decreasing bearing capacity with depth until the sand layer was encountered. Normally the bearing capacity of a soil increases with depth as the lower layers are more condensed. The opposite is true for the Pochuck Quagmire Bridge site. The organic muck layer — 8 feet underground — was completely unsuitable for supporting a structure. It is also important to recognize that clay soils swell and shrink with change in water content and are very susceptible to frost heave. Frost heave was a concern for the bridge because it would be located at the center lowpoint of a narrow valley. One could expect temperatures to be 5 to 10 degrees colder at the bridge site than surrounding higher elevations. In short, the soil conditions were half jokingly - half seriously referred to as among the "Worst in the World."

The tower foundation system must transfer the tower design loads to suitable subsurface bearing stratum. The bearing capacity of a soil is the load in tons per square foot that can be applied to a given area without causing a settlement of more than a given amount. The ultimate bearing capacity of a soil is the load, usually in tons per square foot, that can be applied to a given area without causing a sudden settlement. The allowable bearing capacity is the recommended load per square foot that would be transmitted by the structure under full live and dead loads to the soil, adjusted by proper safety factors. The primary load the foundation for a pedestrian suspension bridge needs to be designed for is the axial column load of the full design live and dead loads. Uplift, overturning, and sliding under every possible combination of forces also need to be addressed. This should include wind and hydrodynamic loads. As important as provisions for preventing excessive settlement are design investigations and elements to prevent differential settlement. Excessive differential settlement would put the bridge towers out of plumb (i.e., Leaning Tower of Pisa).

Utilization of driven piles into the sand layer was not an economically or environmentally viable solution. A shored, pumped mass wet excavation to the sand layer and subsequent backfill with 3/4-inch crushed stone was equally unrealistic. For the project to proceed, a hand constructed shallow foundation addressing the structural needs of the bridge needed to be devised. The eventual foundation is best described as a hybrid. The twin tower foundations consist of a shallow combined reinforced concrete spread footing (12 feet by 16 feet by 12 inches) connected to Chance® Helical Anchors and Tensar® UX-1400 Geogrid. It was nicknamed "The Snowshoe." The elements of the foundation address settlement, shear strength, overturning, lateral stability, and buoyancy.

Review of Other Timber Tower Pedestrian Suspension Bridge Foundations

Prior to discussing the Pochuck Quagmire Bridge snowshoe foundation in greater detail, this case study shall diverge and briefly review more conventional foundations from other timber tower pedestrian suspension bridges listed on pages 12 and 13. This is presented in recognition that most readers of this case study who are planning a bridge will most likely not have soil conditions as poor as that of the Pochuck Quagmire. Review of more traditional foundations should be helpful. It will also serve to highlight the uniqueness of the "Pochuck Snowshoe."

The Jackson River Bridge is shown in photos 11 and 12. It is located in the Warm Springs Ranger District of the George

Photo 11. Inclined towers of the Jackson River Bridge. *Photo Courtesy of Mr. Tibor Latincsics.*

Photo 12. Jackson River Bridge in the George Washington and Jefferson National Forest. *Photo Courtesy of Mr. Tibor Latincsics.*

Washington and Jefferson National Forest (GW & JNF), Virginia. It was constructed in 1988. It is a trail bridge located a few miles north of Hidden Valley Campground. The author was advised of the bridge's location and particulars upon visiting the GW & JNF Headquarters in Harrisonburg, Virginia. Mr. William Talley, Mr. Terry Smith, and Mr. Lannie Simmons of the Forest Engineering staff were most helpful. They allowed review of the bridge plans and provided background information as well as an inventory of suspension bridges throughout GW & JNF.

The Jackson River Bridge has a 135-foot center span. It is supported by 26-foot tall, inclined, cross-braced southern yellow pine poles. An elegant visual element of the Jackson River Bridge is the inclined poles. This also provides lateral structural stability. The GW & JNF Forest Engineering staff advised the author that the professional contractor had an extremely difficult time setting the poles to the correct angle. This and other design criteria convinced the author to specify vertical poles for the Pochuck Quagmire Bridge. Figure 4 is a diagram of the Wild Oak Bridge, which is very similiar to the Jackson River Bridge. In this case, the Jackson River Bridge poles were set on a 4-foot by 16-foot by 16-inch reinforced concrete footing. The footing is 6 feet below grade. The base of the poles are set into a 2-foot vertical extension of the footing. The Jackson

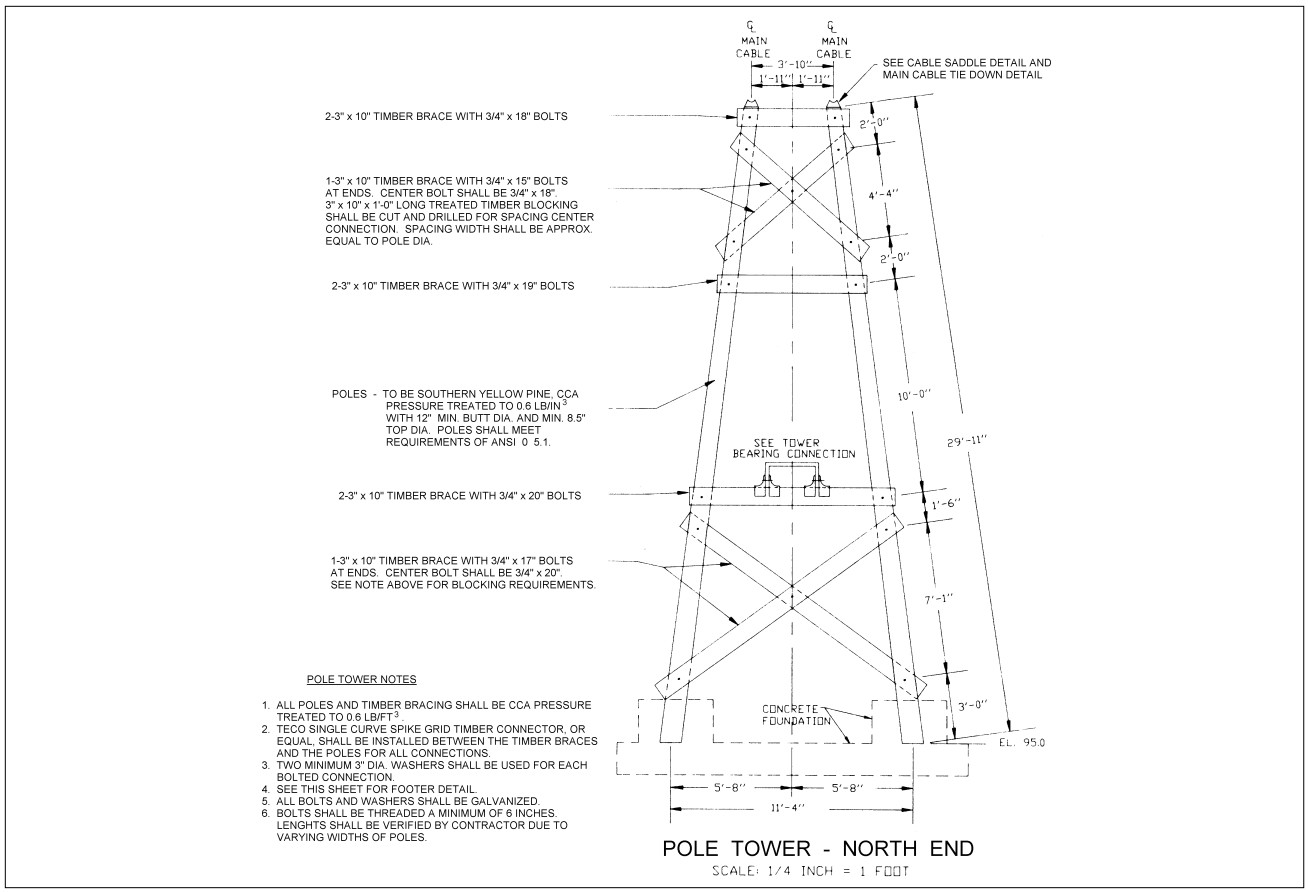
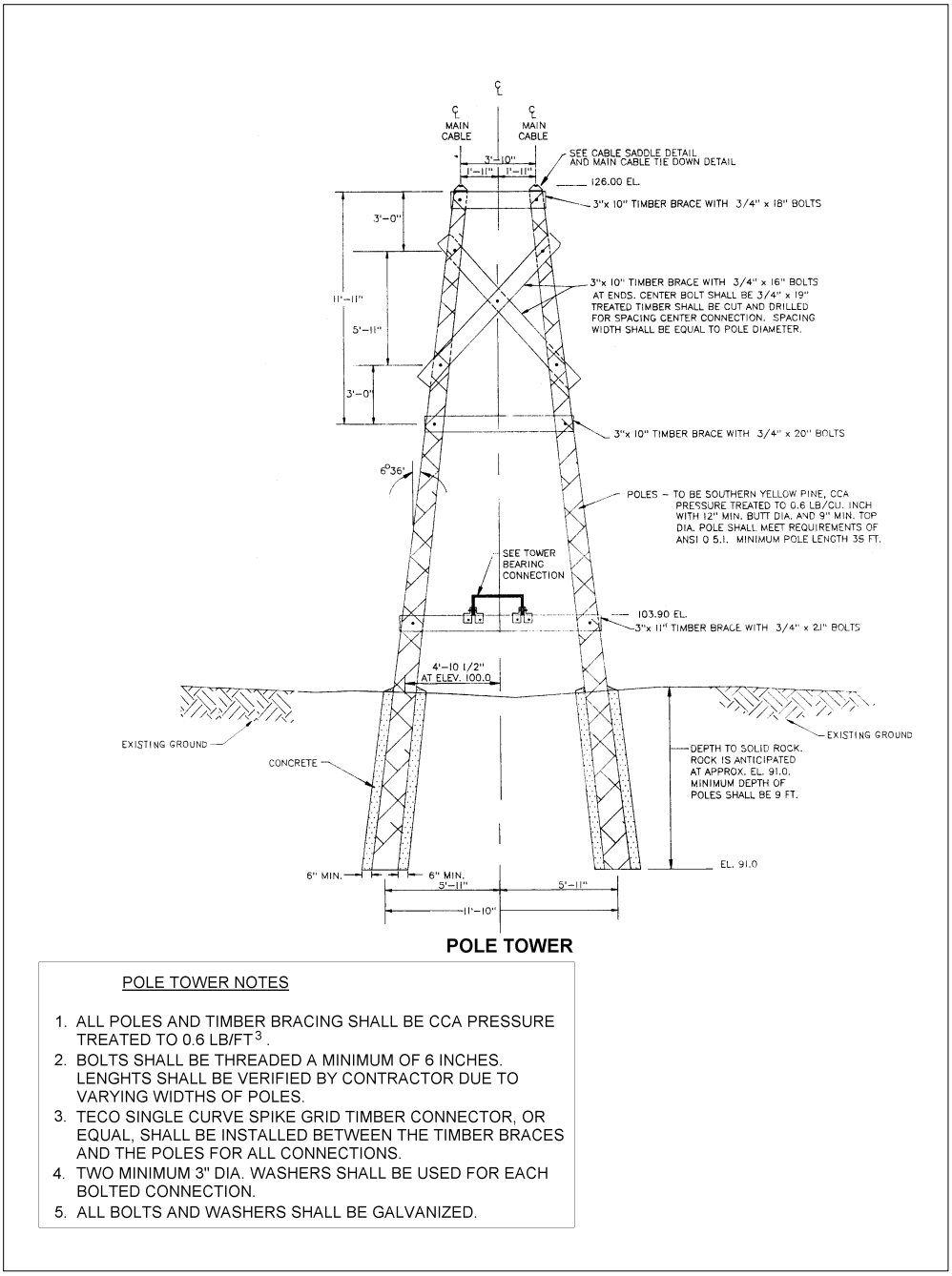


Figure 4. The Wild Oak Bridge Tower. *Diagram courtesy of the George Washington and Jefferson National Forest Engineering Staff.*

River Bridge and its foundation is typical of the suspension bridges in the GW & JNF. This includes the Tye River and Kimberly Creek Bridges, both of which are located on the Appalachian Trail.

A few miles to the northeast of the Jackson River Bridge is the Wallace Tract Trail Bridge. It is located within the Deerfield Ranger District of the George Washington and Jefferson National Forest. It is a 150-foot center span bridge over the Cow Pasture River. Constructed in 1991, it shares many design and construction features of the Jackson River Bridge. In this particular case, the good soil and geologic conditions allowed a simple but effective foundation. The foundation consists of augering down 9 feet to ledge rock, placing the transmission poles, and backfilling with concrete. The tower and foundation are detailed in Figure 5. A second reason this style foundation was utilized is that similar to the Pochuck Quagmire Bridge a local electric power company volunteered the poles, labor, and equipment to set them. The augered hole foundation was more suited to their normal operations. The *AITC Timber Construction Manual* provides a good review of the required embedment depth, allowable direct, and lateral bearing pressure for a pole foundation.



POLE TOWER

POLE TOWER NOTES

1. ALL POLES AND TIMBER BRACING SHALL BE CCA PRESSURE TREATED TO 0.6 LB/FT^3.
2. BOLTS SHALL BE THREADED A MINIMUM OF 6 INCHES. LENGHTS SHALL BE VERIFIED BY CONTRACTOR DUE TO VARYING WIDTHS OF POLES.
3. TECO SINGLE CURVE SPIKE GRID TIMBER CONNECTOR, OR EQUAL, SHALL BE INSTALLED BETWEEN THE TIMBER BRACES AND THE POLES FOR ALL CONNECTIONS.
4. TWO MINIMUM 3" DIA. WASHERS SHALL BE USED FOR EACH BOLTED CONNECTION.
5. ALL BOLTS AND WASHERS SHALL BE GALVANIZED.

Figure 5. Wallace Tract Bridge Pole Towers, George Washington and Jefferson National Forest. *Diagram courtesy of George Washington and Jefferson National Forest Engineering Staff.*

The USDA Forest Service also constructed a series of timber tower suspension bridges in the White Mountain National Forest (WMNF) in New Hampshire and Maine. As listed on pages 12-13, these include the Wilderness Trail Bridge, the Lincoln Woods Trail Bridge, the Dry River Bridge, and the Hastings Trail Bridge.

Photo 13. The Lincoln Woods Trail Bridge. *Photo courtesy of Mr. Tibor Latincsics.*

Photo 14. The Lincoln Woods Trail Bridge. *Photo courtesy of Mr. Tibor Latincsics.*

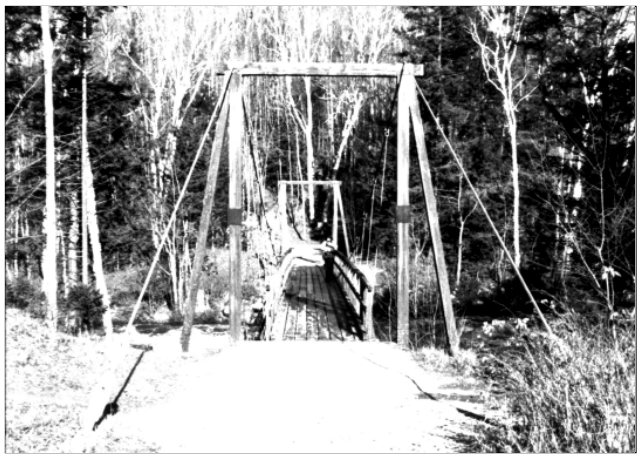


Photo 15. The Lincoln Woods Trail Bridge. *Photo courtesy of Mr. Tibor Latincsics.*

The design of these bridges follows a similar pattern. Photos 13, 14, and 15 show the Lincoln Woods Trail Bridge.

The foundation used for the Wilderness Trail across the East Branch of the Pemigewasset River is typical of the foundations for the WMNF bridges (Figure 6). The design for these bridges utilizes a 3-foot wide reinforced concrete strip footing. A 12-inch reinforced concrete wall is keyed to and atop the centerline of the strip footing. The length of the footing and foundation is determined by the tower dimensions. The foundation wall extends several feet above grade. A 12-inch by 12-inch sill timber is attached to the foundation wall by anchor bolts. The 12-inch by 12-inch timber tower legs are attached to the sill with base plates, drift dowels, and steel angles. This assembly of footing-foundation wall sill connections is very similar to residential and pole style construction.

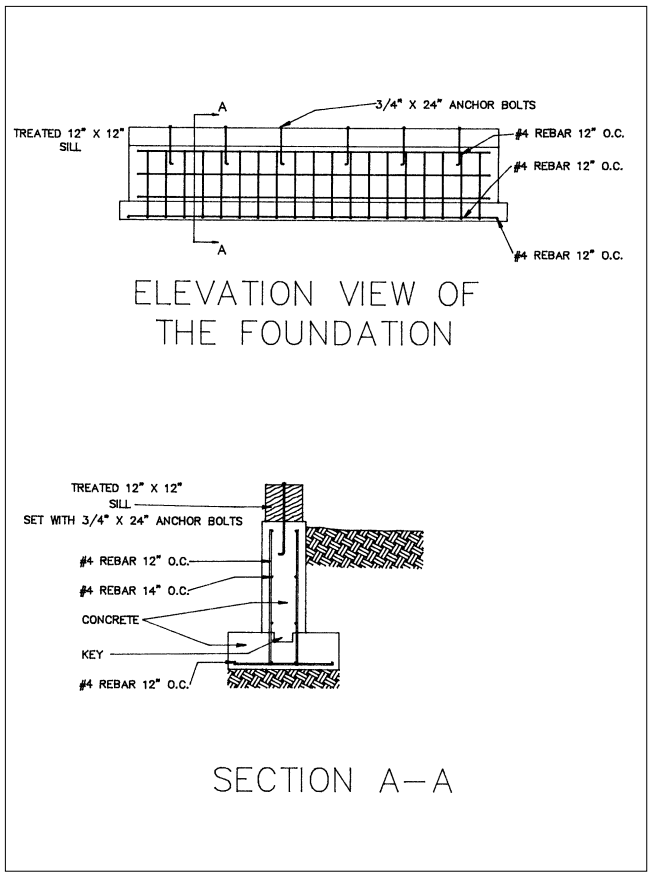


Figure 6. Simplified sketch of a typical foundation of the White Mountain National Forest suspension bridges. *Diagram courtesy of White Mountain National Forest Engineering Staff.*