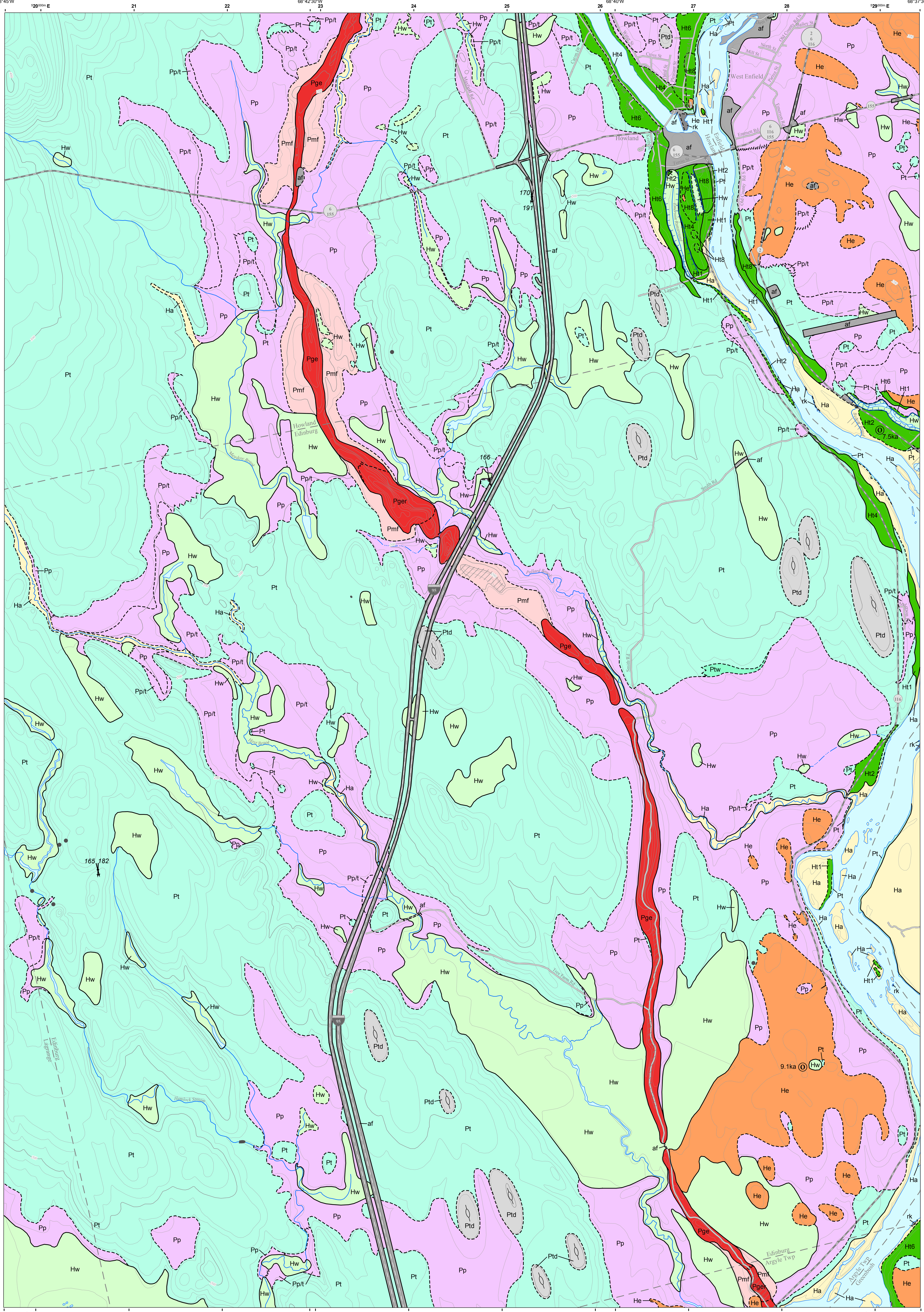
Surficial Geology



Howland Quadrangle, Maine

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SURFICIAL GEOLOGIC HISTORY

During the advance of the Laurentide Ice Sheet in the late Wisconsin, the bedrock in the Howland quadrangle (largely low- to medium-grade metasedimentary rocks of the Siluro-Ordovician Vassalboro Formation (Osberg et al, 1985)) was scoured by the ice and then typically covered by till. During deglaciation, water draining along the bed of the ice sheet melted tunnels upward into the ice. Coarse gravels were deposited in these tunnels. When the ice melted, the gravels were left as ridges (**Figure 1**), now called eskers (**Pge**). One such esker runs the length of the quadrangle. When the eskers were forming, the weight of the ice had depressed the land below sea level and the ice sheet ended in the sea.

Wherever the ice margin remained in one location for a period of years, the esker-forming water melted large portals in the ice margin, and the water velocity decreased as it expanded from the tunnel into these portals. This deceleration led to deposition of coarse-grained "esker heads" (**Pger**) in the portals and of finer grained submarine fans (**Pmf**) (**Figure 2**) downflow from the portals. Further retreat commonly left a drape of fine sand over the esker. Farther from the ice front, silt and clay settled out of the water, forming a layer of marine mud over the till – the Presumpscot Formation. Along the Penobscot River, Presumpscot clay is locally greater than 7 m thick, and because it is weak and plastic, it has a tendency to slowly collapse into the river, sometimes taking roads with it (**Figure 3**).

The ice margin was probably retreating across the Howland quadrangle about 15,400 years ago (Borns and others, 2004). Measurements of the marine limit in nearby areas (Thompson and others, 1989) suggest that only the top 18 m (60 ft) of the hill in the northwestern corner of the quadrangle is likely to have been above sea level at this time. Most of the quadrangle was submerged under up to 60 m (200 ft) of sea water.

By about 14,000 years ago the ice margin had retreated to northern Maine, but the Howland quadrangle was still largely under water and marine muds were still accumulating, albeit slowly. Comparison with a relative sea level curve compiled by Kelley and others (2013) suggests that the quadrangle probably emerged above sea level about 13,500 years ago. As the sea retreated and the land emerged, wave action and then rainfall eroded the Presumpscot from many of the higher areas. As the ice retreated northward and the sea southward, the Penobscot River spread a load of coarse sand and gravel along its lengthening course. Gravel, some of which is likely from this time period, can be observed beneath the modern floodplain in many places (**Figure 4**).

The lowest stand of sea level, ~60 m below present sea level, occurred about 12,000 years ago (Kelley and others, 2013), but bedrock outcrops south of the quadrangle limited the effect this had on the river in the Howland quadrangle.

Between ~12,000 and ~9,000 years ago, flow in the Penobscot River decreased as the last ice in the headwaters melted, the climate became drier (Webb et al. 1993), and rebound of the land shifted the drainage of Moosehead Lake from the West Branch of the Penobscot River into the Kennebec River (Balco et al. 1998; Kelley et al., 2011). The drier climate persisted to ~7,000 years ago.

During the dry spell, sand, likely blown in by prevailing westerly winds, accumulated in eolian dunes (**Figures 5 and 6**). Dates on sand from these dunes, obtained by the optically-stimulated luminescence method, range from 7,700 to 10,800 years ago (Hooke and others, in press). The most extensive dunes lie east of the Penobscot River in the Greenbush quadrangle, the neighboring quadrangle to the south, suggesting that the river was the source of the sand. However, in the Howland quadrangle other dunes lie west of the river, suggesting a source further west as prevailing winds were from that direction. In western Maine, Borns and Hagar (1965) and McKeon (1989) also mapped dunes and a sand blanket. The dune shape and stratification suggested winds from the northwest and west-northwest. The source was inferred to be fluvial sediments, partly glacial (outwash) and partly postglacial in age, in the Kennebec river valley. The sand delivered to the Penobscot River exceeded the river's ability to move it, and although a lot was carried down to Penobscot Bay where it formed a delta that is now submerged (by a further rise in sea level) off Castine (Belknap et al., 2005), a lot was also deposited in the Penobscot valley, resulting in aggradation and formation of a braidplain 6-8 m above the modern floodplain. After ~6,500 years ago the climate became wetter and former sediment sources became stabilized by vegetation so the sediment supply decreased. Consequently, the river began to cut down leaving the braidplain as a terrace (**Ht8** in the northeast quadrant grading to Ht6 in the southeast corner) (**Figure 7**). This terrace is informally named the Sugar terrace as it is well developed on Sugar Island, an island in the river ~3 km south of the Howland quadrangle. In places the braidplain sediments in the Sugar terrace are as much as 8 m thick. Pauses in the downcutting left local strath terraces. These are typically 1 to ~6 m above the modern floodplain (**Figure 7**).

During the period of aggradation, the river was more extensively braided than it is today. Linear wetlands (**Hw**) east of the river in the Greenbush quadrangle are interpreted to be paleochannels dating from this time period. In the Howland quadrangle, two of these paleochannels lie west of the river just south of Howland, and a third is east of the river at UTM coordinates (529,200E, 5,006,100N). A calibrated radiocarbon date on wood from the base of the peat filling the latter suggests that it was abandoned as an active anabranch of the river somewhat before 4,100 years ago (Hooke and others, in press). The sample came from a core taken ~200 m east of this quadrangle's eastern boundary.

Downcutting of the Penobscot was largely arrested by exposure (or re-exposure) of bedrock outcrops. One such outcrop is at the northern edge of the quadrangle and another is ~2 km south of the southern boundary. As a result of these and other bedrock thresholds further north, with stretches of low river gradient between thresholds, the river now carries a finer sediment load, and has been building its present floodplain.

During the last 9,000 years or so, wetlands (**Hw**) have formed throughout the quadrangle as lakes either drained or became filled with sediment.

Optically-stimulated luminescence dating

Optically-stimulated luminescence, or OSL dating is based on the fact that, when sand grains are buried, radioactive decay of potassium (K), uranium (U), and thorium (Th) in the surrounding sediment adds electrons to the grains. The number of electrons in the grains increases with time at a rate dependent on the concentration of K, U, and Th in the surrounding sediment. However, exposure to ultraviolet radiation in sunlight totally depletes the electrons in about 40 seconds!

To obtain an age, one must measure the electron energy stored in the grains and the rate of electron production in the surrounding sediment. Samples are collected by hammering opaque tubes into the sand and capping the tubes (**Figure 4**). Sand at the ends of the tubes is discarded during processing in the laboratory because it has been exposed to sunlight during sampling. The age obtained is the time since the sample was last exposed to sunlight.

Figure 1: Cross section of Hoytville esker looking down-flow about 3 km south of northern edge of quadrangle.

Figure 2: Sand and gravel deposited in submarine fan. View is upflow on downflow side of large esker head in Greenbush quadrangle.

Figure 3: Road (pavement visible on right under fence and in distance) damaged by collapse of Presumpscot Formation in Greenbush Quadrangle. Note exposure of square cement-block casing around old storm drain in center of image.

Figure 4: Excavation in the wall of an abandoned gravel pit. Tubes contain samples that were dated by OSL (9.0±0.8 ka; upper tube) and (11.4±1.2 ka; near lower tube). Fine-grained sediment in upper 0.75 m and flat surface at top are part of modern floodplain. Total depth of excavation: 1.7 m. Site is in the Passadumkeag quadrangle.

Figure 5: Eolian dune in the Greenbush quadrangle. Cross-stratification can be seen. This dune was last active about 10,800 years ago.

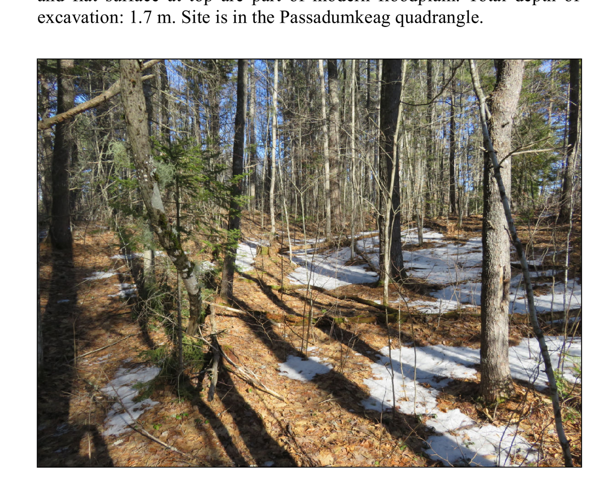
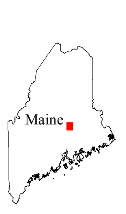


Figure 6: Eolian dune topography in Greenbush quadrangle. OSL dating of sand in an adjacent dune suggests that it was last active about 9,900 years ago.

Figure 7: Terraces Ht2 and Ht8 on west bank of Penobscot River just south of confluence with Piscataquis River in Howland. Photo taken 15 February 2016 when river stage was 3.4 m below the mean annual flood level.

SOURCES OF MAP INFORMATION

Surficial geologic mapping of the Howland quadrangle was conducted by Roger LeB. Hooke from the 2004 to 2014 field seasons.



Hardy Pond	Seboeis	Lincoln West
Lagrange	Howland	Passadumkeag
South Lagrange	Greenbush	Olamon

SCALE 1:24,000

1 0.5 0 1 Mile

1000 0 1000 2000 3000 4000 5000 6000 7000 Feet

1 0.5 0 1 Kilometer

CONTOUR INTERVAL 10 FEET

Magnetic North
True North
Approximate Mean Declination, 2015
16.5° W (not to scale)

Base map features from Maine Office of GIS - 1:24,000 USGS contour lines, E911 roads, 1:24,000 National Hydrography Dataset, USGS GNIS placenames and 1:24,000 political boundaries. Map projection Universal Transverse Mercator, North American Datum, 1927.

Note: The first letter of each map unit indicates the general age of the unit:
H = Holocene (postglacial deposit; formed during the last 11,700 years).
Q = Quaternary (deposit of uncertain age usually late-glacial and/or postglacial).
P = Pleistocene (deposit formed during glacial to late-glacial time, prior to 11,700 yr B.P. [years before present]).

Ha — **Modern floodplain** - Floodplains are those areas that, on average, are flooded once every couple of years. Higher surfaces are terraces, Ht. Records from a gaging station at West Enfield suggest that the gage height of the mean annual flood, that with a recurrence interval of 2.33 years, is 4.6 m. Thus, surfaces that would be flooded at this gage height are mapped as floodplain. Floodplains in the Howland Quadrangle are typically underlain by moderate to dark yellowish brown, unstratified, mature, rather poorly sorted, very-fine sand and silt (**Figure 4**). Coarser sands or small-pebble gravels may occur at depth (**Figure 4**), but some of these are Late Pleistocene or early Holocene in age.

Hw — **Holocene wetlands** - Dark gray or black organic muck. Most boundaries are taken from the U.S. Geological Survey 1:24,000-scale Howland topographic map.

He — **Eolian sand** - Poorly to moderately sorted, moderate yellowish brown, medium sand. Dune stratification was observed in exposures in sand pits (**Figure 5**). Dune topography is diagnostic (**Figure 6**), but some sand in topographically relatively featureless areas is also mapped as eolian. Some of these could be nearshore Pp or abandoned braidplains (terraces - Ht*x*).

Ht*x* — **River terraces** - (**Figure 7**). Medium to coarse sand or larger material, up to pebble gravel underlying topographic terraces. Well stratified in good exposures. Deposited during a period of river aggradation between ~9,000 and ~6,000 years ago and later incised. During incision, pauses in downcutting left strath terraces (Ht1-6). The digit at the end of the symbol is the approximate height, in meters, of the terrace above the modern floodplain. The highest terrace is Ht8 in the northeast, near Howland, and grades to Ht6 in the southeast.

Pmf — **Submarine fan** - Medium sand to pebble gravel (**Figure 2**) deposited downflow from an esker head (Pger). Fans are inferred to have formed in the sea where esker-building glacier meltwater flows, having left their coarse gravel load in an esker head as they emerged from a subglacial tunnel, deposited finer material in a submarine fan. The fan may drape a continuation of the esker.

Pge — **Esker gravels** - Ridges of pebble or small-cobble gravel (**Figure 1**), commonly draped by fine sand (nearshore Pp).

Pger — **Esker head** - These are areas where, when traced southward, an esker rises gradually and then drops off sharply or (in some quadrangles) merges with a delta. Downflow (southward) the coarse esker gravels typically interfinger with and eventually transition to finer gravels and sand in submarine fans. Some esker heads are also draped by fine sand (nearshore Pp).

Pp — **Presumpscot Formation** - Moderately-sorted very fine sand, silt, clayey silt, or silty clay, commonly light gray (ca N6 or N7), but may be light olive gray (5Y 5/2) to pale yellowish brown (10Y 6/2) where oxidized. Commonly stiff or compact. Very fine sand facies is interpreted as having been deposited nearer the source.

Pp/t — **Thin Presumpscot over till** - Marine silt or silty clay, less than ½ m thick, overlying glacial till (Pt).

Pt — **Glacial till** - Poorly sorted silty fine- to medium sand with pebbles, cobbles, and boulders in road cuts and granules and small pebbles in soil probe samples. Scattered cobbles and boulders commonly protrude from the ground surface.

Ptw — **Water-washed glacial till** - Silty sand with boulders, interpreted to be water-washed till

Ptd — **Drumlin** - Glacial till (Pt) molded by ice flow into a streamlined hill aligned with the direction of glacier flow.

af — **Artificial fill** - Areas of fill emplaced by humans.

rk — **Bedrock outcrops** - Size of exposures is typically exaggerated for clarity.

Bedrock outcrops - Small areas of exposed bedrock. Dots mark locations of individual outcrops.

Gravel pit - Areas of disturbed earth.

Contact - Boundary between map units. Dashed where approximately located.

Stream channel (paleochannel bank) - Bank of abandoned stream channel.

125, 165 — **Glacial striation locality** - Arrow shows trend of glacial ice-flow inferred from striations on bedrock. Dot marks point of observation. Number is azimuth (in degrees) of flow direction.

Glacially streamlined hill (drumlin) - Symbol shows long axis of hill or ridge inferred to have been shaped by flow of glacial ice. Axis is parallel to former ice-flow direction.

7.5ka — **Optically stimulated luminesce age** - Ages are in thousands of years before present.

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ACCURACY OF MAPPING

Road cuts, river banks, and gravel pits provided the best exposures in the quadrangle, but were not common. Elsewhere, a soil probe was used to obtain samples from a depth of, usually, ≥0.3 meters. Occasionally a hand auger was used to get samples from as deep as 2 meters. Observation points were located by hand-held GPS; most are shown on the accompanying surficial materials map (Hooke and others, in prep); some were omitted for clarity.

Many of the map units are quite similar in appearance. Poorly sorted fine to medium sand can be found in eolian sand dunes, in the modern floodplain, and in river terraces. Thus, in the absence of other data such as topographic expression and/or the height above the Penobscot River, distinguishing among these units can be problematical. Similarly, silt can be found in the floodplain or in the Presumpscot Formation, although the latter is generally more compact.

Pebble gravels, similar to gravels in modern river bars, were found beneath modern floodplain deposits in several places. In some cases, OSL dates suggest that the gravels are Late Pleistocene or early Holocene in age, and are likely remnants of a braidplain that existed immediately prior to the initiation of river aggradation about 6,000 years ago.

Some wetland (Hw) units and layers of Presumpscot (Pp) silt are <0.5 m thick. Thin accumulations of the latter were locally present on till, and are shown as Pp/t.

Owing to the gradational nature of many contacts and the density of sampling points, some contacts may be mislocated by over 100 m. The size of some units, particularly bedrock outcrops and units exposed in river banks, has been exaggerated for clarity.