Preface

For more than 2500 years, soil tunnels have been used in warfare. Initially, tunnels were utilized to attack fortresses that were underlain by unconsolidated (non-bedrock) soil materials. Later tunnels provided housing and served as smuggling corridors. The medieval warfare undermining technique involved digging soil tunnels with wooden or beam props to hold up the soil ceilings. Then flammable material, such as hay or straw, was put in the tunnel and set on fire. The fire burnt the support beams which collapsed the soil tunnel ceilings and undermined the overlying perimeter wall. Later gunpowder and dynamite replaced fire when attempting to collapse a tunnel, fortress or perimeter defense. Modern warfare soil tunnels were the pathways used to move troops, weapons and supplies to the other side of a border or wall for surprise attacks. Most of the soil tunnels were placed in easy-to-dig unconsolidated soil materials that had a low water table and were not subject to flooding. Eventually, machinery was used to drill through bedrock permitting deeper and longer tunnels for troop movement or smuggling. However, when drilling through bedrock under international borders, the process creates both noise and vibrations which were often detected by the enemy. Once discovered, the tunnels were often collapsed by blowing up the tunnel, injection of gas, filling with water or wastewater, or inserting barriers. A series of case studies will be examined with the goal of determining soil and site criteria required to permit successful tunneling. The most restrictive soil and geologic conditions will be identified as well as potential mitigation methods used to overcome the site restrictions will be documented. Countries with warfare issues along their borders, such as Israel and the United States, need to identify the sections of the border most likely to be undermined by soil tunnels. In the case of Israel, their entire border is susceptible because of the favorable arid climate, soils,

and geology. The US border with Mexico can become vulnerable wherever a new wall is created. Without a wall, there is usually no need for soil tunnels. The US Department of Homeland Security and border patrol will need to monitor the noise and vibrations, just like Israel does, to identify future soil tunnel locations. Eventually, most of 3200 km border will have a wall that will become the target of more soil tunnels for smuggling goods and people from Mexico into the United States.

Kenneth R. Olson, *Ph.D. Emeritus*, *Professor of Soil Science*, *NRES*, *ACES, University of Illinois*, *Champaign-Urbana*, *Illinois*, *USA*