3.0 HYDROGEOLOGIC SETTING

Morrison Cove is hydrogeologically isolated from surrounding areas by mountain ridges, which act as strong surface water and groundwater divides. Surface runoff and groundwater runoff originate as precipitation within Morrison Cove, and leave Morrison Cove as surface water discharge (i.e., streamflow) through the water gaps, or via groundwater discharge from seeps and springs discharging directly into the Frankstown Branch Juniata River.

The hydrogeologic setting of Morrison Cove incorporates aspects of bedrock geology, structural geology, hydrogeology, and other factors. These are addressed below in separate sections.

3.1 Bedrock Geology

The bedrock consists of sedimentary rocks of marine and marginal marine origin. The rocks themselves are of differing types, with quartz-rich sandstones and carbonates being the most common. The rocks were deposited in horizontal layers (beds), and deformed into a series of complex folds with associated faulting during the formation of the ancestral Appalachian Mountains. The current mountains are the result of erosion of a folded bedrock terrain with formations of differing resistance to erosion (i.e., differential erosion). Over geologically long periods of time, the less resistant carbonates were eroded relatively quickly and formed valleys, while the sandstones tended to resist erosion and form high ridges.

The distribution of geologic formations that crop out in Morrison Cove is shown in Figure 3-1. Their lithologic characteristics are summarized in Appendix A. The stratigraphic sequence (order of deposition in geologic time) can be summarized as follows: Cambrian dolostones with interbedded sandy dolostone, sandstone, siltstone, and shale give rise to Lower Ordovician dolostones and minor limestones, which have much less sand, silt, and clay. The dolostones rapidly transition into Middle Ordovician limestones with minor dolostones. These transition into a sequence of siliclastics of late Ordovician to Early Silurian age. These exhibit an overall coarsening upward trend, starting with organic-rich shale (Antes) at the base, and culminating with the Bald Eagle and Tuscarora sandstones. For detailed discussions of the bedrock geology and stratigraphy of the Morrison Cove area, the reader is referred to the relatively extensive previous work on this subject (Berkheiser, 1986; Butts, 1939 and 1945; Harper and Laughrey, 1996; Kay, 1944; Rones, 1969; Wilson, 1952).

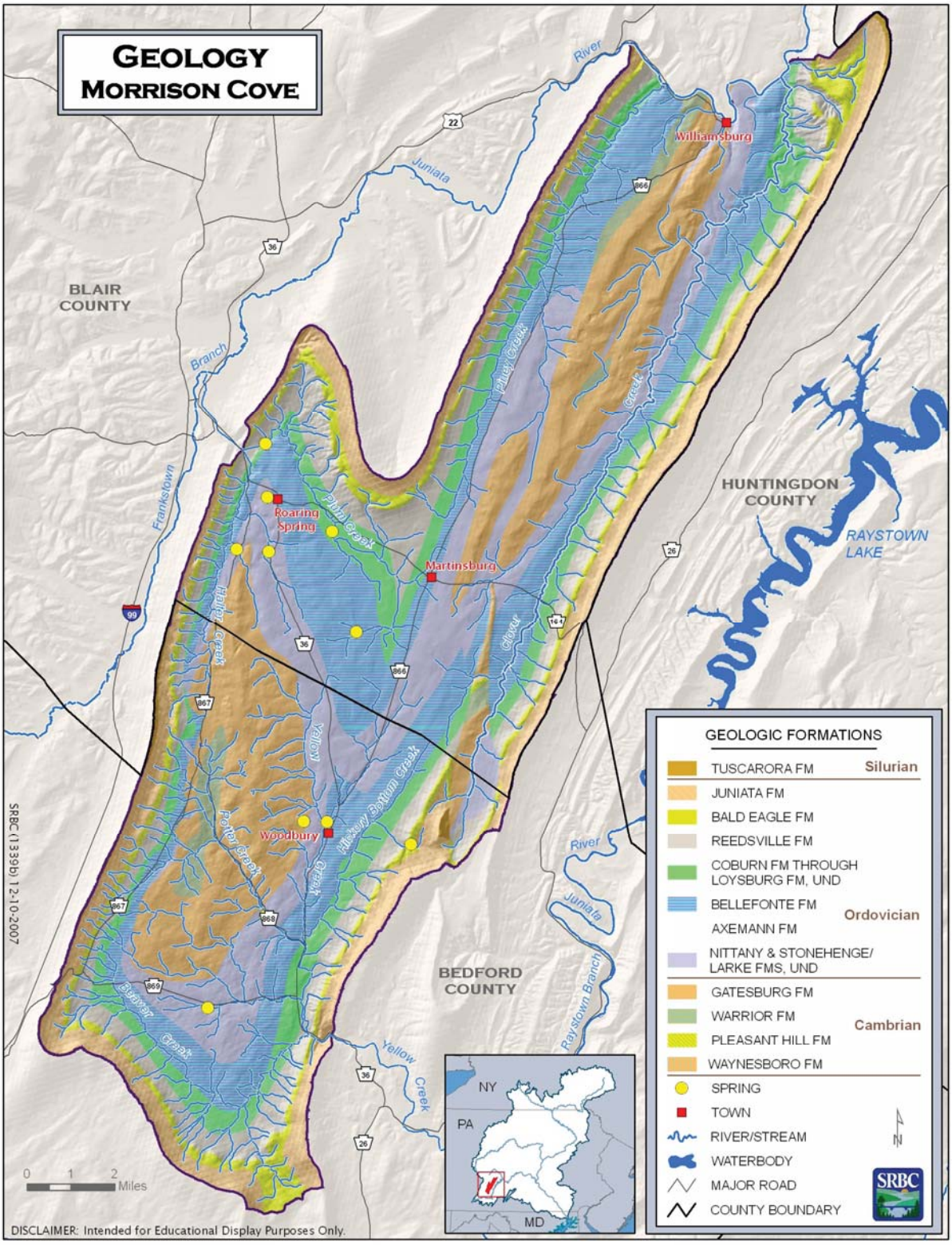

Figure 3-1. Geologic Formations in Morrison Cove (after Berg et al., 2001)

3.2 Structural Geology

The geologic formations discussed under 'Bedrock Geology' were deposited as flat (tabular or prismatic), horizontal bodies of sediment. These rock bodies were complexly folded and faulted during the formation of the ancestral Appalachian Mountains. The major geologic structure in Morrison Cove is the Nittany Anticlinorium, a large anticline with superimposed secondary folds and faults. This feature is more than 130 miles long, and extends from several miles southwest of Morrison Cove, northeast to the vicinity of Williamsport. Although the resulting geologic structure is relatively complex, it can be simplified with little disservice to the goals of this study. The simplified geologic structure is that of a simple anticline, the crest of which is oriented northeast-southwest. The anticline is slightly asymmetric, with the northwest side being steeper than the southeast side. Rock beds on the northwest side are nearly vertical, while those on the southeast side dip (i.e., slope) 50-70 degrees away from the center (Figure 3-2). Beds of sedimentary rock tend to occur as bands that parallel the nearest mountain ridge. Beds are nearly horizontal along the axis of the fold. A more detailed discussion of the structural geology of the Morrison Cove region can be found in Canich and Gold (1985), Parizek and White (1985), and Butts (1939), while a useful overview is provided by Faill and Nickelsen (1999).

Figure 3-2. Roadcut in Loysburg Water Gap, Yellow Creek, Showing Sandstone Beds in the Bald Eagle Formation Dipping at Approximately 50 Degrees to the Southeast

Uplift and differential erosion of the Nittany Anticlinorium has resulted in an elongate valley underlain by carbonates, and bounded by a wall (mountain ridge) of sandstone (Figure 3-3). This intermontain valley complex is over 100 miles in length and extends from Morrison Cove northeastward to the State College area, where it splits into Nittany Valley and Penns Valley. Morrison Cove is the southernmost portion of this intermontain valley. Morrison Cove is approximately 30 miles long and varies from five to eight miles in width.

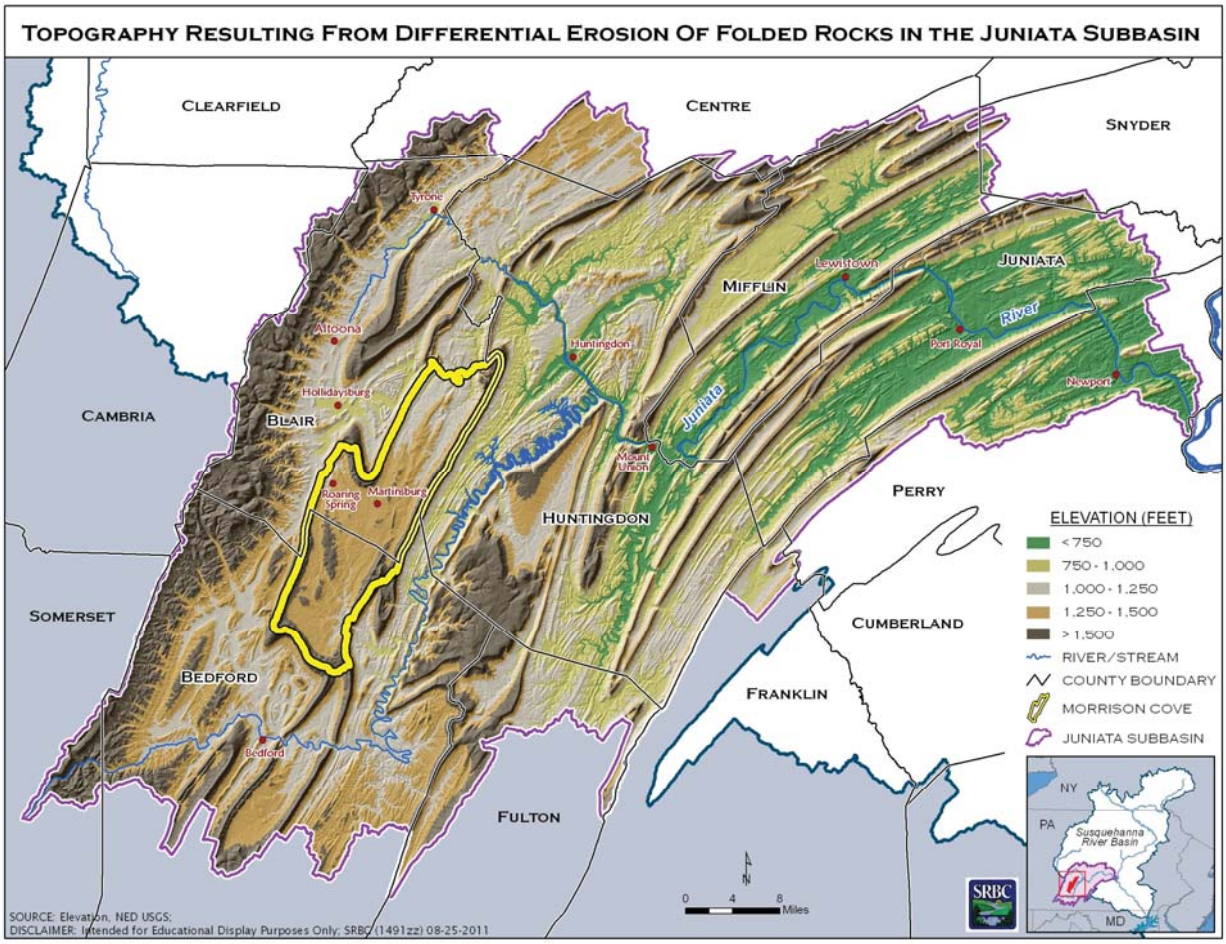

Figure 3-3. Topography Resulting from Differential Erosion of Folded Rocks with Differing Resistance to Erosion

3.3 Hydrogeology

The ability of subsurface materials to store and transmit water (called permeability) depends on the amount of open (pore) space in the rock, and how well the space is interconnected. Primary porosity consists primarily of inter-granular space (for example, the open spaces between adjacent sand grains). Becher (1996) summarizes the water-bearing characteristics and water quality of the individual formations that are stratigraphically below the Bald Eagle Formation (i.e., the formations that underlie the valley). The hydraulic parameters

derived from aquifer tests in the Nittany Valley are reviewed and summarized in Fulton et al. (2005).

3.4 Hydrogeologic Terrains

Hydrogeologic terrains are geographic regions that are characterized by their groundwater flow systems. A hydrogeologic terrain includes all the land area contributing surface water and groundwater to the underlying aquifers, as well as the discharge areas. They may contain multiple aquifers and diverse topography, but are related by the flow of groundwater. Small watersheds may serve a single hydrogeologic terrain, but larger watersheds usually contain multiple hydrogeologic terrains. There are three distinct hydrogeologic terrains in the Morrison Cove study area (Figure 3-4) and they are discussed below.

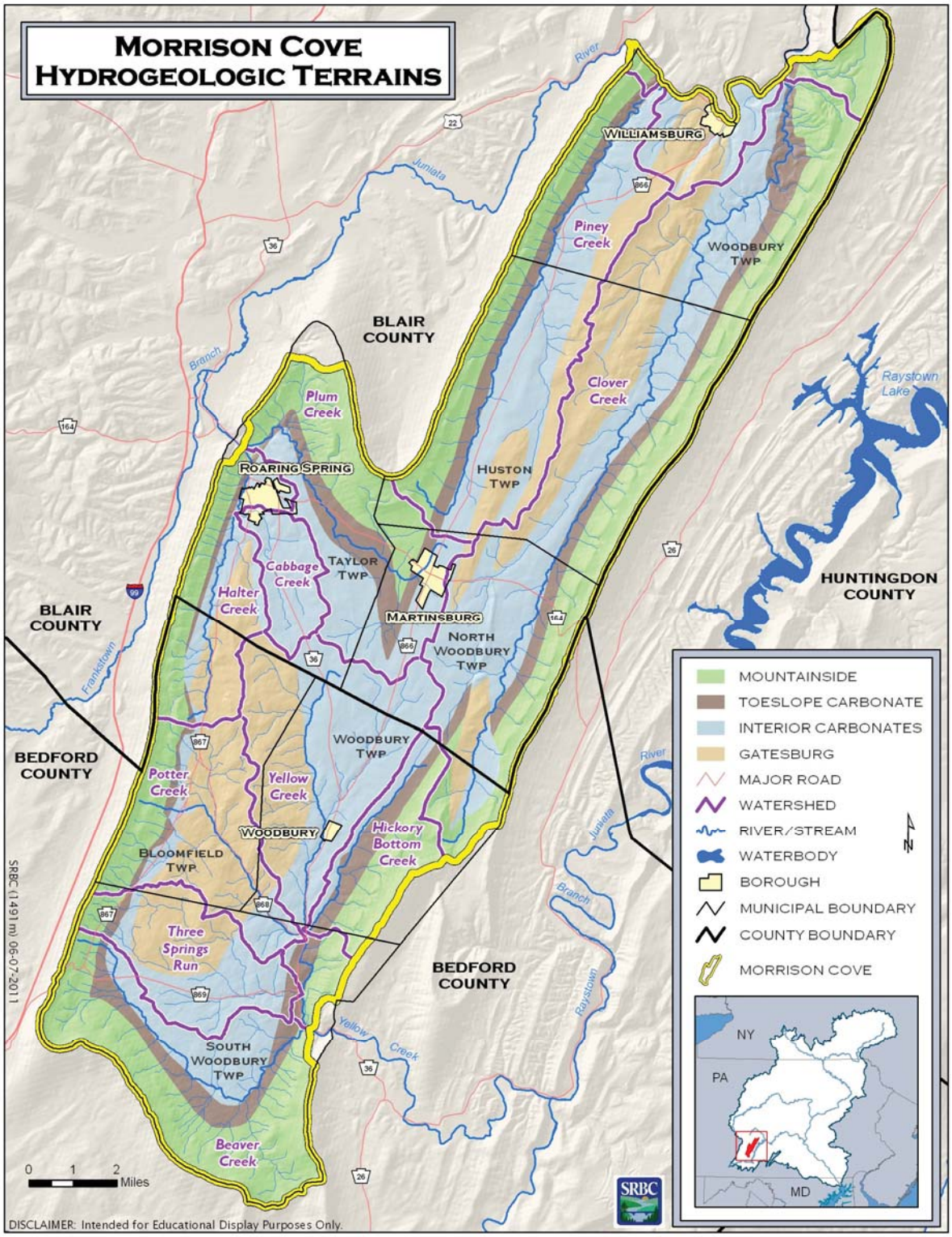

Figure 3-4. Hydrogeologic Terrains and Secondary Watersheds in Morrison Cove

3.4.1 Mountainside/Toeslope Carbonates Terrain

The hydrogeologic characteristics associated with the Mountainside/Limestone Valley Terrain have been studied in Nittany Valley where they are well-developed (Konikow, 1969; Parizek, 1971; Parizek and White, 1985). In the Mountainside/Toeslope Carbonates Terrain, the siliciclastic aquifers underlie a mountainside and contribute acidic groundwater to limestone aquifers in the adjacent valley. Acidic surface water flowing down the mountainside is captured by infiltration and by sinkholes at the base of the mountain, as the streams pass from siliciclastic to limestone bedrock. The acidic water causes the development of the karst conduits in the limestones underlying the valley. The limestone formations occur in a narrow band that parallels the mountain ridge, so the conduits do as well. In essence, the strike parallel conduits in the limestones at the foot of the mountain ridges collect acidic groundwater and surface water runoff from the siliciclastic mountain ridges. The strike-parallel conduits convey this water down gradient and along strike until it emerges as spring flow or discharge beneath stream alluvium. The permeability of the limestones "outside" of the conduit system is essentially that of a fractured bedrock aquifer with localized, poorly-integrated karst. The limestone portion of this terrain includes the following formations: Loysburg, Hatter, Snyder, Linden Hall, Nealmont, Salona, and Coburn. The total thickness of the limestones is approximately 600 feet (Canich and Gold, 1985). The siliciclastic portion of this terrain includes the following formations: Tuscarora, Juniata, Bald Eagle, and Reedsville. The total stratigraphic thickness of the mountainside siliciclastics is approximately 3,700 feet (Canich and Gold, 1985).

3.4.2 Interior Carbonates Terrain

The Interior Carbonates Terrain corresponds to a belt of dolostones and minor limestones of Lower Ordovician age that underlie much of the interior of Morrison Cove. It includes the Stonehenge/Lark, Nittany, Axemann, and Bellefonte Formations, with a total stratigraphic thickness of approximately 3,400 feet. Groundwater flows from hilly uplands to nearby streams. Aquifers in this terrain are of low (Bellefonte Formation) to moderately high (Nittany Formation) permeability. Karst is locally developed and greatly increases permeability.

In Morrison Cove, the Bellefonte Formation is a medium to thick bedded, dark gray dolostone that is rich in silt and organics. These impurities inhibit carbonate dissolution along fractures and bedding partings. As a result, this formation has relatively low permeability. The Bellefonte Formation acts as an aquitard, and forms a discontinuous groundwater flow boundary between the Mountainside/Toeslope Carbonates Terrain and the Interior Carbonates Terrain. The New Enterprise Stone and Lime quarry at Roaring Spring is an approximately 900 by 2,200 foot open pit excavated into the Bellefonte Formation to a depth of over 150 feet below Halter Creek as it flows over the high permeability limestone belt of the adjacent Mountainside/Toeslope Carbonates Terrain. The quarry highwalls exhibit minimal weeping from fractures, and a lack of conduits. Groundwater pumping to maintain dry working conditions is remarkably low, averaging 174,000 gallons per day (121 gpm average for 2006 through 2009: NESL, 2010). The Bellefonte Formation locally forms a low ridge approximately equal in width to its thickness in the western side of Morrison Cove, where the beds are nearly vertical.

In the lower reach of Cabbage Creek, the Bellefonte Formation forms a strong nickpoint on Cabbage Creek as it leaves the Interior Carbonates Terrain, and appears to form a groundwater dam. Behind the dam, the valley is filled with springs. A number of springs and spring fields in the Yellow Creek Watershed likely have a similar cause.

3.4.3 Gatesburg Terrain

The Gatesburg Terrain largely corresponds to the outcrop of the Upper Cambrian Gatesburg Formation. This terrain occurs as a forested, central upland in the southern half of Morrison Cove and as two elongate belts in the northern half, between Martinsburg and Williamsburg. The majority of this terrain is underlain by interbedded dolostone, sandy dolostone, and quartz sandstone that comprise the Upper Sandy and Lower Sandy members of the Gatesburg Formation. The terrain is deeply weathered, with a residuum of silty quartz sand that is typically several tens of feet thick (Parizek and White, 1985). The substantial thickness and relatively high permeability of the residuum make it a nearly ideal recharge material. It can accept water at a high rate and has a large storage capacity. The unusually high capacity of the residuum to accept precipitation and snowmelt is seldom exceeded. As a result, most of the first and second order streams are ephemeral, and there is very little rejected recharge.

The Gatesburg Terrain locally includes the neighboring portions of the Interior Carbonates (Stonehenge/Lark Formations and lowermost Nittany Formation) where these are interpreted to contribute groundwater flow to the Gatesburg Terrain. This may occur where the lowermost Interior Carbonates "overhang" the Gatesburg Formation at shallow depths. Groundwater in these overhung fractured and solutioned carbonates flows into the subjacent Gatesburg Formation, where the hydraulic head is generally lower during extended periods of base flow. Such conditions are common during the months of July through October. These "annexed" contributing areas are especially apparent in the Northern Gatesburg Terrain, where the groundwater flow from two unnamed tributary watersheds appears to be captured. They flow from the interior of the Northern Gatesburg Terrain out onto "overhung" portions of the Interior Carbonates Terrain, and were observed to be dry during the seepage run.

Other formations (the Warrior and Pleasant Hill Formations) that occur in the "interior" of the Gatesburg Formation, along the crest of the Nittany Anticlinorium, have been included in this hydrogeologic terrain, but comprise less than 5 percent of its areal extent. The upper (Mines), middle (Ore Hill), and lower (Stacy) members of the Gatesburg Formation are also included. Together they comprise about one-third of the Gatesburg Formation, but do not share the lithologic and hydrogeologic characteristics of the upper and lower sandy members (see Appendix A). The members of the Gatesburg Formation are generally not mapped separately.

The Gatesburg Terrain is usually structurally complex, so the total stratigraphic thickness is less certain than the other terrains. The stratigraphic thickness of the Gatesburg Formation (by itself) is approximately 1,900 feet (Canich and Gold, 1985). The Upper Sandy member is approximately 500 feet thick. The Lower Sandy member is approximately 700 feet thick (Parizek and White, 1985). They are separated by the Ore Hill member, which is approximately 260 feet thick (Parizek and White, 1985).