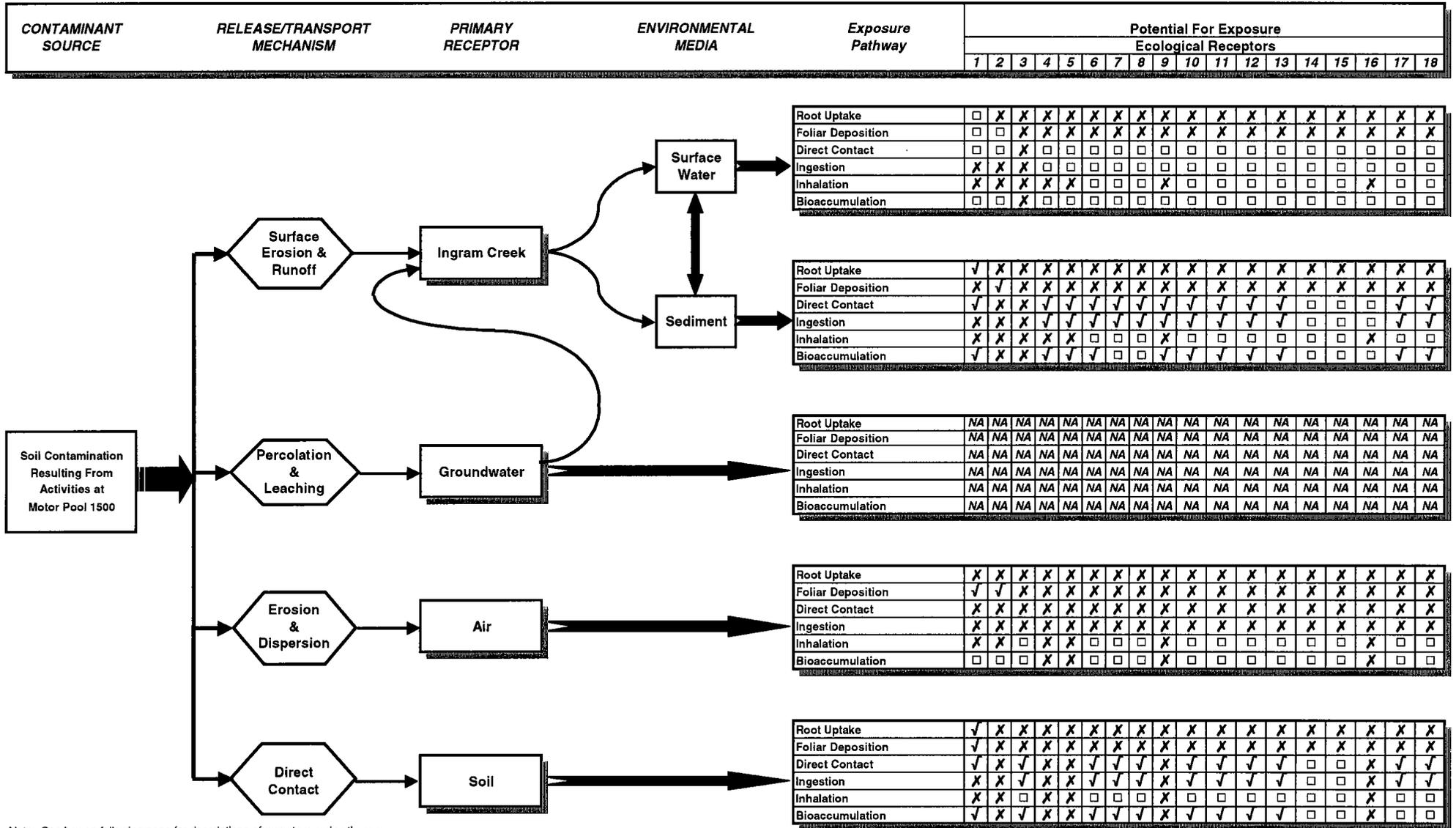
Ecological receptors may be exposed to constituents in soils via direct and/or secondary exposure pathways. Direct exposure pathways include soil ingestion, dermal absorption, and inhalation of COPECs adsorbed to fugitive dust. Significant exposure via dermal contact is limited to organic constituents that are lipophilic and can penetrate epidermal barriers. Mammals are less susceptible to exposure via dermal contact with soils because their fur prevents skin from coming into direct contact with soil. However, soil ingestion may occur while grooming, preening, burrowing, or consuming plants, insects, or invertebrates resident in soil. Exposure via inhalation of fugitive dust is limited to contaminants present in surface soils at areas that are devoid of vegetation. The inherent moisture content of the soil and the frequency of soil disturbance also play important roles in the amount of fugitive dust generated at a particular site.

Ecological receptors could be exposed to constituents in surface water via direct contact or through consumption of water; however, no constituents were detected in surface water samples from Ingram Creek at elevated concentrations relative to ESVs. Therefore, surface water exposure pathways were considered incomplete for this assessment.

Constituents present in the sediment may result from erosion or adsorption of water-borne constituents onto sediment particles. If sediment is present in an area that is periodically inundated with water, then previous exposure pathways for soils would be applicable during dry

Figure 7-1
Site Conceptual Model
Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
Fort McClellan, Calhoun County, Alabama

(Page 1 of 2)



Note: See key on following page for descriptions of receptors and pathways

Figure 7-1

KEY TO SITE CONCEPTUAL MODEL FOR MOTOR POOL 1500, [Parcel 94(7)]
Fort McClellan, Calhoun County, Alabama

(Page 2 of 2)

Key To Potential Receptors

- 1 - Rooted plants
- 2 - Floating aquatic plants
- 3 - Terrestrial invertebrates
- 4 - Benthic invertebrates
- 5 - Water column invertebrates
- 6 - Reptiles and Amphibians
- 7 - Herbivorous mammals
- 8 - Herbivorous birds
- 9 - Planktivorous fish
- 10 - Omnivorous mammals
- 11 - Omnivorous birds
- 12 - Invertivorous mammals
- 13 - Invertivorous birds
- 14 - Piscivorous mammals
- 15 - Piscivorous birds
- 16 - Piscivorous fish
- 17 - Carnivorous mammals
- 18 - Carnivorous birds

Key To Potential Exposure Routes

- ✓ - Potentially complete exposure pathway
- X - Incomplete exposure pathway
- - Potentially complete exposure pathway but insignificant
- NA - Not applicable

1 periods. Water overlying sediments prevents contaminants from being carried by wind erosion.
2 Because the majority of the constituents detected in sediment are either inorganic compounds
3 that are not prone to volatilization or organic compounds that have low Henry's Law constants,
4 volatilization from sediments is not an important fate mechanism. VOCs were detected in
5 sediment samples at very low concentrations. Therefore, inhalation of constituents originating
6 from the sediment is not a significant exposure pathway. Exposure via dermal contact may
7 occur, especially for benthic organisms and wading birds or other animals that may use Ingram
8 Creek as a feeding area. Some aquatic organisms consume sediment and ingest organic material
9 from the sediment. Inadvertent ingestion of sediments may also occur as the result of feeding on
10 benthic organisms and plants.

11
12 While constituents in soils may leach into groundwater, environmental receptors will not come
13 into direct contact with constituents in groundwater since there is no direct exposure route. The
14 only potential exposure pathways for ecological receptors to groundwater would be via surface
15 water exposure routes. As described in previous sections of this report, groundwater discharge to
16 surface water in Ingram Creek is a potentially viable transport mechanism for dissolved
17 constituents; however, exposure to these constituents by ecological receptors is only possible via
18 surface water exposure routes. Potential exposure to groundwater-related constituents is
19 expected to be insignificant, based on the fact that no constituents were detected at elevated
20 concentrations in surface water samples from Ingram Creek adjacent to Parcel 94(7).

21
22 Secondary exposure pathways involve constituents that are transferred through different trophic
23 levels of the food chain and may be bioaccumulated and/or bioconcentrated. This may include
24 constituents bioaccumulated from soil into plant tissues or into terrestrial species ingesting soils.
25 These plants or animals may, in turn, be consumed by animals at higher trophic levels.
26 Sediment-borne COPECs may bioaccumulate into aquatic organisms, aquatic plants, or animals
27 which frequent surface waters and then be passed through the food chain to impact organisms at
28 higher trophic levels.

29
30 In general, the constituents detected in surface soil at Parcel 94(7) may bioaccumulate in lower
31 trophic level organisms (i.e., terrestrial invertebrates may bioaccumulate inorganic compounds
32 and PAHs detected in soil); however, they will not bioconcentrate through the food chain.
33 Inorganic compounds generally do not bioconcentrate to any great extent, and PAHs are readily
34 metabolized by higher trophic level organisms. The only compound detected in surface soil that
35 has a propensity to bioconcentrate is mercury. These surface soil exposure pathways are only

1 potentially complete if the asphalt paving were to be removed from the site. If the asphalt paving
2 remains in place, these surface soil exposure pathways would be incomplete.

3
4 As is the case with surface soil, the constituents detected in sediment may bioaccumulate in
5 lower trophic level organisms (i.e., benthic invertebrates may bioaccumulate inorganic
6 compounds detected in sediment); however, they will not bioconcentrate through the food chain.
7 Inorganic compounds and VOCs generally do not bioconcentrate to any great extent.

8
9 Summaries of the potentially complete exposure pathways for the terrestrial and aquatic
10 ecosystems at Parcel 94(7) are presented in Tables 7-1 and 7-2, respectively.

11 12 **7.5 Screening-Level Risk Estimation**

13 A screening-level estimation of potential risk can be accomplished by comparing the exposure
14 point concentration of each detected constituent in each environmental medium to a
15 corresponding screening-level ecological toxicity value. In order to conduct the SLERA, the
16 following steps must be followed:

- 17
18 • Determine appropriate screening assessment endpoints
- 19
20 • Determine the ecological toxicity values that are protective of the selected
21 assessment endpoints
- 22
23 • Determine the exposure point concentrations of constituents detected at the site
- 24
25 • Calculate screening-level hazard quotients.

26
27 These steps are summarized below.

28 29 **7.5.1 Ecological Screening Assessment Endpoints**

30 Most ecological risk assessments focus on population measures as endpoints since population
31 responses are more well-defined and predictable than are community or ecosystem responses.
32 For screening-level assessments such as this SLERA, an assessment endpoint is any adverse
33 effect on ecological receptors, where receptors are plant and animal populations and
34 communities, habitats, and sensitive environments.

35
36 Adverse effects on populations can be inferred from measures related to impaired reproduction,
37 growth, and survival. Adverse effects on communities can be inferred from changes in

Table 7-1

**Feeding Guilds and Potential Exposure Pathways for Terrestrial Ecosystems
Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
Fort McClellan, Calhoun County, Alabama**

Trophic Level	Feeding Guild	Exposure Pathways
1	Primary Producers	Direct uptake from soil
2	Terrestrial Invertebrates	Ingestion of soil Direct contact with soil
	Herbivorous Birds	Ingestion of soil Ingestion of surface water ^a Ingestion of terrestrial plants
	Herbivorous Mammals	Ingestion of soil Ingestion of surface water ^a Ingestion of terrestrial plants
3	Omnivorous Birds	Ingestion of soil Ingestion of surface water ^a Ingestion of terrestrial plants Ingestion of terrestrial invertebrates
	Omnivorous Mammals	Ingestion of soil Ingestion of surface water ^a Ingestion of terrestrial plants Ingestion of terrestrial invertebrates Ingestion of prey
	Invertivorous Birds	Ingestion of soil Ingestion of surface water ^a Ingestion of terrestrial invertebrates
	Invertivorous Mammals	Ingestion of soil Ingestion of surface water ^a Ingestion of terrestrial invertebrates
4	Carnivorous Birds (raptors)	Ingestion of soil Ingestion of surface water ^a Ingestion of prey
	Carnivorous Mammals	Ingestion of soil Ingestion of surface water ^a Ingestion of prey

^a Insignificant exposure potential due to lack of COPECs identified in surface water

Table 7-2

Feeding Guilds and Potential Exposure Pathways for Freshwater Stream Ecosystems
Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
Fort McClellan, Calhoun County, Alabama

Trophic Level	Feeding Guild	Exposure Pathways
1	Primary Producers	Direct uptake from surface water ^a Direct uptake from sediment
2	Benthic Invertebrates	Ingestion of sediment Direct contact with sediment
	Herbivorous Waterfowl	Ingestion of sediment Ingestion of surface water ^a Ingestion of aquatic plants
	Herbivorous Mammals	Ingestion of sediment Ingestion of surface water ^a Ingestion of aquatic plants
	Forage Fish	Ingestion of plankton Ingestion of aquatic plants and algae Absorption through gills ^a
3	Omnivorous Mammals	Ingestion of sediment Ingestion of surface water ^a Ingestion of aquatic plants Ingestion of benthic invertebrates
	Omnivorous Waterfowl	Ingestion of sediment Ingestion of surface water ^a Ingestion of aquatic plants Ingestion of benthic invertebrates
	Invertivorous Waterfowl	Ingestion of sediment Ingestion of surface water ^a Ingestion of benthic invertebrates
4	Piscivorous Mammals	Ingestion of sediment Ingestion of surface water ^a Ingestion of fish
	Piscivorous Birds	Ingestion of sediment Ingestion of surface water ^a Ingestion of fish

^a Insignificant exposure potential due to lack of COPECs identified in surface water

1 community structure or function. Adverse effects on habitats can be inferred from changes in
2 composition and characteristics that reduce the ability of the habitat to support plant and animal
3 populations and communities.

4
5 Due to the nature of the SLERA process, most of the screening assessment endpoints are generic
6 in nature (e.g., protection of sediment benthic communities from adverse changes in structure or
7 function).

8
9 The assessment endpoints for this SLERA were identified for each environmental medium and
10 are summarized below:

- 11
12 • **Soil**
 - 13 - Protection of the terrestrial invertebrate community from adverse changes in
 - 14 structure and function.
 - 15 - Protection of the terrestrial plant community from adverse changes in structure
 - 16 and function.
 - 17
18 • **Surface Water**
 - 19 - Protection of the aquatic community from adverse changes in structure and
 - 20 function.
 - 21
22 • **Sediment**
 - 23 - Protection of the benthic community from adverse changes in structure and
 - 24 function.
- 25

26 **7.5.2 Ecological Screening Values**

27 The ESVs used in this assessment represent the most conservative values available from various
28 literature sources and have been selected to be protective of the assessment endpoints described
29 above. These ESVs have been developed specifically for FTMC in conjunction with EPA
30 Region IV and are presented in the *Final Human Health and Ecological Screening Values and*
31 *PAH Background Summary Report* (IT, 2000c). The ESVs used in this assessment are based on
32 NOAELs when available. If a NOAEL-based ESV was not available for a given COPEC, then
33 the most health-protective value available from the scientific literature was used in this
34 assessment.

35
36 For each environmental medium sampled at Parcel 94(7) (soil, surface water, and sediment), a
37 hierarchy has been developed which presents an orderly method for selection of ESVs. The
38 hierarchy for selecting ESVs for soil is as follows:

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7.5.3 Determination of Exposure Point Concentrations

Exposure point concentrations represent the chemical concentrations in environmental media that a receptor may contact. Since the exposure point concentration is a value that represents the most likely concentration to which receptors could be exposed, a value that reflects the central tendency of the data set is most appropriate to use. However, at the screening-level stage, the data sets are generally not robust enough for statistical analysis and the level of conservatism in the exposure estimates is high to account for uncertainties. Therefore, at the screening-level stage, the maximum detected constituent concentration in each environmental medium is used as the exposure point concentration. The use of the maximum detected constituent concentration as the exposure point concentration ensures that exposures will not be underestimated and, therefore, constituents will not be inadvertently eliminated from further assessment.

The statistical summaries (including the exposure point concentrations) for soil at Parcel 94(7) and surface water and sediment in Ingram Creek adjacent to Parcel 94(7) are presented in Tables 7-3 through 7-5.

7.5.4 Screening-Level Hazard Quotients

In order to estimate whether constituents detected in environmental media at the site have the potential to pose adverse ecological risks, screening-level hazard quotients were developed. The screening-level hazard quotients were developed via a three-step process as follows:

- Comparison to ESVs
- Identification of essential macro-nutrients
- Comparison to naturally occurring background concentrations.

Constituents that were detected in environmental media at Parcel 94(7) were evaluated against the ESVs by calculating a screening-level hazard quotient (HQ_{screen}) for each constituent in each environmental medium. An HQ_{screen} was calculated by dividing the maximum detected constituent concentration in each environmental medium by its corresponding ESV as follows:

$$HQ_{screen} = \frac{MDCC}{ESV}$$

where:

- HQ_{screen} = screening-level hazard quotient
- $MDCC$ = maximum detected constituent concentration
- ESV = ecological screening value.

Table 7-3

Constituents of Potential Ecological Concern in Surface Soil^a
Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
Fort McClellan, Calhoun County, Alabama

(Page 1 of 2)

Constituent	Background Threshold Value ^b (mg/kg)	Ecological Screening Value ^c (mg/kg)	Maximum Detected Conc. (mg/kg)	Minimum Detected Conc. (mg/kg)	Mean Detected Conc. (mg/kg)	Frequency of Detection	Maximum Hazard Quotient	Mean Hazard Quotient	Constituent Of Potential Ecological Concern ^d
Metals									
Aluminum	1.63E+04	5.00E+01	1.64E+04	2.61E+03	8.47E+03	13 / 13	328.00	169.43	3
Arsenic	1.37E+01	1.00E+01	1.04E+01	2.00E+00	5.29E+00	13 / 13	1.04	0.53	3
Barium	1.24E+02	1.65E+02	1.17E+02	2.20E+01	6.59E+01	13 / 13	0.71	0.40	1,3
Beryllium	8.00E-01	1.10E+00	1.20E+00	8.60E-01	6.76E-01	5 / 10	1.09	0.61	YES
Calcium	1.72E+03	NA	1.56E+04	1.56E+02	3.85E+03	13 / 13	ND	ND	2
Chromium	3.70E+01	4.00E-01	3.18E+01	1.51E+01	2.20E+01	13 / 13	79.50	54.90	3
Cobalt	1.52E+01	2.00E+01	2.66E+01	3.48E+00	1.00E+01	10 / 12	1.33	0.50	YES
Copper	1.27E+01	4.00E+01	4.12E+01	3.60E+00	2.07E+01	13 / 13	1.03	0.52	YES
Iron	3.42E+04	2.00E+02	3.99E+04	6.73E+03	2.47E+04	13 / 13	199.50	123.67	YES
Lead	4.01E+01	5.00E+01	7.80E+01	6.50E+00	2.39E+01	13 / 13	1.56	0.48	YES
Magnesium	1.03E+03	4.40E+05	2.94E+03	2.57E+02	9.21E+02	8 / 13	0.0067	0.0021	1,2
Manganese	1.58E+03	1.00E+02	1.60E+03	5.76E+01	3.93E+02	13 / 13	16.00	3.93	YES
Mercury	8.00E-02	1.00E-01	1.30E-01	2.70E-02	6.84E-02	8 / 13	1.30	0.68	YES
Nickel	1.03E+01	3.00E+01	1.22E+01	2.36E+00	7.81E+00	11 / 12	0.41	0.26	1
Potassium	8.00E+02	NA	8.50E+02	6.37E+02	4.40E+02	3 / 11	ND	ND	2
Selenium	4.80E-01	8.10E-01	2.80E+00	7.90E-01	1.14E+00	8 / 13	3.46	1.41	YES
Vanadium	5.88E+01	2.00E+00	3.94E+01	6.20E+00	1.61E+01	12 / 13	19.70	8.04	3
Zinc	4.06E+01	5.00E+01	1.53E+02	1.36E+01	5.74E+01	10 / 10	3.06	1.15	YES
Semivolatile Organic Compounds									
2-Methylnaphthalene	NA	NA	6.30E-01	1.30E-01	2.33E-01	2 / 13	ND	ND	YES
Acenaphthene	NA	2.00E+01	1.40E+00	6.20E-02	2.62E-01	4 / 13	0.070	0.013	1
Acenaphthylene	NA	6.82E+02	2.30E+00	8.60E-02	4.72E-01	7 / 13	0.0034	0.0007	1
Anthracene	NA	1.00E-01	5.60E+00	9.20E-02	7.15E-01	7 / 13	56.00	7.15	YES
Benzo(a)anthracene	NA	5.21E+00	6.50E+00	1.70E-01	1.08E+00	7 / 13	1.25	0.21	YES
Benzo(a)pyrene	NA	1.00E-01	5.30E+00	3.50E-02	1.30E+00	9 / 13	53.00	13.05	YES
Benzo(b)fluoranthene	NA	5.98E+01	7.20E+00	7.10E-02	1.47E+00	8 / 13	0.12	0.02	1
Benzo(ghi)perylene	NA	1.19E+02	1.70E+00	1.10E-01	4.78E-01	7 / 13	0.0143	0.0040	1
Benzo(k)fluoranthene	NA	1.48E+02	6.50E+00	5.70E-02	1.37E+00	8 / 13	0.0439	0.0093	1
bis(2-Ethylhexyl)phthalate	NA	9.26E-01	1.20E-01	1.20E-01	3.59E-01	1 / 11	0.13	0.39	1
Carbazole	NA	NA	3.00E+00	5.40E-02	4.36E-01	7 / 13	ND	ND	YES
Chrysene	NA	4.73E+00	6.10E+00	5.40E-02	1.22E+00	8 / 13	1.29	0.26	YES
Dibenz(a,h)anthracene	NA	1.84E+01	1.00E+00	6.00E-02	3.19E-01	7 / 13	0.054	0.017	1
Dibenzofuran	NA	NA	2.00E+00	7.20E-02	3.25E-01	3 / 13	ND	ND	YES
Fluoranthene	NA	1.00E-01	2.00E+01	6.70E-02	2.80E+00	9 / 13	200.00	27.96	YES

Table 7-3

**Constituents of Potential Ecological Concern in Surface Soil^a
Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
Fort McClellan, Calhoun County, Alabama**

(Page 2 of 2)

Constituent	Background Threshold Value ^b (mg/kg)	Ecological Screening Value ^c (mg/kg)	Maximum Detected Conc. (mg/kg)	Minimum Detected Conc. (mg/kg)	Mean Detected Conc. (mg/kg)	Frequency of Detection	Maximum Hazard Quotient	Mean Hazard Quotient	Constituent Of Potential Ecological Concern ^d
Fluorene	NA	1.22E+02	5.20E+00	1.10E-01	5.82E-01	4 / 13	0.0426	0.0048	1
Indeno(1,2,3-cd)pyrene	NA	1.09E+02	2.00E+00	1.20E-01	5.50E-01	7 / 13	0.0183	0.0050	1
Phenanthrene	NA	1.00E-01	1.80E+01	2.00E-01	1.79E+00	7 / 13	180.00	17.93	YES
Pyrene	NA	1.00E-01	1.40E+01	5.30E-02	2.13E+00	8 / 13	140.00	21.25	YES
<u>Volatile Organic Compounds</u>									
1,2,4-Trimethylbenzene	NA	1.00E-01	2.90E-02	2.50E-03	4.69E-03	3 / 20	0.29	0.05	1
1,2-Dimethylbenzene	NA	1.00E-01	2.50E-03	2.50E-03	2.91E-03	1 / 20	0.025	0.029	1
1,3,5-Trimethylbenzene	NA	1.00E-01	6.80E-03	9.90E-04	3.05E-03	2 / 20	0.068	0.031	1
2-Butanone	NA	8.96E+01	6.30E-02	8.30E-03	2.74E-02	11 / 14	0.0007	0.0003	1
Acetone	NA	2.50E+00	1.40E+00	1.00E-02	2.90E-01	19 / 19	0.56	0.12	1
Carbon disulfide	NA	9.40E-02	1.50E-02	3.30E-03	5.07E-03	6 / 20	0.16	0.05	1
Chlorobenzene	NA	5.00E-02	2.90E-03	2.90E-03	2.92E-03	1 / 20	0.058	0.058	1
cis-1,2-Dichloroethene	NA	1.00E-01	4.60E-03	4.60E-03	3.00E-03	1 / 20	0.046	0.030	1
m,p-Xylenes	NA	5.00E-02	4.50E-03	8.20E-04	4.12E-03	2 / 20	0.090	0.082	1
Methylene chloride	NA	2.00E+00	1.80E-03	1.10E-03	2.44E-03	2 / 6	0.0009	0.0012	1
Naphthalene	NA	1.00E-01	4.30E-02	2.40E-03	6.19E-03	4 / 20	0.43	0.06	1
p-Cymene	NA	NA	2.70E-02	1.10E-03	5.28E-03	6 / 20	ND	ND	4
Toluene	NA	5.00E-02	7.10E-03	5.80E-04	2.85E-03	10 / 20	0.14	0.06	1

^a Surface soil at Parcel 94(7) is defined as the interval from 0 to 0.5 feet below ground surface.

^b Background threshold value is 2-times the arithmetic mean background concentration as reported in "Final Background Metals Survey Report, Ft. McClellan, Alabama" (SAIC, 1998).

^c Ecological screening values are presented in "Human Health and Ecological Screening Values and PAH Background Summary Report" (IT Corp., 2000).

^d Rationale for exclusion as COPEC:

1 - Maximum detected concentration is less than ecological screening value (ESV).

2 - Essential macronutrient, only toxic at extremely high concentrations (i.e. 10-times naturally-occurring background concentration).

3 - Maximum detected concentration is less than background threshold value.

4 - No ESV available; however, maximum detected concentration is similar to concentrations of other VOAs which are below their respective ESVs.

mg/kg - Milligrams per kilogram.

NA - Not available.

ND - Not determined.

Table 7-4

**Constituents of Potential Ecological Concern in Surface Water
Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
Fort McClellan, Calhoun County, Alabama**

Constituent	Background Threshold Value ^a (mg/L)	Ecological Screening Value ^b (mg/L)	Maximum Detected Conc. (mg/L)	Minimum Detected Conc. (mg/L)	Mean Detected Conc. (mg/L)	Frequency of Detection	Maximum Hazard Quotient	Mean Hazard Quotient	Constituent Of Potential Ecological Concern ^c
Metals									
Aluminum	5.26E+00	8.70E-02	3.71E-01	3.71E-01	2.36E-01	1 / 2	4.26	2.71	3
Calcium	2.52E+01	1.16E+02	6.96E+01	5.38E+01	6.17E+01	2 / 2	0.60	0.53	1,2
Iron	1.96E+01	1.00E+00	4.95E-01	4.95E-01	2.73E-01	1 / 2	0.50	0.27	1,3
Magnesium	1.10E+01	8.20E+01	8.75E+00	7.84E+00	8.30E+00	2 / 2	0.11	0.10	1,2,3
Manganese	5.65E-01	8.00E-02	3.72E-01	2.34E-02	1.98E-01	2 / 2	4.65	2.47	3
Volatile Organic Compounds									
Methylene chloride	NA	1.93E+00	1.50E-03	1.50E-03	1.50E-03	1 / 5	0.00078	0.00078	1
Trichloroethene	NA	2.19E+01	2.30E-04	2.30E-04	1.65E-03	1 / 5	0.00001	0.00008	1

^a Background threshold value is 2-times the arithmetic mean background concentration as reported in "Final Background Metals Survey Report, Ft. McClellan, Alabama" (SAIC, 1998).

^b Ecological screening values are presented in *Human Health and Ecological Screening Values and PAH Background Summary Report* (IT, 2000).

^c Rationale for exclusion as COPEC:

- 1 - Maximum detected concentration is less than ecological screening value (ESV).
- 2 - Essential macronutrient, only toxic at extremely high concentrations (i.e. 10-times naturally-occurring background concentration).
- 3 - Maximum detected concentration is less than background threshold value.
- 4 - No ESV available; however, maximum detected concentration is similar to concentrations of other VOAs which are below their respective ESVs.

mg/L - Milligrams per liter.

NA - Not Available

ND - Not Determined

Table 7-5

**Constituents of Potential Ecological Concern in Sediment
Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
Fort McClellan, Calhoun County, Alabama**

(Page 1 of 2)

Constituent	Background Threshold Value ^a (mg/kg)	Ecological Screening Value ^b (mg/kg)	Maximum Detected Conc. (mg/kg)	Minimum Detected Conc. (mg/kg)	Mean Detected Conc. (mg/kg)	Frequency of Detection	Maximum Hazard Quotient	Mean Hazard Quotient	Constituent Of Potential Ecological Concern ^c
Metals									
Aluminum	8.59E+03	NA	3.06E+03	2.70E+03	2.88E+03	2 / 2	ND	ND	3
Arsenic	1.13E+01	7.24E+00	7.70E+00	5.40E+00	6.55E+00	2 / 2	1.06	0.90	3
Barium	9.89E+01	NA	6.55E+01	3.15E+01	4.85E+01	2 / 2	ND	ND	3
Beryllium	9.70E-01	NA	1.00E+00	7.30E-01	8.65E-01	2 / 2	ND	ND	YES
Calcium	1.11E+03	NA	1.77E+03	1.13E+03	1.45E+03	2 / 2	ND	ND	2
Chromium	3.12E+01	5.23E+01	2.09E+01	1.82E+01	1.96E+01	2 / 2	0.40	0.37	1,3
Cobalt	1.10E+01	5.00E+01	1.19E+01	1.00E+01	1.10E+01	2 / 2	0.24	0.22	1
Copper	1.71E+01	1.87E+01	1.15E+01	1.10E+01	1.13E+01	2 / 2	0.61	0.60	1,3
Iron	3.53E+04	NA	2.92E+04	2.17E+04	2.55E+04	2 / 2	ND	ND	3
Lead	3.78E+01	3.02E+01	1.59E+01	1.49E+01	1.54E+01	2 / 2	0.53	0.51	1,3
Magnesium	9.06E+02	NA	7.78E+02	7.78E+02	5.46E+02	1 / 2	ND	ND	2,3
Manganese	7.12E+02	NA	6.78E+02	4.81E+02	5.80E+02	2 / 2	ND	ND	3
Nickel	1.30E+01	1.59E+01	2.00E+01	8.60E+00	1.43E+01	2 / 2	1.26	0.90	YES
Selenium	7.20E-01	NA	8.20E-01	8.20E-01	5.63E-01	1 / 2	ND	ND	YES
Zinc	5.27E+01	1.24E+02	3.39E+01	3.39E+01	3.39E+01	1 / 1	0.27	0.27	1,3
Semivolatile Organic Compounds									
Acenaphthylene	NA	3.30E-01	1.00E-01	1.00E-01	1.53E-01	1 / 2	0.30	0.46	1
Anthracene	NA	3.30E-01	1.90E-01	1.90E-01	1.98E-01	1 / 2	0.58	0.60	1
Benzo(a)anthracene	NA	3.30E-01	5.60E-01	5.60E-01	3.83E-01	1 / 2	1.70	1.16	YES
Benzo(a)pyrene	NA	3.30E-01	4.40E-01	4.40E-01	3.23E-01	1 / 2	1.33	0.98	YES
Benzo(b)fluoranthene	NA	6.55E-01	3.70E-01	3.70E-01	2.88E-01	1 / 2	0.56	0.44	1
Benzo(ghi)perylene	NA	6.55E-01	1.90E-01	1.90E-01	1.98E-01	1 / 2	0.29	0.30	1
Benzo(k)fluoranthene	NA	6.55E-01	6.30E-01	6.30E-01	4.18E-01	1 / 2	0.96	0.64	1
Carbazole	NA	NA	6.20E-02	6.20E-02	1.34E-01	1 / 2	ND	ND	4
Chrysene	NA	3.30E-01	5.40E-01	5.40E-01	3.73E-01	1 / 2	1.64	1.13	YES
Dibenzo(a,h)anthracene	NA	3.30E-01	1.10E-01	1.10E-01	1.58E-01	1 / 2	0.33	0.48	1
Fluoranthene	NA	3.30E-01	1.30E+00	1.30E+00	7.53E-01	1 / 2	3.94	2.28	YES
Fluorene	NA	3.30E-01	4.10E-02	4.10E-02	1.23E-01	1 / 2	0.12	0.37	1

Table 7-5

**Constituents of Potential Ecological Concern in Sediment
Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
Fort McClellan, Calhoun County, Alabama**

(Page 2 of 2)

Constituent	Background Threshold Value ^a (mg/kg)	Ecological Screening Value ^b (mg/kg)	Maximum Detected Conc. (mg/kg)	Minimum Detected Conc. (mg/kg)	Mean Detected Conc. (mg/kg)	Frequency of Detection	Maximum Hazard Quotient	Mean Hazard Quotient	Constituent Of Potential Ecological Concern ^c
Indeno(1,2,3-cd)pyrene	NA	6.55E-01	2.10E-01	2.10E-01	2.08E-01	1 / 2	0.32	0.32	1
Phenanthrene	NA	3.30E-01	7.50E-01	7.50E-01	4.78E-01	1 / 2	2.27	1.45	YES
Pyrene	NA	3.30E-01	9.20E-01	9.20E-01	5.63E-01	1 / 2	2.79	1.70	YES
<u>Volatile Organic Compounds</u>									
2-Butanone	NA	1.37E-01	3.00E-02	3.00E-02	1.61E-02	1 / 5	0.22	0.12	1
Acetone	NA	4.53E-01	2.30E-01	1.30E-01	1.93E-01	3 / 3	0.51	0.43	1
Carbon disulfide	NA	1.34E-01	2.50E-03	2.50E-03	3.04E-03	1 / 5	0.019	0.023	1
m,p-Xylenes	NA	2.50E-02	4.30E-04	4.30E-04	3.49E-03	1 / 5	0.017	0.139	1
Methylene chloride	NA	1.26E+00	1.40E-03	1.40E-03	1.72E-03	2 / 3	0.0011	0.0014	1
p-Cymene	NA	NA	1.10E-02	1.60E-03	4.65E-03	2 / 5	ND	ND	4
Toluene	NA	6.70E-01	7.10E-03	9.50E-04	3.74E-03	2 / 5	0.011	0.006	1
<u>Other</u>									
Total Organic Carbon	NA	NA	2.95E+03	1.15E+03	2.05E+03	2 / 2	ND	ND	NA

^a Background threshold value is 2-times the arithmetic mean background concentration as reported in "Final Background Metals Survey Report, Ft. McClellan, Alabama" (SAIC, 1998).

^b Ecological screening values are presented in *Human Health and Ecological Screening Values and PAH Background Summary Report* (IT, 2000).

^c Rationale for exclusion as COPEC:

- 1 - Maximum detected concentration is less than ecological screening value (ESV).
- 2 - Essential macronutrient, only toxic at extremely high concentrations (i.e. 10-times naturally-occurring background concentration).
- 3 - Maximum detected concentration is less than background threshold value.
- 4 - No ESV available; however, maximum detected concentration is similar to concentrations of other VOAs which are below their respective ESVs.

mg/kg - Milligrams per kilogram.

NA - Not Available

ND - Not Determined

1
2 A calculated HQ_{screen} value of one indicated that the MDCC was equal to the chemical's
3 conservative ESV and was interpreted in this assessment as a constituent that does not pose the
4 potential for adverse ecological risk. An HQ_{screen} value less than one indicated that the MDCC
5 was less than the conservative ESV and that the chemical is not likely to pose adverse ecological
6 hazards to most receptors. Conversely, an HQ_{screen} value greater than one indicated that the
7 MDCC was greater than the ESV and that the chemical might pose adverse ecological hazards to
8 one or more receptors.

9
10 In order to better understand the potential risks posed by chemical constituents at Parcel 94(7), a
11 mean hazard quotient was also calculated by comparing the arithmetic mean constituent
12 concentrations in each environmental medium to the corresponding ESVs. The calculated
13 screening-level hazard quotients for surface soil, surface water, and sediment at Parcel 94(7) are
14 presented in Tables 7-3 through 7-5.

15
16 The EPA recognizes several constituents in abiotic media that are necessary to maintain normal
17 function in many organisms. These essential macro-nutrients are iron, magnesium, calcium,
18 potassium, and sodium (EPA, 1989). Most organisms have mechanisms designed to regulate
19 nutrient fluxes within their systems; therefore, these nutrients are generally only toxic at very
20 high concentrations. Although iron is an essential nutrient and is regulated within many
21 organisms, it may become increasingly bioavailable at lower pH values, thus increasing its
22 potential to elicit adverse affects. Therefore, iron was not evaluated as an essential nutrient in
23 this SLERA. Essential macro-nutrients were only considered COPECs if they were present in
24 site samples at concentrations ten times the naturally occurring background concentration.

25
26 A study of the natural geochemical composition associated with FTMC (SAIC, 1998) determined
27 the mean concentrations of 24 metals in surface soil, surface water, and sediment samples
28 collected from presumably unimpacted areas. Per agreement with EPA Region IV, the
29 background threshold value (BTV) for each metal was calculated as two times the mean
30 background concentration for that metal. The BTV for each metal was used to represent the
31 upper boundary of the range of natural background concentrations expected at FTMC and was
32 used as the basis for evaluating metals concentrations measured in site samples.

33
34 In order to determine whether metals detected in site samples were the result of site-related
35 activities or were indicative of naturally occurring conditions, the maximum metals

1 concentrations measured in site samples were compared to their corresponding BTVs. Site
2 sample metal concentrations less than or equal to the corresponding BTV represent the natural
3 geochemical composition of media at FTMC and not contamination associated with site activity.
4 Site sample metal concentrations greater than the corresponding BTV represent contaminants
5 that may be the result of site-related activities and require further assessment.

6
7 Thus, the first step in determining screening-level hazard quotients was a comparison of
8 maximum detected constituent concentrations to appropriate ESVs. Constituents with HQ_{screen}
9 values less than one were considered to pose insignificant ecological risk and were eliminated
10 from further consideration. Constituents with HQ_{screen} values greater than one were eliminated
11 from further consideration if they were macro-nutrients. Those constituents that had HQ_{screen}
12 values greater one and were not considered macro-nutrients were then compared to their
13 corresponding BTVs. If constituent concentrations were determined to be less than their
14 naturally occurring background concentration, then a risk management decision could result in
15 eliminating these constituents from further assessment.

16 17 **7.6 Identification of Constituents of Potential Ecological Concern**

18 Constituents were identified as COPECs if the following conditions were met:

- 19
- 20 • The maximum detected constituent concentration exceeded the ESV;
- 21
- 22 • The maximum detected constituent concentration was 10-times the BTV if the
- 23 constituent was identified as a macro-nutrient; and
- 24
- 25 • The maximum detected constituent concentration exceeded the BTV for
- 26 inorganics.
- 27

28 If a constituent in a given environmental medium did not meet these conditions, then it was not
29 considered a COPEC at Parcel 94(7) and was not considered for further assessment. If a
30 constituent met one of these conditions, then it was considered a COPEC. Identification of a
31 constituent as a COPEC indicates that further assessment of that particular constituent in a given
32 environmental medium may be appropriate. It does not imply that a particular constituent poses
33 risk to ecological receptors.

34
35 The COPECs that have been identified for surface soil, surface water, and sediment at Parcel
36 94(7) are presented in Tables 7-3 through 7-5 and summarized in Table 7-6.

Table 7-6

**Summary of Constituents of Potential Ecological Concern
Former Chemical Laundry and Motor Pool Area 1500, Parcel 94(7)
Fort McClellan, Calhoun County, Alabama**

Constituent of Potential Ecological Concern	Motor Pool 1500 Surface Soil	Ingram Creek Surface Water	Ingram Creek Sediment
Beryllium	√ ¹		√ ²
Cobalt	√ ¹		
Copper	√ ¹		
Iron	√ ¹		
Lead	√ ¹		
Manganese	√ ¹		
Mercury	√ ¹		
Nickel			√
Selenium	√ ¹		√ ²
Zinc	√ ¹		
2-methylnaphthalene	√ ^{2,3}		
Anthracene	√ ³		
Benzo(a)anthracene	√ ³		√
Benzo(a)pyrene	√ ³		√
Carbazole	√ ^{2,3}		
Chrysene	√ ³		√
Dibenzofuran	√ ^{2,3}		
Fluoranthene	√ ³		√
Phenanthrene	√ ³		√
Pyrene	√ ³		√

¹ Statistical and geochemical analyses have shown that these inorganic constituents are closely associated with iron oxides in surface soil at Motor Pool 1500; thus, they are naturally occurring and may not be present as a result of site-related activities

² Identified as a COPEC because no ESV is available to determine the potential for ecological risk.

³ Mean detected concentrations were less than background threshold values for soil beneath asphalt as presented in *Human Health and Ecological Screening Values and PAH Background Summary Report* (IT, 2000).

1 Inorganic constituents that were initially identified as COPECs in surface soil at Parcel 94(7)
2 include the following: beryllium, cobalt, copper, iron, lead, manganese, mercury, selenium, and
3 zinc. In order to more closely scrutinize the relationship between site-related chemicals and
4 naturally occurring soil constituents, an integrated statistical and geochemical evaluation was
5 conducted (Appendix L). The results of the additional statistical and geochemical evaluations
6 indicated that all of these metals were associated with iron oxides in the soil at relatively constant
7 ratios. These results indicate that these inorganic constituents of soil are naturally occurring and
8 may not be the result of site-related activities. Thus, these inorganic constituents may not be
9 considered COPECs in soil at Parcel 94(7).

11 **7.7 Uncertainty Analysis**

12 Uncertainties are inherent in any risk assessment and even more so in a SLERA, due to the
13 nature of the assessment process and the assumptions used in the process. A number of major
14 areas of uncertainty in this assessment are presented below.

15
16 A significant level of uncertainty is introduced into this SLERA due to the presence of asphalt
17 over the entire surface area of Parcel 94(7). The asphalt currently precludes surface soil
18 exposures for all ecological receptors. However, for this SLERA, it was assumed that the asphalt
19 would be removed or would degrade significantly over time, such that soil exposures could occur
20 at some time in the future.

21
22 Uncertainty was introduced into the assessment of sediments in Ingram Creek due to the
23 presence of the driver training course directly across Ingram Creek from Parcel 94(7). The man-
24 made drainage ditches from the driver training course discharge runoff directly to Ingram Creek
25 and confound the results of the sediment analyses. It is difficult to discern between constituents
26 originating from Parcel 94(7) and those originating from the driver training course.

27
28 An area of uncertainty that is inherent in a SLERA is the use of the maximum detected
29 constituent concentration as the exposure point concentration for all receptors in a given medium.
30 Most receptors have a home range large enough that precludes individuals from being exposed to
31 the maximum constituent concentration for their entire lifetimes. Therefore, the actual exposure
32 point concentration of a given constituent for many receptor species would be less than the
33 maximum detected concentration. The use of the maximum detected constituent concentrations
34 as the exposure point concentrations for all receptors may result in an overestimation of exposure
35 for many receptors.

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Additionally, there is no consideration given to the bioavailability of COPECs to different organisms. In this SLERA it is assumed that all constituents are 100 percent bioavailable to all receptor organisms. It is known that many constituents (particularly inorganic compounds) have significantly lower bioavailabilities than the 100 percent that was assumed in this assessment (e.g., 1 to 10 percent for some inorganics in soil). This assumption has the potential to greatly overestimate exposures to certain COPECs.

Several COPECs do not have ESVs. The lack of toxicity data for certain COPECs makes it impossible to determine the potential for ecological risk posed by those constituents. Risks may be underestimated due to this uncertainty.

The ESVs used in this assessment are all the most conservative values from the scientific literature, and many are based on the most sensitive endpoint (NOAEL values) for the most sensitive species tested. A less sensitive endpoint that is still protective of the ecological populations or communities of interest may be the LOAEL or some other endpoint. The use of NOAEL-based ESVs may overestimate potential for risks from certain COPECs. Additionally, certain ESVs may not be applicable to conditions at Parcel 94(7). For instance, a number of the sediment ESVs are referenced from MacDonald (1994), which presents sediment benchmark values for coastal waters (saline) in Florida. The surface water of Ingram Creek is fresh water and exhibits significantly different physical and chemical characteristics compared to those found in the coastal waters of Florida. Therefore, the use of sediment ESVs developed for the coastal waters of Florida to determine risks in the freshwater streams of FTMC introduces a significant level of uncertainty. Similarly, the surface water and soil ESVs do not take into account site-specific conditions at Parcel 94(7) and, thus, introduce a potentially significant level of uncertainty into the assessment.

Another area of uncertainty is the lack of consideration of synergisms and/or antagonisms between COPECs. Although it is widely accepted that synergisms and antagonisms occur between certain constituents under certain conditions, the SLERA process does not provide methods for assessing these potential synergisms/antagonisms.

7.8 Summary and Conclusions

The potential for ecological risks at Parcel 94(7) was evaluated through a SLERA. This ecological screening process consisted of a characterization of the ecological setting at Parcel

1 94(7), development of an SCM, a description of the fate and transport of constituents detected in
2 various environmental media, a description of the ecotoxicity of the various constituents detected
3 at the site, a description of the ecological receptors, a description of the complete exposure
4 pathways, calculation of screening-level hazard quotients, and a description of the uncertainties
5 within the process.
6

7 **7.8.1 SLERA Summary**

8 The Parcel 94(7) study area is approximately 5 acres in size. The site is bounded by Langley
9 Avenue on the west and mixed deciduous/coniferous forest on the north, south, and east. The
10 buildings that were reported to exist on this site have been removed, and the entire site is covered
11 with asphalt pavement. The site slopes slightly to the north and east towards Ingram Creek, a
12 tributary of Cane Creek. Ingram Creek has been identified as providing moderate quality
13 foraging habitat for the federally listed endangered gray bat. Elevation at the site ranges from
14 approximately 800 to 825 feet above mean sea level. There are two general types of ecological
15 habitat in the near vicinity of Parcel 94(7): terrestrial (mixed deciduous/coniferous forest) and
16 aquatic (Ingram Creek).
17

18 The SLERA at Parcel 94(7) determined that the MDCs of several inorganic constituents and
19 several SVOCs in surface soil exceeded their respective ESVs. Additionally, several inorganic
20 compounds and SVOCs in sediment exceeded their respective ESVs. Further review of these
21 COPECs is important in making risk management decisions.
22

23 The inorganic constituents whose MDCs exceeded their respective ESVs in surface soil were the
24 following: beryllium, cobalt, copper, iron, lead, manganese, mercury, selenium, and zinc. These
25 nine constituents exhibited maximum hazard quotients ranging from 1.03 to 16, not including
26 iron which had a maximum hazard quotient of 199.5, but its MDC only slightly exceeded its
27 background threshold value. Mean concentrations of all of the inorganic constituents were less
28 than their respective background threshold values and/or ESVs except for manganese, selenium,
29 and zinc, indicating that these inorganic COPECs may be indicative of naturally occurring
30 background concentrations of inorganics in soil and may not be attributable to site activities.
31

32 The integrated statistical and geochemical evaluation conducted for inorganic constituents in
33 surface soil at Parcel 94(7) indicated that all of the inorganic constituents that exhibited MDCs
34 greater than their respective ESVs were associated with iron oxides in soils at a relatively

1 constant ratio. This analysis indicated that these inorganic constituents are naturally occurring
2 and may not be present as a result of site-related Army activities.

3
4 The SVOCs whose MDCs exceeded their respective ESVs in surface soil were the following:
5 anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and
6 pyrene. These seven constituents exhibited maximum hazard quotients ranging from 1.25 to 200.
7 Hazard quotients for 2-methyl naphthalene, carbazole, and dibenzofuran could not be calculated
8 because no ESVs were available for these constituents. It is important to note that the mean
9 concentrations of all of the SVOCs that were detected at elevated concentrations in surface soil
10 were less than the background concentrations for soil beneath pavement as presented in the *Final*
11 *Human Health and Ecological Screening Values and PAH Background Summary Report* (IT,
12 2000c). Thus, the SVOCs in surface soil at Parcel 94(7) are characteristic of soil beneath
13 pavement at similar sites at FTMC and may not be indicative of site-related Army activities.

14
15 None of the detected constituents in surface water from Ingram Creek adjacent to Parcel 94(7)
16 were identified as COPECs.

17
18 Nickel was the only inorganic constituent detected in sediment samples at an elevated
19 concentration relative to ESVs. Hazard quotients for beryllium and selenium could not be
20 calculated because there are no ESVs available for these constituents; however, the MDCs of
21 these two constituents only slightly exceeded their respective background threshold values. The
22 maximum detected nickel concentration slightly exceeded the ESV ($HQ_{\text{screen}} = 1.26$) and the
23 background threshold value. The mean nickel concentration in sediment was less than the ESV.

24
25 SVOCs benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, and pyrene
26 were detected in sediment samples at an elevated concentrations relative to ESVs. Maximum
27 hazard quotients for these SVOCs in sediment ranged from 1.33 to 3.94. The SVOCs that were
28 detected at concentrations that exceeded their respective ESVs were found in a single sediment
29 sample. It is important to note that the sediment sample that exhibited the slightly elevated
30 concentrations of SVOCs was located directly downgradient of a stormwater discharge point for
31 the former driving course. The former driving course is a large area, mostly covered by asphalt
32 paving, used for driver training. The driving course is located approximately 100 feet east of
33 Ingram Creek. Several concrete-lined drainage ditches that run throughout the driving course
34 receive runoff from the driving course and eventually discharge to Ingram Creek directly
35 upstream of the sampling point that exhibited elevated concentrations of SVOCs. It is probable

1 that these SVOCs originated from the asphalt paving at the driving course and not from Parcel
2 94(7).

3
4 The COPECs at Parcel 94(7) (Table 7-6) have been identified through a very conservative
5 screening process that uses ESVs based largely on NOAEL values from the scientific literature.
6 If additional lines of evidence are considered, it could be concluded that there are no constituents
7 in surface soil, surface water, or sediment associated with Parcel 94(7) that have the potential to
8 pose adverse ecological effects to terrestrial or aquatic populations at FTMC. If, based on a risk
9 management decision, the potential ecological risks at Parcel 94(7) are determined to be
10 “unacceptable” at this screening-level stage, then a baseline ecological risk assessment (BERA)
11 is appropriate. The goal of the BERA, if deemed necessary, will be to reduce the levels of
12 uncertainty and conservatism in the assessment process and to determine the potential for
13 ecological risk at Parcel 94(7) through a number of lines of evidence.

14 15 **7.8.2 Conclusions of SLERA**

16 The SLERA at Parcel 94(7) determined that the maximum concentrations of several constituents
17 in surface soil and sediment exceeded their respective ESVs. Further review of these COPECs is
18 important in making risk management decisions. The integrated statistical and geochemical
19 evaluation conducted for inorganic constituents in surface soil at Parcel 94(7) indicated that all of
20 the inorganic constituents that exhibited MDCs greater than their respective ESVs were
21 associated with iron oxides in Parcel 94(7) soils at a relatively constant ratio. This analysis
22 indicated that these inorganic constituents are naturally occurring and may not be present as a
23 result of site-related Army activities. It is important to note that the mean concentrations of all of
24 the SVOCs that were detected at elevated concentrations in surface soil were less than the
25 background concentrations for soil beneath pavement as presented in the *Final Human Health
26 and Ecological Screening Values and PAH Background Summary Report* (IT, 2000c). Thus, the
27 SVOCs in surface soil at Parcel 94(7) are characteristic of soil beneath pavement at similar sites
28 at FTMC and may not be indicative of site-related Army activities.

29
30 None of the detected constituents in surface water from Ingram Creek adjacent to Parcel 94(7)
31 were identified as COPECs.

32
33 The maximum detected nickel concentration in sediment slightly exceeded the ESV ($HQ_{\text{screen}} =$
34 1.26) and the background threshold value. The mean nickel concentration in sediment was less
35 than the ESV. The SVOCs that were detected in sediment at concentrations that exceeded their

1 respective ESVs were found in a single sediment sample. It is important to note that the
2 sediment sample that exhibited the slightly elevated concentrations of SVOCs was located
3 directly downgradient of a stormwater discharge point for the former driving course. Several
4 concrete-lined drainage ditches that run throughout the driving course receive runoff from the
5 driving course and eventually discharge to Ingram Creek directly upstream of the sampling point
6 that exhibited elevated concentrations of SVOCs. It is probable that these SVOCs originated
7 from the asphalt paving at the driving course and not from Parcel 94(7).

8

9 Based on further review (including additional lines of evidence) of the COPECs identified in
10 surface soil at Parcel 94(7) and sediment from Ingram Creek adjacent to Parcel 94(7) via the
11 conservative assessment techniques used in the SLERA process, it could be concluded that none
12 of the constituents in surface soil or sediment present risks to terrestrial or aquatic ecosystems at
13 FTMC. Therefore, further ecological assessment is not warranted at Parcel 94(7).

14