EVALUATION OF THE SURFICIAL GEOLOGY AND DEPTH TO BEDROCK ALONG THE ROUTE OF THE PROPOSED NORTHERN PASS TRANSMISSION LINE IN THE VICINITY OF NEW HAMPTON, NEW HAMPSHIRE

October 2016

Presented to:
Ms. Barbara Lucas
Town of New Hampton

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October 28, 2016

Ms. Barbara Lucas
Town Administrator
Town of New Hampton
6 Pinnacle Hill Road
New Hampton, NH 03256

Subject: Estimated Probability of Encountering Shallow Bedrock based on an Evaluation of the Surficial Geology of the Proposed Northern Pass Transmission Line Route in the Vicinity of New Hampton, New Hampshire

Dear Ms. Lucas,

Emery & Garrett Groundwater Investigations, LLC (EGGI) has evaluated the surficial geology of the proposed route of the Northern Pass Transmission Line in the vicinity of New Hampton, New Hampshire. The purpose of this study was to compile and analyze existing geologic data along the proposed route to provide general background data that the Town can use to assess the feasibility of burying the transmission power lines.

EGGI estimated the probability of encountering bedrock at a depth of less than ten feet below ground surface (bgs) along a portion of the Northern Pass Transmission Line route based on available geologic data. This *was not intended to be a comprehensive engineering or geotechnical study* of the route, but is only intended as a preliminary background evaluation. No field work or subsurface investigations (drilling or geophysics) were performed by EGGI as part of this work effort.

Study Area

EGGI studied the 15.8-mile segment of the proposed Northern Pass Transmission Line from the point where it transitions from underground to overhead power lines in Bridgewater to the common Hill/Franklin Town line (Figures 1 and 2). The route was digitized by EGGI from a series of plans accessed from the Northern Pass website (Northern Pass, 2015). It generally follows existing power line right-of-ways. In Bridgewater, Ashland, and northwestern New Hampton, the route is generally situated in the Pemigewasset River Valley, while the southern portion of the route in Bristol, southwestern New Hampton, and Hill traverses several hills (Figure 3).

Surficial Geology

The surficial geology of the study area (Figure 4) was mapped by EGGI geologists as part of the New Hampshire Geologic Survey Surficial Mapping Program (Tinkham and Brooks, 2009, 2010, and 2012). Deglaciation occurred approximately 14,000 years ago in central New Hampshire. Prior to and during the recession of the glacier, the landscape was covered with a layer of poorly-sorted, silt to boulder-sized material collectively referred to as glacial till. In the

vicinity of the proposed Northern Pass Transmission Line, upland areas on the sides and tops of hills are generally mapped as either Till or Shallow Till (places where rock was inferred to be less than 10 feet below ground surface (Figure 4).

Large volumes of glacial meltwater carried sediment loads that formed extensive stratified drift deposits, consisting of sand and gravel, in the valleys. Glacial lakes periodically filled the valleys during deglaciation and allowed finer sand, silt, and clay-sized sediment to be deposited. After the glaciers receded and the glacial lakes drained, some of the remaining sediment was reworked by fluvial processes to form stream terraces and alluvial deposits. For the purpose of this study, non-till surficial deposits (including stratified drift and alluvial deposits) are shown for simplicity as one geologic unit on Figure 4. Generally speaking, the non-till areas shown on Figure 4 can be considered to be greater than 10 feet thick.

Bedrock Exposures

The locations of bedrock exposures (Figure 4) were compiled from published sources (Cotton and Olimpio, 1996; Tinkham and Brooks, 2009, 2010, and 2012), in-house EGGI mapping data, and from remote sensing performed for this project. A remote sensing analysis was performed to identify bedrock outcrops that are present in close proximity to the proposed Northern Pass route using 1-foot resolution air photos. Bedrock outcroppings are prevalent in three primary settings: a) on steeply sloping valley walls, b) on or near hill tops, and (c) where the rivers or streams have eroded down to bedrock. Bedrock exposures are more common in the southern portion of the study area (generally south of Route 104).

Surficial Aquifers and Existing Well Data

Saturated stratified drift deposits form extensive valley-fill aquifers in the study area (Figure 5). The aquifers were characterized in terms of transmissivity (Cotton and Olimpio, 1996), which is a measure of how easily groundwater flows through the sediments. In general, portions of the aquifers mapped as having a higher transmissivity tend to be located where sediment deposits are greater than 20 feet thick. In places, the aquifers in the study area can be greater than 200 feet thick (EGGI In-house Well Data).

Bedrock depth data for wells were obtained from the NHDES Water Well Inventory GIS layer. These data are plotted on Figure 5. Wells that encountered shallow bedrock (< 20 feet below ground) are depicted with warm colors (red), while deeper bedrock is illustrated with shades of blue. All of the existing wells located in aquifers with transmissivities mapped as >2,000 feet^2/day encountered bedrock at greater depths than 20 feet below ground. Bedrock was less than 20 feet below ground surface in some wells located in aquifers with transmissivities of < 2,000 feet^2/day, suggesting the margins of the aquifers can be located in areas with thinner surficial deposits. The well data show that bedrock depth is highly variable on the till-covered hillsides[1].

[1]Sixty-eight percent (68%) of the wells in the study area that are located in areas mapped as *"shallow till"* encountered bedrock at less than or equal to 10 feet below ground surface, while only 4% of the wells in areas mapped as *"till"* encountered bedrock at depths less than or equal to 10 feet below ground surface.

Probability of Encountering Shallow Bedrock

Two of the datasets presented herein provide direct measurements of the depth to bedrock beneath the surficial sediments. Bedrock outcrops show specific places where the depth to bedrock is zero. NHDES well data provide point locations where the depth to bedrock was reported by well drillers. Since the bedrock outcrops and well data points are not evenly distributed throughout the study area, other datasets were used to estimate/extrapolate the depth to bedrock.

EGGI evaluated the geology of various types of surficial deposits, topographic settings, and landforms to develop a means of qualitatively estimating the probability of hitting bedrock along the entire length of the proposed Northern Pass Transmission Line within the study area. The Northern Pass route was divided into segments that were assigned a probability of encountering bedrock at a depth that is less than 10 feet below the ground surface (bgs). These probabilities ranged from Very Low to Very High (Figure 6 and Table I). Where the proposed transmission line crossed areas where well data and/or aquifer maps show thick sediments are present, the segment was assigned a Very Low probability of encountering bedrock at shallow depths. At the other end of the probability spectrum, sections of the Northern Pass route that pass through areas with numerous bedrock outcrops were assigned a Very High probability of encountering bedrock at depths of less than 10 feet below ground surface (bgs). The depth to bedrock is highly variable and difficult to predict in the *"till unit"*, so segments crossing till were assigned a medium chance of encountering bedrock less than 10 feet bgs to reflect the level of uncertainty inherent with this unit. Probability assignments were adjusted by EGGI geologists depending on the presence of well data, bedrock outcrops, or topographic slope anomalies.

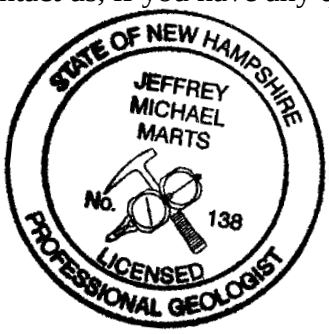
Results

EGGI used several data sources to qualitatively assess the probability of encountering bedrock at a depth of less than 10 feet bgs along the 15.8 mile-long study area (Figure 6 and Table I). A total of 7.31 miles of the studied route (46.3%) is classified as having a Low to Very Low probability of encountering bedrock at a depth of less than 10 feet bgs. A Medium probability of encountering bedrock less than 10 feet bgs was assigned to 4.39 miles (27.8%). Collectively, only 4.09 miles (25.9%) of the route is rated with a High to Very High probability of hitting shallow rock.

Bedrock is generally deeper, with few mapped outcroppings, along the northern segment of the route that follows the Pemigewasset River Valley. Bedrock outcrops are more common in the portion of the study area located south of Route 104, and this section of the route is generally more likely to encounter bedrock at shallow depths compared to the northern segment that follows along the Valley.[2]

[2] Areas where the depth to bedrock will be less than 10 feet below ground surface are more likely to require blasting for installation of power lines.

We hope you find this information responsive to your needs. Please do not hesitate to contact us, if you have any questions.



Best regards,

Jeffrey M. Marts, P.G.
Project Manager/Senior Geologist

James M. Emery, P.G.
President

REFERENCES

Cotton, J.E., and Olimpio, J.R., 1996, Geohydrology, Yield, and Water Quality of Stratified-Drift Aquifers in the Pemigewasset River Basin, Central New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 94-4083, 176 p., 10 pls.
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Tinkham, D.J., and Brooks, J.A. 2010, Surficial Geology of the Holderness, 7.5 minute Quadrangle, Belknap, Grafton, and Carroll Counties, New Hampshire, scale 1:24,000, NH Geologic Survey open file report.

Tinkham, D.J. and Brooks, J.A., 2012, Surficial Geology of the Ashland 7.5 minute Quadrangle, Belknap and Grafton Counties, New Hampshire, scale 1:24,000, NH Geologic Survey Surficial Geologic Map Open-File Series GEO-096-02400-SMOF.

FIGURES

FIGURE 1

Topographic Setting of the
Proposed Northern Pass
Transmission Line
from Bridgewater to Franklin
New Hampshire

Legend

Northern Pass Transmission Line *Proposed Route*

Town Lines

N

Scale is 1:90,000
1 inch = 7,500 feet

0 1,000 2,000 4,000 Meters

0 3,750 7,500 15,000 Feet

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FIGURE 1

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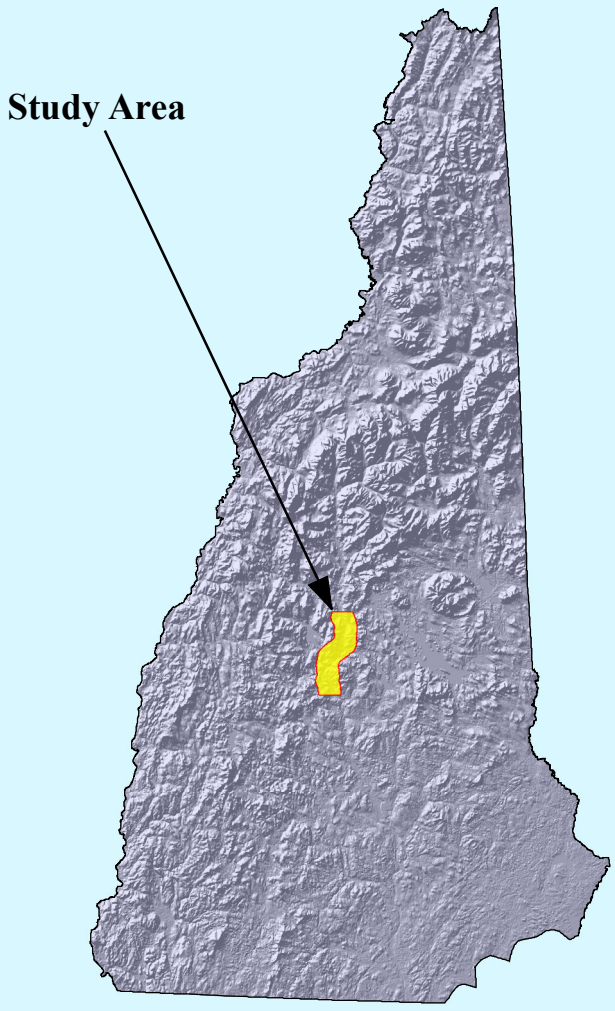
FIGURE 2

Aerial Photo of the
Proposed Northern Pass
Transmission Line
from Bridgewater to Franklin
New Hampshire



Legend

Towns

Northern Pass Transmission Line *Proposed Route*

N

Scale is 1:72,000

1 inch = 6,000 feet

0 750 1,500 3,000 Meters

0 3,000 6,000 12,000 Feet

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FIGURE 2

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FIGURE 3

Digital Elevation Model
for the Proposed Northern Pass
Transmission Line
from Bridgewater to Franklin
New Hampshire

Legend

Towns

Northern Pass Transmission Line *Proposed Route*

Digital Elevation Model

Elevation Value (feet)

High : 571

Low : 93

10-meter Digital Elevation Model (DEM) is derived from data obtained from the National Elevation Dataset (NED).

Black and white topographic image is from the USGS 30'x60' Grid, 1:100,000 scale Lake Winnipesaukee Quadrangle.

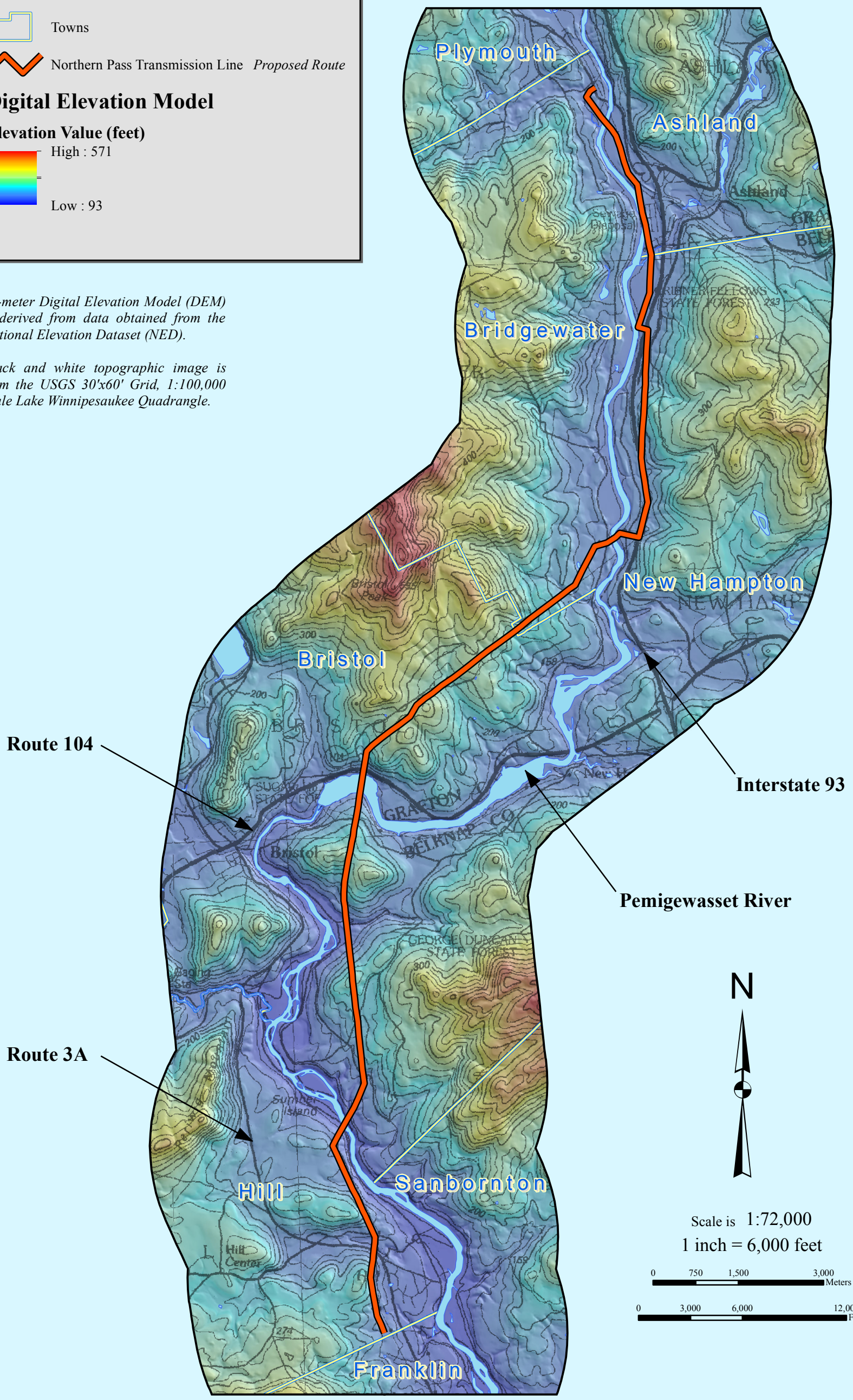

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FIGURE 3

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FIGURE 4

Surficial Geology
for the Proposed Northern Pass
Transmission Line
from Bridgewater to Franklin
New Hampshire

Legend

Towns

Northern Pass Transmission Line *Proposed Route*

Rock Outcrops

Mapped by EGGI

Mapped remotely *Outcrops along the Northern Pass Route were identified by EGGI using a 2010 aerial photo (1-foot resolution).*

USGS Outcrop *Cotton and Olimpio, 1996*

Surficial Geology

(Tinkham and Brooks, 2009, 2010, and 2012)

Non-Till Surficial Deposits *Includes glacial stratified drift and alluvial deposits.*

Artificial Fill *Artificial Fill*

Wetlands

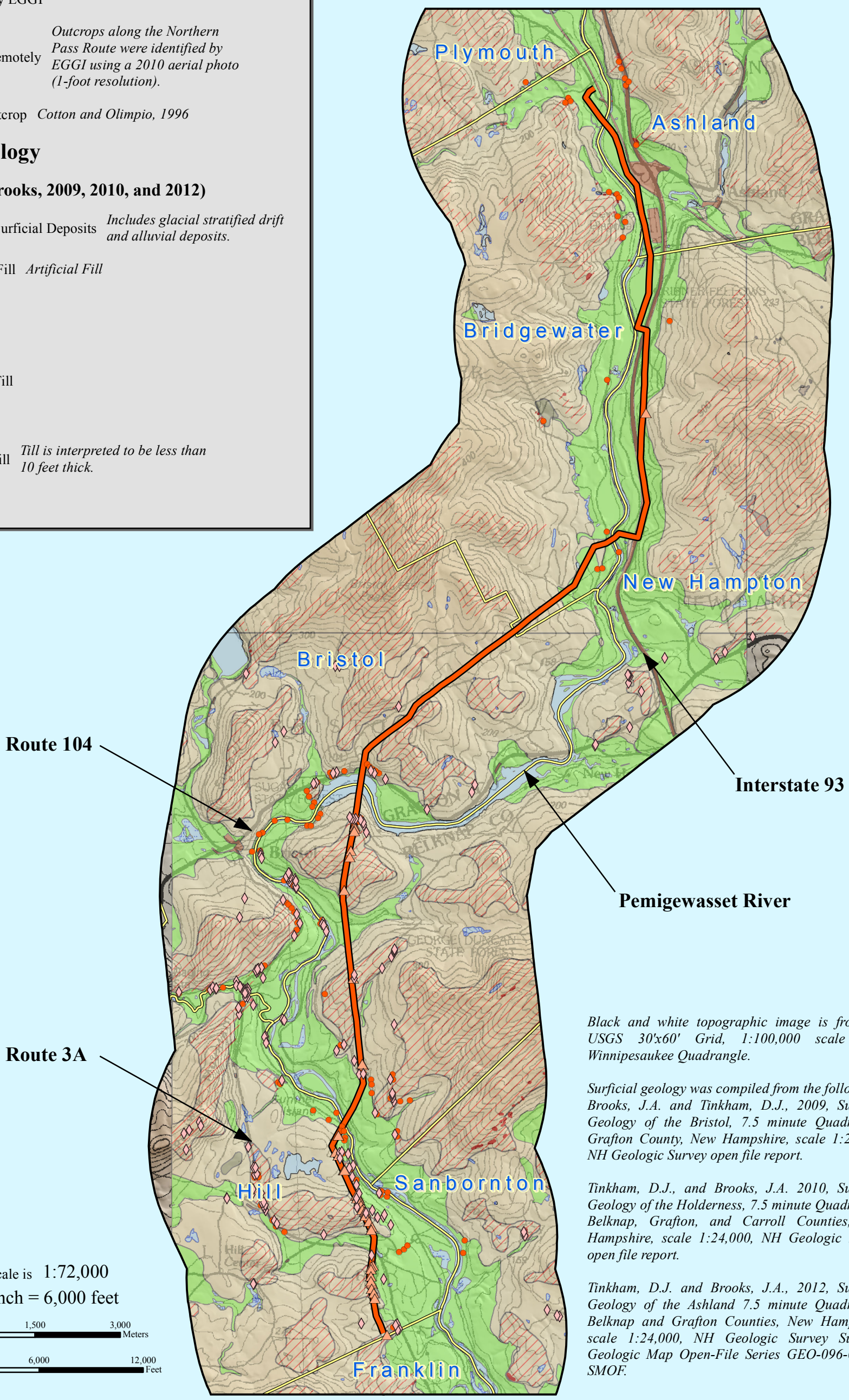
Water

Ablation Till

Till

Shallow Till *Till is interpreted to be less than 10 feet thick.*

bedrock



N

Scale is 1:72,000
1 inch = 6,000 feet

0 750 1,500 3,000 Meters

0 3,000 6,000 12,000 Feet

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Tinkham, D.J., and Brooks, J.A. 2010, Surficial Geology of the Holderness, 7.5 minute Quadrangle, Belknap, Grafton, and Carroll Counties, New Hampshire, scale 1:24,000, NH Geologic Survey open file report.

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FIGURE 5

Aquifer Map and Depth to Bedrock from Well Data Evaluated Along the Proposed Northern Pass Transmission Line from Bridgewater to Franklin New Hampshire

Legend

Towns

Northern Pass Transmission Line *Proposed Route*

NHDES Water Well Inventory

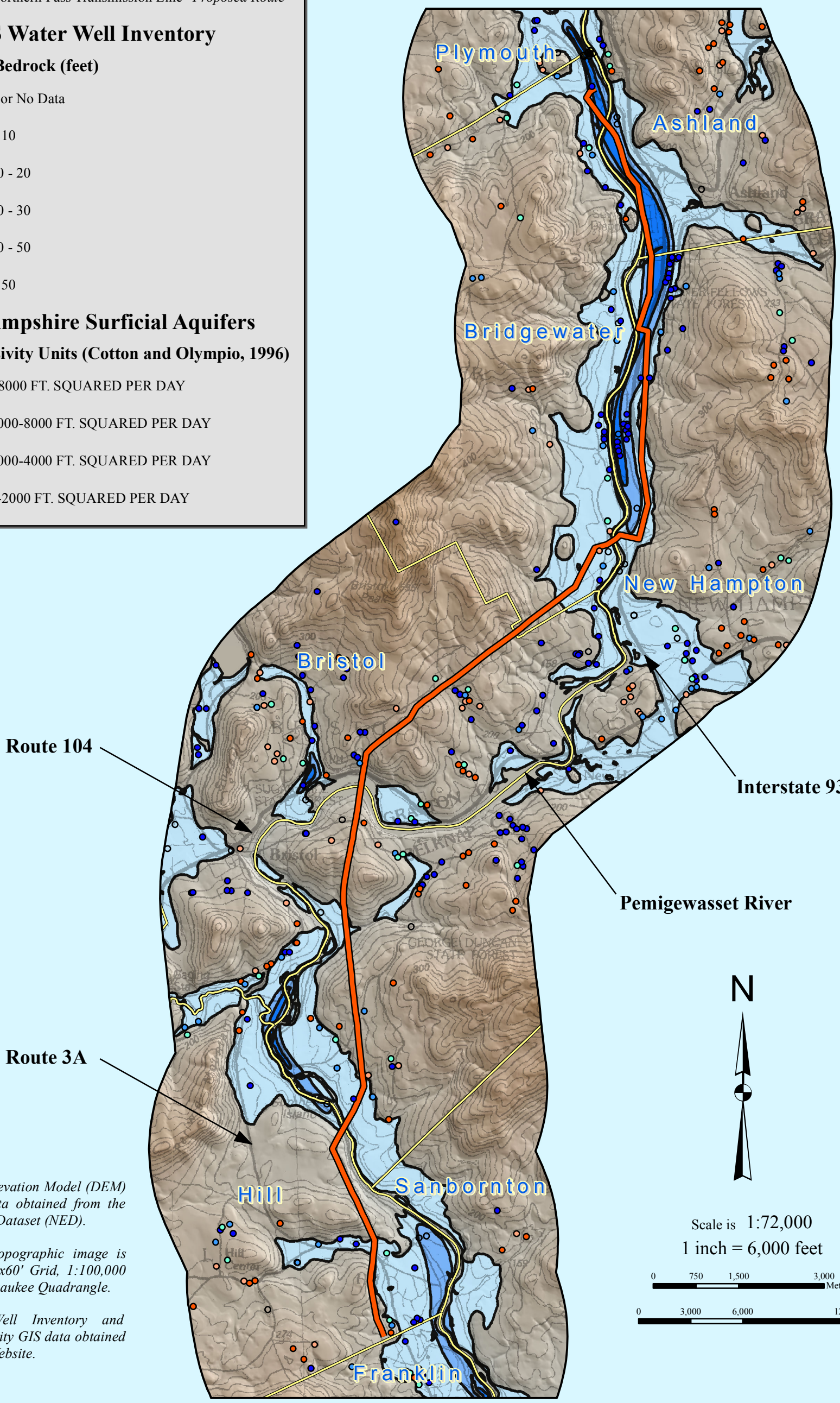
Depth to Bedrock (feet)

- 0 or No Data
- < 10
- 10 - 20
- 20 - 30
- 30 - 50
- > 50

New Hampshire Surficial Aquifers

Transmissivity Units (Cotton and Olympio, 1996)

- >8000 FT. SQUARED PER DAY
- 4000-8000 FT. SQUARED PER DAY
- 2000-4000 FT. SQUARED PER DAY
- 0-2000 FT. SQUARED PER DAY



N

Scale is 1:72,000

1 inch = 6,000 feet

0 750 1,500 3,000 Meters

0 3,000 6,000 12,000 Feet

10-meter Digital Elevation Model (DEM) is derived from data obtained from the National Elevation Dataset (NED).

Black and white topographic image is from the USGS 30'x60' Grid, 1:100,000 scale Lake Winnipesaukee Quadrangle.

NHDES Water Well Inventory and Aquifer Transmissivity GIS data obtained from the GRANIT Website.

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FIGURE 5

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FIGURE 6

Estimated Probability of Encountering Rock at a Depth of Less Than Ten Feet Below Ground Surface along the Proposed Northern Pass Transmission Line from Bridgewater to Franklin New Hampshire

Legend

Town Boundary

Northern Pass Transmission Line

Estimated Probability that the Depth to Bedrock Will Be Less than 10 Feet Below Ground Surface

- Very High
- High
- Medium
- Low
- Very Low

Rock Outcrops

- ◊ Mapped by EGGI
- △ Mapped remotely

Outcrops along the Northern Pass Route were identified by EGGI using a 2010 aerial photo (1-foot resolution).

- ● USGS Outcrop *(Cotton and Olimpio, 1996)*
- Bedrock - Shown on Surficial Maps *(Tinkham and Brooks, 2009, 2010, and 2011)*
- Shallow Till — *Till is interpreted to be less than 10 feet thick.*

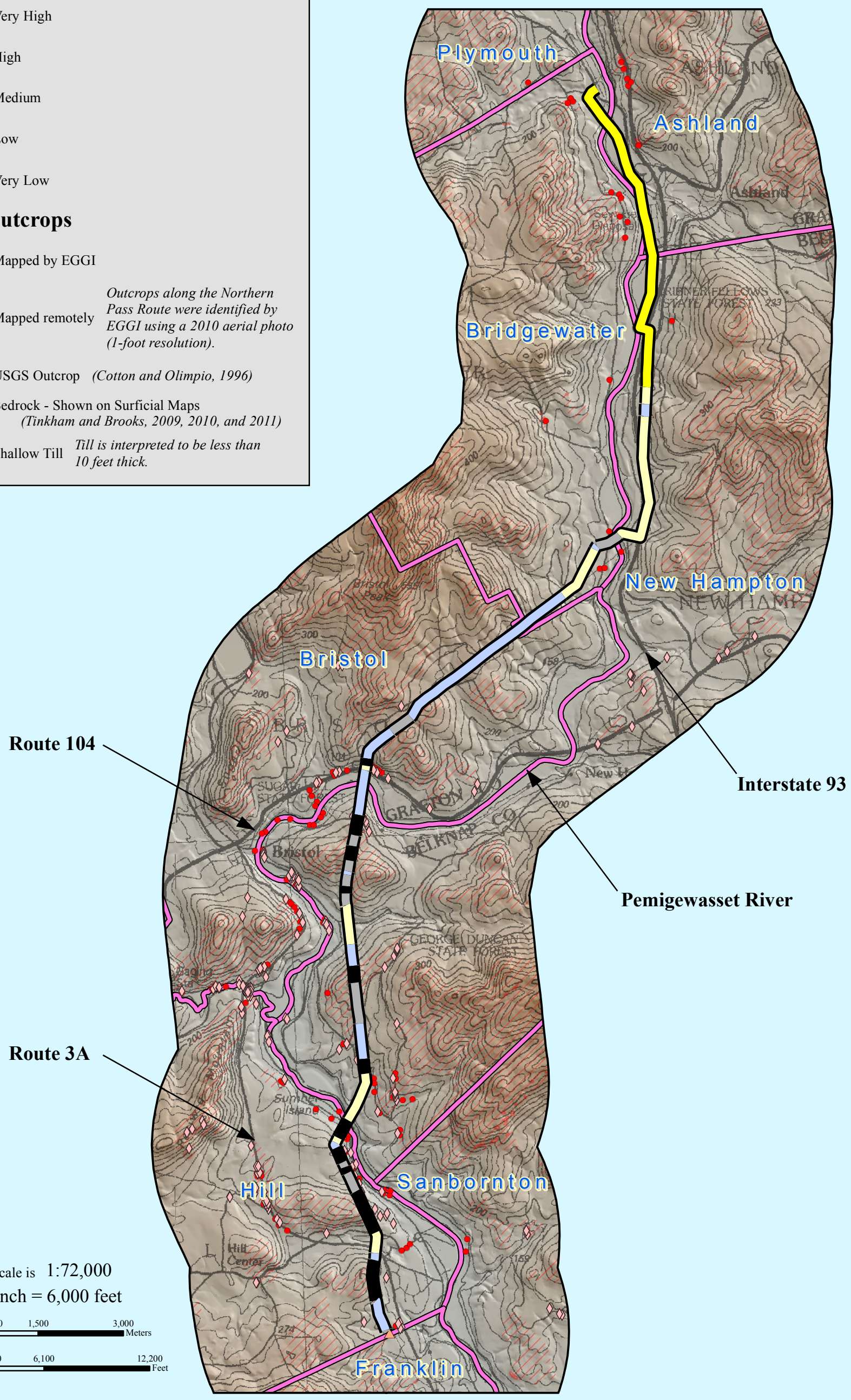

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FIGURE 6

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TABLE

Table I
Probability Matrix Table
Illustrating the Potential of Encountering Bedrock Less Than Ten Feet Below Ground Surface
Northern Pass Transmission Line Study -- New Hampton, New Hampshire

Probability of Hitting Bedrock at a Depth of less than 10' Below Ground	Length of Segments (Miles)	Percent of Route	Confidence in Probability Estimate	Description
Very Low	3.60	22.8%	High	A *"very low"* probability was assigned to route segments where there is well information or published aquifer maps that indicate (with a high degree of confidence) that bedrock is much deeper than 10 feet below ground surface (bgs).
Low	3.71	23.5%	Medium	Areas assigned a *"low"* probability of intercepting bedrock between 0 and 10 feet below ground surface, include places mapped as non-till deposits and/or aquifers with transmissivity values < 2000 $feet^2$/day.
Medium	4.39	27.8%	Low	Areas underlain by glacial till (Qt) and lacking nearby well data and/or lacking exposed bedrock outcrops, were assigned a *"medium"* probability of hitting bedrock at a depth of less then 10 feet bgs. This reflects the high degree of variability of the till thickness, making it difficult to accurately predict the depth to bedrock.
High	1.78	11.3%	Medium	Thin till (Qtt) by definition defines areas where rock is estimated to be less than 10 feet below ground surface. Therefore, areas mapped as thin till were assigned a *"high"* probability of encountering bedrock at a depth less than 10 feet bgs. Sections of the proposed route that are close to wells with shallow depths to bedrock may be included in this category.
Very High	2.31	14.6%	High	Those areas where a *"very high"* probability of encountering bedrock exists where bedrock exposures are near (or within) the proposed Northern Pass route. (Blasting will likely be required in those areas to install power lines.)

bgs = below ground surface

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