6.0 Complete Exposure Pathways

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

- A source mechanism for constituent 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 are absent, then a pathway is generally considered incomplete. Potentially complete exposure pathways are depicted in the site conceptual model (SCM) shown on Figure 6-1.

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 volatile COPECs or 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 constituents 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. Aquatic organisms inhabiting contaminated waters would be in constant contact with the surface water COPECs.

Constituents present in 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 periods. Water overlying sediments prevents constituents from being carried by wind erosion. Because the majority of the constituents detected in sediment are inorganic compounds that are not prone to volatilization, volatilization from sediments is not an important fate mechanism at the BBGR Ranges. VOCs were detected in sediment samples albeit at very low concentrations.

Therefore, inhalation of constituents originating from the sediment is not a significant exposure pathway. Exposure via dermal contact may occur, especially for benthic organisms and wading birds or other animals that may use South Branch of Cane Creek or Ingram Creek tributaries as feeding areas. Some aquatic organisms consume sediment and ingest organic material from the sediment. Inadvertent ingestion of sediments may also occur as the result of feeding on benthic organisms and plants.

While constituents in soils may leach into groundwater, environmental receptors will not come into direct contact with constituents in groundwater since there is no direct exposure route. The only potential exposure pathways for ecological receptors to groundwater would be via surface water exposure routes. As described in previous sections of this report, groundwater discharge to surface water in the tributaries to South Branch of Cane Creek and Ingram Creek is a potentially viable transport mechanism for dissolved constituents during periods of heavy precipitation; however, exposure to these constituents by ecological receptors is only possible via surface water exposure routes. Potential exposure to groundwater-related constituents is expected to be insignificant compared to other exposure pathways (i.e., exposure to constituents in surface water as a result of surface runoff) since groundwater discharge to the tributaries of South Branch of Cane Creek or Ingram Creek is expected to be localized and sporadic.

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

In general, the constituents detected in surface soil at the BBGR Ranges may bioaccumulate in lower trophic level organisms (i.e., terrestrial invertebrates may bioaccumulate inorganic compounds and PAHs detected in soil); however, they will not bioconcentrate through the food chain. Inorganic compounds generally do not bioconcentrate to any great extent and PAHs are readily metabolized by higher trophic level organisms. However, several of the chlorinated herbicides and pesticides detected in surface soil have a propensity to bioconcentrate (4,4'-DDE, 4,4'-DDT, MCPP, aldrin, alpha-BHC, dieldren, and endrin). These chlorinated herbicides and pesticides have a propensity to bioconcentrate through the food chain, and therefore may be available to higher trophic level organisms through food chain interactions.

The constituents detected in sediment may bioaccumulate in lower trophic level organisms (i.e., benthic invertebrates may bioaccumulate inorganic compounds detected in sediment); however, they will not bioconcentrate through the food chain. Inorganic compounds and VOCs generally do not bioconcentrate to any great extent. The exception to this is gamma-chlordane detected in the sediment of Ingram Creek tributaries. Gamma-chlordane has the propensity to accumulate in fatty tissues of organisms and my bioconcentrate through the food chain. The constituents detected in groundwater are not expected to bioaccumulate or bioconcentrate significantly.

Potential ecological receptors at the BBGR Ranges fall into two general categories: terrestrial and aquatic. Within these two general categories there are several major feeding guilds that could be expected to occur at the BBGR Ranges: herbivores, invertivores, omnivores, carnivores, and piscivores. All of these feeding guilds have the potential to be directly exposed to various combinations of surface soil at the BBGR Ranges and surface water and sediment in the tributaries to South Branch of Cane Creek and Ingram Creek in the vicinity of the BBGR Ranges via various activities (e.g., feeding, drinking, grooming, bathing, etc.). These feeding guilds may also be exposed to site-related chemicals via food web transfers.

As discussed above, ingestion of COPECs in soil, surface water, and sediment are the pathways that pose the greatest potential for exposure for ecological receptors at the BBGR Ranges. Dermal absorption and inhalation exposures are expected to be insignificant. Food web transfers of COPECs are also possible exposure pathways for ecological receptors at the BBGR Ranges, although none of the COPECs at the BGR ranges have high bioconcentration or biomagnification potential.

Potentially complete exposure pathways are depicted in the SCM (Figure 6-1) and are described in the following sections for the various feeding guilds.

6.1 Herbivorous Feeding Guild

The major route of exposure for herbivores is through ingestion of plants that may have accumulated constituents from the soil, surface water, or sediment. The vegetation at the formerly maintained areas at the BBGR Ranges is mainly grasses and sedges, which are remnants of the maintained grass that was present when the BBGR Ranges were operational. Since terrestrial herbivores by definition are grazers and browsers, they could be exposed to chemicals that have accumulated in the vegetative tissues of the plants at the site. Terrestrial herbivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while grazing, grooming, or other activities.

Typical herbivorous species that could be expected to occur at the BBGR Ranges and are commonly used as sentinel species in ecological risk assessment include eastern cottontail (*Sylvilagus floridanus*), eastern gray squirrel (*Sciurus carolinensis*), pine vole (*Pitymys pinetorum*), whitetail deer (*Odocoileus virginianus*), and wild turkey (*Meleagris gallopavo*).

Aquatic herbivores, such as muskrat (*Ondatra zibethica*) and mallard (*Anas platyrhynchos*), could be exposed to site-related constituents in surface water and sediment; however, the ephemeral drainage features at the BBGR Ranges do not provide suitable habitat to support aquatic herbivores. The exception to this is the creek that flows through the southern portion of Range 23, which is perennial in nature. This creek has the potential to support smaller aquatic herbivorous species.

6.2 Invertivorous Feeding Guild

Invertivores specialize in eating insects and other invertebrates. As such, they may be exposed to site-related chemicals that have accumulated in insects and other invertebrates. Invertivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while probing for insects, grooming, or other activities. Ingestion of soil while feeding is a potential exposure pathway for terrestrial invertivores since much of their food (i.e., earthworms and other invertebrates) lives on or below the soil surface.

Typical terrestrial invertivorous species that could be expected to occur at the BBGR Ranges and are commonly used as sentinel species in ecological risk assessment include American woodcock (*Philohela minor*), Carolina wren (*Thryothorus ludovicianus*), shorttail shrew (*Blarina brevicauda or Blarina carolinensis*), and eastern mole (*Scalopus aquaticus*). Aquatic invertivores (those species that live in water) could include the wood duck (*Aix sponsa*) and blacknose dace (*Rhinichthys atratulus*).

The ephemeral drainage features at the BBGR Ranges do not provide suitable habitat to support aquatic invertivores. The exception to this is the creek that flows through the southern portion of Range 23, which is perennial in nature. This creek has the potential to support smaller aquatic invertivorous species.

6.3 Omnivorous Feeding Guild

Omnivores consume both plant and animal material in their diet, depending upon availability. Therefore, they could be exposed to chemicals that have accumulated in the vegetative tissues of plants at the site and also chemicals that may have accumulated in smaller animal tissues that the omnivores prey upon. Omnivores may be exposed to site-related chemicals in soil through incidental ingestion of soil while feeding, grooming, or other activities. Omnivores may also be exposed to surface water through ingestion of water in the ephemeral drainage features at the BBGR Ranges.

Typical omnivorous species expected to occur at the BBGR Ranges and are commonly used as sentinel species in ecological risk assessment include red fox (*Vulpes vulpes*), white-footed mouse (*Peromyscus leucopus*), and American robin (*Turdus migratorius*). Aquatic omnivores, such as raccoon (*Procyon lotor*) and creek chub (*Semotilus atromaculatus*) could be exposed to COPECs in surface water and sediment in the drainage features at the BBGR Ranges; however, the ephemeral nature of most of the drainage features precludes their presence due to the lack of suitable habitat. The exception to this is the creek that flows through the southern portion of Range 23, which is perennial in nature. This creek has the potential to support smaller aquatic omnivorous species.

6.4 Carnivorous Feeding Guild

Carnivores are meat-eating animals and are, therefore, potentially exposed to site-related chemicals through consumption of prey animals that may have accumulated constituents in their tissues. Carnivores are quite often top predators in a local food web and are often subject to exposure to constituents that have bioaccumulated in lower trophic-level organisms or biomagnified through the food web. Food web exposures for carnivores are based on the consumption of prey animals that have accumulated COPECs from various means. Smaller, herbivores, omnivores, invertivores, and other carnivores may consume soil, surface water, sediment, plant, and animal material as food and accumulate COPECs in their tissues. Subsequent ingestion of these prey animals by carnivorous animals would expose them to COPECs. Most inorganic compounds and VOCs are not accumulated in animal tissues to any great extent (Shugart et al., 1990 and U.S. Army Environmental Hygiene Agency, 1994). Therefore, food web exposures to these chemicals are expected to be minimal. PAHs have the potential to accumulate in lower trophic level organisms but not in higher trophic level organisms because they have mechanisms for metabolizing and excreting this class of compounds. Chlorinated herbicides and pesticides have the potential to bioaccumulate and biomagnify through the food chain; therefore, there is the potential for significant exposure to these classes of chemicals by carnivores. Carnivores may also be exposed to site-related chemicals in soil through incidental ingestion of soil while feeding, grooming, or other activities.

Typical carnivorous species expected to occur at the BBGR Ranges and are commonly used as sentinel species in ecological risk assessment include red-tailed hawk (*Buteo jamaicensis*), black vulture (*Coragyps atratus*), and bobcat (*Lynx rufus*).

Because the drainage features at the BBGR Ranges are relatively narrow and shallow and ephemeral in nature, they do not have the capability to support large aquatic carnivores on a full-time basis. Carnivorous fish such as largemouth bass (*Micropterus salmoides*) and spotted gar (*Lepisosteus oculatus*) would not be expected to occur in the drainage features at the BBGR Ranges due to the habitat restrictions. Carnivorous mammals such as the mink (*Mustela vison*), may feed along the creek that flows through the southern portion of Range 23 during certain periods of the year when significant water is present in the creek, but most likely would not live adjacent to any of the drainage features at the BBGR Ranges because of the inability of these small drainage features to support large individuals of fish or other aquatic species.

6.5 Piscivorous Feeding Guild

Piscivores are specialists that feed almost exclusively on fish. Therefore, they may be exposed to site-related chemicals that have accumulated in small fish that may inhabit the small drainage features at the BBGR Ranges during periods of significant precipitation. They may also be exposed to surface water and sediment in these drainage features through ingestion of drinking water and during feeding. Because most of the drainage features at the BBGR Ranges are ephemeral in nature, they would only provide a drinking water supply during periods of significant precipitation. The small creek in the southern portion of Range 23 may provide a perennial drinking water source. Although piscivorous species might visit the drainage features at the BBGR Ranges during certain periods of the year when the creek flow is significant, they would not be expected to live near the BBGR Ranges because these drainage features are not large enough to support larger fish species.

Food web exposures for piscivores are based on the consumption of fish that have accumulated COPECs from surface water and sediment. Forage fish may consume surface water, sediment, benthic invertebrates, aquatic plants, and planktonic material as food and accumulate COPECs in their tissues. Subsequent ingestion of these forage fish by piscivorous animals would expose them to COPECs. However, most inorganic compounds are not accumulated in fish tissues to any great extent. Therefore, food web exposures to these chemicals are expected to be minimal. VOCs and SVOCs are readily metabolized by most fish species and are not accumulated to any extent. Thus, the piscivorous feeding guild is not expected to have significant exposure to VOCs or SVOCs at the BBGR Ranges through the food web. Chlorinated herbicides and pesticides have the potential to bioaccumulate and biomagnify through the food chain; therefore, there is the potential for significant exposure to these classes of chemicals by piscivores, if they are present at the BBGR Ranges.

Typical piscivorous species that could occur near the BBGR Ranges and are commonly used as sentinel species in ecological risk assessment include great blue heron (*Ardea herodias*) and belted kingfisher (*Ceryle alcyon*). Larger piscivorous fish species (e.g., smallmouth bass, spotted gar) and piscivorous mammals (e.g., mink) are not expected to occur in the vicinity of the BBGR Ranges due to the habitat limitations of the small drainage features in this area and their inability to support larger fish and other aquatic species.

6.6 Threatened and Endangered Species

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

- Gray Bat (*Myotis grisescens*)
- Blue Shiner (*Cyprinella caerules*)
- 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 the BBGR Ranges is the gray bat (Garland, 1996). The drainage features at the BBGR Ranges have either been designated as providing "low quality" foraging habitat for the gray bat or have not been classified for their potential to provide gray bat foraging habitat (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 the drainage features at the BBGR Ranges. Because gray bats are flying mammals and the BBGR Ranges do 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. Radiotelemetry surveys conducted by 3DI (1997) indicated gray bats do not roost at FTMC and foraging mostly occurs in the vicinity of the Cane Creek golf course. The small, ephemeral streams in the vicinity of the BBGR Ranges do not provide the habitat favored by gray bats and their presence in the vicinity of the BBGR Ranges is unlikely. However, gray bat surveys have not been conducted on the small streams in the vicinity of the BBGR Ranges.

7.0 Selection of Assessment and Measurement Endpoints

Assessment and measurement endpoints are the basis of the Study Design phase of the BERA and define the ecological values that require protection and the methodologies by which those ecological values are measured, respectively. The following sections describe the assessment endpoints that have been identified for the BBGR Ranges, the risk hypotheses, and the corresponding measurement endpoints.

7.1 Assessment Endpoints

An assessment endpoint is "an explicit expression of the environmental value that is to be protected" (EPA, 1992). Assessment endpoints focus the risk assessment on particular valuable components of the ecosystem(s) that could be adversely affected by contaminants at a site. Individual assessment endpoints usually encompass a group of species or populations with some common characteristic, such as a specific exposure route or contaminant sensitivity.

Assessment endpoints for the BERA were selected based on the ecosystems, communities, and species present at the BBGR Ranges. Selection of the assessment endpoints was dependent upon the following factors:

- The COPECs, their characteristics, and their concentrations at the BBGR Ranges;
- The mechanisms of toxicity of the COPECs to different groups of organisms;
- Ecologically relevant receptors that are potentially sensitive or highly exposed to the COPECs; and
- The presence of complete exposure pathways contributing to potential risk.

The potential for toxic effects to individual receptors can have consequences at the population, community, and ecosystem level. Population level effects may determine the nature of changes in community structure and function, such as reduction in species diversity, simplification of food webs, and shifts in competitive advantages among species sharing a limited resource. Ecosystem function may also be affected by contaminants, which can cause changes in productivity or disruption of key processes.

Population level assessment endpoints are generally recognized in ecological risk assessments because of their role in maintaining biological diversity, ecological integrity, and productivity in ecosystems.

The terrestrial habitat types and receptor assemblages at the BBGR Ranges are similar in structure and function and should be considered as a single ecological unit to the extent practicable. As such, terrestrial assessment endpoints were selected to be inclusive of the terrestrial systems and receptors at greatest risk across all of the BBGR Ranges. The habitat and receptor assemblages of South Branch of Cane Creek and Ingram Creek tributaries at the BBGR Ranges were also determined to be similar in structure and function, but drain different areas. Therefore, the assessment endpoints for South Branch of Cane Creek and the Ingram Creek tributaries were the same, even though these tributary systems drain different ranges.

Based on the fact that the COPECs in surface soil at the BBGR Ranges (antimony, beryllium, copper, lead, and zinc) do not bioconcentrate or biomagnify appreciably through the food chain and do not accumulate appreciably in plant tissues (Kabata-Pendias and Pendias, 1992), the terrestrial ecological receptors with the potential for the greatest exposure to COPECs at the BBGR Ranges were determined to be invertivorous and omnivorous small mammals and birds. Herbivores were considered to have a lower exposure potential because the COPECs do not accumulate appreciably in plant tissues, the herbivores' main food source. Carnivores were determined to have lower exposure potential because the COPECs do not biomagnify in the food chain and would not be expected to occur at elevated concentrations in prey animal tissues. Additionally, carnivores in general have larger home ranges which would tend to minimize their exposures to COPECs at the BBGR Ranges. Likewise, piscivores were determined to have lower exposure potential because the COPECs do not bioconcentrate or biomagnify in fish tissue to any appreciable extent and fish are not readily found in the tributaries of South Branch of Cane Creek or Ingram Creek at the BBGR Ranges. Therefore, the terrestrial assessment endpoints focus on the protection of the terrestrial omnivorous and invertivorous feeding guilds present at the BBGR Ranges.

The aquatic assessment endpoints for the BBGR Ranges focus on the protection of benthic communities present in the tributaries of South Branch of Cane Creek and the tributaries of Ingram Creek. Additionally, the protection of riparian insectivorous mammals and birds is an assessment endpoint for the BBGR Ranges. COPECs were not identified in surface water; therefore, no assessment endpoints are identified specifically for surface water. Sediment COPECs were limited to copper, lead, and gamma-chlordane in the Ingram Creek tributaries only. Because COPECs are limited to the sediment in the Ingram Creek tributaries, the maximally exposed receptor populations are those that live in close proximity to the sediment (e.g., benthic invertebrates) and those receptor populations that rely on benthic invertebrates as a major food source (e.g., invertivorous birds and mammals).

7.1.1 Terrestrial Assessment Endpoints

Given the overall goal of protecting the integrity and quality of the terrestrial forest and old field ecosystems at the BBGR Ranges, the terrestrial assessment endpoints focus on critical community niches within the mixed deciduous/coniferous forest and old field systems. As discussed above, the ecological receptors with the potential for the greatest exposure to COPECs at the BBGR Ranges were determined to be invertivorous and omnivorous small mammals and birds. Additionally, the terrestrial plant and terrestrial invertebrate communities have the potential for significant exposure to COPECs. These ecological communities formed the basis for the assessment endpoints described herein.

The terrestrial plant community has the potential to be significantly exposed to COPECs in surface soil and constitutes a critical food source for herbivorous and omnivorous birds and mammals. Terrestrial plants may also accumulate COPECs in their tissues and act as a conduit for the transfer of COPECs to higher trophic level organisms in the food chain. For these reasons, the terrestrial plant community was identified as an important ecological resource at the BBGR Ranges. The assessment endpoint that has been identified with respect to the terrestrial plant community is the following:

- Survival and growth of the terrestrial plant community at the BBGR Ranges.

The terrestrial invertebrate community forms a critical link in many terrestrial food webs and constitutes a food source for many omnivorous and invertivorous birds and mammals. Terrestrial invertebrates also perform an important function in the degradation of organic matter in soil through their bioturbative activities. Terrestrial invertebrates may also accumulate COPECs in their tissues and act as a conduit for the transfer of COPECs to higher trophic level organisms in the food chain. For these reasons, the terrestrial invertebrate community was identified as an important ecological resource at the BBGR Ranges. The assessment endpoint that has been identified with respect to the terrestrial invertebrate community is the following:

- Survival and growth of the terrestrial invertebrate community at the BBGR Ranges.

Invertivorous mammals and birds were identified as having significant potential for exposure to COPECs at the BBGR Ranges, mainly through ingestion of terrestrial invertebrates that may have accumulated COPECs in their tissues. In addition to the fact that this feeding guild has the potential to be maximally exposed to COPECs due to their feeding habits, these species also form an important food group for higher trophic level organisms. Carnivorous mammals and/or birds may prey on small invertivorous mammals and birds and thus become exposed to COPECs through ingestion of COPECs that have become incorporated into the prey species' tissues. For these reasons, invertivorous mammals and birds were identified as being an important ecological resource at the BBGR Ranges. It is important to assess the survival, growth, and reproduction of terrestrial invertivorous small mammals and birds at the BBGR Ranges for the protection of these species themselves, and potentially more importantly, because these species constitute an important food source and a possible conduit for COPECs to upper trophic level organisms. The assessment endpoint that has been identified with respect to the terrestrial invertivorous mammal and bird feeding guilds is the following:

- Survival, growth, and reproduction of terrestrial invertivorous small mammals and birds at the BBGR Ranges.

Omnivorous mammals and birds were identified as having significant potential for exposure to COPECs at the BBGR Ranges, mainly because a portion of their diet includes terrestrial plants and terrestrial invertebrates that may have accumulated COPECs in their tissues. In addition to the fact that this feeding guild has the potential to be maximally exposed to COPECs due to their feeding habits, these species also form an important food group for higher trophic level organisms. Carnivorous mammals and/or birds may prey on small omnivorous mammals and birds and thus become exposed to COPECs through ingestion of COPECs that have become incorporated into the prey species' tissues. For these reasons, omnivorous mammals and birds were identified as being an important ecological resource at the BBGR Ranges. The assessment endpoint that has been identified with respect to the terrestrial omnivorous mammal and bird feeding guilds is the following:

- Survival, growth, and reproduction of terrestrial omnivorous small mammals and birds at the BBGR Ranges.

The assessment endpoints identified for the terrestrial ecosystems at the BBGR Ranges are summarized in Table 7-1.

Because these terrestrial assessment endpoints are highly dependent upon the bioavailability of the COPECs in soil, a study of the binding capacity of soils commonly found at FTMC was conducted and the results presented in the BERA for the Iron Mountain Road (IMR) and Bains Gap Road (BGR) ranges (Shaw, 2004b). In summary, a total of eight surface soil samples from the IMR ranges (Parcels 69Q, 70Q, 71Q, and 75Q) and the BGR ranges (Parcels 77Q, 78Q, 80Q, and 85Q) were collected from five soil mapping units (U.S. Department of Agriculture, 1961): Anniston and Allen gravelly loams; Anniston and Allen stony loams; Stony rough land, sandstone; Jefferson stony fine sandy loam; and Jefferson gravelly fine sandy loam. The results of the binding capacity study showed that the soils at the IMR and BGR ranges could be classified as "low", "medium", or "high" with regard to their potential metal–binding capacity. However, the terrestrial invertebrate toxicity testing and bioaccumulation testing conducted as part of the BERA for the IMR and BGR ranges showed no significant differences in toxicity or bioaccumulation potential between the "high", "medium", or "low" binding capacity soils. Therefore, it was assumed that all of the soils at the IMR and BGR ranges exhibited similar metal-binding capacities.

The vast majority of the soils at the BBGR Ranges are mapped as Anniston and Allen gravelly loams, which is also one of the dominant soil mapping units at the IMR and BGR ranges. The other soil mapping units present at the BBGR Ranges are: Stony Rough Land, sandstone; Stony Rough Land, limestone; Anniston gravelly clay loam; Anniston and Allen stony loam; Philo and Stendal fine sandy loam; and Montevallo shaly silty clay loam. Because the soil mapping units at the BBGR Ranges are the same or similar to the soil mapping units at the IMR and BGR ranges, and all the soil mapping units at the IMR and BGR ranges were found to have similar metal binding capacities, it is assumed for this BERA that the binding capacities for the soils at the BBGR Ranges are all similar and no differentiation will be made between soil mapping units.

7.1.2 Aquatic Assessment Endpoints

The overall goal of the aquatic assessment endpoints is the protection of the integrity and quality of the aquatic ecosystem in South Branch of Cane Creek and its tributaries, and Ingram Creek and its tributaries at the BBGR Ranges. The aquatic assessment endpoints focus on critical community niches within the sediment of South Branch of Cane Creek and its tributaries, and Ingram Creek and its tributaries. Because no COPECs were identified in surface water, surface water will not be the focus of the aquatic assessment at the BBGR Ranges. The ecological receptors with the potential for the greatest exposure to COPECs in the sediment of South Branch of Cane Creek and Ingram Creek at the BBGR Ranges are those populations and communities that live in direct contact with the sediment within South Branch of Cane Creek and Ingram Creek and their tributaries, and those feeding guilds that utilize these creek systems as a major food source. These ecological communities formed the basis for the aquatic assessment endpoints described herein.

The benthic invertebrate community forms a critical link in many aquatic food webs and constitutes a food source for many aquatic and riparian omnivorous and invertivorous birds and mammals. Aquatic benthic invertebrates also perform an important function in the degradation of organic material in sediment. Aquatic benthic invertebrates may also accumulate COPECs in their tissues and act as a conduit for the transfer of COPECs to higher trophic level organisms in the food chain. For these reasons, the aquatic benthic invertebrate community was identified as an important ecological resource at the BBGR Ranges. The assessment endpoint that has been identified with respect to the aquatic benthic invertebrate community is the following:

- Survival, growth, and reproduction of aquatic benthic invertebrates in South Branch of Cane Creek and Ingram Creek and their tributaries at the BBGR Ranges.

Riparian invertivorous mammals and birds were identified as having significant potential for exposure to COPECs at the BBGR Ranges, mainly through ingestion of aquatic benthic invertebrates that may have accumulated COPECs in their tissues. In order to differentiate the invertivores that feed mainly on terrestrial invertebrates from those that feed mainly on aquatic invertebrates, this latter group is termed "riparian invertivores" for this assessment. In addition to the fact that this feeding guild has the potential to be maximally exposed to COPECs in sediment due to their feeding habits, these species also form an important food group for higher trophic level organisms (i.e., raptors). Raptors may prey on flying invertivorous mammals (e.g., bats) and invertivorous birds (e.g., swallows, wrens) and thus become exposed to COPECs through ingestion of COPECs that have become incorporated into the prey species' tissues. For these reasons, riparian invertivorous mammals and birds were identified as being an important ecological resource at the BBGR Ranges. The assessment endpoint that has been identified with respect to the riparian invertivorous mammal and bird feeding guild is the following:

- Survival, growth, and reproduction of riparian invertivorous small mammals and birds at the BBGR Ranges.

The assessment endpoints identified for the BBGR Ranges are summarized in Table 7-1.

7.2 Risk Hypotheses

The risk hypotheses (or risk questions) in a BERA are questions about the relationships among the assessment endpoints and the predicted responses at a given site. The risk hypotheses are based on the assessment endpoints and provide a basis for developing the study design. The most basic question applicable to most sites is whether site-related contaminants are causing or have the potential to cause adverse effects on the assessment endpoints. Using this basic premise, risk hypotheses were developed for the assessment endpoints identified in the previous section.

7.2.1 Terrestrial Risk Hypothesis

Two risk hypotheses were identified as being appropriate to address the assessment endpoint of "survival and growth of the terrestrial plant community" at the BBGR ranges. These risk hypotheses were the following:

- Are concentrations of COPECs in surface soil at the BBGR ranges greater than ecological benchmarks for the survival or growth of terrestrial plants?
- Is the survival and growth of terrestrial plants exposed to surface soil from the BBGR Ranges significantly lower than that for terrestrial plants exposed to soil from reference sites?

The risk hypothesis regarding ecological benchmark values will aid in the interpretation of the toxicity tests results and may help in the identification of the most likely causative agent(s) in the terrestrial plant toxicity tests. The risk hypothesis relative to the terrestrial plant toxicity tests will identify differences in terrestrial plant survivability and growth when exposed to on-site soils and off-site reference soils in laboratory toxicity tests.

Two risk hypotheses were also identified as being appropriate to address the assessment endpoint of "survival and growth of the terrestrial invertebrate community" at the BBGR ranges. These risk hypotheses were the following:

- Are concentrations of COPECs in surface soil at the BBGR ranges greater than ecological benchmarks for the survival or growth of terrestrial invertebrates?
- Is the survival and growth of terrestrial invertebrates exposed to surface soil from the BBGR Ranges significantly lower than that for terrestrial invertebrates exposed to soil from reference sites?

The risk hypothesis regarding ecological benchmark values will aid in the interpretation of the toxicity test results and may help in the identification of the most likely causative agent(s) in the terrestrial invertebrate toxicity tests. The risk hypothesis relative to the terrestrial invertebrate toxicity tests will identify differences in terrestrial invertebrate survivability and growth when exposed to on-site soils and off-site reference soils in laboratory toxicity tests.

The risk hypothesis that was identified as being appropriate to address the assessment endpoint of "survival, growth and reproduction of terrestrial invertivorous small mammals and birds" was determined to be the following:

- Does the daily dose of COPECs received by invertivorous mammals or birds via consumption of the tissues of prey species and from other media at the BBGR Ranges exceed the toxicity reference values (TRV) for survival, reproduction, or growth?

This risk hypothesis will determine whether calculated daily doses of COPECs exceed feeding guild-specific toxicity reference values.

The risk hypothesis that was identified as being appropriate to address the assessment endpoint of "survival, growth, and reproduction of terrestrial omnivorous small mammals and birds" was determined to be the following:

- Does the daily dose of COPECs received by omnivorous small mammals or birds via consumption of tissues of prey species and from other media at the BBGR Ranges exceed the TRVs for survival, reproduction, or growth?

This risk hypothesis will determine whether calculated daily doses of COPECs exceed feeding guild-specific toxicity reference values.

Table 7-1 presents risk hypotheses for each of the terrestrial assessment endpoints. It is important to note that the hypotheses are expressed as a positive response in order to minimize the likelihood of Type II statistical errors (i.e., a false negative decision) at a standard confidence level of $p = 0.05$.

Daily doses of COPECs for terrestrial invertivorous and omnivorous small mammals and birds will be calculated using standard exposure algorithms. These algorithms will incorporate species-specific natural history parameters (i.e., feeding rates, water ingestion rates, dietary composition, etc.) and will also utilize site-specific area use factors (AUF). Additionally, measured COPEC concentrations in earthworms will be used as input to the exposure algorithm as the concentration in the invertebrate portion of the food of the terrestrial invertivorous and omnivorous small mammals and birds. Site-specific bioaccumulation factors will be used to estimate COPEC concentrations in the terrestrial vegetation portions of the receptor species' diets and measured COPEC concentrations in terrestrial plants sampled from on-site locations will also be used in the terrestrial food web model.

In order to calculate COPEC exposures, indicator species that represent the feeding guilds of interest must be identified. For this risk assessment, the small terrestrial invertivorous mammal will be represented by the shorttail shrew (*Blarina brevicauda*) and the terrestrial invertivorous bird will be represented by the American woodcock (*Philohela minor*). The small terrestrial omnivorous mammal will be represented by the white-footed mouse (*Peromyscus leucopus*) and the terrestrial omnivorous bird will be represented by the American robin (*Turdus migratorius*). Natural history parameters for these indicator species (Table 7-2) will be used in combination with site-specific exposure parameters to estimate exposures to terrestrial invertivorous and omnivorous small mammals and birds at the BBGR Ranges.

The algorithm that will be used to estimate exposures to COPECs by terrestrial invertivorous and omnivorous small mammals and birds is the following:

$$TDD_{wildlife} = [(IR_{food} \times f_{worm} \times C_{worm}) + (IR_{food} \times f_{veg} \times C_{veg}) + (IR_{water} \times C_{water}) + (IR_{food} \times f_{soil} \times \{1 - M_{diet}\} \times C_{soil})] \times AUF$$

where:

$TDD_{wildlife}$	=	total daily dose of COPEC received by omnivorous or invertivorous mammals or birds through ingestion (mg/kg/day);
IR_{food}	=	ingestion rate of food by receptor species (kg/kg/day);
f_{worm}	=	fraction of daily diet comprised of invertebrates (percent);
C_{worm}	=	concentration of COPEC in invertebrate tissue (mg/kg);
f_{veg}	=	fraction of daily diet comprised of vegetation (percent);
C_{veg}	=	concentration of COPEC in terrestrial vegetation (mg/kg);
IR_{water}	=	ingestion rate of water by omnivorous mammals or birds (L/kg/day);
f_{water}	=	fraction of drinking water from the BBGR Ranges (percent);
C_{water}	=	concentration of COPEC in drinking water (mg/L);
f_{soil}	=	fraction of daily diet comprised of soil (percent);
M_{diet}	=	weighted average moisture content of diet (percent);
C_{soil}	=	concentration of COPEC in soil (mg/kg); and
AUF	=	area use factor (fraction of site used by receptor species (percent).

Because portions of the receptor species' diets consist of vegetative material, COPEC concentrations in terrestrial plant matter will need to be estimated in order to calculate a total COPEC dose. The COPEC concentrations in terrestrial plant matter will be estimated using site-specific plant BAFs determined through the collection and analysis of co-located soil and terrestrial plant tissue samples. These plant BCFs will be applied to the soil concentrations of COPECs to estimate concentrations of COPECs in terrestrial vegetative food material in the following manner:

$$C_{veg} = C_{soil} \times BCF_{veg} \times (1 - M_{veg})$$

where:

C_{veg} = COPEC concentration in terrestrial vegetation (mg/kg, wet weight);
C_{soil} = COPEC concentration in soil (mg/kg, dry weight);
BCF_{veg} = soil-to-plant bioconcentration factor (unitless); and
M_{veg} = average moisture of vegetative material in diet (percent).

Measured plant tissue concentrations from on-site terrestrial plant samples will also be used in the terrestrial food web model.

The soil ingestion rate for the receptor species is most often represented as a percentage of a receptor species' diet. In order to account for the methodology used in the estimation of the soil ingestion rates, the moisture content of the receptor species' diets must be accounted for. The relationship used to estimate the soil ingestion rates for the terrestrial invertivorous and omnivorous small mammals and birds that have been identified as receptors in this ecological risk assessment is as follows:

$$IR_{soil} = IR_{food} \times Diet_{soil} \times (1 - M_{diet})$$

where:

IR_{soil} = ingestion rate of soil (kg/kg/day, dry weight);
IR_{food} = ingestion rate of food (kg/kg/day, wet weight);
$Diet_{soil}$ = portion of diet that is soil (percent); and
M_{diet} = weighted-average moisture content of receptor species' diet (percent).

The moisture contents of the invertebrate and vegetative material in the receptor species' diets were referenced from the EPA's *Wildlife Exposure Factors Handbook* (EPA, 1993) and are as follows:

- Earthworms - 84%
- Fruit - 77%
- Roots / young grass - 82%
- Seeds - 9.3%
- Fruit / young grass - 78%

The weighted-average moisture contents of the diets of the receptor species of interest are as follows:

		Percent Moisture	Weighted-Average Moisture Content
White-footed mouse:			
invertebrates	=	84%	53.9%
vegetation	=	43.6%	
American robin:			
invertebrates	=	84%	79.6%
vegetation	=	77%	
Shorttail shrew:			
invertebrates	=	84%	83.8%
vegetation	=	82%	
American woodcock:			
invertebrates	=	84%	80.3%
vegetation	=	9.3%	

It was also assumed that if a receptor species' diet contained multiple vegetative components, then the percentage of each vegetative component would be equal. For instance, the vegetative component of the shorttail shrew's diet was assumed to be comprised of 50 percent roots and 50 percent young grass.

Dietary composition of the indicator species will be simplified for modeling purposes but will incorporate the major food types for the different feeding guilds. It will be assumed that food intake for invertivores is comprised almost entirely of terrestrial invertebrates (i.e., earthworms). It will also be assumed that omnivores consume both plant and animal material, a portion of which will consist of terrestrial invertebrates.

The AUFs for each of the indicator species will take into account the home range and habitat requirements for each species and the size of the contaminated areas and viable habitat at the BBGR Ranges.

The use of measured COPEC concentrations in earthworms and terrestrial plants from a broad range of soil concentrations will allow for the calculation of daily doses at a number of different COPEC concentrations. Different COPEC concentrations in the various exposure media will provide valuable information necessary to estimate media concentrations that are protective of the ecological communities at the BBGR Ranges.

7.2.2 Aquatic Risk Hypothesis

Three risk hypotheses were identified as being appropriate to address the assessment endpoint of "survival, growth, and reproduction of aquatic benthic invertebrates in South Branch of Cane Creek and Ingram Creek at the BBGR Ranges." The first risk hypothesis relative to benthic invertebrates in South Branch of Cane Creek and Ingram Creek and their tributaries was the following:

- Are the concentrations of COPECs in sediment samples from South Branch of Cane Creek and Ingram Creek and their tributaries at the BBGR Ranges greater than ecological benchmark values for the survival, growth, and reproduction of aquatic invertebrates?

This risk hypothesis will aid in the interpretation of the toxicity test results and may help in the identification of the most likely causative agent(s) in the aquatic invertebrate toxicity tests.

The second risk hypothesis relative to benthic invertebrates in South Branch of Cane Creek and Ingram Creek and their tributaries was the following:

- Is the survival and growth of aquatic benthic invertebrates exposed to sediment from South Branch of Cane Creek and Ingram Creek and their tributaries at the BBGR Ranges significantly lower than that for aquatic benthic invertebrates exposed to sediment from reference sites?

This risk hypothesis will identify differences in aquatic benthic invertebrate survivability and growth when exposed to on-site sediments from South Branch of Cane Creek and Ingram Creek, and off-site reference sediments in laboratory toxicity tests.

The third risk hypothesis relative to benthic invertebrates in South Branch of Cane Creek and Ingram Creek and their tributaries was the following:

- Is the benthic community structure (using Rapid Bioassessment Protocol [RBP] II) significantly different in reaches of the South Branch of Cane Creek and Ingram Creek and their tributaries at the BBGR Ranges compared to benthic communities in a non-impacted reference stream?

This risk hypothesis will identify differences in aquatic benthic invertebrate community structure in reaches of the South Branch of Cane Creek and Ingram Creek and their tributaries when compared to the benthic invertebrate community structure in a non-impacted stream using in-situ RBP II assessment techniques.

The risk hypothesis that was identified as being appropriate to address the assessment endpoint of "survival, growth, and reproduction of riparian invertivorous mammals and birds" was determined to be the following:

- Does the daily dose of COPECs received by riparian invertivorous small mammals or birds via consumption of tissues of prey species and from other media at the BBGR Ranges exceed the TRVs for survival, reproduction, or growth?

This risk hypothesis will determine whether calculated daily doses of COPECs exceed feeding guild-specific toxicity reference values and will determine if COPECs in sediment have the potential to be transferred through the riparian food chain via aquatic insects.

Table 7-1 presents risk hypotheses for each of the aquatic assessment endpoints. It is important to note that the hypotheses are expressed as a positive response in order to minimize the likelihood of Type II statistical errors (i.e., a false negative decision) at a standard confidence level of $p = 0.05$.

Daily doses of COPECs for riparian invertivorous mammals and birds will be calculated using standard exposure algorithms. These algorithms will incorporate species-specific natural history parameters (i.e., feeding rates, water ingestion rates, dietary composition, etc.) and will also use site-specific AUFs. Laboratory-derived bioaccumulation factors will be used to estimate COPEC concentrations in the aquatic insect portions of the receptor species' diets. In addition, measured concentrations of COPECs in chironomid tissues will also be used as input to the riparian food web model to calculate dosages of COPECs potentially received by the riparian receptor species.

In order to calculate COPEC exposures, indicator species that represent the feeding guilds of interest must be identified. For this risk assessment, the riparian invertivorous mammal will be represented by the little brown bat (*Myotis lucifugus*) and the riparian invertivorous bird will be represented by the marsh wren (*Cistothorus palustris*). Natural history parameters for these indicator species (Table 7-3) will be used in combination with site-specific exposure parameters to estimate exposures to riparian invertivorous mammals and birds at the BBGR Ranges.

The following algorithm will be used to estimate exposures to COPECs by riparian invertivorous mammals and birds:

$$TDD_{wildlife} = \left[\left(IR_{food} \times f_{insect} \times \left\langle C_{sed} \times BCF_{insect} \times \{1 - M_{insect}\}\right\rangle\right) + \left(IR_{water} \times C_{water}\right)\right] \times AUF$$

where:

$TDD_{wildlife}$	=	total daily dose of COPEC received by riparian invertivorous mammals or birds through ingestion (mg/kg/day);
IR_{food}	=	ingestion rate of food by receptor species (kg/kg/day);
f_{insect}	=	fraction of daily diet comprised of benthic invertebrates (percent);
C_{sed}	=	concentration of COPEC in sediment (mg/kg);
IR_{water}	=	ingestion rate of water by invertivorous mammals or birds (L/kg/day);
f_{water}	=	fraction of drinking water from the BBGR ranges (percent);
C_{water}	=	concentration of COPEC in drinking water (mg/L);
M_{insect}	=	average moisture content of benthic invertebrates (percent); and
AUF	=	area use factor (fraction of site used by receptor species) (percent).

It will be assumed that the receptor species' diets consist entirely of emergent benthic invertebrates; therefore, COPEC concentrations in benthic invertebrate tissues will need to be estimated in order to calculate a total COPEC dose. The COPEC concentrations in benthic invertebrate tissue will be estimated using laboratory-derived sediment-to-invertebrate BCF values as described in Appendix B. Measured COPEC concentrations in chironomid tissues from the bioaccumulation tests will also be used as input to the riparian food web model. The total daily doses of COPECs received by the riparian invertivorous mammals and birds will not include the ingestion of soil or sediment as the receptors' diets are assumed to consist solely of emergent aquatic insects and the potential for exposure to site-related soil or sediment is minimal for these receptors. The moisture content of the receptor species' diets will be assumed to be 84 percent (moisture content of terrestrial invertebrates) (EPA, 1993).

The AUFs for each of the indicator species will take into account the home range and habitat requirements for each species and the size of the contaminated areas and viable habitat at the BBGR Ranges.

The calculation and measurement of COPEC concentrations in benthic invertebrates from a broad range of sediment concentrations will allow for the calculation of daily doses at a number of different COPEC concentrations. Different COPEC concentrations in the sediment will provide valuable information necessary to estimate media concentrations that are protective of the aquatic ecological communities at the BBGR Ranges.

7.3 Selection of Measurement Endpoints

A measurement endpoint is "a measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint" and is a measure of biological effects (e.g., mortality, reproduction, growth) (EPA, 1992). Measurement endpoints are frequently numerical expressions of observations (e.g., toxicity test results, community diversity measures) that can be compared statistically to a control or reference site to detect adverse responses to site contaminants.

7.3.1 Terrestrial Measurement Endpoints

The terrestrial measurement endpoints described herein have been designed such that the information garnered from them can adequately address the assessment endpoints identified previously.

In order to facilitate the interpretation of the plant toxicity tests results and aid in the identification of the most likely causative agent(s) in the terrestrial plant toxicity tests, the following measurement endpoint has been identified:

- Comparison of COPEC concentrations in surface soil at the BBGR ranges to ecological benchmarks for the survival or growth of terrestrial plants.

The measurement endpoint that has been identified to address the assessment endpoint of "survival and growth of the terrestrial plant community at the BBGR Ranges" is the following:

- Statistical comparison of perennial ryegrass seed germination success, plant height, above ground biomass, root length, and root biomass between plants grown in on-site soils from the BBGR Ranges to plants grown in soils from a non-impacted reference location.

In order to facilitate the interpretation of the terrestrial invertebrate toxicity test results and aid in the identification of the most likely causative agent(s) in the terrestrial invertebrate toxicity tests, the following measurement endpoint has been identified:

- Comparison of COPEC concentrations in surface soil at the BBGR ranges to ecological benchmarks for the survival or growth of terrestrial invertebrates.

The measurement endpoint that has been identified to address the assessment endpoint of "survival and growth of terrestrial invertebrate community at the BBGR Ranges" is the following:

- Statistical comparison of earthworm survival rates and body weights between earthworms exposed to on-site soils from the BBGR Ranges to earthworms exposed to soils from a non-impacted reference location.

The measurement endpoint that has been identified to address the assessment endpoint of "survival, growth, and reproduction of terrestrial invertivorous small mammals and birds at the BBGR Ranges" is the following:

- Comparison of calculated total daily doses of COPECs for invertivorous mammal (shorttail shrew) and invertivorous bird (American woodcock) using measured earthworm tissue concentrations of COPECs to TRVs.

The measurement endpoint that has been identified to address the assessment endpoint of "survival, growth, and reproduction of terrestrial omnivorous small mammals and birds at the BBGR Ranges" is the following:

- Comparison of calculated total daily doses of COPECs for omnivorous mammal (white-footed mouse) and omnivorous bird (American robin) using measured earthworm tissue concentrations of COPECs and modeled terrestrial vegetation concentrations to TRVs.

In order to estimate the bioavailability of the COPECs in soil at the BBGR Ranges, and to provide data for the other assessment endpoints, a second measurement endpoint has been established to address the assessment endpoints of "survival, growth, and reproduction of terrestrial invertivorous small mammals and birds at the BBGR Ranges" and "survival, growth, and reproduction of terrestrial omnivorous small mammals and birds at the BBGR Ranges". This measurement endpoint is the following:

- Quantification of COPEC concentrations in tissues of earthworms exposed to soils from the BBGR Ranges and tissues of earthworms exposed to soils from a non-impacted reference location.

In order to provide site-specific information regarding the potential for COPEC accumulation in plant tissues, and its effect on the food web interactions of herbivores and omnivores at the BBGR Ranges, the following measurement endpoint has been identified:

- Quantification of COPEC concentrations in above-ground plant tissues exposed to soils from the BBGR Ranges and above-ground plant tissues exposed to soils from a non-impacted reference location.

These measurement endpoints will provide the necessary data to answer the risk hypotheses for the terrestrial ecosystems at the BBGR Ranges presented in previous sections of this report. An important factor in assessing these measurement endpoints is an understanding of the degree of impairment to a biological attribute that is understood to be biologically or ecologically significant. Statistically significant differences in population survivability, growth, reproduction, or hazard quotient values that cannot be related to biological or ecological significance should not be interpreted as indicating a population or community is at risk or that a remedy is necessary. Therefore, ecological and biological significance will be considered within the context of these measurement endpoints.

Table 7-1 presents the measurement endpoints corresponding to each assessment endpoint and risk hypothesis. The methodologies used to collect the necessary data and how the data will be used to answer the risk hypotheses are presented in the following chapters.

7.3.2 Aquatic Measurement Endpoints

The aquatic measurement endpoints described herein have been designed such that the information garnered from them can adequately address the assessment endpoints identified previously.

In order to facilitate the interpretation of the aquatic benthic invertebrate toxicity test results and aid in the identification of the most likely causative agent(s) in the benthic invertebrate toxicity tests, the following measurement endpoint has been identified:

- Comparison of COPEC concentrations in sediment from the South Branch of Cane Creek and Ingram Creek and their tributaries at the BBGR Ranges to ecological benchmarks for the survival or growth of aquatic benthic invertebrates.

The measurement endpoints that have been identified to address the assessment endpoint of "survival, growth, and reproduction of aquatic benthic invertebrates in South Branch of Cane Creek and Ingram Creek and their tributaries at the BBGR Ranges" are the following:

- Comparison of survival and growth of the benthic amphipod *Chironomus riparius* exposed to "on-site" sediment to survival and growth of *Chironomus riparius* exposed to sediment from a reference stream.
- Comparison of the benthic community assemblage from South Branch of Cane Creek and Ingram Creek and their tributaries at the BBGR Ranges with the benthic community assemblages from a reference stream using RBP II methodology.

The measurement endpoint that has been identified to address the assessment endpoint of "survival, growth, and reproduction of riparian invertivorous small mammals and birds at the BBGR Ranges" is the following:

- Comparison of calculated total daily doses of COPECs for riparian invertivorous mammal (little brown bat) and invertivorous bird (marsh wren) using modeled and measured tissue concentrations of COPECs in emergent benthic invertebrates to TRVs.

In order to provide site-specific information regarding the potential for COPEC accumulation in benthic invertebrate tissues, and its effect on the food web interactions of riparian invertivorous mammals and birds, the following measurement endpoint has been identified:

- Quantification of COPEC concentrations in tissues of chironomids exposed to sediment from South Branch of Cane Creek and Ingram Creek and their tributaries and tissues of chironomids exposed to sediment from a non-impacted reference stream.

These measurement endpoints will provide the necessary data to answer the risk hypotheses for the aquatic ecosystems at the BBGR Ranges presented in previous sections of this report. An important factor in assessing these measurement endpoints is an understanding of the degree of impairment to a biological attribute that is understood to be biologically or ecologically significant. Statistically significant differences in population survivability, growth, reproduction, or hazard quotient values that cannot be related to biological or ecological significance should not be interpreted as indicating a population or community is at risk or that a remedy is necessary. Therefore, ecological and biological significance will be considered within the context of these measurement endpoints.

Another important factor to recognize while interpreting the results of the toxicity tests is the fact that the organisms used in the laboratory toxicity tests may not be indigenous to the Fort McClellan area. As such, the laboratory species may be more or less sensitive to the COPECs than indigenous organisms. Therefore, the results of the toxicity tests and the conclusions rendered from these tests will consider these uncertainties.

Table 7-1 presents the measurement endpoints corresponding to each assessment endpoint and risk hypothesis. The methodologies used to collect the necessary data and how the data will be used to answer the risk hypotheses are presented in the following chapters.

8.0 Data Quality Objectives

Data quality objectives (DQO) are "qualitative and quantitative statements that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions" (EPA, 2000b). The DQO process enables investigators to define performance criteria and limit the likelihood of committing Type I or Type II decision errors. EPA's DQO process is a seven-step process for the development of acceptance criteria. The initial five steps of the process are focused on identifying qualitative criteria, while the sixth and seventh steps define quantitative criteria and a data collection design, respectively. The seven steps are addressed below in Sections 8.1 through 8.7.

8.1 Problem Statement

The SLERA conducted for the BBGR Ranges (Shaw, 2004a) identified five metals (antimony, beryllium, copper, lead, and zinc) as COPECs in surface soil. In addition, copper, lead, and gamma-chlordane were identified as COPECs in sediment in Ingram Creek tributaries. No COPECs were identified in surface water or groundwater.

The BBGR Ranges Problem Formulation and SCM (Chapters 1.0 through 7.0) suggest that COPEC exposure pathways to terrestrial and aquatic receptors do exist and, therefore, require further study. The Problem Formulation process further identified the need for additional information to address questions related to constituent bioavailability, bioaccumulation potential, and site-specific toxicity.

Based on the findings of the SLERA and Problem Formulation, the objectives of the BERA for the BBGR Ranges include the following:

- Collect site-specific data to address bioavailability and bioaccumulation potentials in lower trophic level organisms that form the basis of the terrestrial and aquatic food webs at the BBGR Ranges.

- Collect site-specific data to address the existence and level of site-specific toxicity to terrestrial and aquatic receptors resulting from exposure to the COPECs.

- Determine the concentrations of the COPECs within the surface soils and sediment at the BBGR Ranges at which the ecological receptors are at risk.

- Provide data of sufficient quality to develop a technically defensible characterization of risk at the BBGR Ranges for use by risk managers in their acceptance or rejection of present and future ecological risks posed by the COPECs in surface soil and sediment and, if necessary, develop ecologically-based cleanup criteria.

8.2 Decision Identification

The following decisions require site-specific data in order to address the issues identified in the Problem Statement presented in the previous section.

- Determine if the COPECs at the BBGR Ranges are available for uptake (i.e., bioavailable) in terrestrial or aquatic systems
- Determine what levels of COPECs in soil and sediment promote acute or chronic toxicity to terrestrial and aquatic receptors
- Determine if the COPECs bioaccumulate in the tissues of terrestrial invertebrates (e.g., earthworms), terrestrial plants, or benthic invertebrates, and if so, to what extent
- Determine whether the tissue burdens of COPECs in terrestrial invertebrates have the potential to pose adverse effects to higher trophic level organisms that utilize terrestrial invertebrates as a major food source
- Determine whether the tissue burdens of COPECs in terrestrial plants have the potential to pose adverse effects to higher trophic level organisms that utilize terrestrial plants as a major food source
- Determine whether benthic communities within South Branch of Cane Creek and Ingram Creek and their tributaries are adversely affected by exposure to COPECs in sediment
- Determine whether the concentrations of COPECs in emergent benthic invertebrates have the potential to pose adverse effects to higher trophic level organisms that utilize emergent benthic invertebrates as a major food source
- Develop constituent-specific cleanup goals for soil or sediment if the BERA concludes that there is the potential for unacceptable ecological risk.

8.3 Decision Inputs

This step identifies the information required to support the decisions identified above. The information that will be required includes the following:

- Surface soil concentrations (mg/kg) of the five surface soil COPECs;
- Earthworm mortality based on earthworm LC_{50} (lethal concentration killing 50 percent of the test population) data (mg/kg);

- Earthworm growth based on total tissue weight measured at the termination of the toxicity test;
- Bio-uptake and accumulation potential in terrestrial invertebrates based on the ratio of soil COPEC concentrations to earthworm tissue concentrations;
- Terrestrial plant growth and reproduction based on seed germination success, plant height, above-ground biomass, root length, and below-ground biomass;
- Bio-uptake and accumulation potential in terrestrial plants based on the ratio of soil COPEC concentrations to plant tissue concentrations;
- Total daily dose estimates of the five soil COPECs in the terrestrial invertivorous shorttail shrew and American woodcock, as well as the omnivorous American robin and white-footed mouse (milligrams of COPEC per unit of body mass per day);
- Estimated levels of concern for the invertivorous shorttail shrew and American woodcock as well as the omnivorous American robin and white-footed mouse based on modeled hazard quotient (HQ) values (estimated total daily dose/literature-based effect value);
- Sediment concentrations of copper, lead, and gamma-chlordane;
- *Chironomus riparius* mortality based on exposure to various COPEC concentrations in sediment and derivation of sediment LC50 values;
- Bio-uptake and accumulation potential based on the ratio of sediment COPEC concentrations in South Branch of Cane Creek and Ingram Creek to *Chironomus sp*. tissue concentrations;
- Projected dose estimates of the COPECs in the riparian invertivorous little brown bat and marsh wren (mg COPEC per unit of body mass per day);
- Estimated levels of concern to the riparian invertivorous little brown bat and marsh wren based on modeled HQ values (estimated total daily dose/literature-based effect value);
- Benthic invertebrate community structure as determined by rapid bioassessment measurements.

These data will be used to help determine whether COPECs in surface soil or sediment at the BBGR Ranges present (or will present) significant risk to ecological receptors. If ecological risks are predicted using the information presented above, then this information will also be used to determine the concentrations of COPECs in surface soil or sediment that are protective of the terrestrial and aquatic receptors at the BBGR Ranges.

8.4 Study Boundaries

Study boundaries define the spatial scale of the assessment at the BBGR Ranges. In order to conduct a useful BERA, it is imperative to define the geographic and temporal boundaries of the potential risk and to identify the target populations of interest. The BBGR Ranges consist of eight small-arms firing ranges (Ranges 18, 20, 23, 25, 25-East, 28, 26, and the Ranges South of Range 25) as well as South Branch of Cane Creek and Ingram Creek and their tributaries. The BBGR SLERA identified the terrestrial forest and oldfield ecosystems at the BBGR Ranges and the aquatic habitats associated with South Branch of Cane Creek and Ingram Creek as the habitats at greatest potential risk given their quality, level of contamination, and receptors likely to be exposed to the COPECs. Therefore, the BBGR BERA will focus on the forest and oldfield terrestrial and aquatic ecosystems associated with these ranges.

Additionally, based on the historical nature of the contamination at the BBGR Ranges, and the physical/chemical properties of most of the COPECs themselves, the concentrations of the COPECs in surface soil and sediment are not likely to change over time due to natural processes. Therefore, temporal variability of COPEC concentrations is not considered an important variable for these relatively static upland and riparian habitats.

The target populations for the BERA are the resident aquatic and terrestrial invertebrate communities and the wildlife feeding guilds that may be present within the bounds of the BBGR Ranges. Given the COPECs' relatively low propensity for biomagnification up food chains, the target populations of greatest concern are the lower trophic level organisms (e.g., earthworms and benthic invertebrates) and the wildlife receptors that feed on them.

8.5 Decision Rule

The objective in developing specific decision rules is to construct theoretical "if…then…" statements relative to the ecological habitats, populations, and COPECs. These statements can then be used by risk managers in deciding whether to accept or reject the characterized risk and, if necessary, in generating ecological-based cleanup goals. The decision rules proposed for the BBGR Ranges BERA include the following:

- If COPECs in soils from the BBGR Ranges cause terrestrial plant toxicity (e.g., reduced seed germination, reduced plant height, reduced above-ground biomass, reduced root length, reduced root biomass) which is statistically greater than plant toxicity in soils from a reference site, then there is the potential for unacceptable risks to terrestrial plants at the BBGR Ranges.

- If terrestrial plants exposed to soils from the BBGR Ranges demonstrate statistically higher tissue concentrations of COPECs than terrestrial plants exposed to reference soils, then there is the potential for significant COPEC accumulation in terrestrial plant tissues.

- If COPECs in soils from the BBGR Ranges cause acute earthworm toxicity which is statistically greater than earthworm toxicity in soils from a reference site, then there is the potential for unacceptable risks to terrestrial invertebrate receptors at the BBGR Ranges.

- If earthworms exposed to soils from the BBGR Ranges demonstrate statistically higher tissue concentrations of COPECs than earthworms exposed to reference soils, then there is the potential for significant COPEC accumulation in terrestrial invertebrate tissues.

- If calculated doses of COPECs for terrestrial invertivorous mammals or birds are greater than literature-derived toxicity reference values, then there is the potential for risk to terrestrial invertivorous mammals or birds at the BBGR Ranges.

- If calculated doses of COPECs for terrestrial omnivorous mammals or birds are greater than literature-derived toxicity reference values, then there is the potential for risk to terrestrial invertivorous mammals or birds at the BBGR Ranges.

- If, based on the collective evaluation of the lines-of-evidence, COPECs are determined to pose unacceptable risks to terrestrial receptors at the BBGR Ranges, then remedial goals for soil will be developed using the data collected during the BERA.

- If COPECs within the sediments of South Branch of Cane Creek or Ingram Creek and their tributaries cause acute toxicity to the benthic invertebrate *Chironomus sp.*, which is statistically greater than toxicity from reference sediments, then there is the potential for risk to emergent benthic invertebrates at the BBGR Ranges.

- If chironomids exposed to sediment from South Branch of Cane Creek or Ingram Creek and their tributaries demonstrate statistically higher tissue concentrations of COPECs than chironomids exposed to reference sediment, then there is the potential for significant COPEC accumulation in benthic invertebrate tissue.

- If the benthic community assemblage in South Branch of Cane Creek or Ingram Creek and their tributaries at the BBGR Ranges is significantly different than the benthic community assemblage in a non-impacted reference stream, then there is the potential for risk to South Branch of Cane Creek or Ingram Creek benthic ecosystem.

- If calculated doses of COPECs for riparian invertivorous mammals or birds are greater than literature-derived toxicity reference values, then there is the potential for risk to riparian invertivorous mammals or birds at the BBGR Ranges.

It is important to consider the role of background concentrations of COPECs when developing specific decision rules. It is possible that naturally occurring concentrations of certain inorganic constituents in environmental media could result in a determination of unacceptable risk. Therefore, background will be considered within the context of each of the aforementioned decision rules.

It is also important to consider the effects that physical disturbance of the ecosystems at many of the BBGR Ranges may have on the ecology. Routine maintenance activities at many of these ranges (e.g., grading of soil, removal of trees, continuous mowing of grass) have altered the ecosystems greatly from their "native" state and it may take many years for the "native" ecosystems to re-establish themselves. For instance, the grading of soil may have removed the very shallow layer of topsoil from certain range areas. Without the layer of topsoil, it is very difficult for certain plant species to establish themselves and grow successfully. Therefore, physical disturbance of a site will also be considered when interpreting the results the established decision rules.

8.6 Tolerable Limits on Decision Errors

Chemical and biological data obtained as part of the BERA process will be collected in a manner such that they are representative of the abiotic media and biotic communities at the BBGR Ranges. Since the collected data are only small sub-populations of the entire BBGR Ranges, they can only be used to predict responses that may actually occur at these ranges under natural conditions. As such, these data must be interpreted with a level of confidence or probability that will be less than 100 percent error free. The objective in establishing tolerable probability limits is to generate the proper quantity and quality of data to meet the targeted limit. The decision data employed in the BERA will be of sufficient quantity and quality as to result in a decision confidence level of 95 percent. The tolerable limit will be made on statistical probabilities of less than 95 percent.

8.7 Design Optimization

The objective in design optimization is to develop a "resource-effective" sampling and analysis plan for generating data. The sampling and analysis plans presented in Appendices A and B have been optimized to ensure that the tolerable limits on decision errors will be met.

9.0 Site Investigation Tasks

The BERA for the BBGR Ranges will focus on characterizing risk associated with the COPECs in surface soil within the forest and oldfield terrestrial habitats, as well as sediments within South Branch of Cane Creek and Ingram Creek and their tributaries. The site investigation tasks are directly linked to the assessment and measurement endpoints described within Chapter 7.0.

The principal objective of this investigation is to outline a laboratory- and field-based approach to reduce uncertainty associated with the SLERA process and to provide risk managers with information to incorporate into site remedial decisions. It is important to note that the study outlined in this section is designed to provide a number of lines of evidence relative to present and future risks to terrestrial and aquatic receptors.

9.1 Terrestrial Receptor Study Design

The tasks involved in the study design for terrestrial ecosystems at the BBGR Ranges are described in the following sections.

9.1.1 Soil Samples for Chemical Analysis

Surface soil samples (0 to 0.5 feet below ground surface) will be collected from nine locations within the study areas of the BBGR Ranges. Figure 9-1 presents the sample locations for each of the surface soil samples at the BBGR Ranges. These nine locations will represent the lead concentrations most likely to elicit adverse effects on terrestrial plants and terrestrial invertebrates at the BBGR Ranges. Table 9-1 presents the proposed surface soil sampling locations and the historical lead concentrations detected at these locations. Locations for soil sampling will be identified using in-situ x-ray fluorescence technology. These surface soil samples will be analyzed for TAL metals, VOCs, SVOCs, chlorinated pesticides, organophosphorus pesticides, chlorinated herbicides, total organic carbon, pH, and grain size. Additionally, one soil sample will be collected from an area that is un-impacted by FTMC activities. This soil sample will represent the reference soil.

Analytical data from these surface soil samples will be used in conjunction with the perennial ryegrass and earthworm toxicity test results to derive LOAELs and NOAELs for terrestrial plants and earthworms. These soil data will also be used in the food web models to calculate total COPEC doses for the terrestrial invertivorous and omnivorous birds and mammals. Additionally, these soil data will be used in conjunction with the measured tissue concentrations of COPECs in earthworms and terrestrial plants to estimate soil-to-earthworm bioaccumulation factors, and soil-to-plant bioaccumulation factors, respectively.

Details of the collection methods, decontamination procedures, quality assurance/quality control, and other sampling procedures are presented in the installation-wide sampling and analysis plan (IT, 2002) and are summarized in Appendix A of this report.

9.1.2 Soil Samples for Earthworm Toxicity Tests

Assessment of the terrestrial invertebrate community associated with BBGR Ranges surface soils will be based on quantitative laboratory testing using the detritivorous earthworm. The earthworm's bioturbative feeding habits, its ability to bioaccumulate the identified COPECs, and its critical position in terrestrial food webs make it an ideal surrogate to represent the terrestrial invertebrate community.

Earthworm toxicity testing will use surface soil from the nine on-site sample locations identified in the previous section. As is the case with the soil samples for chemical analysis, soil samples for earthworm toxicity testing will be collected from nine locations within the study areas of the BBGR Ranges and one location (reference site) outside of the influence of the BBGR Ranges.

Quantification of possible adverse effects to terrestrial invertebrates and the potential for constituent transfer up the food chain to higher trophic level feeding guilds will be accomplished with the use of earthworm toxicity tests and tissue burden analysis. As a soil-boring detritivore, the common earthworm *(Eisenia fetida)* is an excellent sentinel not only to assess surface soil toxicity, but also to approximate food chain bioaccumulation potential. The earthworm survival test recommended by the EPA (1989) will be employed to assess the potential for risk to members of this critical ecological trophic level. Earthworms have been shown to be acutely sensitive to soil-bound metal toxicity, and they represent a key prey item for mammalian and avian omnivores and invertivores.

Appendix A provides details relative to the EPA-recommended earthworm toxicity test. In brief, the 28-day static earthworm test will consist of exposing 10 worms per test chamber to 100 percent undiluted soil from the BBGR Ranges, soil from a reference location, and laboratory control soil. At the halfway point of the 28-day exposure period (14 days), mortality will be assessed within each test chamber/tray and dead worms will be removed. The 14-day mortality rate will be noted, along with soil pH and temperature. All live worms will be carefully re-introduced into the test soils. This same procedure will be followed upon completion of the test

(28 days), with the exception that all living worms will be preserved in separate containers for COPEC whole-body burden analysis.

Since surface soil lead concentration gradients will be used as exposure gradients, as described in the sampling and analysis plan (Appendix A), data from earthworm tests will consist of 14-day NOAELs and LOAELs as well as 28-day NOAELs and LOAELs. In addition, whole-body tissue burdens for each of the COPECs will be determined. The maximum, mean, and minimum COPEC concentrations in exposed earthworms will be used in the food web models to calculate HQ values for terrestrial omnivorous and invertivorous birds and mammals. By providing three HQ values (maximum, mean, and minimum), a line of evidence will be established regarding biotransfer to higher trophic levels.

Details of the collection methods, decontamination procedures, quality assurance/quality control, and other sampling procedures are presented in the installation-wide sampling and analysis plan (IT, 2002) and are summarized in Appendix A of this report.

9.1.3 Soil Samples for Plant Toxicity Tests

Assessment of the terrestrial plant community associated with BBGR Ranges surface soils will be based on quantitative laboratory testing using the perennial ryegrass (*Lolium perenne*). Perennial ryegrass is a commonly used species for toxicity testing and is an ideal surrogate to represent a number of terrestrial plant species that could colonize the BBGR Ranges.

Perennial ryegrass toxicity testing will use surface soil from the same locations identified in the previous section. As is the case with the soil samples for chemical analysis, soil samples for perennial ryegrass toxicity testing will be collected from nine locations within the study areas of the BBGR Ranges and one location (reference site) outside the influence of the BBGR Ranges.

Quantification of possible adverse effects to terrestrial plants will be accomplished with the use of perennial ryegrass toxicity tests. As a terrestrial perennial plant, the perennial ryegrass *(Lolium perenne)* is an excellent sentinel to assess surface soil toxicity to terrestrial plant species. The perennial ryegrass toxicity test recommended by the American Society for Testing and Materials (ASTM) (1998) will be employed to assess the potential for risk to members of this critical ecological trophic level (primary producers). Perennial ryegrass has been shown to be acutely sensitive to soil-bound metal toxicity, and it represents a key food item for herbivores and omnivores.

Appendix A provides details relative to the ASTM-recommended terrestrial plant toxicity tests. The 28-day perennial ryegrass toxicity test will consist of exposing 10 seeds per container to 100 percent undiluted soil from the BBGR Ranges, soil from a reference location, and laboratory control soil. Five replicates for each of the nine surface soil locations, reference station, and laboratory controls, will be used in the perennial ryegrass toxicity tests. At the termination of the tests, the number of seedlings out of the total number of seeds planted that emerge above the soil will be counted and the germination success calculated. Additional measurements that will be taken include above-ground plant height, total above-ground biomass, below-ground root length, and total below-ground biomass. Additionally, abnormal patterns in growth and development, or abnormal plant morphology as compared to laboratory controls will be noted.

Since surface soil lead concentration gradients will be used as exposure gradients, as described in the sampling and analysis plan (Appendix A), data from perennial ryegrass tests will consist of 21-day NOAELs and LOAELs.

Details of the collection methods, decontamination procedures, quality assurance/quality control, and other sampling procedures are presented in the installation-wide sampling and analysis plan (IT, 2002) and are summarized in Appendix A of this report.

9.1.4 Plant Collection for COPEC Chemical Analysis

The potential for COPEC accumulation in terrestrial plant tissues will be assessed through the collection and chemical analysis of terrestrial plants. Herbivorous and omnivorous animals using the BBGR Ranges as feeding grounds could potentially be exposed to COPECs via plant uptake and accumulation from the soil, with subsequent ingestion by animals. In order to assess this potential uptake and accumulation, terrestrial plants will be collected from the same locations identified in the previous section. As is the case with the soil samples for chemical analysis, terrestrial plant samples will be collected from nine locations within the study areas of the BBGR Ranges and one location (reference site) outside the influence of the BBGR Ranges.

The target plant species for collection at the BBGR Ranges will be grass species since the perennial ryegrass (*Lolium perenne*) is the species that will be used in the laboratory toxicity tests. A grass species will be collected so that inferences can be made between the COPEC accumulation measured in the grass species from the BBGR Ranges and the results of the terrestrial plant toxicity tests conducted in the laboratory using perennial ryegrass. An attempt will be made to collect the same plant species at each sampling location. Only the above-ground portion of each plant will be sampled as most herbivorous and omnivorous species only consume the above-ground portions of most plants.

Plant tissue samples will be analyzed for the COPECs identified in surface soil at the BBGR Ranges (Sb, Be, Cu, Pb, and Zn) so that relationships can be drawn between concentrations of COPECs in surface soil and concentrations of COPECs in co-located terrestrial plant tissues. Details of the collection methods, decontamination procedures, quality assurance/quality control, and other sampling procedures are presented in the installation-wide sampling and analysis plan (IT, 2002) and are summarized in Appendix A of this report.

9.2 Aquatic Study Design

The freshwater stream habitat to be addressed in this quantitative BERA is the sediments in South Branch of Cane Creek and Ingram Creek and their tributaries. The aquatic study design is designed to address exposure and potential effects to receptors within and around South Branch of Cane Creek and Ingram Creek and their tributaries as they flow through the BBGR Ranges. Elevated levels of COPECs may or may not pose a risk to aquatic receptors depending upon their availability for uptake (bioavailability) from the sediments. Therefore, the study is designed to assess bioavailability of the COPECs in sediment as well as the potential for acute or chronic toxicity and biomagnification up the food chain.

The sediment assessment will focus on characterization of risks to benthic invertebrates as well as the upper trophic level organisms that may feed on them. In many ways, sediments represent a more definite assessment of potential risks to aquatic systems because the receptors are generally less mobile and the COPECs can accumulate within depositional zones. Sediment samples will be collected from 12 locations within South Branch of Cane Creek and Ingram Creek and their tributaries representing the full range of lead concentrations detected in sediment during previous investigations at the BBGR Ranges. Lead will be used as the indicator of COPEC concentrations because it has been detected in sediment and has been used as an indicator of contamination resulting from small-arms range activity. Figure 9-2 presents the proposed locations for sediment samples that will be collected to represent the range of COPEC concentrations in sediment at the BBGR Ranges. These sediment samples will be used in the toxicity and bioaccumulation tests described in the following sections. Additionally, a sediment sample will be collected from a stream with similar substrate characteristics as South Branch of Cane Creek and Ingram Creek but outside the influence of the BBGR Ranges. This sediment sample will be used as the reference sediment. Table 9-2 presents a summary of the sediment sample locations and the historical lead and copper concentrations detected in sediment from these locations. All sediment samples will be analyzed for a full suite of inorganic and organic constituents. The COPEC concentrations in sediment samples from South Branch of Cane Creek and Ingram Creek and their tributaries will also be used in the food web models that will be used to calculate the total dose of COPECs potentially received by riparian invertivorous mammals and birds.

Details of the collection methods, decontamination procedures, quality assurance/quality control, and other sampling procedures are presented in the installation-wide sampling and analysis plan (IT, 2002) and are summarized in Appendix B of this report.

9.3 Benthic Invertebrates

In order to evaluate potential toxicity to benthic invertebrates, the standard 10-day *Chironomus riparius* survival and growth test will be conducted using sediment samples collected from South Branch of Cane Creek and Ingram Creek and their tributaries representative of the range of lead detected in sediment samples during previous investigations at the BBGR Ranges. Appendix B references the test protocol for *Chironomus riparius* survival and growth tests. *C. riparius* was selected as the benthic invertebrate test species rather than *C. tentans* because *C. riparius* is more sensitive to metal toxicity. Eight replicates for each of the 12 sediment sample locations, reference stations, and laboratory controls will be used for measurements of lethality and growth. All test organisms will be laboratory reared and less than 24 hours old at test initiation. At the termination of the test, all living chironomids will be preserved in separate containers for COPEC whole-body burden analysis.

Although collected sediments will not be "cut" with reference or laboratory grade sediments to generate a concentration series, the 13 sediment collection sites will represent a gradient of lead concentrations. This field-collected concentration gradient will allow investigators to generate a sediment concentration-based NOAEL and LOAEL in comparison to off-site reference sediments. Additionally, the various sediment concentrations and corresponding chironomid tissue concentrations of COPECs will provide data for the calculation of sediment-to-biota bioaccumulation factors.

In addition to laboratory-based sediment toxicity testing, direct in-field measurements of benthic invertebrate community structure using RBP will be conducted. Direct measurement of biological condition is considered the most effective means of evaluating cumulative impacts of non-point source contamination patterns such as those that may exist within the BBGR Ranges. The presence or absence of habitat degradation assists in evaluating the present level of risk to existing receptors. When combined with laboratory toxicity testing, direct field measurements reduce uncertainty and strengthen the line-of-evidence relative to potential risk levels.

For South Branch of Cane Creek and Ingram Creek and their tributaries in and around the BBGR Ranges, benthic macroinvertebrate surveys will be conducted within riffle and pool zones within South Branch of Cane Creek and Ingram Creek and their tributaries as they flow through and adjacent to the BBGR Ranges. It is important to note the need to carefully compare benthic communities in the areas of concern with comparable communities present in reference areas. For example, due to natural erosional processes and the presence of gravelly/rocky bottoms throughout much of South Branch of Cane Creek and Ingram Creek, a diverse and well-established in-faunal community may not be present. A similar reference area will be located in order to properly compare the benthic assemblage in South Branch of Cane Creek and Ingram Creek to a similar stream un-impacted by small arms range activities. Therefore, great care will be taken in establishing off-site reference locations to ensure that the sediment grain size, total organic carbon, and stream bank makeup are comparable.

The advantages of employing benthic macroinvertebrates as a measure of risk to stream communities include the following (EPA, 1997):

- Macroinvertebrate assemblages are good indicators of localized conditions. Because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life, they are particularly well-suited for assessing site-specific impacts (upstream-downstream studies).

- Macroinvertebrates integrate the effects of short-term environmental variations. Most species have a complex life cycle of approximately one year or more. Sensitive life stages will respond quickly to stress; the overall community will respond more slowly.

- Degraded conditions can often be detected by an experienced biologist with only a cursory examination of the benthic assemblage. Macroinvertebrates are relatively easy to identify to family; many "intolerant" taxa can be identified to lower taxonomic levels with ease.

- Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects.

- Sampling is relatively easy, requires few people and inexpensive gear, and has no detrimental effect on the resident biota.

- Benthic macroinvertebrates serve as a primary food source for many recreationally and commercially important fish.

- Benthic macroinvertebrates are abundant in most streams. Many small streams (i.e., South Branch of Cane Creek and Ingram Creek) may support a diverse macroinvertebrate fauna, but only support a limited fish fauna.

Observations that will be made during the RBP benthic invertebrate survey will include substrate type, surrounding land use, evidence of erosion and pollutant sources, vegetative stream canopy, and other relevant data. In addition to benthic sampling, which will consist of one kick net sample and one coarse particulate organic matter (CPOM) sample, in-situ water quality parameters (temperature, conductivity, dissolved oxygen, pH) will be measured with the use of a Horiba U-10, or similar, water quality instrument. Measurements will be taken at mid-stream at approximately mid-depth. Water quality parameters will be obtained prior to any sampling activities in the stream.

Two macroinvertebrate samples will be collected at each sampling station; the riffle/run sample will be collected with a kick net and the CPOM sample will be collected by hand. All macroinvertebrate samples will be transported to Shaw's Technology Development Laboratory located in Knoxville, Tennessee.

The kick net sample provides data as to the abundance of the scraper and filtering functional feeding groups and is generally collected in a riffle and a run area of the stream. The riffle and run sample will be composited in the field for processing as one sample per location. The kick net consists of a 0.9mm mesh bag attached to a rectangular 8- by 18-inch frame mounted on a handle. The use of the sampler is described as follows:

1. The sampler is positioned securely on the substrate with the opening of the net facing upstream.

2. An area of one square-meter immediately upstream of the sampler is disturbed by overturning and scraping rocks and large stones by shifting the feet to dislodge clinging or attached organisms. Any rocks or other large items that have been swept into the net are examined to ensure that organism removal is complete.

3. The remaining sediment is agitated with the feet to dislodge epibenthic and burrowing organisms.

All organisms and debris such as sticks and leaves will be removed from the kick net bag and placed into a container with 95 percent ethanol to preserve the organisms.

One CPOM sample will be collected at each location from depositional areas of little or no current velocity in the stream. The CPOM sample, which provides data as to the abundance of the shredder feeding group, will be collected by hand including a composite variety of leaves, twigs, bark and other fragments. The collected material and organisms will be placed into a sample container with 95 percent ethanol.

Organisms will be identified in the laboratory to Family level or to the lowest practical taxon. Identification of organisms will be made using published keys such as those developed by Merritt and Cummins (1984), Peckarsky et al. (1990), and Pennak (1989 and 1978). Each family of organisms identified at each location will be placed into separate vials containing ethanol as a preservative in order to assemble a reference collection for the project.

Eight metrics will be calculated from the benthic macroinvertebrate data obtained at each sampling station in accordance with the procedures outlined in EPA's RBP II guidance (EPA, 1999c). Each metric result will be given a score based on percent comparability to a reference station. Scores will be totaled, and a Biological Condition Category will be assigned based on percent comparability with the reference station score. The following metrics will be calculated:

Metric 1: Taxa Richness. Taxa richness will be calculated by counting the number of taxa present in the sample. In general, taxa richness increases with increasing water quality.

Metric 2: Modified Family Biotic Index. This index, developed by Hilsenhoff (1988), summarizes the tolerances of the benthic arthropod community to organic pollutants with a single value. Tolerance values used in the calculation of the Family Biotic Index (FBI) were obtained from Hilsenhoff (1988) and Bode (1988). The FBI is calculated by multiplying the number of organisms in each taxon by the tolerance value for that taxon, summing the products, and dividing by the total number of organisms in the sample for which an index will be calculated. Values for the FBI range from 0.00 to 10.00 with higher values corresponding to greater levels of organic pollution as shown in the following:

Family Biotic Index	Water Quality	Degree of Organic Pollution
3.5	Excellent	Organic pollution unlikely
3.51-4.5	Very good	Possible slight organic pollution
4.51-5.5	Good	Some organic pollution probable
5.51-6.5	Fair	Fairly substantial pollution likely
6.51-7.5	Fairly poor	Substantial pollution likely
7.51-8.5	Poor	Very substantial pollution likely
8.51-10	Very poor	Severe organic pollution likely

It is important to note that although the FBI was originally designed to assess water quality based on the ability of benthic families to tolerate organic pollution (Hilsenhoff, 1988), the FBI has been used successfully to indicate other forms of pollution (Resh and Jackson, 1993), and Family tolerance is generally non-specific to the type of stressor (Barbour, et al., 1995).

Metric 3: Ratio of Scraper and Filtering Collector Functional Feeding Groups. The relative abundance of scrapers and filtering collectors in the riffle/run habitat is an indicator of the food sources available. Functional feeding group designations for the taxa identified will be obtained from Merritt and Cummins (1984) and Barbour et al. (1999). This metric is calculated by dividing the relative abundance of scrapers by the relative abundance of filter feeding organisms.

Metric 4: Ratio of EPT and Chironomidae Abundances. The ratio of Ephemeroptera, Plecoptera and Trichoptera (EPT) and chironomidae abundance will be calculated by dividing the relative abundance of EPT taxa by the relative abundance of chironomidae. The ratio of EPT to chironomidae will indicate if there is an even distribution between the pollution sensitive EPT taxa and more pollution tolerant chironomidae.

Metric 5: Percent Contribution of Dominant Taxon. The percent contribution of the dominant taxon will be calculated by dividing the abundance of the taxon which is numerically dominant by the total number of organisms in the sample. A low percent contribution of the dominant family indicates a balanced community. Factors influencing this percentage include environmental stress, habitat quality, and life histories of the organisms collected in the sample.

Metric 6: EPT Index. This result of the EPT index is determined by counting the number of distinct taxa within the groups Ephemeroptera, Plecoptera, and Trichoptera. The EPT index usually increases with increasing water quality as EPT taxa are generally considered pollution sensitive.

Metric 7: Community Similarity Index. This index evaluates the benthic populations at specific locations relative to populations present at a reference location. For this metric, the upstream and/or downstream stations (where pesticide related effects are not expected) will be used as the reference stations for each of the RBP sites. The community loss (CL) index is calculated by subtracting the number of taxa common to both locations (B) from the number of taxa present at the reference location R divided by the number of taxa present at the potential impact location (I), as follows:

$$CL = \frac{R - B}{I}$$

Metric 8: Ratio of Shredder Functional Feeding Group and Total Number of Individuals Collected. The ratio of the relative abundance of shredders to the abundance of all other functional feeding groups will be calculated by dividing the relative abundance of shredders by the total number of organisms in the sample. The abundance of shredders in comparison to other functional feeding groups can be influenced by climate, seasonality, and vegetation within the riparian zone, as well as by levels of toxicants adsorbed to CPOM while in the riparian zone, or adsorption of toxicants to the CPOM while it is in the water.

10.0 Data Analysis, Validation, and Interpretation

Data usefulness is paramount relative to the BERA and related testing and analysis. The principal objective in the Study Design is to ensure that the hypotheses are effectively tested and rejected or accepted with a high degree of confidence. A summary of the statistical methods is provided below and a discussion of hypothetical results follows. These hypothetical results should assist the reader in better understanding the usefulness of the collected data as they relate to characterizing risk to terrestrial receptors within and around the BBGR Ranges, as well as the aquatic data associated with South Branch of Cane Creek and Ingram Creek and their tributaries.

10.1 Data Analysis and Validation

As described in the previous sections, surface soils will be collected from the full range of lead concentrations found at the BBGR Ranges. Figure 9-1 presents the sample locations of the nine surface soil samples that will be collected at the BBGR Ranges.

The hypothetical results for the earthworm toxicity tests presented in Table 10-1 would indicate that the NOAEL for earthworms in soil may be as low as 800 mg/kg for lead, and the LOAEL for earthworms could be as high as 2,300 mg/kg lead. Results such as these could be useful to risk managers in setting possible soil cleanup goals.

The hypothetical test results for the perennial ryegrass toxicity tests presented in Table 10-2 indicate that the NOAEL for terrestrial plants may be as low as 300 mg/kg for lead, and the LOAEL for terrestrial plants could be as high as 800 mg/kg lead. Results such as these could be useful to risk managers in setting possible cleanup goals.

The sediment chironomid toxicity tests in conjunction with the RBP will provide lines of evidence regarding potential sediment toxicity (e.g., NOAEL and LOAEL values for sediment) and also quantitative comparisons of benthic invertebrate assemblages in South Branch of Cane Creek and Ingram Creek tributaries with benthic invertebrate assemblages from an un-impacted reference stream. The no-effect level of the most sensitive test or indicator could be used as a sediment cleanup goal.

The overall objective in conducting the field- and laboratory-based studies is to test the null hypotheses stated in Chapter 7.0. Each hypothesis will be accepted or rejected based on findings from the relevant toxicity test or field measurement. Acceptance or rejection of each hypothesis will be instrumental in characterizing ecological risks associated with the surface soils and sediment at the BBGR Ranges.

LC_{50} values for soil and sediment will be computed using the EPA-recommended Probit Analysis (EPA, 1989); NOAEL and LOAEL values will be derived using Dunnett's procedure or Steel's Many-One Rank Test.. Dunnett's procedure is a parametric test that assumes that observations within treatments are independent and normally distributed and that the variance of the observations is homogenous across all toxicant concentrations. The Shapiro-Wilk's test will be used to test for normality in order to decide whether to use parametric (Dunnett's) or nonparametric (Steel's Many-One Rank) analyses. In order to test the variances of the data obtained from each toxicant concentration and the control, Bartlett's test for variance will be employed.

It is important to note that the soil samples will not be cut or diluted into a dilution series but will be tested as 100 percent "un-cut" samples. Derivation of toxicity response curves in the form of LC_{50} values, NOAELs, and LOAELs will be done via the lead concentration gradient. By collecting soil samples with varying concentrations of lead, a gradient series will be present and appropriate toxicity response curves can be computed. Therefore, Dunnet's Procedure (for parametric distributions) or Steel's Many-One Rank Test (for nonparametric distributions) can be applied.

In addition to deriving toxicant dose-response curves (i.e., LC_{50}, LD_{50}, NOAEL, LOAEL), it is critical to apply Analysis of Variance (ANOVA) tests to determine if soil and sediment samples differ from off-site reference samples, thus dictating whether null hypotheses are accepted or rejected. A significance level of = 0.05 will be adopted as a probability of committing a Type I or Type II error. In comparing toxicity or biomeasurement results, single and nested ANOVAs will be conducted coincident with appropriate normality and variance testing.

Data validation will be conducted in accordance with the Installation Wide Sampling and Analysis Plan (IT, 2002).

10.2 Data Interpretation

Interpretation of bioassay results is dependent upon bracketing a response or effect level and a no-effect level. Effects will be measured via toxicity responses within a specified exposure period, depending on the exposure medium and test species. At a confidence level of 95 percent ($p \leq 0.05$), test responses consisting of acute toxicity will be compared to reference soil or sediment responses. Test chambers that are statistically different from reference chambers will be characterized as "effect concentrations," while those exhibiting no significant difference will be listed as "no-effect concentrations." The highest no-effect concentration and the lowest effect concentration will be reported as the NOAEL and LOAEL, respectively.

A second use of the data relates to COPEC concentrations measured within tissues following completion of exposure periods. Organisms from each replicate chamber will be tested as separate and distinct composite samples. The mean concentration and 95 percent UCL for each exposure concentration will be used to derive body burden concentrations which will then be used as input values for the food chain models as described in Chapter 5.0. These models, representing the various terrestrial and riparian trophic levels, will then be employed for HQ derivations.

11.0 Data Management Plan

The primary data management activities for the BBGR Ranges BERA will include:

- Data transfer from field and laboratory activities to a project filing system
- Data management to ensure that data are stored and output in a manner that continues the chain of custody
- Review of requirements to ensure that plans for data collection were fulfilled
- Validation of analytical data that will report data to be used for treatment interpretation activities
- Evaluation of analytical and field data resulting in a report of guidance to be followed for using project data in treatment interpretation
- Reporting functions, which may include outputting data for report tables, statistical analysis, interpretation of data, and electronic transfer.

The FTMC ShawView™ database will be used for data management. A series of programs allows electronic reporting of data. The laboratory is responsible for reporting data in both hard copy and electronic data deliverable formats.

11.1 Records Control

All project documentation and original reports will be maintained in a central file for the project.

11.2 Document Filing and Access

At least two copies of all data forms and deliverables will be generated during the project and sorted at different locations. Wherever practical, original forms will be archived at the Shaw office in Knoxville, Tennessee, and the laboratory and field personnel will retain copies. Analytical data, hard copy, and electronic files will be archived at least seven years by the laboratory.

12.0 References

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