HydroQuest

Paul A. Rubin, Hydrogeologist

HydroQuest
414 E. Kerley Corners Rd.
Tivoli, New York, 12583
845-657-8111
hydroquest@yahoo.com

May 5, 2020

Surface Hydrology, Hydrogeology, Bluestone Quarries, and Glacial Geology Proximal to Pickerel Pond and the Proposed 850 Route 28 Manufacturing Facility

Catskill Mountainkeeper and Woodstock Land Conservancy contracted with HydroQuest to conduct an assessment of the surface hydrology, physical setting, and hydrogeology at and surrounding a proposed structural steel and precast concrete manufacturing facility on a 110.6-acre parcel within Bluestone Wild Forest. This unreclaimed stone quarry site is located in the Town of Kingston, Ulster County, NY. Watershed boundaries and flow paths of surface water runoff were delineated using a combination of 2-foot elevational contours derived from a 2014 LiDAR dataset and 2015 topographic 1-meter Digital Elevation Model by Ulster County Information Services. Additionally, multiple years of orthoimagery were evaluated along with some field data. Graphic depiction is presented in a GIS format. While field checking is warranted in low gradient areas, surface flow directions and watershed boundaries are reasonably accurate. Lake, pond, and wetland shorelines vary depending on water level. Analysis of the hydrology found that project construction would permanently remove some 8 percent of the Pickerel Pond watershed, potentially impacting the hydrologic fluxes that make its ecosystem healthy and viable.

HydroQuest also reviewed two hydrogeology reports authored by Miller Hydrogeologic, Incorporated (MHI) for the project applicant. A May 28, 2019 report details a well test conducted on a single 273-foot bedrock well for 24 hours with no observation wells. Bedrock well tests are normally conducted for a minimum of 72 hours in accordance with Department of Health guidelines. The May 20-21, 2019 test determined that the well could supply 5.26 gallons per minute (gpm). A second MHI report, dated February 3, 2020, used water level drawdown and recovery data from the 2019 well test and modeled likely aquifer drawdown levels outward from three project wells (two not yet drilled) after 180 days of continuous pumping at a stated daily project water demand of 2,900 gallons per day (gpd) or 2.0 gpm. Even at this low daily pumping rate, water levels in the aquifer would be lowered over 2,000 feet outward from pumping wells. This impact extends beneath homes, wetlands, streams, Onteora Lake, and Pickerel Pond. The impact to surface water inputs to Pickerel Pond and to its shallow depth may impact its ecology.

HydroQuest is currently mapping glacial and bedrock features throughout Bluestone Wild Forest. The proposed project site is centrally located within a unique and unusually well protected geological/glacial landform that is herein documented for the first time. Geologically, little is known about glacial drainage and glacial positioning at low elevations along the eastern Catskill front during the waning stages of the last glaciation (Wisconsin). Geologic mapping documents the presence of multiple glacial meltwater channels and a knoll and kettle landscape positioned well above Glacial Lake Albany which formerly occupied the Hudson Valley. A lobe of a large glacier that once occupied the Hudson Valley, impounded the southeasterly flowing Sawkill resulting in drainage of a glacial lake south-southwestwardly out of the Sawkill Valley. This study documents relict meltwater channels that drained this proglacial lake and a melting glacier, perhaps during multiple glaciations. It also documents plucking of bedrock cliffs by overriding glacial ice and the downflow transport of massive rock debris. As the last glacier stagnated and melted, large isolated ice blocks, or the wasting ice mass itself, melted from amidst and below ablation till and rock debris called drift, resulting in hummocky topography with hollows (kettles) and surrounding mounds largely comprised of small to very large boulders (knolls). Small and large sandstone boulders perched atop melting stagnant ice were lowered onto the land surface, sometimes angled downslope into kettle holes. Solitary boulders are widely scattered throughout the Bluestone Wild Forest, inclusive of on raised bedrock plateau areas, such as those along the red and blue trails. Exemplary geological features not documented elsewhere in the Catskills extend around, through, and over the proposed project site.

Two outstanding and interrelated geological features make the Bluestone Wild Forest worthy of recognition and preservation. One is a nearly level, steep-walled, 3,345-foot long gorge (i.e., "*Onteora Channel*") that is elevated some 160 feet above and 2,200 feet away from the nearest river capable of carving it. This glacially-carved channel served as a spillway that drained a glacial lake. The second outstanding geological feature is the knoll and kettle topography that has largely not been altered by anthropogenic activities. When these glacial features are viewed within their full interrelated context, their geologic significance provides rationale for preservation, as well as a unique educational opportunity for schools, colleges, and the public.

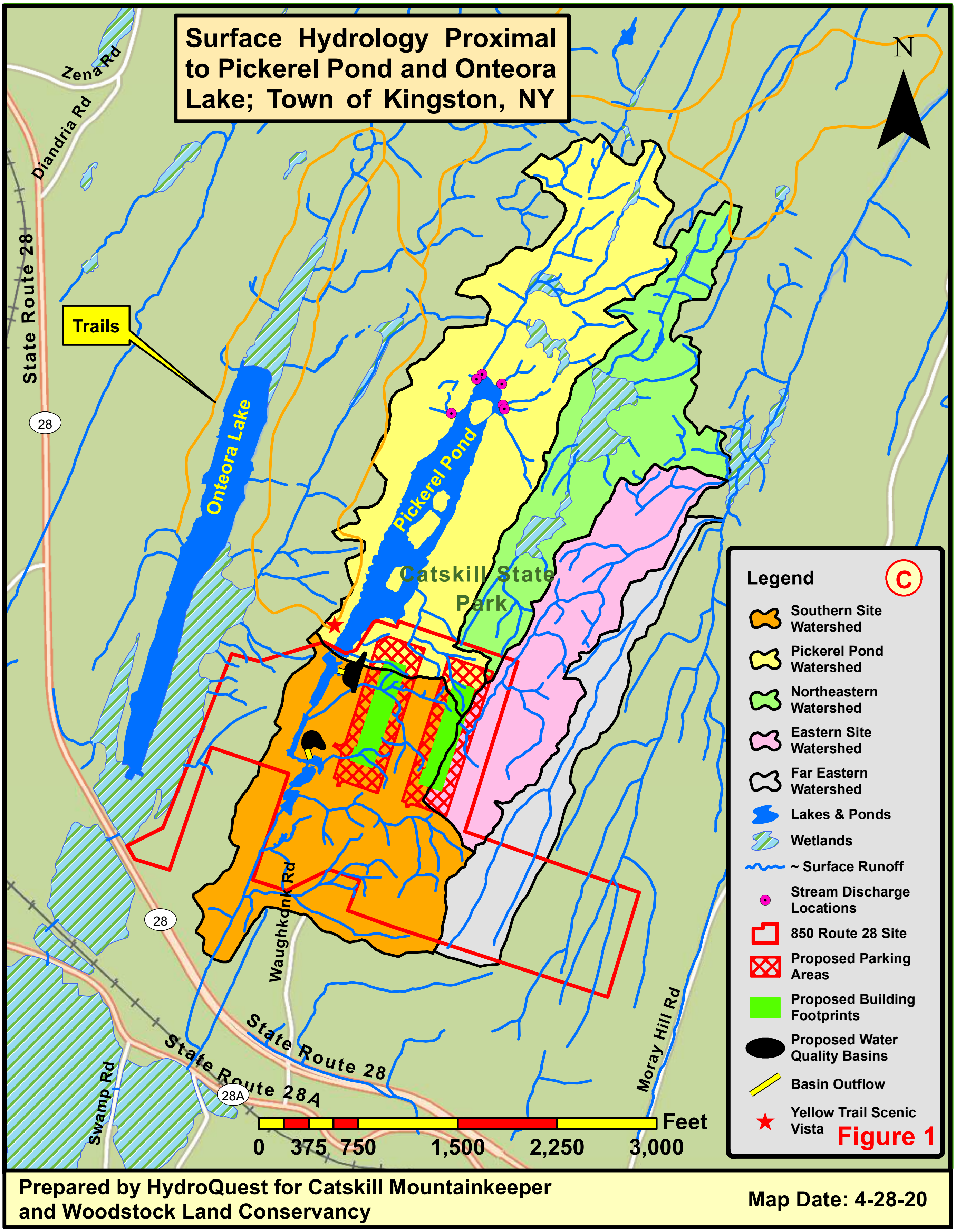
This report focuses specifically on hydrologic concerns associated with the proposed development of the 850 Route 28 project site. Potential hydrologic and biologic impacts associated with related off-site activities impacting NYS Wetland KW-3 have not been evaluated (e.g., permanent fill and a retaining wall construction within the protected wetland).

Hydrology, Diversion of Surface Water Away from Pickerel Pond & Physical Setting

Project construction would result in diversion of surface water away from Pickerel Pond and diversion of groundwater from beneath and adjacent to Pickerel Pond. Study findings to date include:

- The proposed 850 Route 28 manufacturing facility straddles a hydrologic divide (see Figure 1). The southern site, Pickerel Pond, and Onteora Lake watersheds drain southward through a large wetland complex (NYS DEC Wetland KW-3) and then as Praymaher Brook alongside Thielpape Road until flowing into Esopus Creek.

- The northeastern, eastern, and far eastern watersheds drain northeastward as a stream until a confluence with the Sawkill northeast of Jockey Hill. The Sawkill then flows southeastward until it joins the Esopus Creek which then flows northward to Saugerties where it discharges into the Hudson River. The distance along the Sawkill and Esopus Creek between where project site drainage enters them is 10.3 creek miles.


Surface Hydrology Proximal to Pickerel Pond and Onteora Lake; Town of Kingston, NY
N
Zena Rd
Diandria Rd
State Route 28
28
Trails
Onteora Lake
Pickerel Pond
Catskill State Park
Waughkonk Rd
State Route 28
State Route 28A
28A
Swamp Rd
Moray Hill Rd
Feet
0 375 750 1,500 2,250 3,000
Legend
C
Southern Site Watershed
Pickerel Pond Watershed
Northeastern Watershed
Eastern Site Watershed
Far Eastern Watershed
Lakes & Ponds
Wetlands
~ Surface Runoff
Stream Discharge Locations
850 Route 28 Site
Proposed Parking Areas
Proposed Building Footprints
Proposed Water Quality Basins
Basin Outflow
Yellow Trail Scenic Vista
Figure 1
Prepared by HydroQuest for Catskill Mountainkeeper and Woodstock Land Conservancy
Map Date: 4-28-20

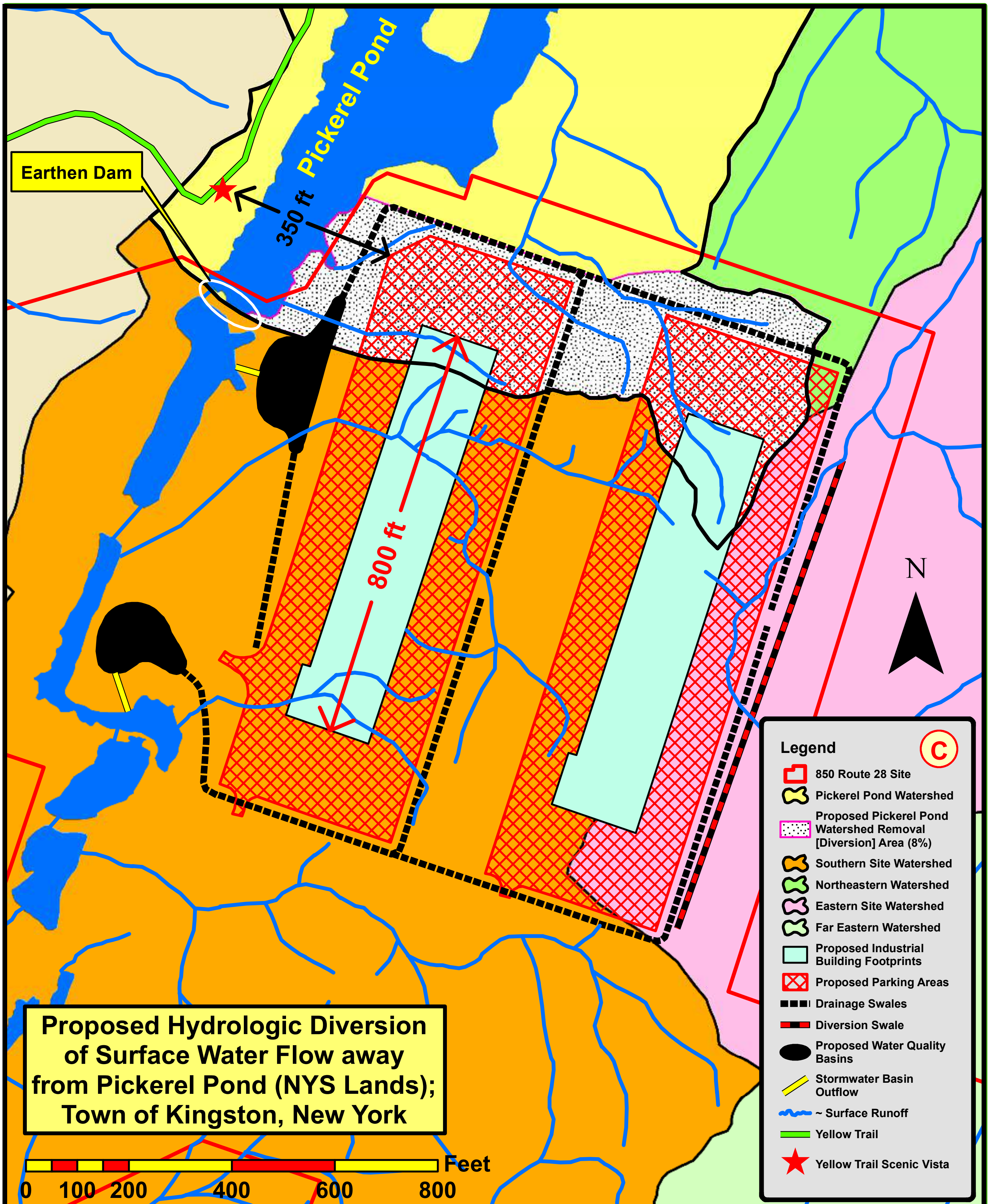
- Surface runoff from the footprint of the proposed 850 Route 28 project site enters Pickerel Pond, Onteora Lake (formerly Binnewater Lake; 17.8 acres), and both the Sawkill and Esopus Creek. The physical setting of the project site is in the headwater reach of the illustrated surface flow network. Disruption of hydrologic boundaries and surface flow patterns will alter the natural fluxes present that provide for healthy ecosystems.

- Site grading, inclusive of cut and fill and bedrock blasting, would result in changes in surface water quality if strict sediment control is not maintained. Review of historic orthoimagery reveals extensive sediment input and water quality degradation within ponds and the streamway in the southern site watershed that was almost certainly derived from quarry site runoff (i.e., 2009 orthoimagery).

- Pickerel Pond, at an elevation of approximately 460 ft msl, was formerly a large wetland prior to construction of an earthen dam across it sometime between 1972 and 1981 (based on review of historic topographic maps and orthoimagery). The dam extends about six feet above the surface level of Pickerel Pond, except near its eastern terminus where it has been breached (Photo 1). Figure 2A shows the location of this dam (highlighted by a white ellipse) that is not acknowledged in the Full EAF, Part 1, Section E.1.e. (Site and Setting of Proposed Action) that states that the 850 Route 28 project site does not contain an existing dam. For comparative purposes, Figures 2B and 2C show the same area on 2013 high resolution orthoimagery with and without 2-foot elevational contour lines. This dam-impounded 16.3-acre pond, inclusive of several islands, is now a gem within the Bluestone Wild Forest. Its habitat is actively used by beavers, waterfowl, turtles, and other species (Photos 5 and 6). At this time, the water level of Pickerel Pond is somewhat raised by a beaver dam (Photo 1). While project design would not impact this structure, it is likely that the dam requires periodic structural strengthening for long-term pond and habitat protection.

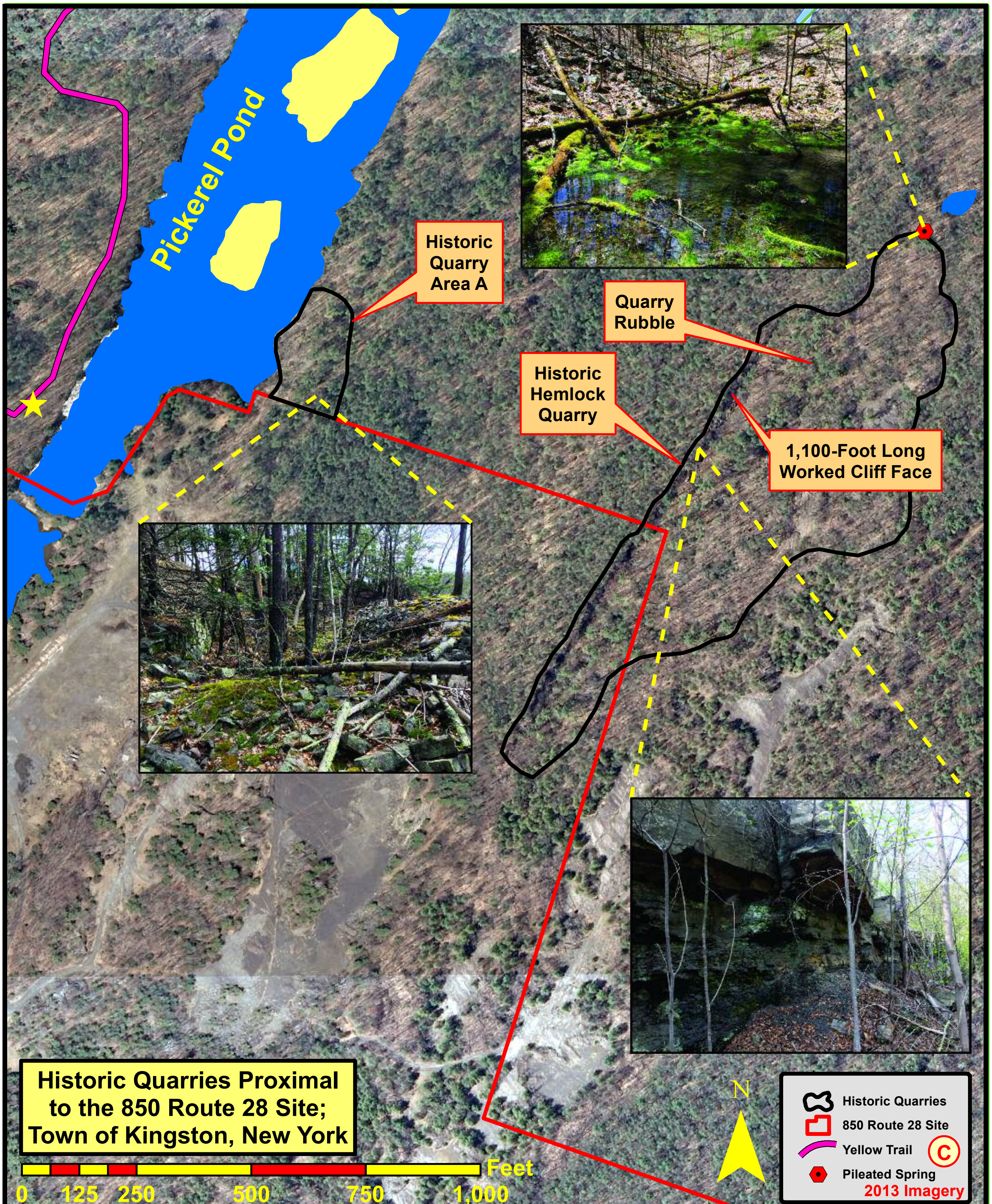
Photo 1. Earthen dam that impounds Pickerel Pond. Yellow ellipse: beaver dam currently elevates pond level. Also, see Photo 28 at the end of the report.

Photo 2. Island in Pickerel Pond.



Prepared by HydroQuest for Catskill Mountainkeeper and Woodstock Land Conservancy

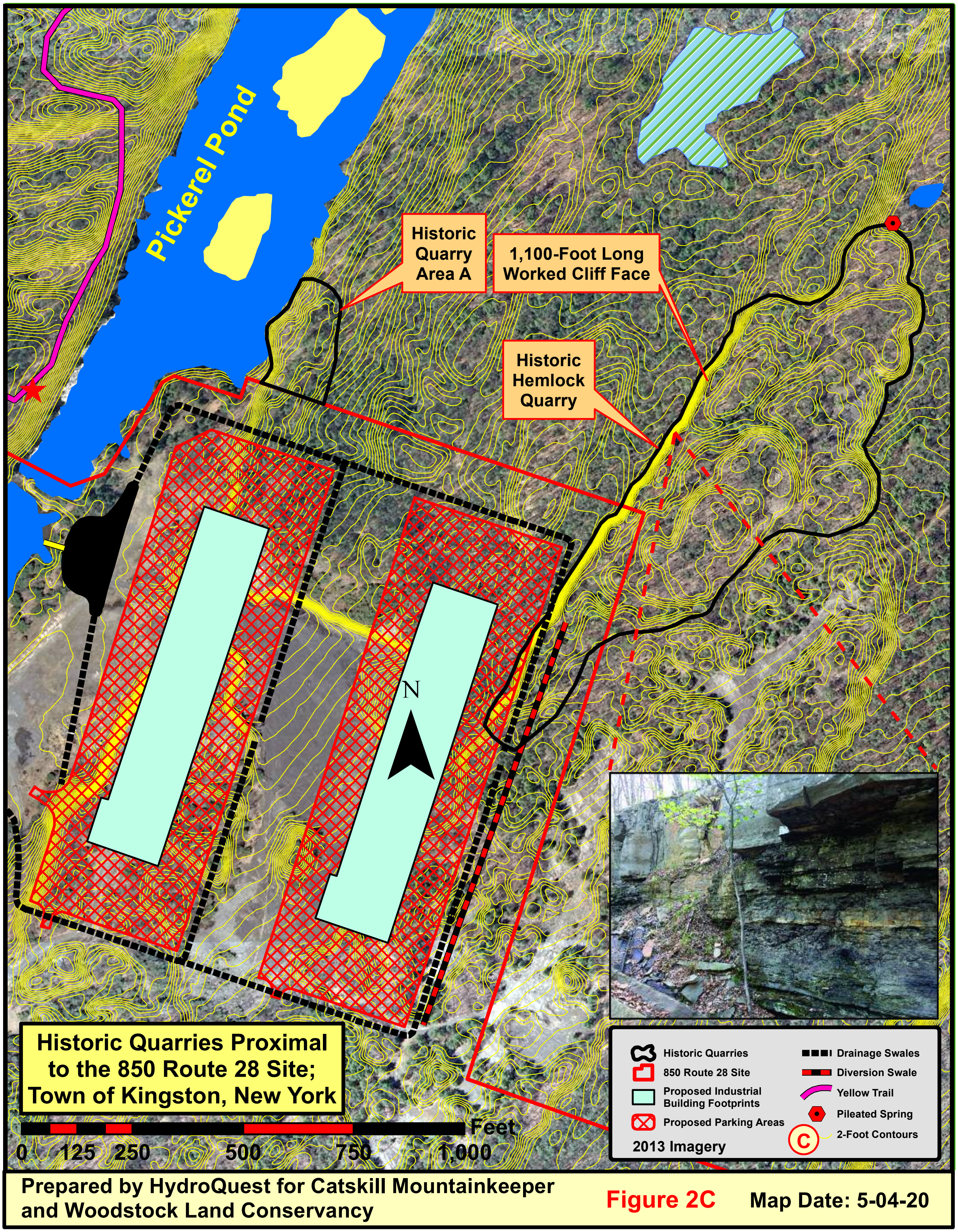
Figure 2A Map Date: 5-04-20



Prepared by HydroQuest for Catskill Mountainkeeper and Woodstock Land Conservancy

Figure 2B

Map Date: 5-04-20



Pickerel Pond
Historic Quarry Area A
1,100-Foot Long Worked Cliff Face
Historic Hemlock Quarry
N
Historic Quarries Proximal to the 850 Route 28 Site; Town of Kingston, New York
Feet
0
125
250
500
750
1,000
Historic Quarries
850 Route 28 Site
Proposed Industrial Building Footprints
Proposed Parking Areas
2013 Imagery
Drainage Swales
Diversion Swale
Yellow Trail
Pileated Spring
C
2-Foot Contours
Prepared by HydroQuest for Catskill Mountainkeeper and Woodstock Land Conservancy
Figure 2C
Map Date: 5-04-20

- The southern boundary of the 87-acre Pickerel Pond watershed was drawn along the dam that separates it from the small 0.8-acre pond situated immediately downstream of it. Historic orthoimagery from 2009 shows significant water quality degradation (i.e., turbid water from sediment input) in this and other downstream ponds constructed directly within the waterway (Figure 1). These ponds were used as sediment settling basins for the bedrock quarry (Stormwater Pollution Prevention Plan [SWPPP]).

- North of the earthen dam that impounds Pickerel Pond, pristine water, islands, bedrock cliffs, logs, and trees provide healthy ecosystems (Photos 2, 3, 4, 5, and 6).

Photo 3. Northern Pickerel Pond.

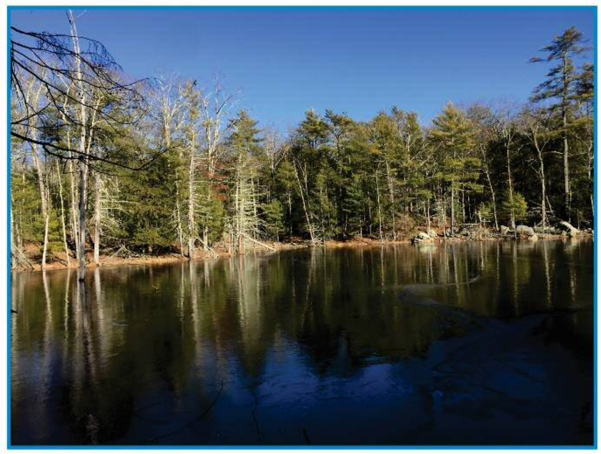


Photo 4. Northern Pickerel Pond.

Photo 5. Beaver chewed tree alongside Pickerel Pond.

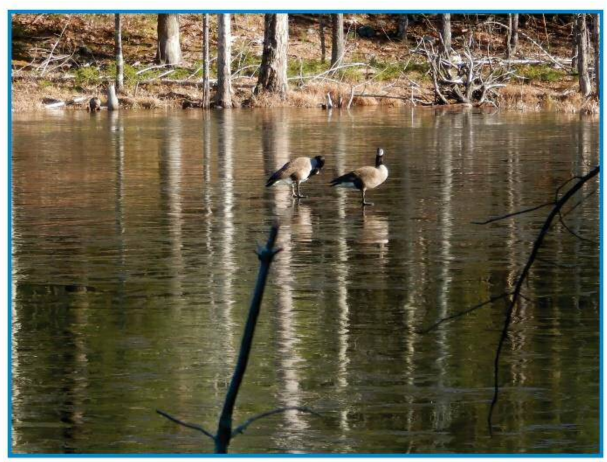


Photo 6. Geese on Pickerel Pond ice.

- Figures 1 and 2 show the proposed 850 Route 28 project parking and building areas extending into the Pickerel Pond watershed. Field reconnaissance conducted on March 1, 2020 found only two of six streams actively flowing into the northeastern end of Pickerel Pond. Their combined discharge was estimated as only 25 gallons per minute (Photos 7 and 8). It is highly likely that there is no surface inflow during dry and drought times both here and immediately downstream of the earthen dam. This is important from the perspective of potential dilution and assimilation of chemical contaminants and stormwater runoff that the manufacturing facility may discharge into the waterway. The extreme headwater setting of the proposed industrial facility will, at times, have no natural streamflow.

Photo 7. Low flow stream flowing into the northern end of Pickerel Pond on 3-01-20 (~20 gpm).

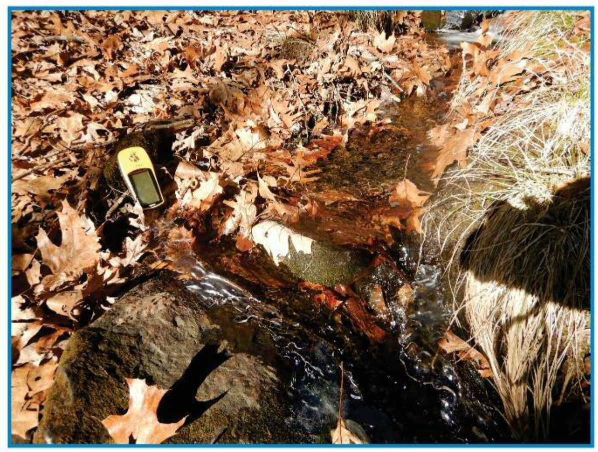


Photo 8. Low flow stream flowing into the northern end of Pickerel Pond on 3-01-20 (~5 gpm).

- From a water quality and species habitat perspective, the proposed industrial facility is situated in an extremely vulnerable hydrologic setting. Additionally, rock dust particulates generated from crusher operation may impact water quality.

- The Full Environmental Assessment Form, Part 1, states that "*Wastewater treatment will be provided on site to the west of the existing storage building on site.*" Additional clarification is warranted regarding disposal of 900 gallons per day of sanitary liquid waste.

- When evaluating potential environmental impacts of projects, it is important to look beyond project-specific boundaries. Figure 2A shows that project grading and construction would extend well into the southern end of the Pickerel Pond watershed, resulting in the removal and flow diversion of some 8 percent of the Pond's tributary watershed (black stippled area) into project drainage swales (black dashed lines; portrayed on the 252nd page of Medenbach and Eggers May 14, 2019 SWPPP, map of Post-Development Drainage Area). Surface water that naturally flows into Pickerel Pond, helping to sustain its hydrologic and biologic fluxes, would be removed. Project construction would effectively behead part of the Pickerel Pond watershed, diverting it away from New York State forest land. This may be an infringement of landowner littoral or riparian rights, as permanently diverting water from its natural channel and changing the natural course of a watercourse is generally not legally permitted.

- While the hydrologic impact to Pickerel Pond would be significant, reference to Figures 1 and 2 reveals that project construction would also result in disruption of surface flow in other watersheds straddling the hydrologic divide discussed above.

- A significant portion of the northern project area was clear cut of trees sometime between 2016 and late 2019, as shown on 9-18-19 Google Earth imagery. This area encompasses both the proposed project site and tributaries to Pickerel Pond. Large felled trees are present within the proposed industrial development area (Photos 9a and 9b). Clear cutting typically results in increased runoff and sediment load and forest fragmentation.

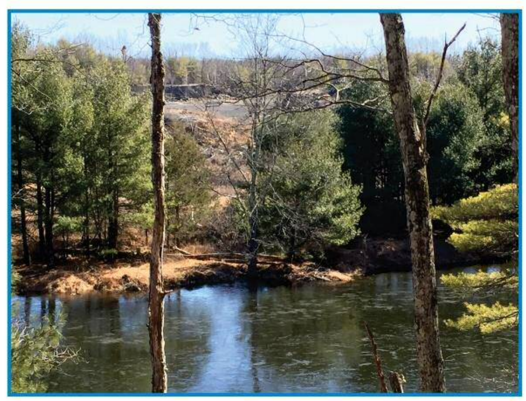


Photo 9a. Oblique view of quarry site looking NW. Felled trees are circled in yellow (9-18-19 imagery).

Photo 10. View of proposed industrial site from the Yellow Trail looking across Pickerel Pond.

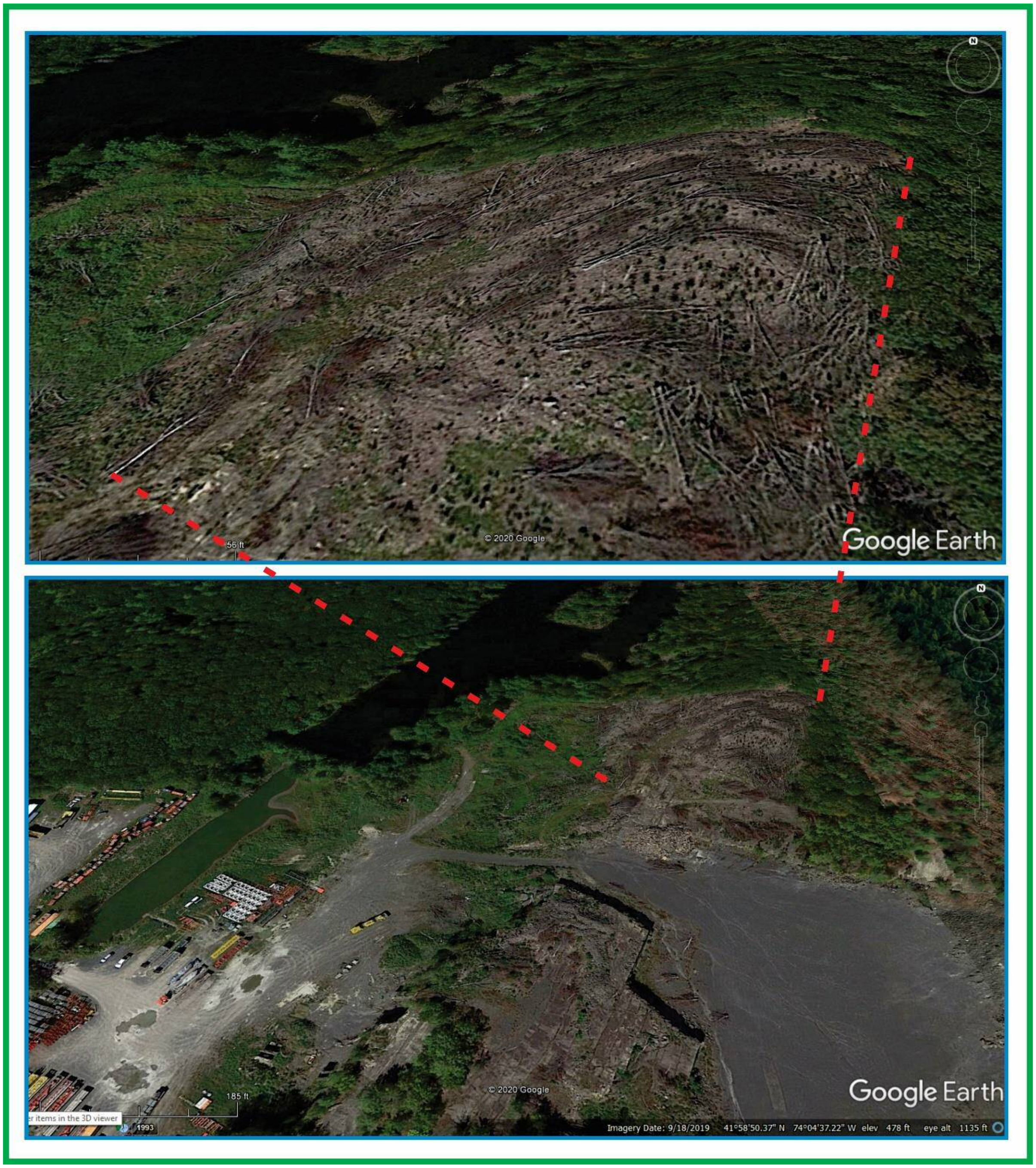


Figure 9b. Oblique photograph of cut trees on the project site.

- The proposed industrial site is visible from the yellow nature trail in the Bluestone Wild Forest. As the crow flies, a scenic trail vista location depicted by a star on Figures 1 and 2 is some 350 feet from the nearest proposed parking lot and 470 feet from the nearest building corner. A clear view would be afforded from hillslope to hillslope across the valley bottom (Pickerel Pond) which is about 28 feet below trail elevation (Photo 10).

- For comparative purposes, prospective of project scale is provided on Figure 2A. Each of the two proposed buildings is slated to be 800 feet long, 150 feet wide, and 35 feet high. Building length would be 1/3 the length of Pickerel Pond (2,400 ft). The current land surface elevational range of the project's footprint is approximately 80 feet (464 ft to 544 ft msl), indicating the likely magnitude and duration of time required for blasting and grading during site preparation. Much of the grading activity would be visible and audible from the southern Yellow Trail in the Bluestone Wild Forest.

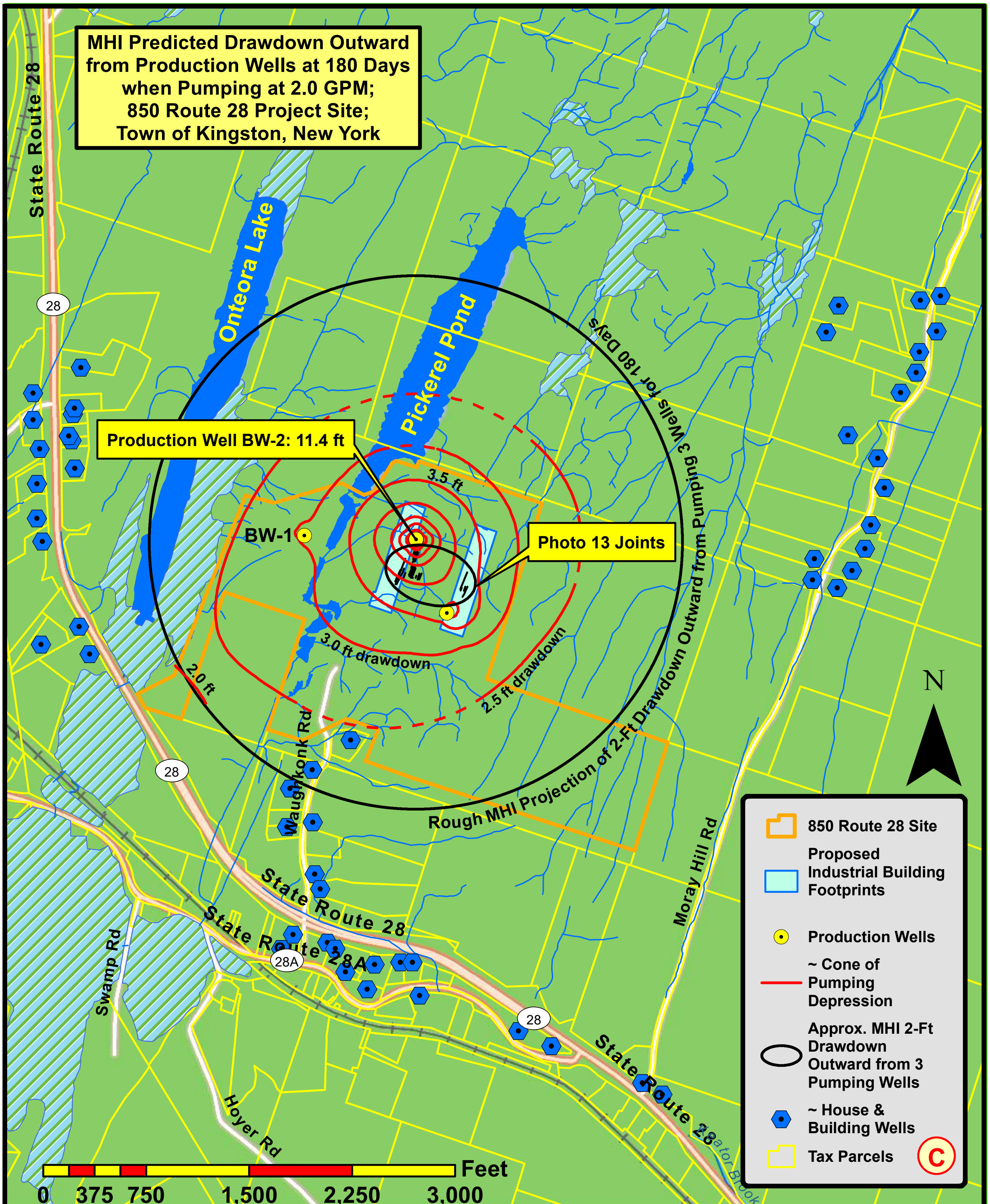
Diversion of Groundwater from Beneath and Adjacent to Pickerel Pond

- The MHI well test was conducted on a single 273-foot deep bedrock well for only 24 hours with no observation wells. The well was pumped at a rate of 5.26 gallons per minute and resulted in a drawdown of 26.71 feet at the well. This contrasts with an MHI modeled drawdown of 11.4 feet at yet to be installed well BW-2 (Figure 3) at the stated project water demand of 2.0 gpm. The drawdown values portrayed in this figure would be larger, as would the cone of pumping influence (i.e., depression), if industrial project demand were to be greater than the applicant's stated demand of 2.0 gpm (2,900 gpd).

- Upon belief that water use at the applicant's 6 Kieffer Lane facility is roughly analogous to that required at the proposed 850 Route 28 industrial facility, it is possible that the applicant's proposed water use is understated. Review of water records from the Kieffer Lane facility metered between 12-04-18 and 12-5-19 reveals average daily water use in successive quarters as 3.3 gpm, 5.6 gpm, 9.1 gpm, and 7.5 gpm. Unless there are appreciable differences in facility manufacturing, aquifer drawdown, and possibly Pickerel Pond drawdown, may be considerably greater than that presented in the 2-03-20 MHI report and portrayed here on Figure 3.

- Well BW-1 is approximately 175 feet west of the nearest pond (Figure 3). Unless special permission was obtained from the local Department of Health (DOH) to modify this test, DOH guidance calls for a minimum test duration of 72 hours to assess potential aquifer boundary and safe yield limitations. Longer test durations provide a means of assessing increased aquifer drawdown as the cone of depression expands outward from a pumping well.

- The Ashokan/Plattekill Formation sandstone and shale bedrock aquifer that Well BW-1 obtains water from is highly fractured (Photos 11 and 12). These photos show planar joints in outcrop exposures close to the project site. Groundwater moves within vertical fractures called joints and along horizontal bedding planes. Vertical joints in the bedrock, visible in 2016, 2013, and 2001 imagery, are highlighted in red on the bottom photograph of Photo 13. They serve as preferential groundwater flow pathways (i.e., secondary porosity). The fractures are closely spaced and very clearly show a preferred north-northeast to south-southwest orientation (N23°E to N27°E), perhaps overlying an unconfined upgradient portion of the bedrock aquifer. Further reference to Photos 11, 12, and 13 reveals cross joints nearly perpendicular to the major joint set (~ N64°W) that interconnect north-northeast (NNE) to south-southwest (SSW) joints.



Prepared by HydroQuest for Catskill Mountainkeeper and Woodstock Land Conservancy

Figure 3

Map Date: 4-10-20

Photo 11. Sandstone overlying shale. Note planar vertical joints that provide groundwater flow pathways below ground.

Photo 12. Note vertical joint faces.

Photo 13. Closely spaced and interconnected north-northeast to south-southwest joints, as well as nearly perpendicular joints, extend far below ground surface where they transmit groundwater to streams, lakes, ponds, and wells. Figure 3 shows the location of the red highlighted fractures.

- The water level in well BW-1 (Figure 3) was found to be below the level of the nearby pond and surface waterway. This implies that groundwater in this well is under confined conditions, meaning that it is not directly connected to the nearby surface water. While this condition is present in the valley bottom, it is highly likely that up-valley and upslope fractures in the bedrock are open to infiltration of surface runoff that recharges the underlying aquifer that the project seeks to withdraw groundwater from. This natural continuum from upslope unconfined recharge conditions to valley bottom confined conditions is common. It is important to recognize this because pumping of project site wells will draw groundwater into them that may otherwise have contributed to and helped maintain the water level that supports the Pickerel Pond ecosystem. If installed, upgradient observation wells would provide additional hydrogeologic insight into this. Figure 3 portrays MHI's modeled water levels (i.e., not measured water levels in observation wells) and shows that even at a low pumping rate of 2.0 gpm, under long-term (180-day) drought-like conditions, that groundwater will be drawn down beneath virtually all of Pickerel Pond. This is important because a hydraulic connection between Pickerel Pond and the groundwater that feeds it and project pumping wells could impact the healthy ecosystem.

- Figure 3 depicts MHI's modeled groundwater drawdown outward from one existing site well and two proposed site wells as predicted at 180 days under continuous pumping conditions at a daily use rate of 2.0 gpm with no recharge. This impact extends beneath homes, wetlands, streams, Onteora Lake, and Pickerel Pond. While the impact to homeowner well water levels would be small, the impact to surface water inputs to Pickerel Pond and to its shallow depth may impact its ecology.

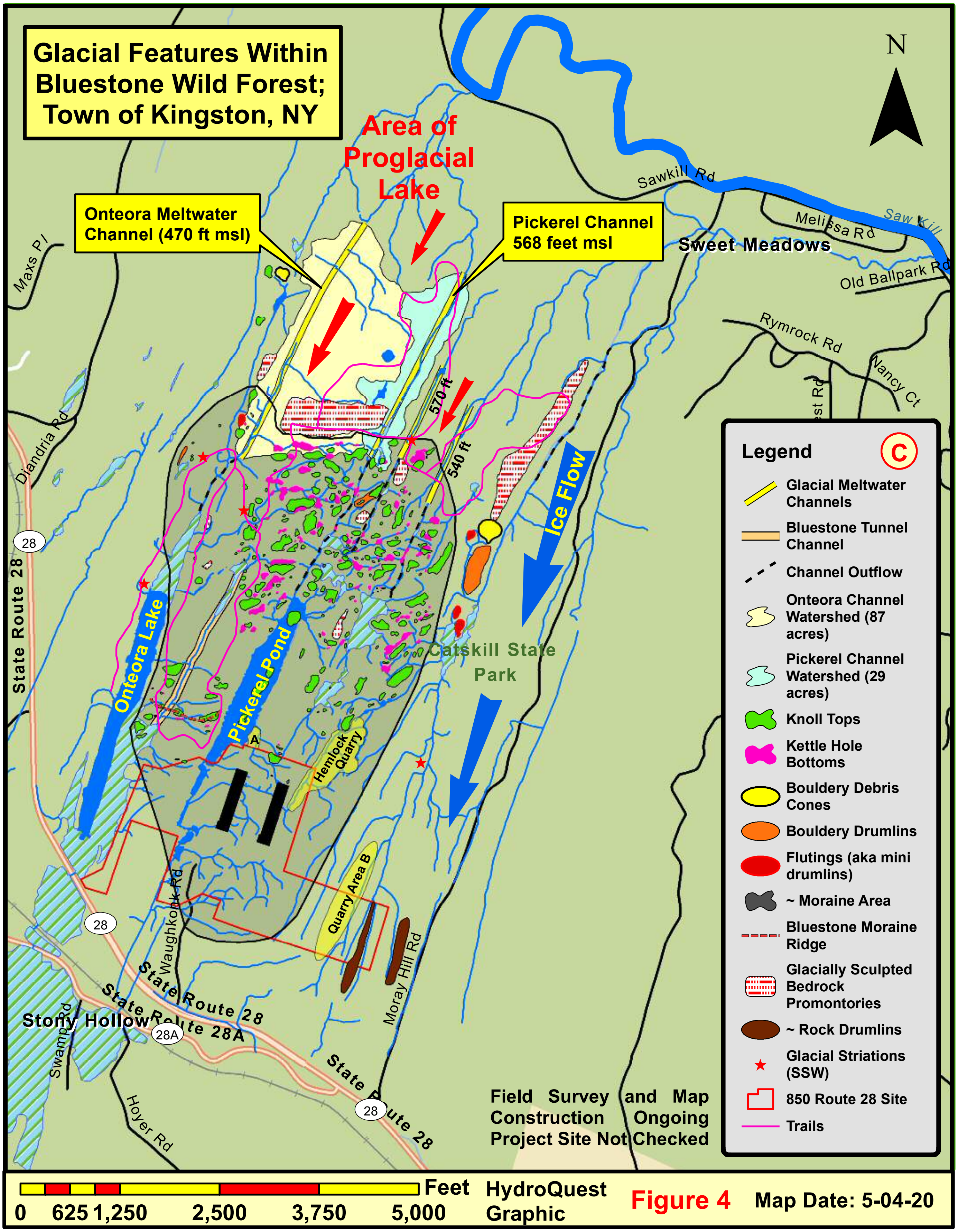
- The project applicant documents that, at times, Pickerel Pond has no outflow. For example, text in the applicant's materials (page 20 of 28 of a revised 2-26-20 document titled: NYS Environmental Quality Review Act EAF Addendum for 850 Route 28 LLC Proposed Manufacturing Facility) states:

  > "*As mentioned above, Ponds A-G and the stream channel located immediately south of the pond complex are considered by the NYSDEC to be a connected watercourse. However, as stated in the SWPPP and the H2H Associates Wetland Assessment, the ponds do not have a perennial connection of flow, though some subsurface seeping may exist between the ponds.*"

  The applicant confirms the seasonal no outflow condition of Pickerel Pond and, thus, its hydrologic and ecologic sensitivity. As such, project advancement that would remove 8 percent of its watershed and involve pumping of production wells that would potentially induce downward infiltration of pond water and groundwater that naturally feeds the pond may jeopardize or irreparably harm the shallow pond ecosystem. As indicated above, it is possible that water use at the industrial facility may require more than four times the stated project water demand. If so, the groundwater drawdown values presented on Figure 3 may be conservative.

Unique Geologic Features (Glacial Landforms)

HydroQuest is conducting geologic research within the Bluestone Wild Forest. This field work includes examination of a series of linear, incised, valleys that are interpreted to be relict channels (i.e., spillways) that were carved by and transmitted rushing glacial meltwater south-southwest out of the Sawkill Valley drainage. They and their foreground area, which encompasses Onteora Lake, Pickerel Pond, wetlands, a portion of the project site, and surrounding forest preserve setting are geologically unique.



Glacial Features Within Bluestone Wild Forest; Town of Kingston, NY
Area of Proglacial Lake
Onteora Meltwater Channel (470 ft msl)
Pickerel Channel 568 feet msl
570 ft
540 ft
Ice Flow
Onteora Lake
Pickerel Pond
Catskill State Park
Hemlock Quarry
Quarry Area B
A
Sawkill Rd
Saw Kill
Melissa Rd
Sweet Meadows
Old Ballpark Rd
Rymrock Rd
Nancy Ct
Maxs Pl
Diandria Rd
State Route 28
28
28A
Waughkonk Rd
State Route 28
State Route 28A
Stony Hollow
Swamp Rd
Hoyer Rd
Moray Hill Rd
N
Legend
C
Glacial Meltwater Channels
Bluestone Tunnel Channel
Channel Outflow
Onteora Channel Watershed (87 acres)
Pickerel Channel Watershed (29 acres)
Knoll Tops
Kettle Hole Bottoms
Bouldery Debris Cones
Bouldery Drumlins
Flutings (aka mini drumlins)
~ Moraine Area
Bluestone Moraine Ridge
Glacially Sculpted Bedrock Promontories
~ Rock Drumlins
Glacial Striations (SSW)
850 Route 28 Site
Trails
Field Survey and Map Construction Ongoing
Project Site Not Checked
0 625 1,250 2,500 3,750 5,000 Feet
HydroQuest Graphic
Figure 4
Map Date: 5-04-20

The glacial landscape within the Bluestone Wild Forest is characterized by numerous features, including drumlins (streamlined boulder and sediment material), flutes (aka mini drumlins), a large boulder-rich debris cone, sculpted bedrock promontories, rounded boulder-rich knolls, and kettles. Observation and provenance of these features is sufficient to allow preliminary geologic interpretation. As the last glacier stagnated and melted, large isolated ice blocks melted from amidst and below till and rock debris, resulting in hummocky topography with hollows (kettles) and surrounding rocky mounds (knolls). Many of these features are depicted on Figures 4, 5, and 6. Boulders and till comprising drumlins and knolls were glacially scraped or plucked off raised bedrock upland, plateau-like, areas, some of which are now traversed by the Bluestone Wild Forest red and blue trails. Reference to Figure 4 shows the distribution of knolls and kettles south of bedrock outcroppings (i.e., promontories), from which angular boulders fan outward. As the glacier plucked bedrock off these promontories, it sometimes preferentially transported large angular boulders far from their source areas. Their darker color versus that of surrounding ice resulted in differential melting, more so outward from boulder accumulations, resulting in an on-ice knoll and kettle setting. As ice melting expanded outward from the small closed basins of kettle holes, boulders sometimes slid downward remaining inclined on knoll slopes. It is no surprise that some of the larger boulder knolls are directly south (down-gradient) of bedrock promontories. Additionally, small and large sandstone boulders perched atop melting stagnant ice were lowered onto the land surface throughout the Bluestone Wild Forest, including on upland areas.

All of these geologic features are interrelated and, together, provide an amazing, new, picture of the glacial history of the region. Much remains to be learned through ongoing study. Important findings to date include:

- The project site is central to a geologically unique glacial drainageway formed along and under an ice margin. The relative ease with which NNE-SSW trending joints can be enlarged by flowing water (vs. slow-flowing groundwater) is belied by the presence of several ice and water-carved, parallel, bedrock-walled valleys that formerly served as proglacial meltwater channels. These scoured channels drained south-southwestward directly from meltwater streams flowing away from an overlying stagnant ice margin and, in part, from a proglacial lake situated in the Sawkill Valley along an ice margin.

- These channels are depicted on Figure 4 as yellow elongate linear features. Here, the westernmost two channels are referred as "*Onteora Channel*" and "*Pickerel Channel*", respectively. Pickerel Channel (Photo 14) and the next channel to the east once drained south-southwestward into, through, and beyond Pickerel Pond. Both of these overflow channels have bottom (i.e., spillway invert) elevations of approximately 570 feet msl, indicating that they provided spillways most likely for a proglacial lake along what Dineen (1986) depicts as a Woodstock ice margin.

- The four yellow channels depicted on Figure 4 have lengths of approximately 3,345 feet, 2,580 feet, 1,264 feet, and 1,338 feet, respectively. Their invert elevations from west to east are approximately 470 feet, 568 feet, 570 feet, and 540 feet above mean sea level (msl). Additional field work relative to the origin of the three easternmost channels is currently underway. For example, the Pickerel Channel is well-defined, yet its small tributary watershed (29 acres) is not sufficiently large to account for its formation (Figure 4).

Photo 14. Pickerel Meltwater Channel: A) Pooled water along U-shaped channel invert, B) Relict bluestone quarry, C) Sandstone caprock at channel top, D) Channel floor near NNE terminus.

- By far, the most prominent relict meltwater channel within the Bluestone Wild Forest is one that drained south-southwestward into, through, and beyond Onteora Lake (Figure 4). The width of the Onteora Channel (Photo 15) varies from 50 feet (at the NNE channel infeeder) to about 250 feet between valley top cliffs further down valley, with a valley bottom depth below vertical cliffs typically ranging between 40 feet and 125 feet (near the westernmost portion of the red trail). A 3,345-foot linear portion of this channel has a very low gradient (0.0066 or 35 ft/mile) with an invert or lake spillway elevation of 470 ft msl - some 100 feet lower than the two channels that once drained into Pickerel Pond. This is in sharp contrast to the initial precipitous drop of the channel bottom immediately beyond its northern terminus (Photos 15A & 15B) downward to the north-northeast of 60 feet over a distance of 500 feet (a gradient of 0.12 or 634 ft/mile). This is the location where aggressive meltwater drained a proglacial lake southward out of the Sawkill drainage that was blocked by the Hudson Valley ice lobe (not depicted on Figure 4), as well a subglacial meltwater flow route. A view northward from cliffs bordering this channel would fall on glacier ice to the east, an iceberg-laden lake to the north and west, and icy meltwater surging southward into the Onteora Channel.

- Additional evidence supporting the fact that the Onteora Channel is not part of the natural drainage includes the grossly underfit stream present within it (versus what would be needed to carve the channel) and the small 87-acre watershed tributary to it (Figure 4, Photos 15 and 16). Surface water flow from this watershed is not sufficient to carve this channel. It is likely that this meltwater channel was used during multiple glaciations.

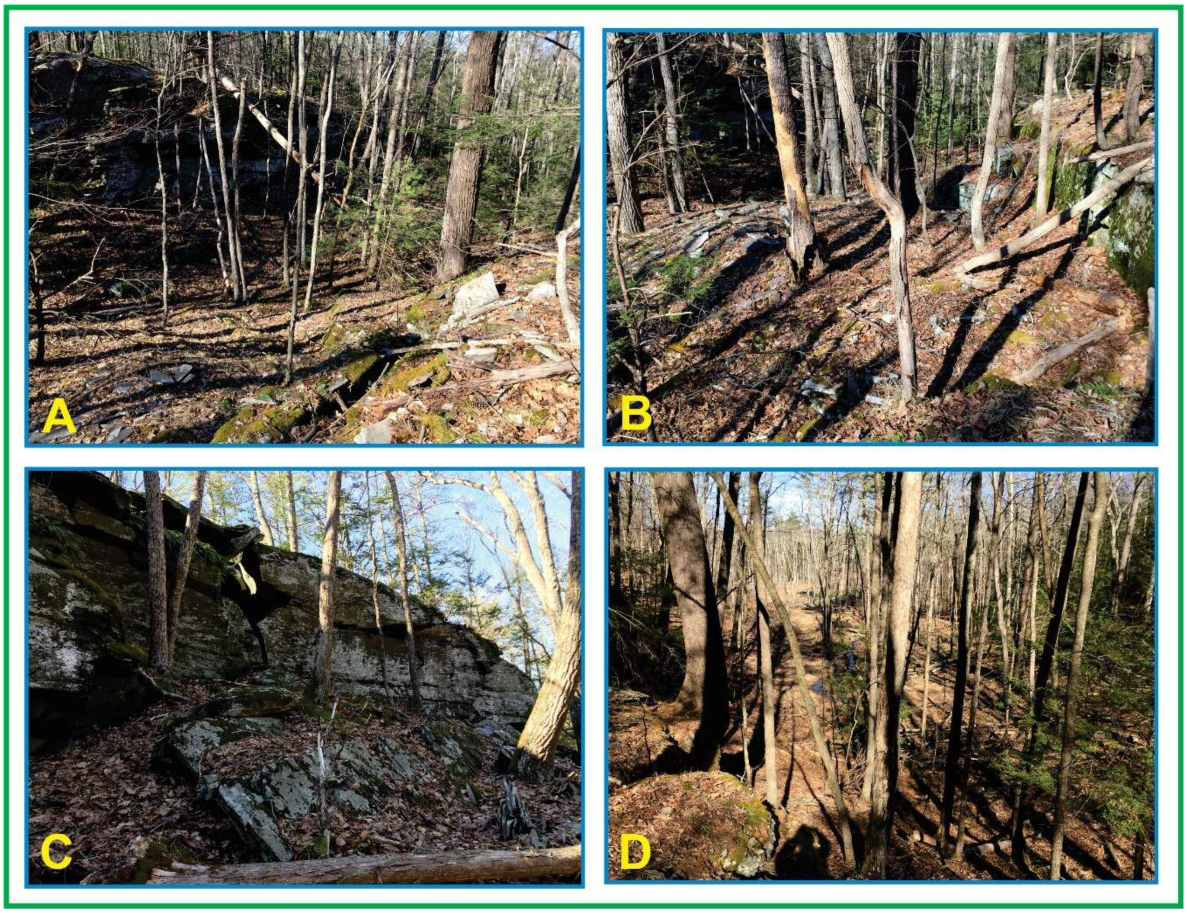


Photo 15. Onteora Meltwater Channel. All photos of the NNE end of the Onteora Channel where glacial meltwater entered and carved the channel. A) and C) West bedrock wall of the channel, B) East bedrock wall of the channel, D) Looking north-northeastward from the channel floor down a steep slope that now drains to the Sawkill. This entire slope area was formerly filled with a glacial lake.

- The different channel elevations may reflect falling proglacial lake levels (stage) coincident with glacier thinning. Alternately, the three easternmost channels may have only served as subglacial meltwater channels. Their U-shaped cross-sections (Figure 18), nearby glacially striated bedrock, and higher topographic elevations may argue solely for glacial sculpting and a subglacial meltwater channel function. Linear, low-gradient, segments of these now largely abandoned glacial meltwater channels are up to 3,345 feet (0.63 mile) in length, signifying the geologic uniqueness of these heretofore unrecognized glacial gorges and the southern foreground area now occupied by wetlands, Onteora Lake, Pickerel Pond, and a portion of the project site. A receding glacial lake formed and drained through different elevation channels coincident with downwasting ice and lowering lake levels. Jointed bedrock cliffs along some of these paleo-channel walls were historically and heavily exploited for bluestone. Comparison between one of these channels that was not quarried (Onteora Channel; Photo 15) and one that was shows how nature has reclaimed old quarry workings (Photos 16 and 17) within the Bluestone Wild Forest.

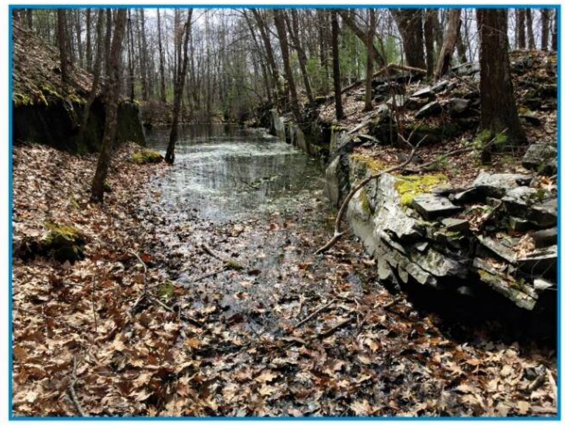


Photo 16. Steep-sided valley bottom interpreted to be a relict glacial meltwater channel that once drained a glacial lake SSW out of the Sawkill drainage. No bluestone quarrying occurred to bedrock cliffs. Ice-cold meltwater once roared through this gorge (Onteora Meltwater Channel).

Photo 17. Trees and a quarry pond used by ducks and spring peepers attest to natural restoration over time. Both channels are linear for over 1,200 feet.

Photo 18. U-shaped channel bottoms and sides provide evidence of glacial sculpting.

- Bluestone Wild Forest is riddled with evidence of historic bluestone (i.e., sandstone) quarrying. Quarry workers exploited sandstone cliffs exposed along meltwater channels, low cliff faces, bedrock mounds, and even massive boulders on top of knolls. For example, historical quarry works are present along both the east and west side of Pickerel Pond, with three quarry zones extending into the 850 Rt 28 project site. Enormous rubble piles associated with many of these quarry workings provide evidence that it was difficult to extract quality stone of desired thickness and extent, even with vertical fractures and horizontal bedding planes to guide extraction (Photos 19A, 19B, 19C). Relict forest workshop areas reveal evidence of methods used to cut sandstone blocks to desired specifications (e.g., nail holes and round drill holes used in the shaping process, Photos 19D, 19E, 19F). Detailed cultural assessment of these features, workshop areas, and their locations is warranted.

Figure 19. Quarry workings in Bluestone Wild Forest.

- Two historic quarry sites extend directly into the 850 Rt 28 industrial project area. Figure 4 shows their locations within light yellow polygons. In addition, it is highly likely that one or more quarry sites are present within the yellow Quarry Area B oval, also depicted on Figure 4, as other quarries are present along the same steep slope further to the north-northeast. Reconnaissance of this area is recommended.

- Historic Quarry area A (Figures 2B, 2C, and 4) extends southward into the proposed project site beyond the property border line depicted. Figure 2B includes a photograph of this quarry area. It is largely comprised low excavated cliff faces and massive quantities of quarry rubble that drape steeply downslope into Pickerel Pond. In one location, a low laid stone wall helps prop up quarry rubble. This quarry area is typical of many of the small bluestone quarry workings along the east and west flanks of Pickerel Pond, as well as elsewhere within the Bluestone Wild Forest. It is likely that any historic quarries that may be present in Quarry Area B will be similar in nature.

- Figures 2B, 2C, and 4 show the location of a premier historic quarry, referred to here as "*Hemlock Quarry.*" Portions of this quarry are present on preserved lands and part of it is in private ownership (approximately 600 feet). The nature of the quarry is discerned here based on field reconnaissance on preserved lands, detailed assessment of LiDAR-derived 2-foot elevational contours, review of a number of years of high resolution orthoimagery, and geologic assessment. Field evaluation of that portion of the quarry on private land is recommended. The undisturbed nature of this quarry and working area provide an outstanding opportunity for geologists and cultural archaeologists to study and interpret historic quarrying methods.

- The areal extent of the quarried Hemlock Quarry cliff face is well-approximated on 2013 imagery (Figure 2B) and on a 2-foot elevational map (Figure 2C). Together, they show a linear north-northeast to south-southwest oriented vertical cliff face extending continuously for a distance of approximately 1,100 feet. Photographs on Figures 2B (labeled black linear feature) and 2C show a portion of this worked cliff face. The upper portion of the cliff is comprised of about 10 to 12 feet of massive, bedded, sandstone. Beneath this, some 15 to 20 plus feet of interbedded sandstone, shale, and mudstone provided access to thin sandstone beds sandwiched between weak, easily removed, shale beds. The height of exposed bedrock below the massive sandstone caprock shows that quarrymen sought both the upper massive sandstone layers and lower thin sandstone beds. The presence and exploitation of these lower sandstone and shale beds is not seen elsewhere in the Bluestone Wild Forest.

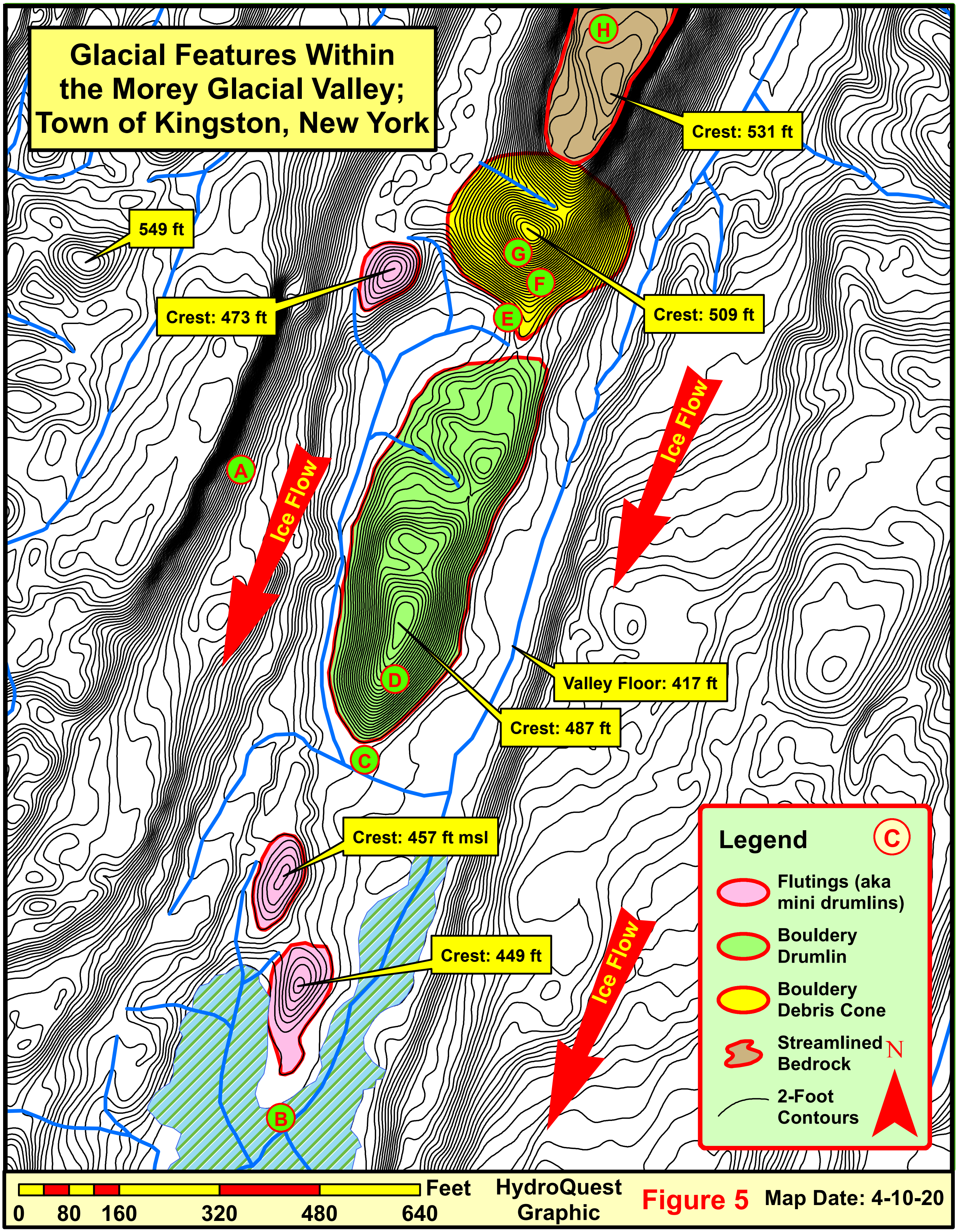
- Massive irregular blocks of sandstone quarry rubble extend outward to the southeast from the cliff face that almost assuredly was worked forward in a northwesterly direction. Alf Evers (1972) provides insight into the means by which the quarrying process used horse drawn derricks to leverage and swing blocks cut from quarry faces to the top of rubble piles where stonecutters shaped and sent them away for use. Drill holes present in rubble blocks provide evidence of quarrying processes that date back some 170 years. This wooden derrick arrangement was probably used at the Hemlock Quarry, with derricks positioned atop the massive rubble piles located southeast of the working cliff face labeled on Figure 2B.

- While additional field work is warranted to verify the physical boundary, working areas, and attributes of quarry rubble associated with the Hemlock Quarry, assessment of elevational contour data and initial field reconnaissance allowed the reasonable 9-acre approximation depicted on Figure 2C. See, for example, the sharp change in gradient proximal to *Pileated Spring* that issues from the base of an arcuate and steeply sloped sandstone rubble pile (Figures 2B [top right photo] and 2C). With the exception of tree growth amidst quarry rubble and mass wasting of massive cliff top blocks, one can imagine the sounds of men drilling, blasting, sledge hammering, and chiseling the Hemlock Quarry cliff face, the neighing of working horses, and creaking of heavy stone on iron-rimmed wagons being loaded for transport as if it were only yesterday. Hemlock Quarry provides a superb example of a relict, undisturbed, large-scale bluestone quarry operation - a markedly different setting than observed elsewhere in smaller sandstone quarries within Bluestone Wild Forest. This cultural resource is of great historic value and, as such, warrants protection, preservation, and further study.

- Construction of the 850 Route 28 manufacturing facility would irreparably compromise the integrity of Hemlock Quarry. Project plans show that blasting and site grading would occur through the southwestern end of the Hemlock Quarry for construction of a large parking area and diversion and drainage swales (Figure 2C).

- Streamlined glacial features present within the broad valley area through which Morey Hill Road traverses document the former presence of a south-southwesterly flowing glacier. These features include cigar-shaped sediment and boulder debris mounds referred to as flutings (to 200 feet long, 95 feet wide, and 16 feet high; Figure 5 and Photo 20B) and a boulder-rich drumlin (670 feet long, 210 feet wide, and 50 feet high) (Figure 5 and Photos 20C and 20D). Boulders on the north end of the boulder-rich drumlin range in size up to 10 feet x 8 feet x 7 feet. They were deposited beneath the glacier or ripped off the bedrock cliff a short distance to the north (Figures 4 and 5). The pointed southern ends of these features document the southerly flow direction of the glacier.

- North-northeast of the flutings and boulder drumlin, the regional glacier sculpted an elongate streamlined bedrock plateau (small tableland) elevated above the surrounding valley (Figures 4 and 5). This resistant plateau has a long axis of about 2,334 feet with perpendicular axes ranging from about 77 feet to 318 feet. It narrows in the up-ice direction as a result of ice streaming around the obstacle. Several large boulders on top of this plateau attest to its being overridden by the glacier that carved it and the nearby flutings, as well as the bedrock cliffs alongside it (Figure 5 and Photo 20H).


Glacial Features Within the Morey Glacial Valley; Town of Kingston, New York
549 ft
Crest: 473 ft
Crest: 531 ft
Crest: 509 ft
H
G
F
E
A
D
C
B
Ice Flow
Ice Flow
Ice Flow
Valley Floor: 417 ft
Crest: 487 ft
Crest: 457 ft msl
Crest: 449 ft
Legend
C
Flutings (aka mini drumlins)
Bouldery Drumlin
Bouldery Debris Cone
Streamlined Bedrock
2-Foot Contours
N
0
80
160
320
480
640
Feet
HydroQuest Graphic
Figure 5
Map Date: 4-10-20

- In places, rock and sediment debris frozen in the base of the glacier smoothed and rounded the underlying sedimentary bedrock as the glacier moved, forming elongate rounded ridges referred to as rock drumlins (Figure 4). Today, trees and other vegetation mask the bedrock except where historic bluestone quarrying exposed it. Elsewhere, debris on the bottom of the moving glacier left tell tail signs of glacier movement direction as linear striations etched in the bedrock (Figure 4 and Photo 21F). Note the south-southwesterly alignment of flutings, drumlins, and the streamlined bedrock plateau with the S19°W-trending glacial striations.

- A most unusual glacial feature is present between the boulder drumlin and the streamlined bedrock plateau (Figures 4 and 5 and Photos 20E, 20F, 20G, and 21A to 21E). This is a conical, boulder-rich, debris mound some 300 feet in diameter and 60 feet high. It is not streamlined by glacial movement, as are the other nearby glacial features. Two possible mechanisms of formation seem plausible. One holds that its development post-dates the subglacial sculpting that formed the other features, forming as a powerful on-glacier (supraglacial) stream poured boulders and other debris into a crevasse or moulin (sinkhole in the glacier) immediately south of the bedrock promontory. This would have occurred during the final downwasting or melting stage of the glacier, well after drumlin deposition.

Photo 20. Glacial features present in the Morey Valley. Refer to Figure 5 and report text to correlate photograph letters with physical locations. H is a glacial erratic on top of the streamlined bedrock plateau depicted on Figure 4.

Photo 21. A through E. Debris, boulders, and a remnant segment of bedrock that, together, form the conical mound portrayed on Figure 5. The small segment of bedrock on top of the mound serves as a protective caprock. Scree of various sizes covers what may be a bedrock mound core. F. Etched striations in bedrock formed by rocks bound in ice grinding against the rock as a glacier moved.

- A second more likely mechanism of formation that may account for the shape and composition of the conical feature holds that the core of the cone is largely a remnant of the intact bedrock cliff situated about 125 feet to the north (Figure 5). Reference to Photographs 21D and 21E show large bedrock boulders and, quite likely, a small intact segment of bedrock at the top of the conical mound. Reference to Photographs 21A, 21B, and 21C show that while much of the debris material is relatively small in size, that much of it is comprised of massive bedrock blocks. The physical position of these blocks is consistent with downslope gravity sliding, much of which may have occurred within a subglacial cavity present beneath glacier ice. This cavity would have been positioned directly south of the streamlined bedrock blockage as glacier ice arced downward off the bedrock plateau. Under this scenario, boulders, rocks, and sediment from within debris-rich basal ice would have dropped out into the cavity as glacial melting occurred. The V-shaped space between the crest of this conical mound and the bedrock cliff to the north, versus an elongated drumlin-like shape, provides evidence that both subglacial and bedrock material fell and slid downward into an ice-free cavity – allowing development of the cone-shaped mound. Similarly, massive sandstone boulders are present immediately south of two other bedrock promontories situated further to the west (Figure 4).

- Ongoing geologic field mapping has documented the presence of knoll and kettle topography present within Bluestone Wild Forest (Figures 4 and 6, Photos 22, 23, and 24). A combination of field reconnaissance, Global Positioning System (GPS), 2-foot LiDAR-derived elevational contours, and Geographic Information Systems (GIS) software is being used to delineate types and locations of glacial features. While many features have now been documented others require field checking and initial investigation. All told, there is fantastic glacial geology throughout the Bluestone Wild Forest warranting permanent protection and preservation.

- Some of the depressions or kettle holes amidst rounded mounds (knolls, Figure 6, Photos 22 and 23) have either permanent ponds (e.g., Turtle Kettle: Figure 6, Photo 24) or seasonal vernal pools (Figure 6, Photo 25).

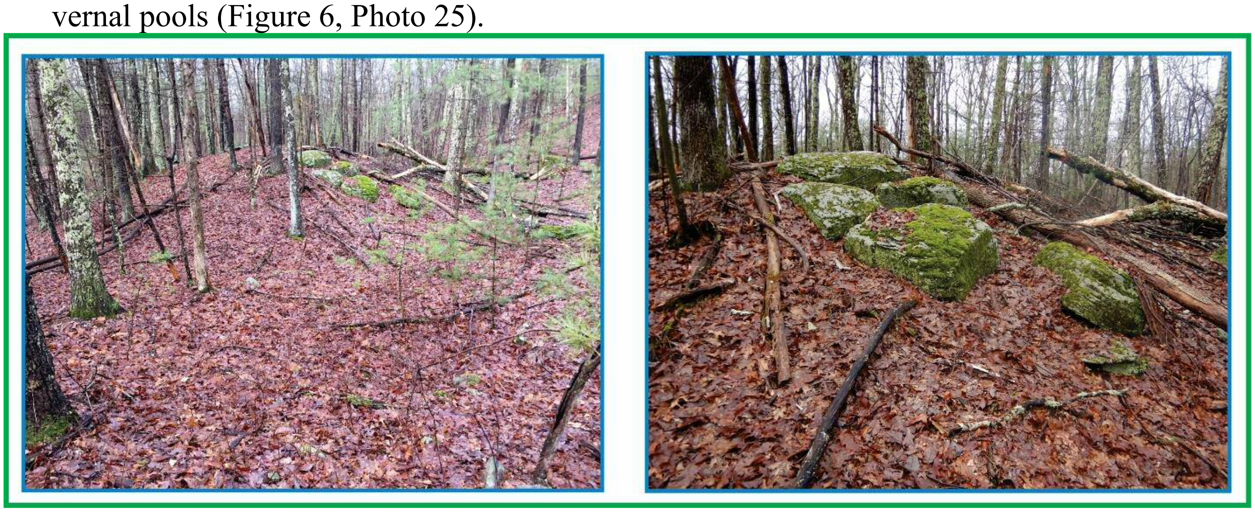


Photo 22. Circular mound near the southern terminus of a meltwater channel. See Figure 6 for location. Large boulders commonly top these mounds.

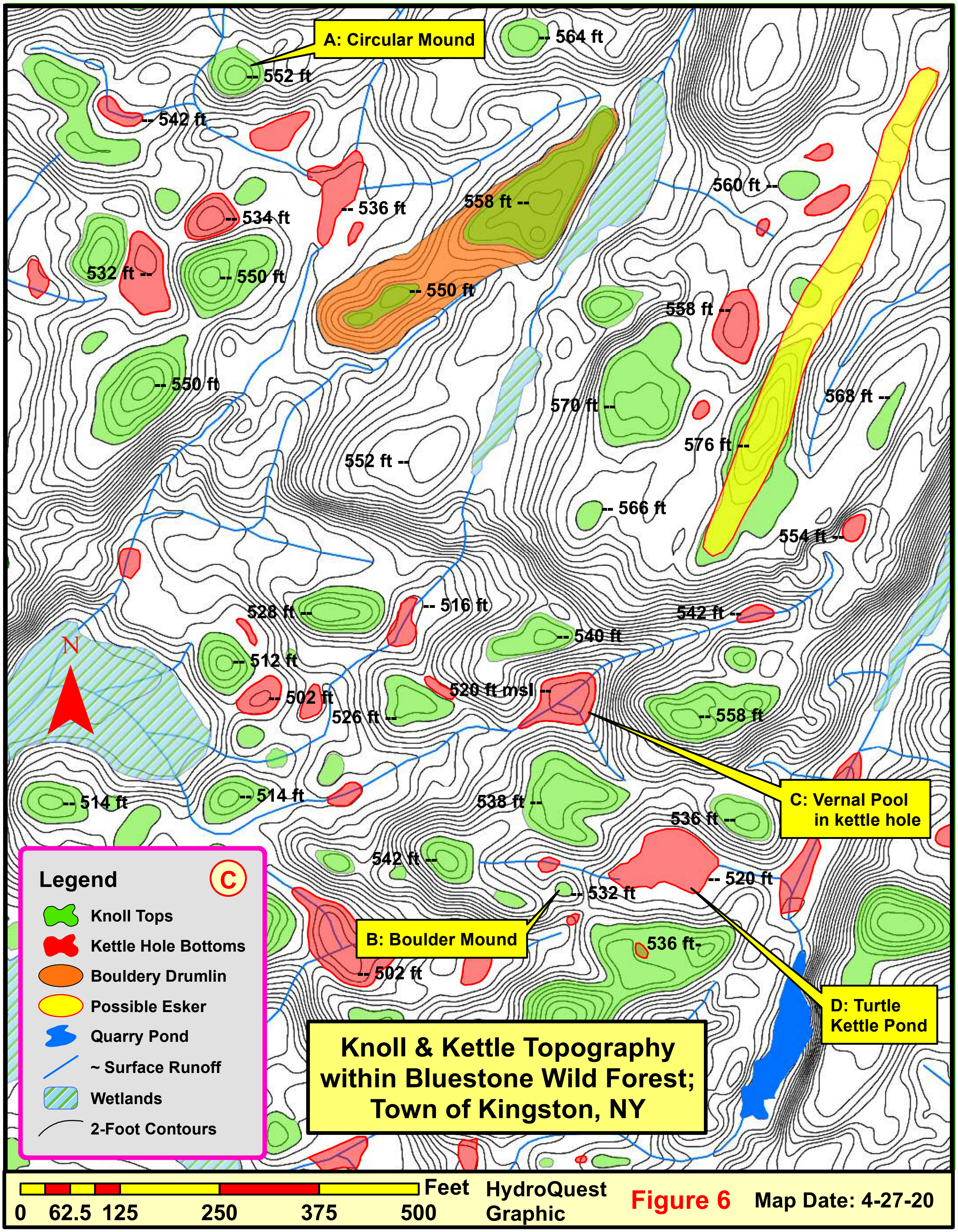

A: Circular Mound
-- 564 ft
-- 552 ft
-- 542 ft
-- 534 ft
-- 536 ft
558 ft --
560 ft --
532 ft --
-- 550 ft
-- 550 ft
558 ft --
-- 550 ft
570 ft --
568 ft --
576 ft --
552 ft --
-- 566 ft
554 ft --
528 ft --
-- 516 ft
542 ft --
-- 540 ft
-- 512 ft
520 ft msl --
-- 502 ft
526 ft --
-- 558 ft
-- 514 ft
-- 514 ft
538 ft --
C: Vernal Pool in kettle hole
536 ft --
542 ft --
-- 520 ft
-- 532 ft
B: Boulder Mound
536 ft-
-- 502 ft
D: Turtle Kettle Pond
N
Legend
C
Knoll Tops
Kettle Hole Bottoms
Bouldery Drumlin
Possible Esker
Quarry Pond
~ Surface Runoff
Wetlands
2-Foot Contours
Knoll & Kettle Topography within Bluestone Wild Forest; Town of Kingston, NY
0
62.5
125
250
375
500
Feet
HydroQuest Graphic
Figure 6
Map Date: 4-27-20

Photo 23. Well-rounded knoll within and near the northern end of Pickerel Pond. With few exceptions, most of the boulder material on this mound is of small and medium size.

Photo 24. Turtle Kettle hole and nearby boulder-rich mound. Note hummocky knoll hills surrounding the kettle pond. Nearby elevations are labeled on Figure 6.

Photo 25. Vernal pool surrounded by hummocky mounds. See Figure 6 for elevations. The top of the mound to the east of the kettle pool (C above) is about 40 feet above the invert of the pool. D and E look down on the kettle pool from the 40-foot mound.

- Large boulders present on knolls are often angled downslope. This probably reflects preferential ice melting away from darker colored drift atop glacier ice (Photo 26).

Photo 26. Steeply angled boulders on the slopes of knolls. The yellow circle in the left photograph encircles a large boulder in a kettle. A seasonal kettle pool is visible in the right photograph.

- The area situated south-southwest of the southern ends of the Onteora and Pickerel channels provides a particularly good example of the outward distribution of glacially plucked boulders. Not only are there bouldery knolls and kettles present, but toward the southern end of the yellow trail there is a chaotic zone of hummocky terrain or moraine that at first glance appears difficult to make sense of. This area is referred to as an end moraine, which is an accumulation of drift (i.e., a mix of rocks, boulders, and sediment of varying sizes) built along a margin of a glacier. Here, it is comprised of a complex of at least three arcuate ridges, each of which marks a temporary terminus of glacier ice. The arcuate red-dashed line here (Figure 4) traces the southernmost, and most pronounced, ridge labeled "*Bluestone Moraine*". It has a particularly steep-sided southern face ending in kettle pools (Photo 27D). Assorted knolls and small kettles in this area on and between moraine ridges form the irregular, boulder-riddled, landscape. Note the bounder-rich mound just southwest of the trail's southern end (Photo 27E). Boulders throughout the moraine document the southwesterly transport of angular boulders, extending into the wetland margin of Onteora Lake (Photo 27F). Near here, a valley is present north of where the yellow trail crosses a small stream. This incised valley cuts directly through the outermost (aka southern) hummocky moraine. Once, this prominent "*Bluestone Tunnel*" channel (Figure 4, Photos 27A and 27B) served as a primary drainageway beneath melting, stagnant, glacier ice. At that time, this would have been the entrance to a sculpted ice cave that extended almost one-half mile northward.

Photo 27. Bluestone Moraine area proximal to the yellow trail. A) Wetland near the northern end of the Bluestone Tunnel. B) Midway within the Bluestone Tunnel with missing overhead glacier ice. C) Steep-sloped knoll in moraine. D) Bouldery knoll and kettle pool at the southern base of the prominent Bluestone Moraine ridge. E) Rounded knoll just northeast of the Onteora Lake wetland. F) Six-foot high boulder on small island within the Onteora Lake wetland (Figure 4).

- Documentation of these glacial features (e.g., meltwater channels, drumlins, knolls, kettles) accents the importance of understanding and preserving these unique geologic features within the natural context of the full glacial landform. No doubt, many more glacial features and geologic revelations will come to light as field mapping continues.

Conclusions

- The health of the Pickerel Pond ecosystem relies on limited and episodic surface water inflow and groundwater baseflow into it. Under dry and drought conditions, removal of 8 percent of the tributary watershed for project construction could have adverse environmental impacts to the pond's ecological health. Similarly, potential reduction in groundwater baseflow to Pickerel Pond resulting from groundwater pumping may compound hydrologic and biologic impacts to the existing, vibrant, ecosystem. With the exception of the dam impounding it (Photo 28), Pickerel Pond is on New York State lands.

- Project construction-based loss of 8 percent of the surface watershed tributary to Pickerel Pond may be further compounded via downward infiltration and loss of pond water resulting from groundwater pumping. Even at a groundwater pumping rate of 2.0 gpm, MHI documented a cone of depression extending nearly to the northern terminus of Pickerel Pond. While the area proximal to pumping well BW-1 may have confined aquifer conditions, it is likely that up-slope pond recharge areas or the pond invert itself may have unconfined conditions whereby the pond water level may be lowered via site production wells. This may impact pond and ecosystem health.

- Hemlock Quarry is documented here as a premier historic quarry that extends southwestward into the proposed industrial site. Construction of the 850 Route 28 manufacturing facility would irreparably compromise the quarry. Hemlock Quarry provides a superb example of a relict (approximately 170-year old), undisturbed, large-scale bluestone quarry operation - a markedly different setting than observed elsewhere in smaller sandstone quarries within Bluestone Wild Forest. The undisturbed nature of this quarry and working area provide an outstanding opportunity for geologists and cultural archaeologists to study, interpret, and refine our knowledge of historic quarrying methods. This cultural resource is of great historic value and, as such, warrants protection, preservation, and further study.

- The proposed project site is centrally located within a unique and unusually well-preserved geological/glacial landform (i.e., knoll and kettle topography, major glacial meltwater channels) that is documented here for the first time. When these glacial features are viewed within the full context of their geologic significance and the wide physical area that they encompass, they provide rationale for preservation of the entire <u>interrelated landform</u>, as well as a unique field-oriented educational opportunity for schools, colleges, and the public.

Photo 28. Earthen dam impounding Pickerel Pond. The outlet water elevation is currently enhanced by beavers. With the exception of the dam, 16.3-acre Pickerel Pond is on New York State lands.