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EVALUATION OF THE ORNL AREA FOR FUTURE WASTE BURIAL FACILITIES

T. F. Lomenick
D. W. Byerly*
Serge Gonzales**

*Consultant, The University of Tennessee, Knoxville, Tennessee
**Consultant, Earth Resources Associates, Athens, Georgia

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ABSTRACT

Additional waste-burial facilities will be needed at ORNL within this decade. In order to find environmentally acceptable sites, the ORNL area must be systematically evaluated. This document represents the first step in that selection process. Geologic and hydrologic data from the literature and minor field investigations are used to identify more favorable sites for Solid Waste Storage Area (SWSA) 7. Also underway at this time is a companion study to locate a Central Waste Storage Area which could be used in the future to accommodate wastes generated by the X-10, Y-12, and K-25 facilities.

From the several watershed options available, the Whiteoak Creek drainage basin is selected as the most promising hydrologic regime. This area contains all past and present waste-disposal facilities and is thus already well monitored. The seven bedrock units within the ORNL area are evaluated as potential burial media. Shales of the Conasauga Group, which are currently used for waste burial in the Whiteoak Creek drainage basin, and the Knox Group are considered the leading candidates.

Although the residuum derived from and overlying the Knox dolomite has many favorable characteristics and may be regarded as having a high potential for burial of low-level wastes, at the present it is unproven. Therefore, the Conasauga shales are considered a preferable option for SWSA 7 within the ORNL area. Since the Conasauga interval is currently used for waste burial, it is better understood. One tract in Melton Valley that is underlain by Conasauga shales is nominated for detailed site-characterization studies, and several other tracts are recommended for future exploratory drilling. Exploration is also suggested for a tract in the upper Whiteoak Creek basin where Knox residuum is the shallow subsurface material.

1. INTRODUCTION

A systematic approach is desirable for evaluating the ORNL area for a future solid-waste burial facility, which will be needed within the current decade when present facilities are filled to capacity. This report, based on a review of literature and a modest amount of field study, documents the first step in this process — the identification of tracts of land within the area which should be evaluated by more detailed site-characterization studies.

Soils and regolith at ORNL have been utilized for the shallow burial of low-level radioactive wastes since initiation of operations here in 1943.[1] At present, six burial grounds and several waste pits and trenches are located within Melton and Bethel Valleys on the Oak Ridge Reservation (ORR). These are shown in Fig. 1. The earliest burial facilities (SWSAs 1, 2, and 3) were located in Bethel Valley near the source of the wastes. Because convenience was the primary siting consideration, preoperational geological investigations were not undertaken. SWSA 3, the last to be operated in Bethel Valley, was closed in 1951 when geologic considerations prompted development of burial grounds in the more favorable Conasauga shales within Melton Valley.[2] Waste disposal in Melton Valley commenced that year with operation of SWSA 4 (11 ha). Subsequently, SWSA 5 (15 ha) and SWSA 6 (27 ha) were developed nearby. SWSA 6 was placed into operation in 1973 and is presently in use, but it is expected to reach capacity within 8 to 10 years.[3]

Historical records of wastes buried prior to 1961 are incomplete.[1] Few records were kept for SWSAs 1 and 2, and the records for SWSAs 3, 4, and some of those for 5 were destroyed by fire. Since 1961, however, electronic data processing has been used to keep accurate records of the amounts and locations of all buried wastes.[1,3]

An inventory of long-lived radioactive wastes (exclusive of tritium) has estimated that <10,000 Ci were present in the first five burial grounds.[3] This same study also estimated that >50,000 Ci of tritium, 13,000 g of transuranics, and 100 kg of uranium were buried there.

Burial procedures at the first three facilities involved digging trenches, dumping in the wastes, and backfilling with soil. More thought has been given to the design and construction of subsequent disposal grounds. For example, trenches have been designed in accordance with the topography and the condition of the regolith. Trenches range from 15 to 120 m in length, 2.5 to 9 m in width, and 2.5 to 4 m in depth and are excavated to slope along their length to facilitate the collection of infiltrated water. Hydrologic monitoring is by means of cased wells.[4]

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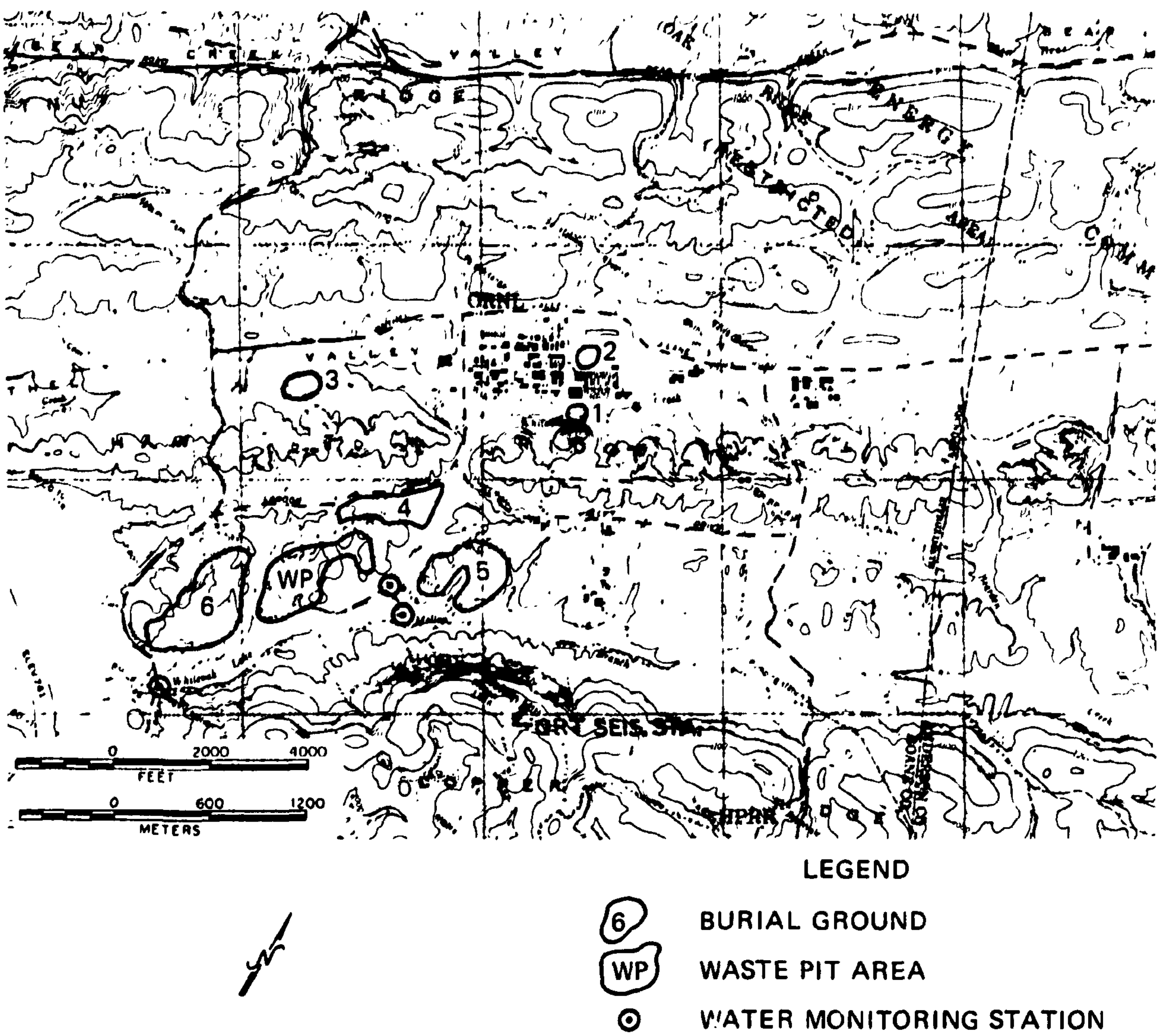

Fig. 1. Locations of existing burial grounds in the ORNL area.

Trench bottoms are at least 1 m above the highest observed elevation of the groundwater table. Trenches are spaced approximately 1.5 m apart. At least 1 m of backfill has been placed on top of emplaced wastes, and in some experimental trenches, polyvinyl chloride or bentonite has been installed to reduce infiltration. In the case of SWSA 4, asphalt-lined ditches were constructed to divert surface-water drainage around the burial ground.[4]

Monitoring the quality of surface water draining from the ORNL area has been more or less continuous since 1943, when a water-sampling program was initiated on Whiteoak Creek.[5] The discharge across Whiteoak Dam represents drainage from all ORNL facilities and has been monitored since the 1960s by a continuous collection unit that samples in proportion to the flow volume. In the late 1950s radiostrontium was detected in Whiteoak Creek. In order to locate potential sources, continuous samplers were installed on Melton Branch and Whiteoak Creek above their confluence, and also on Whiteoak Creek near the plant's discharge (Fig. 1). The first wells to monitor groundwater in burial grounds were installed in 1964. An extensive network of wells presently exists for SWSAs 3, 4, 5, and 6 to provide routine monitoring of groundwater behavior and quality.[1,5]

The disposal of low-level radioactive wastes at ORNL has improved significantly since the first material was buried in 1943. Not only have burial techniques improved, but also the selection and monitoring of sites. Nevertheless, more should be learned concerning the potential of geologic media (other than the Chickamauga or Conasauga), such as the residuum above the Knox Group, for the shallow burial of wastes on the ORR. The Knox Group is, moreover, the focus of a study for a "central" disposal facility for wastes generated by the X-10, Y-12, and K-25 plants, and extensive study will be required before it can be proven suitable. In the interim, there remains the need to locate and develop SWSA 7 to handle wastes when the existing burial ground is filled.

The location of SWSA 7 should be on the basis of a systematic evaluation of the geology and hydrology of the area such that the maximum number of proposed guidelines or criteria are achieved. The diverse geologic conditions at ORNL present a number of options that are reviewed and evaluated in this report.

2. GENERAL SETTING

2.1 GEOLOGY

The 24,000-ha ORR lies physiographically within the Valley and Ridge province, which is characterized by alternating valleys and ridges that trend northeast-southwest. Although composed of geologic materials that are more resistant to erosion than those found in the valleys, the ridges vary morphologically depending upon the composition of bedrock beneath them. Steep-sided, relatively high ridges with shallow, acidic soils are developed above sandstones and siltstones, whereas low-lying, generally knobby ridges (sometimes found within broad valley floors) are underlain by shales. Broad, relatively high ridges with thick residuum and summits separated by intervening swales are formed upon cherty dolomitic rocks. Valleys have formed through the erosion of rock sequences that are dominantly limestone or shale.

The alternation of rock types and the northeasterly orientation of the ridges and valleys are attributable to deformation of these strata ∿200 million years ago. Rock units were folded and faulted during Late Paleozoic deformation, thereby creating an imbricate pattern of units that are inclined to the southeast and resemble a series of overlapped shingles. Subsequent differential erosion has produced a trellis drainage pattern and the characteristic ridge and valley topography that is clearly shown in the geological map of the Whiteoak Creek drainage basin (Fig. 2).[6]

Bedrock exposed over most of the Reservation consists of nearly 3200 m of Lower and Middle Paleozoic sandstones, siltstones, shales, and cherty carbonates. Besides the tendency of these rocks to create the alternating ridges and valleys, each rock unit in the sequence has distinct properties that control the rates of weathering, the composition and thickness of regolith (including soil), and the behavior of surface and subsurface water. Each rock unit, therefore, can be evaluated as an option for siting waste-burial grounds. Figure 3 is a geologic cross section of the rock units present in the ORNL area.

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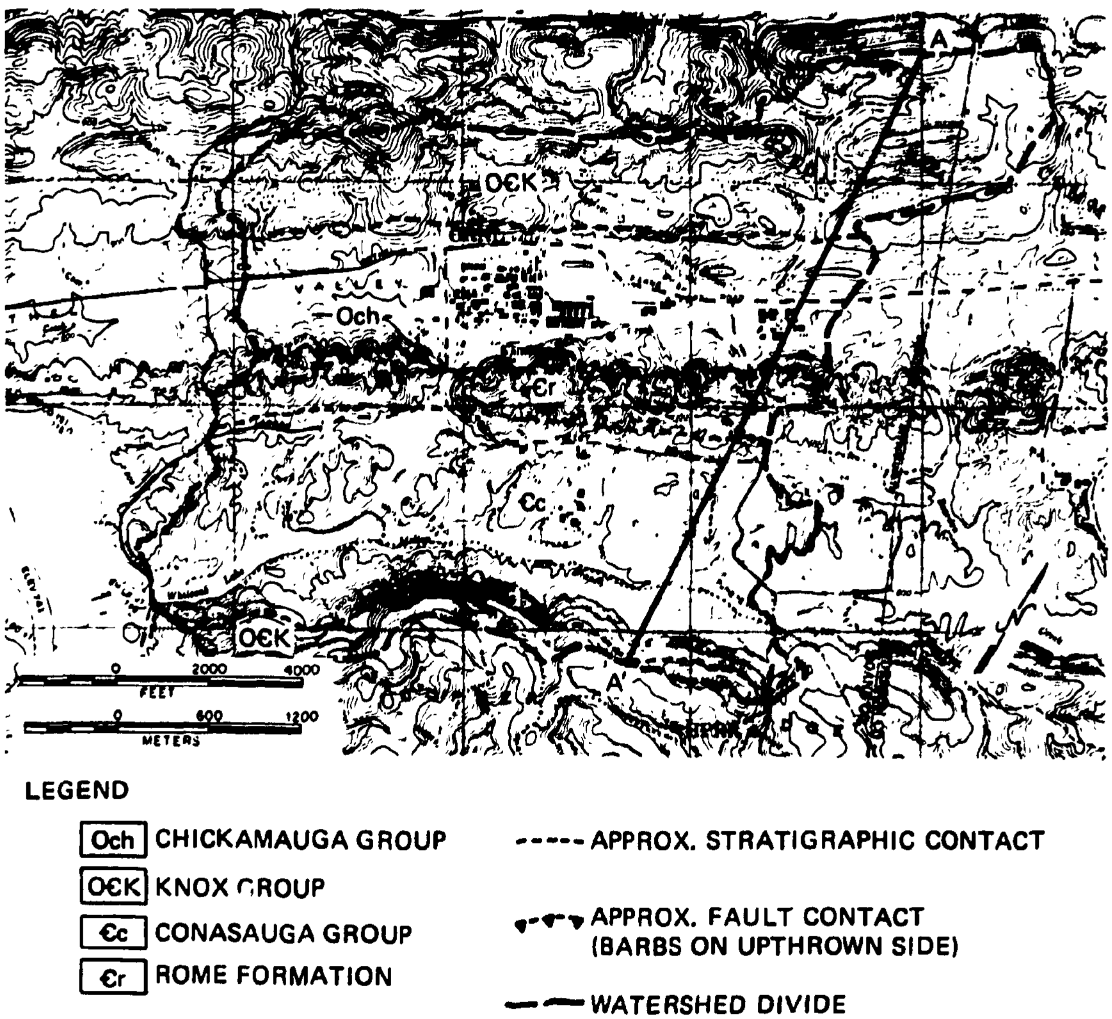

Fig. 2. Geologic map of the Whiteoak Creek drainage basin. W. M. McMaster, Geologic Map of the Oak Ridge Reservation, Tennessee, UCC-ND, Health Physics Division, ORNL (1963).

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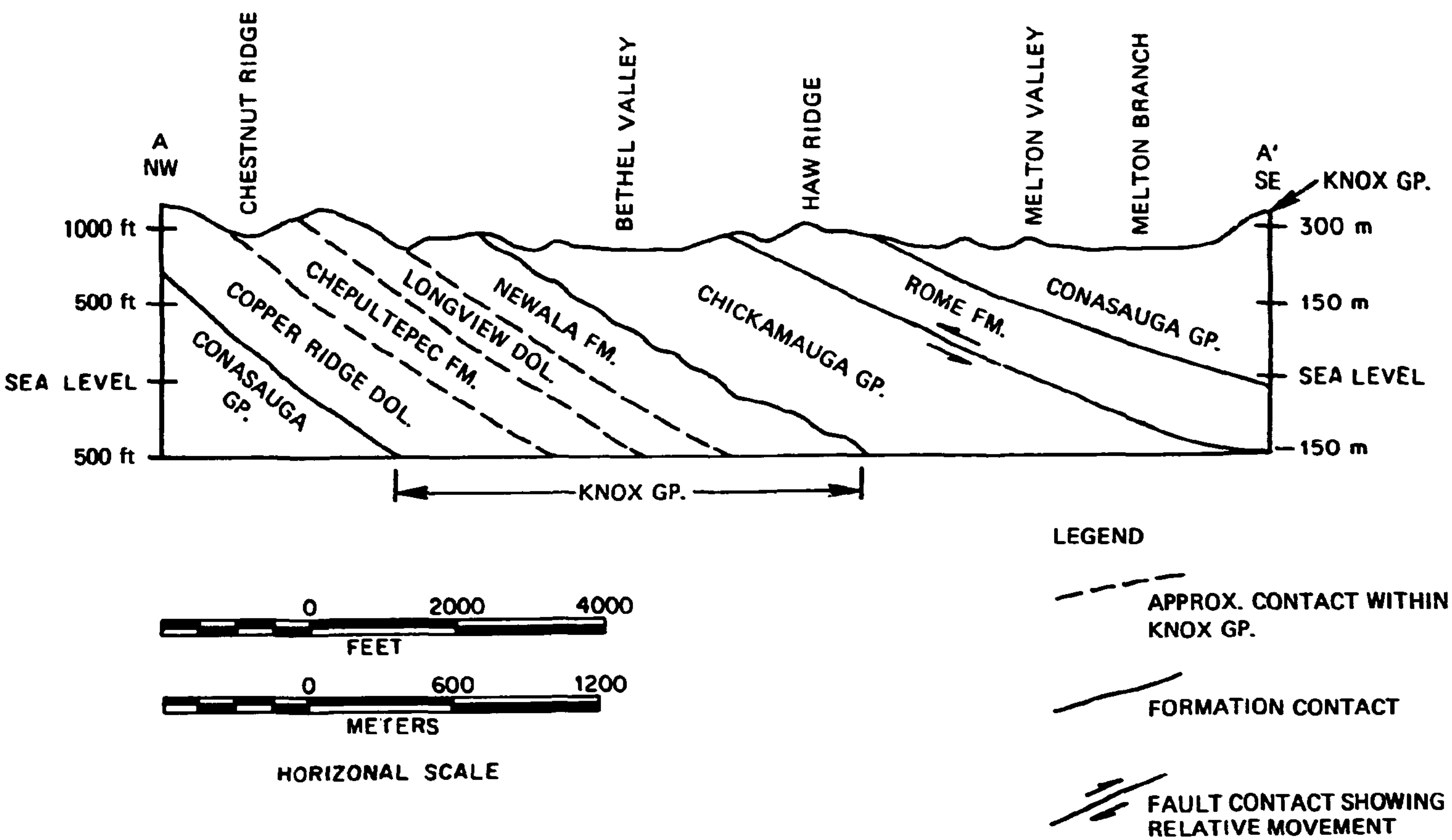

Fig. 3. Geologic cross section of Whiteoak Creek drainage basin.

2.2 HYDROLOGY

The humid climate in eastern Tennessee provides an average annual precipitation of 133 cm, of which approximately 79% is lost through evapotranspiration.[7] The balance of the water becomes runoff and recharge to the groundwater regime within a drainage basin that connects to the Tennessee River. This drainage system consists of numerous suborder watersheds that drain to the Clinch River, a major tributary of the Tennessee River. Average annual flow rates from the Whiteoak Creek basin through the Tennessee River system are shown in Table 1.

Table 1. Average annual flow rates downstream from ORNL

Station	Discharge m^3/s
Whiteoak Creek (0.16 km above confluence with Melton Branch)[a]	0.27
Melton Branch (0.1 km above confluence with Whiteoak Creek)[a]	0.07
Whiteoak Creek (at Whiteoak Dam)[a]	0.38
Clinch River (at Oak Ridge, TN)	130.1
Tennessee River (at Chattanooga, TN)	1045.6

[a]See locations on Fig. 1.

Sources of data: J. W. Elwood and Hendersen, "Hydrologic and Chemical Budgets at Oak Ridge, Tennessee," in: A. D. Hasler [Ed.], Coupling of Land and Water Systems, pp. 31-51, Springer-Verlag Ecological Studies Series (1973) and D. A. Webster, "A Review of Hydrologic and Geologic Conditions Related to the Radioactive Solid Waste Burial Grounds at Oak Ridge National Laboratory, Tennessee," U.S.G.S. Open-File Report 76-727 (1976).

The relationship between surface-water drainage and the local groundwater is seasonally dependent, but it also varies among watersheds depending upon the bedrock present. Regional groundwater flow patterns within certain bedrock units are becoming better understood as a result of data provided by the monitoring wells installed in proximity to existing burial grounds.

Water tables generally tend to be deeper in higher terranes where water infiltrates and recharges the base flow of perennial streams such as Whiteoak Creek, but are shallower beneath valley floors.[4] Figure 4 illustrates the depth to the water table relative to topography in an area underlain by Conasauga shales within the Whiteoak Creek drainage basin of Melton Valley.

3. GEOTECHNICAL EVALUATIONS

3.1 EVALUATION GUIDELINES

Proposed guidelines or criteria for selecting shallow land burial sites for low-level radioactive wastes have been reviewed to determine their applicability to the systematic evaluation of the ORNL area for such sites. Guidelines and criteria reviewed tended to be similar in scope, but ranged from being generalized or generic to being specific. Two sets of proposed guidelines applicable to the systematic geotechnical evaluation of the ORNL area for locating a SWSA are reviewed here.

Guidelines for the disposal of low-level radioactive/hazardous wastes in the ORNL area have been prepared by the Engineering Division of Union Carbide Corporation, Nuclear Division (UCC-ND) using a combination of federal regulations and state requirements. The latter were applied where they are more stringent.[8] The guidelines, referred to as the "Design Basis Document" (DBD), are idealistic, and it is highly improbable that any existing site on the ORR can meet all of the requisites. Finding a site with conditions reasonably approximating the guidelines appears to be achievable. The salient guidelines expressed in the DBD are listed here:

1. Waste trenches must be more than 900 m from any standing body of surface water.

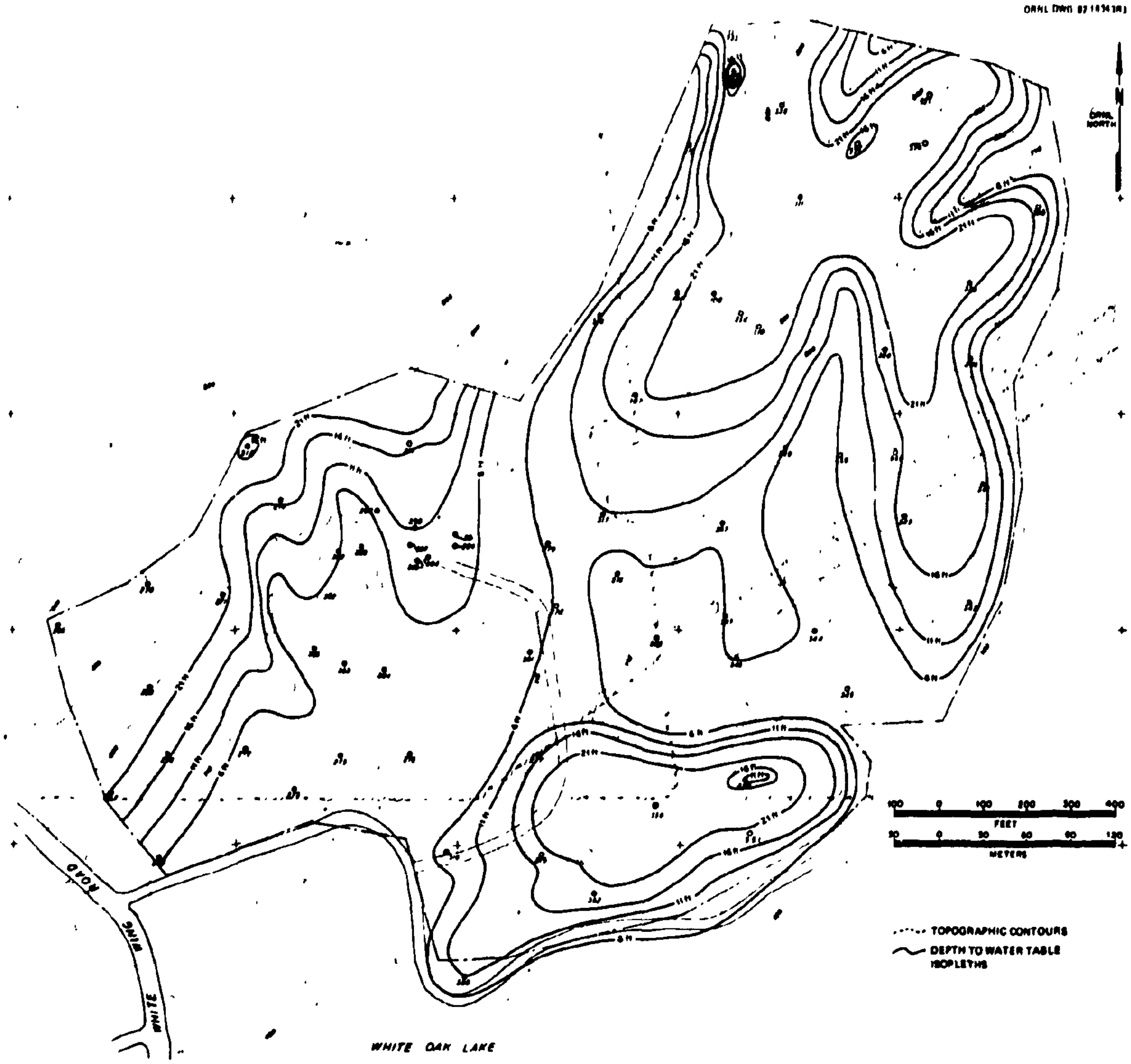

Fig. 4. Water table depth relative to topography in Conasauga terrane. Depth-to-water contour map of SWSA 6 (April 22, 1965).

2. Waste trenches must be 105 m from any water-supply systems.
3. A 60-m buffer zone must exist between any trench and the facility's barrier fence.
4. Onsite soil permeability should not exceed 10^{-7} cm/s.
5. Waste should be emplaced at least 3 m above the maximum known elevation of the groundwater table.
6. Burial must be above the 500-year flood surface, regulatory flood-ways, and wet level areas, as well as above anticipated floods resulting from dam failure or wave action.
7. Burial should not be within the recharge area of a single-source aquifer, nor should it be within a zone of ground-water discharge.
8. Disposal facilities should not be developed within a zone of active faulting.
9. Areas susceptible to erosional processes that might enhance waste migration should be avoided.
10. Geologic conditions such as extensive fracturing and karst development, or anomalous hydrologic conditions that might enhance waste migration or lessen the detection of potential waste migration should be avoided.
11. The facility should not affect an endangered species nor its habitat.

A draft set of generic criteria has also been prepared by the DOE Oak Ridge Operations Radioactive Waste Management Program (ORO-RWMP).[9] These criteria are similar to those of the DBD and provide useful guidance for evaluating sites by recognizing that geologic and geohydrologic differences exist between areas considered for waste burial. Assumptions that can be addressed by site-specific factors were used in establishing the criteria. These assumptions include: (1) the site will be selected, designed, and operated to meet performance objectives; zero release is not achievable; (2) performance objectives can be met by natural and engineered barriers; (3) the site will be suitable for normal surface use after institutional control, but will not be designed to prevent human excavations into the wastes; (4) wastes will be solid and have low liquid content; and (5) wastes will be treated or processed to minimize subsidence.

The ORO-RWMP criteria[9] are summarized here.

1. The site shall be of sufficient area and depth to accommodate the projected volume of waste, an administrative area, and a three-dimensional buffer zone of sufficient size to allow unrestricted human use beyond its boundary.
2. The site shall allow waste to be buried either completely above or below the transition between the saturated and unsaturated zones.
3. The site shall be located where flooding will not jeopardize performance.
4. The site shall be located where erosion from wind and water will not jeopardize performance.
5. The site shall be located in areas where hydrogeologic conditions allow reliable prediction of performance.
6. The site shall be located where geologic hazards will not jeopardize performance.
7. The site shall be selected with consideration given to those characteristics of earth materials and water chemistry that favor increased residence times and/or attenuation of radionuclide concentrations.
8. The site shall be selected with consideration given to current and projected population distributions.
9. The site shall be selected with consideration given to current and projected land use and resource development.
10. To the extent consistent with other criteria, the site shall be selected with consideration given to location of waste generation, access to all-weather highway and rail routes, and access to utilities.
11. The site shall be selected consistent with federal laws and regulations.
12. The site shall not be located within areas that are protected from such use by federal laws and regulations.

As indicated in the guidelines or criteria above, the geologic and hydrologic parameters of any area being considered as a candidate site for SWSA 7 must be thoroughly comprehended in order that a sound evaluation can be made. Earth materials, namely bedrock units and regolith (including soil), must provide the primary confinement for any emplaced wastes and any water that infiltrates into the burial ground. Water is an important parameter because it is the most likely means by which wastes and waste byproducts could be transmitted to the biosphere.

Siting options may be considered under the two broad categories of earth materials and hydrology. Each of the seven distinctly different rock units and their related residuum or soils at ORNL can be considered as a potential disposal medium, and each suborder watershed can be viewed as a distinct option for the location of a waste-burial facility. These parameters are interdependent, and the most nearly favorable option in one category must be compatible with similar options in the second category. For example, a suitable host-rock medium must exist within an acceptable drainage basin. Favorable options can be determined by general screening; however, detailed site-characterization studies will be necessary for the ultimate selection of SWSA 7 from among the viable candidates.

Factors that should be considered along with the above guidelines for evaluating drainage-basin options include the following:

1. SWSA 7 should preferably be sited entirely within the bounds of a single surface-water and subsurface-water drainage basin. This is necessary to facilitate installation of an efficient monitoring network, as well as an emergency control system. Care must be taken to assure that ground-water boundaries relative to SWSA 7 define the discharge system for the surface water to be monitored in the basin.
2. The basin geomorphology should lend itself to the establishment of a water-quality monitoring system.
3. The basin should contain suitable space (see geologic factors below) sufficiently high in elevation along an interfluve so as to minimize ground-water recharge through any buried wastes.
4. The water table should be deep enough to provide a workable depth for burial within the unsaturated zone and above the transition interval.
5. Both the vertical and horizontal pathways of water movement within the bedrock and the soil should be determined in as much detail as possible.

Characteristics of the rock formations found within a drainage basin control the local topography, surface- and subsurface-water behavior, rates of weathering and erosion, and the composition and thickness of regolith (including soil). The following geologic factors should be considered in evaluating the options provided by rock formations.

1. Bedrock must weather to form an adequate thickness of workable regolith above the water table. Workability as defined here depends upon engineering properties such as compactibility, ease of excavation, erodability, slope stability, and drainage.
2. Composition of the burial medium should exhibit optimum sorptive coefficients and exchange capacities that would help to attenuate the migration of any radionuclides.
3. The candidate site should exhibit a moderately gentle topography with slopes <20%. Steeper slopes accelerate erosion, tend to be unstable, and create accessibility problems. Overly flat terrain is also undesirable because of possible poor surface drainage.
4. Bedrock should have a minimal number of partings such as bedding planes and fractures, which, if present and open, provide conduits for free movement of ground water and radioactive leachates, thus limiting the sorption or exchange capability necessary for confinement of the wastes.
5. Bedrock and regolith must be stable and not prone to slope failure or subsidence. Stability must be evaluated on the basis of natural conditions as well as those that would result from the construction of the burial facility.

Table 2 summarizes the applicability of guidelines and considerations used to evaluate the ORNL area for future waste burial facilities.

3.2 DRAINAGE BASIN OPTIONS

Geohydrologic investigations, though critical during the site selection process, also must consider monitoring of water quality during the operational phase and following closure. Locating a site within a single, well-defined drainage basin is advantageous for such monitoring. Although several subbasins at ORNL must be considered viable options for SWSA 7, the Whiteoak Creek drainage basin appears most suitable because it is already extensively equipped with monitoring devices.

Waste facilities within the Whiteoak Creek basin include burial grounds, waste pits, treatment operations, and a hydraulic-fracturing plant. During the 40 years that this area has been used for waste disposal, an elaborate water-quality monitoring network has been

Table 2. Relationships of guidelines, criteria, and considerations used to evaluate the ORNL area for future waste burial facilities

Site characteristic addressed	DBD guideline number[a]	ORO-RWMP criterion number[b]	Hydrogeologic factor number[c]	Rock formation option number[d]
Standing water	1		1, 2, 3	5
Water supply	2	5	1, 2, 3	
Buffer zone	3	1	4	1
Permeability	4	5	1, 2, 3, 5	
Water table	5	2	1, 2, 3, 4	1
Flooding	6	3	2	
Aquifers	7	5	1, 2, 3, 5	
Faulting	8	6		5
Erosion	9	4		3, 5
Subsidence	10			4
Legal issues	11	11, 12		
Earth materials		7		1, 2
Demography		8		
Resources		9		3
Accessibility		10		

[a]The Design Basis Document guidelines are explained and listed on pp. 9–11 of this report.

[b]These criteria are listed on p. 12 of this report.

[c]Hydrogeologic factors are discussed and listed on p. 13 of this report.

[d]Rock formation options to be considered are listed on p. 14 of this report.

established,[1] and, unless absolutely necessary, it would be wasteful to duplicate this in another drainage basin. Therefore, if an acceptable option based upon earth-material parameters exists within the Whiteoak Creek basin, it should be strongly considered as an area in which to locate SWSA 7.

3.3 GEOLOGIC OPTIONS AVAILABLE WITHIN WHITEOAK BASIN

Based upon the rock units present in this basin (Fig. 3), there are seven primary options from which to choose. Due to variations in composition, topography, and other factors, each rock unit may offer several secondary options for final evaluation. The areal extent of three of these units has been delineated to date. The other four units, although mapped separately in nearby areas such as Walker Branch basin, have been collectively treated as the Knox Group here because they exhibit gross similarities. The general characteristics of the four units assigned to the Knox Group are included in this discussion, along with descriptions of the other rock units exposed in the basin.

3.3.1 Rome Formation

The Rome Formation underlies and supports the portion of Haw Ridge which transects the basin. Although the Rome Formation is the oldest rock unit in the basin, it appears geographically in the middle of the basin due to faulting. The formation consists predominantly of fine-grained, maroon or gray sandstone and siltstone and shale (commonly green because of the glauconite content). Illite is the principal clay mineral, but bentonite layers have been described locally. Dolostone also is known to be present in the basal portion of the rock sequence in certain areas. These dolostones, along with a substantial portion of other lower Rome strata, are missing along Haw Ridge due to the faulting that has thrust the Rome Formation onto the younger overlying Chickamauga Group. About 200 m of Rome strata underlie Haw Ridge even though the average thickness for the formation is $\sim$300 m.

Resistant sandstones cap Haw Ridge and account for the steep topography that is characteristic of ridges underlain by this formation throughout the Valley and Ridge province. The acidic regolith above the

Rome Formation is normally less than 4.5 m thick and is regarded as a lithosol that contains abundant siltstone and shale fragments. Pine forests are normally indigenous to ridges underlain by this formation.

3.3.2 Conasauga Group

The Rome Formation grades upward into the Conasauga Group which, throughout eastern Tennesee, exhibits a varied lithologic expression. Carbonate rocks generally dominate the eastern end of this stratigraphic interval, whereas shale is predominant toward the western edge. A transition zone involving interbeds of both these lithologies separates the two trends. The Conasauga Group underlying Melton Valley southeast of Haw Ridge is composed mainly of shale.

Variegated shales, commonly calcareous, comprise the lower part of the Conasauga Group; however, interbeds of silty to pure limestone may be present as lenses. Limestone becomes more abundant in the upper part of the sequence as it grades upward into the Knox Group. The Maynardville Formation, normally ∿100 m thick and predominantly carbonate, forms the uppermost division of the Conasauga Group at the base of the Knox Group and persists throughout most of the Valley and Ridge.

The knobby topography of Melton Valley is typical of weathered and eroded shales. Rows of knobs run parallel to the regional structure from above shaley units, whereas the intervening low areas are ordinarily underlain by carbonates.

Regolith above the Conasauga Group is quite variable. It is thickest on crests of low hills (to 9 m) and thinnest in the flat, low-lying areas (<1.5 m). The total thickness of the Conasauga Group is ∿600 m. The contacts with the underlying Rome Formation and the overlying Knox Group are gradational; hence, the stratigraphic boundaries are somewhat arbitrary.

3.3.3. Knox Group

In the ORNL area, the Knox Group is a thick sequence of limestones and dolostones. Abundant chert and some interbedded sandstone units within the Knox are sufficiently resistant to erosion to support broad ridges. In the Whiteoak Creek basin, the Knox Group underlies both Chestnut Ridge, which forms the divide at the headwaters of Whiteoak Creek, and a small portion of Copper Ridge at the southeastern edge of the basin. Configuration of Knox-supported ridges can be correlated with the two rock units containing the highest amounts of chert, which form a double set of parallel crests along the broad ridges.

The Knox Group can be subdivided into four or five formations; however, such subdivision in the field is usually difficult due to the paucity of outcrops. Efforts to subdivide the Knox Group in the field are generally based upon the characteristics of chert and sandstone float found within the overlying thick residuum. The normal vegetation found on uncleared ridges underlain by Knox lithologies is mixed hardwood forest consisting mainly of oak and hickory.

3.3.3.1 Copper Ridge Dolomite

The lowest unit in the Knox Group is a coarse-grained dolostone named the Copper Ridge Dolomite which averages ∿300 m in thickness. The most distinctive characteristic of this formation is the fetid odor generated when the rock is freshly broken. Residuum developed from the Copper Ridge Dolomite is characterized by copious quantities of chert float, usually with a banded or waffle-iron appearance.

Due to its high chert content, the Copper Ridge Dolomite forms a well-defined series of ridge crests along the northwestern flank of the broad Knox-supported ridges. Lateral and vertical variations in chert content, as well as fracture patterns in the rock, lead to differential weathering. The result is a very irregular bedrock-residuum interface marked by steep-sided pinnacles. The clayey residuum between pinnacles may approach thicknesses of 30 m or more. Clay also fills solution cavities within the weathered bedrock.

3.3.3.2 Chepultepec Dolomite

The Chepultepec Dolomite is generally less cherty than the subjacent Copper Ridge Dolomite. Chert present in the residuum derived from this formation is distinguished by being porcelainous and dolomoldic. A significant characteristic of this formation is the presence of several sandstone beds, 30- to 45-cm thick, that may outcrop in the lower portion of the section or produce a very sandy residuum. Other than these sandstone units, the Chepultepec Dolomite is mainly a light-gray, fine- to medium-grained dolostone.

The thickness and development of residuum above the Chepultepec Dolomite is very similar to that above the Copper Ridge Dolomite. The Chepultepec Dolomite underlies swales commonly marked with insipient sinkholes and situated between ridge crests formed by the underlying Copper Ridge and the overlying Longview formations. An average thickness for the Chepultepec Dolomite is 210 m.

3.3.3.3 Longview Dolomite

Bedrock in this unit consists mainly of siliceous fine- to medium-grained dolostone, but the percentage of limestone increases as it grades upward into the overlying Kingsport or Newala Formations. The most distinctive aspect of the Longview Dolomite is the massive beds of chert that outcrop or form large float blocks in the residuum. This preponder-ance of chert forms slopes armored with rubble that resists erosion and creates topographic highs. The thickness and development of residuum above the Longview Dolomite is similar to that of the Copper Ridge Dolomite. The average thickness of the Longview Dolomite is 75 m.

3.3.3.4 Newala Formation

Strata above the Longview Dolomite have been considered in several ways. Where the rock sequence is well exposed, two units may be recognized. The lower unit, termed the Kingsport Formation, is mainly limestone, whereas the upper formation, called the Mascot Dolomite, is predominantly dolostone. The boundary between these two units has been arbitrarily placed at the lowest occurrence of a very thin ∿2.5 cm) chert-matrix sandstone. The problem in subdividing this interval is that the chert-matrix sandstone may or may not be observable in the residual float. Where such difficulties occur, the single stratigraphic term Newala Formation is applied.

The Newala Formation is conspicuously less cherty than the rest of the Knox Group, even though its weathering characteristics are similar. Thick clay residuum and pinnacle development are common. The thickness of the Newala Formation varies considerably due to an unconformity developed at the top of the Mascot Dolomite. An average thickness is 285 m.

3.3.4 Chicakamauga Group

The Chickamauga Group, like the Conasauga Group, consists of several rock types, and its lithologic expression varies from place to place as a result. In general the lithology of the Chickamauga Group varies from dominantly clastic rocks (sandstones and shales) in the eastern portion of East Tennessee to a predponderance of limestone in the western part. Within the Whiteoak Creek basin, Bethel Valley is underlain by Chickamauga strata that are mainly limestone; however, there are intervals which are shaley or silty, especially in the lower portion of the section. Chert is distinctive to parts of the Chickamauga Group, though not comparable in quantity and characteristics to that produced by weathering from the Knox Group.

Residuum above this formation is considerably thinner than that generated above the Knox Group, and yields soils that support volunteer growth of juniper trees, a characteristic botanical association. The average thickness of Chickamauga strata in Bethel Valley is 525 m.

3.3.5 Summary of Rock Units

A summary describing the rock units in the Whiteoak Creek basin offering options for waste burial is presented in Table 2. A relative rating of the most likely candidate units appears in Table 3. This subjective comparison rates the Conasauga and Knox Groups as the two most attractive options for siting SWSA 7. Both clearly have favorable and unfavorable attributes, and one unit may not be preferable to the other in the final analysis. Because low-level radioactive wastes have already been successfully emplaced within the Conasauga Group, it seems the better choice for the location of a new waste disposal site.[4,5]

The Knox Group remains a viable candidate for the future disposal of radioactive and hazardous wastes, provided that several geohydrologic uncertainties about the unit can be favorably resolved. The Knox Group is currently endorsed for waste disposal by Tennessee state officials, is

Table 3. Summary description of rock units

Rock unit	General location	General composition	Time-stratigraphy
Chickamauga Group	Bethel Valley	Limestone and shaley limestone; blocky chert	Middle Ordovician
Newala Formation	Southeastern flank of Chestnut Ridge	Mostly dolostone with limestone; some chert	
Longview Dolomite	Southeastern crest of Chestnut Ridge	Dolostone; abundant massive chert	Lower Ordovician
Chepultepec Dolomite	Swale or low area in middle of Chestnut Ridge	Dolostone and sand-stone; some chert	
Copper Ridge Dolomite	Northwestern crest along Chestnut Ridge and Copper Ridge	Dolostone; abundant chert	Upper Cambrian
Conasauga Group	Melton Valley between Haw Ridge and Copper Ridge	Shale, limey shale, and some limestone	Middle-Upper Cambrian
Rome Formation	Haw Ridge	Mostly shale with siltstone and sand-stone	Lower Cambrian

Table 4. Relative rating of rock units in ORNL area

Criteria	Rock unit[a]			
	Rome Formation	Conasauga Group	Knox Group	Chickamauga Group
Hydrologic data	2	3	2	2
Thick regolith	1	2	3	2
Attenuating clays	2	3	3	2
Areas with <20% slopes	1	3	3	3
Stable surface, including subsidence	1	3	1	1
Performance data	1	3	3	2
Total rating	8	17	15	12

[a]Using a relative scale of 1 to 3, 1 = low degree of acceptability based on available data; 2 = moderate acceptability, with uncertainties warranting thorough field investigations; 3 = acceptable based on available data.

presently used as the burial medium for waste generated at the Y-12 facility, and has been proposed as the topic of study for the central waste disposal facility which is intended to dispose of low-level wastes generated by the X-10, Y-12, and K-25 plants.

Therefore, a prudent site-selection program for the ORNL Reservation at this time consists of site-characterization investigations of the Conasauga Group in the Whiteoak Creek basin and evaluation of the Knox Group's potential for possible future use.

4. GEOTECHNICAL EVALUATION OF MELTON VALLEY

The portion of Whiteoak Creek basin underlain by the Conasauga Group is restricted to Melton Valley, bounded on the northwest by Haw Ridge and on the southeast by Copper Ridge. Melton Branch drains most of this valley and enters Whiteoak Creek about 0.5 km upstream from Whiteoak Lake.

A geologic survey in the early 1950s suggested that the shales of the Conasauga Group in Melton Valley were more suitable for the burial of low-level wastes than the residuum of the Chickamauga Group then being utilized for burial in Bethel Valley.[2] Based on this assessment, SWSAs 4, 5, and 6 were developed in the Melton Valley. Considerable knowledge concerning the characteristics of the Conasauga shales has been gained through the operation of these burial grounds.[4]

The depth to which the shales and siltstones are weathered to form regolith varies with the topography. This depth also controls the ability to excavate the rock. In lower areas, the depth of weathering may be 1.5 m or less; on the crests of low hills, regolith may be 9 to 12 m in thickness. Water-table elevations also tend to conform to the topography. In low areas such as those adjacent to perennial streams like Melton Branch or to the ephemeral streams in gullies dissecting the low hills in Melton Valley, the water table is found within 1.5 m below the land surface. Around hill summits, the depth to the water table can exceed 6 m. One well drilled in SWSA 6 did not encounter the water table until a depth of ∿10 m.[10]

The clay content of the Conasauga shales is mainly illitic. This is a favorable characteristic, because these clays normally have the high sorptive coefficients and cation-exchange capacities necessary to attenuate the movement of certain radionuclides.

Measurement of ground water movement indicates a preferred lateral direction along the strike of the bedding (primarily northeast-southwest). Jointing and other fractures, if locally present, can modify this pattern. An average rate of 15 cm/d has been determined for ground-water flow in these Conasauga shales.[10,11] In some cases, perched water tables have also been detected above the regional water table, due to compositional changes or irregularities in the degree of weathering caused by minor structural features. Most inherent characteristics of the Conasauga sequence that pose potential problems for burial operations have been addressed by virtue of operational experience. However, additional detailed site-characterization studies focused on the petrology and hydrology of the Conasauga Group and a careful pathway analysis should improve upon this experience and result in the selection of an acceptable site.

The outcrop belt of the Conasauga Group in Melton Valley extends from its lower contact with the Rome Formation (along the base of Haw Ridge) to its upper contact with the Knox Group (along the base of Copper Ridge). The average width of this belt is 1.3 km and the average length of the valley is ∿4.3 km. The total area of exposed Conasauga strata in the Whiteoak Creek Basin (Melton Valley) therefore approximates 550 ha. Of this area, existing physical facilities, including all disposal areas, occupy about 80 ha; roads, stream beds, and areas with slopes exceeding 20% account for another 366 ha. This leaves ∿104 ha that can be considered for locating SWSA 7.

Within this remaining acreage, there are 17 tracts (designated A–Q), which vary in size from 2.4–15 ha (Fig. 5). Because of the probability of encountering unfavorable water-table depth, the usable size of each of these tracts will probably be reduced further. For this reason, tracts containing <8 ha should be eliminated from further consideration. The remaining tracts designated H, I, L, M, and P that are shown in Fig. 5 on the northwest side of Melton Branch, and tract N to the southeast will be discussed further.

Tracts L and M are nearly contiguous; together they constitute an area of nearly 20 ha containing suitable slopes of 20% or less. Also, there are

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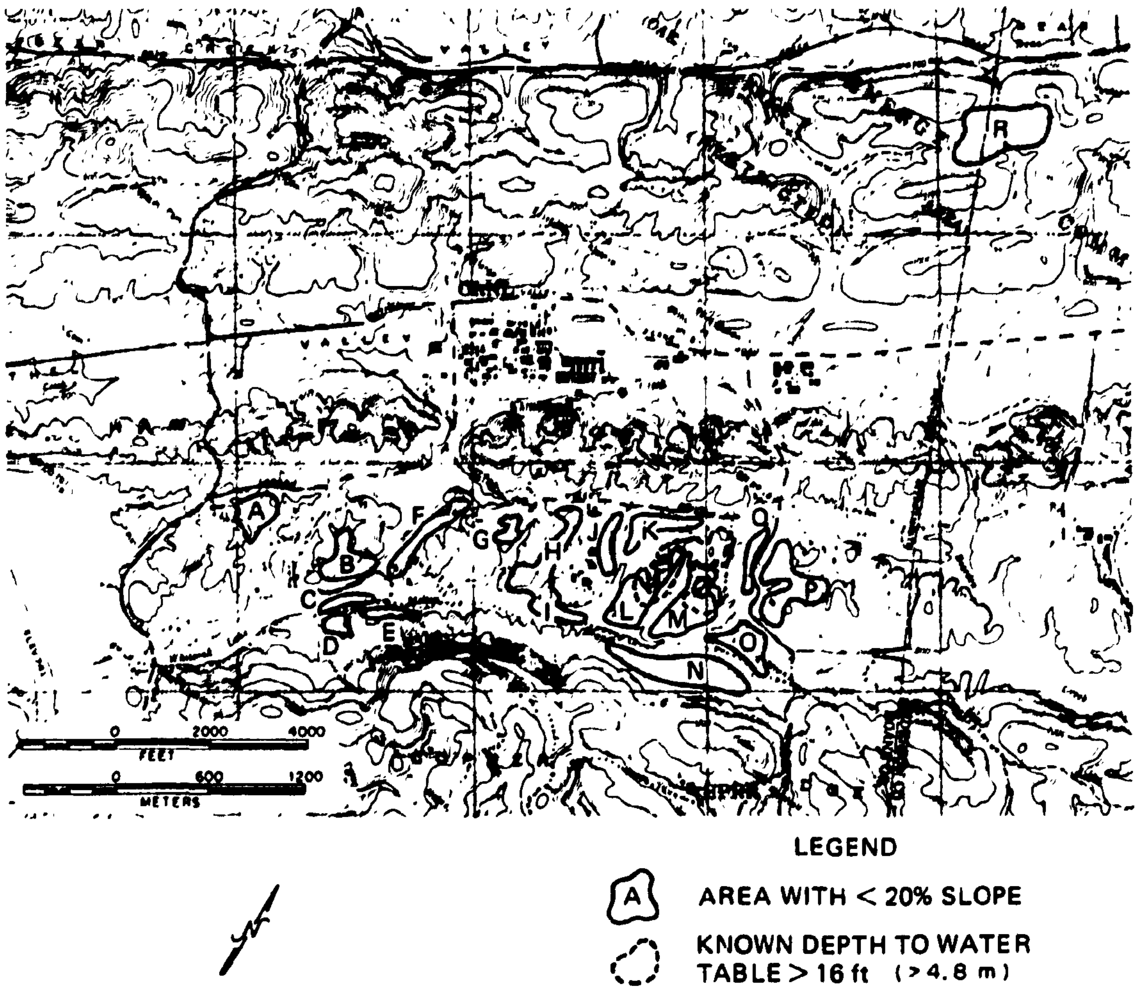

Fig. 5. Tracts in Melton Valley with <20% slope and unoccupied by existing facilities.

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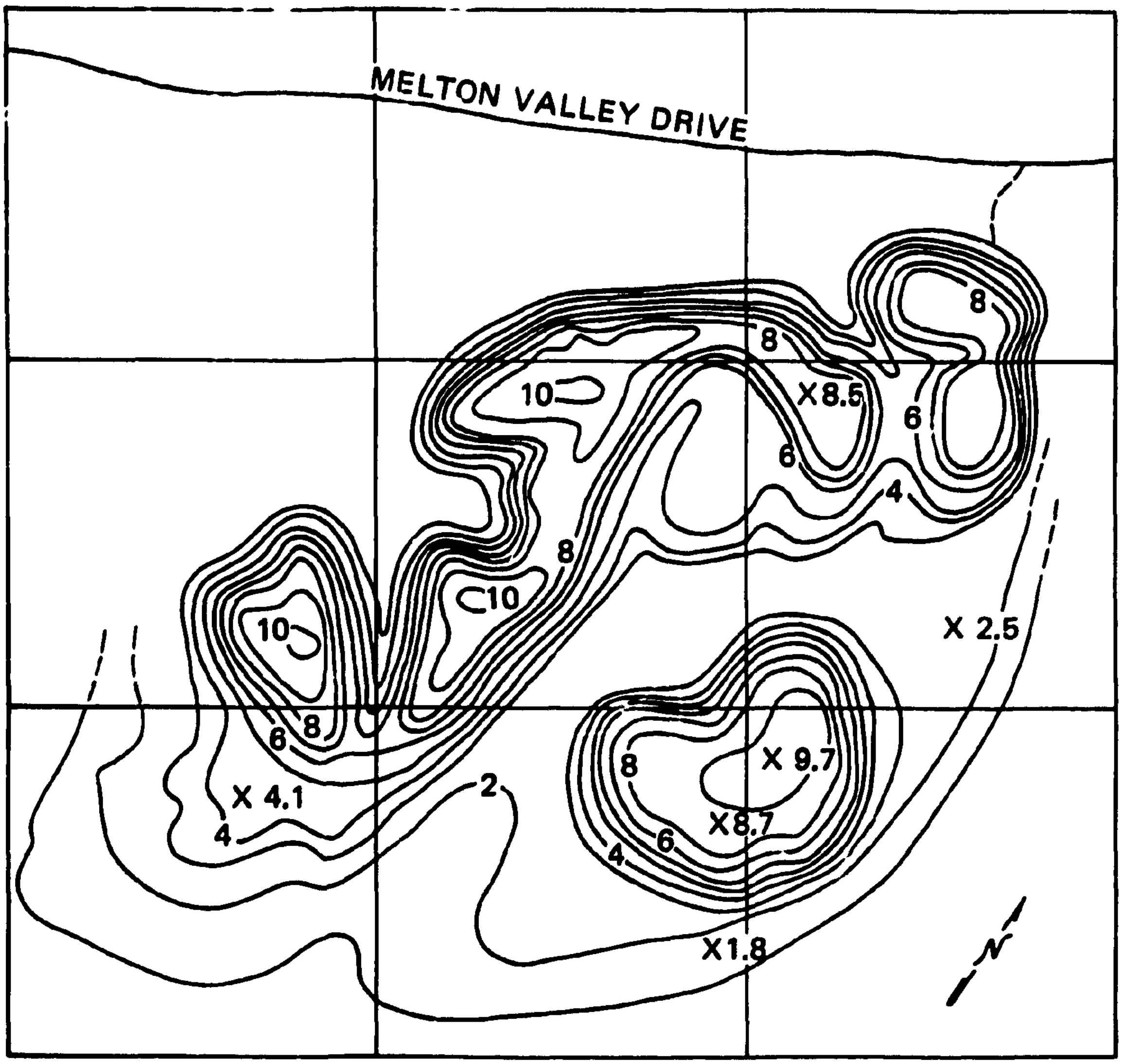

Fig. 6. Depth to water table (in meters) in the vicinity of tracts M and L.

11 water-monitoring wells that have provided preliminary data on the depth to the water table located on this acreage. About 6.5 ha on these tracts have depths to water >5.0 m which may be considered favorable (Fig. 6). Detailed site-characterization studies of this tract should delineate this area more precisely.

Tract N is next largest in size and contains 15 ha situated on the southea[illegible] side of Melt[illegible] he upper portion of the Conasauga Group. The more abundant li[illegible] within the upper Conasauga Group in this location could pose excavation and water problems. With an average elevation of 250 m, tract N receives its ground-water recharge from the main drainage-basin divide along Copper Ridge (elevation nearly 360 m) immediately to the southwest. This relationship could result in relatively shallow depths to water over most of the tract. Several drill holes are needed to make this determination and appear warranted because of the large size of the tract.

Tracts H and I collectively cover 14 ha and should have favorable bedrock, because they lie along strike with SWSAs 5 and 6. However, no data on water conditions are available. There is speculation that favorable water-table depths might be encountered only along the north-south trending hill designated H in Fig. 5. This area would account for ∿35% of the total area, reducing the land useable for burial to no more than 5 ha.

Tract P, involving 10 ha, lies within the headwaters of Melton Branch, and is the only site in proximity to the Whiteoak Creek Basin divide where it crosses the outcrop belt of the Conasauga Group. A location near this interfluve might provide favorable water-table conditions as well as a reduced runoff volume. Elevations throughout tract P range from 250 to 270 m. As in tracts H and I, the bedrock should be correlative with rocks encountered in SWSAs 5 and 6. Even with a conservative 30% reduction in size due to possible unfavorable factors, this tract could potentially provide 7 ha of burial space. Several drill holes are also needed here to establish the feasibility of further characterization studies.

In summary, the following statements can be made concerning the location of SWSA 7 within Conasauga terrane in Melton Valley:

1. The most promising site, based on current data, is the area embraced by tracts L and M. At least 6 ha appear suitable for waste burial, and this total might be increased as more data are gathered during site characterization.
2. Several bore holes should be drilled in both tracts N and P to determine water-table depths; petrologic information about the bedrock and the regolith would also be acquired.

5. SUMMARY AND CONCLUSIONS

This report completes the initial surveillance of the ORR area for siting SWSA 7 and has considered as parameters the watersheds and the bedrock formations and regolith forming the land surface within these watersheds.

For the immediate future, a location within the Whiteoak Creek watershed appears to be the best burial site option because (1) it contains all waste-burial facilities presently utilized with reasonable success by ORNL; (2) it has an existing water-quality monitoring system; (3) portions of the basin are underlain by formations that are acceptable as burial media; (4) appreciable hydrologic data are available; and (5) the watershed is near the sources of low-level wastes.

Of the seven rock units that form the bedrock at ORNL, two have characteristics that make them the most likely choices as burial media for low-level wastes. These units are the Conasauga and Knox Groups, both of which occur within the Whiteoak Creek basin. The Conasauga Group appears preferable because of its performance under the waste-disposal program currently active on the ORR. Knox residuum, while apparently successful for sanitary landfills in East Tennessee, has not been sufficiently investigated at this time to evaluate its potential as a burial medium for low-level radioactive wastes at ORNL. However, a tract in northeastern Whiteoak Creek basin underlain by Knox strata ("R" in Fig. 5) should be characterized in detail for consideration as a future burial ground.

Four tracts, each containing >8 ha, within the 550-ha Melton Valley portion of the Whiteoak Creek drainage basin are underlain by the Conasauga

Group and have been tentatively evaluated as deserving further site-characterization studies. Based upon the guidelines, criteria, and considerations herein, tracts L and M, when considered together, are the leading candidates for these future studies, since they already have monitoring wells installed on them and lie along strike with the same rock units in which existing disposal facilities are located. Of secondary interest are tracts N and P, which contain approximately 15 and 10 ha, respectively, and appear to have characteristics potentially suitable for waste burial.

Our recommendations are that site-characterization studies should proceed on the combined L and M tracts with an intent toward utilizing this area for SWSA 7. Exploratory drilling is, however, warranted for tracts N and P. As noted, all these tracts are underlain by strata of the Conasauga Group. Detailed geologic mapping and exploratory drilling should also be performed on a tract underlain by the Knox Group and located in the extreme northeastern portion of the Whiteoak Creek watershed.

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