5-2018

# The Alderbrook and Riverton Stages of Glacial Lake Israel and their Significance to the Indigenous Peoples of the Israel River Complex

Hazel Cashman
*Bates College*, hcashman@bates.edu

# The Alderbrook and Riverton Stages of Glacial Lake Israel and their Significance to the Indigenous Peoples of the Israel River Complex

An Honors Thesis
Presented to
The Faculty of the Departments of Geology and Anthropology
Bates College

In partial fulfillment of the requirements for the
Degree of Bachelor of Science

By
Hazel Maura Cashman

Lewiston, Maine
March 28, 2018

## Acknowledgements

Thank you to my advisors Kristen Barnett and Dyk Eusden for their incredible support and flexibility throughout the thesis process. You have both taught me so much: how to be a better writer, a critical researcher, how to stay curious, and how to keep everything in balance. I truly appreciate the effort you put in to this project and the ideas you encouraged me to pursue. I would also like to extend a sincere thank you to Dick Boisvert and Woody Thompson, without whom this project would not be possible. Your knowledge of the study area is incredible, and your generosity even more so. Thank you to Kerry O'Brien, to the Bates Student Research Fund's Hoffman Research Support Grant for funding fieldwork in July of 2017, and to the gracious crew at the AMC's Camp Dodge for cooking up some amazing meals, letting us share their space, and telling some hilarious stories.

At Bates, I'd like to thank Christine Murray for help with ArcGIS. In Jefferson, many thanks to Mitch and Kricket Ingerson for their time, help, and curiosity about the project and to Mr. Neil Gross for his generosity and for sharing with me one (really) important piece of wood. Thanks to my partners in the field, Kurt and Thorn, for digging a few holes in the kitty litter for me, and of course thank you to everyone in the Bates Geology Department for their support, encouragement, and feedback with thesis and throughout my Bates geology career. Thank you as well to the Bates Anthropology Department, for encouraging me to think differently and be an everyday anthropologist. Additionally, a sincere thanks to everyone on my thesis review panel - Dyk and Kristen, Mike Retelle, Patrick Otim, Josh Rubin, and Dick Boisvert- for taking the time to read this behemoth of a document and engage with my work.

Finally, thank you to my friends here at Bates who have lent their input, their encouragement, and their warmth throughout this process. I could not have done it without you all and your confidence in me. Thank you to my parents who have supported me since day one; I love you both more than I can say and am so incredibly grateful for the opportunities I have had because of you. Last but not least, a huge thank you to my fellow geology and anthropology majors- watching your theses develop over the course of this year has been incredible and humbling and I am so proud to call you my peers. I am so happy to have found in you a community that I know I will always be able to come back to; thank you for being my teachers.

# Table of Contents

## Table of Figures

## Table of Tables

# Abstract

Through an analysis of Indigenous knowledge, archaeological data, and geological mapping, this study investigates the environmental and human history of the Israel River valley, New Hampshire, after deglaciation-- from roughly 14,000 to 10,000 years ago. The focus of this study is the relationship between the proposed postglacial Alderbrook and Riverton stages of Glacial Lake Israel and the Israel River Complex (IRC) archaeological sites on/among till hummocks on the eastern valley wall (Boisvert et al., 2017). Maps were made in GIS of the glacial and postglacial stages using LiDAR (from the Lancaster E and Jefferson 7.5' quadrangles) obtained through NH Granit. Alderbrook and Riverton Stage shorelines were modeled using elevations from a spillway at Riverton, NH, (Thompson, pers comm.). Wave cut shoreline features seen in elevation profiles made using the DEM support the spillway elevation for the Alderbrook Stage. The three glacial stages, named the Bowman, Pine Knob, and Bailey's stages, have been mapped by Thompson et al., 2017 and new maps were made as part of this study.

Mapping of geomorphologic landscape units in the study area showed four classes: hummocky till (stagnation moraine), smooth till, bedrock, and what is referred to as lake bottom (even topography in the floor of the Israel River Valley, overlain by alluvium). Spatial patterning of the units was compared to models of Bailey's, Alderbrook, and Riverton Stage shorelines made using LiDAR in GIS to determine agreement/disagreement with the GIS modeling method. Good correlation was found between boundaries of hummocky till and smooth lake bottom and the Alderbrook and Riverton shoreline models.

A radiocarbon date obtained from a fragment of Alnisedi (eastern hemlock) confirms the coexistence of the postglacial Alderbrook Stage with the occupation period of the IRC sites, and models of this stage show that the lakeshore was proximal to the sites. The existence of the Alderbrook Stage (and the Riverton stage after it) in the Israel River valley certainly had impacts on plant and animal species and the humans that lived there. In addition to impacting caribou migration routes and hunting patterns/strategies, (Boisvert, 2012; Boisvert et al., 2017) these postglacial lakes supported the existence of numerous other species that were important resources for the valley's human occupants. A consideration of Indigenous knowledge (oral histories, traditional ecological knowledge) and use of some modes of the Indigenous Research Paradigm (Lambert, 2018) is equally important to understanding past interactions between humans and the environment in this region, and is woven in to the analysis alongside archaeological data.

## Introduction

This study focuses on a region northwest of the White Mountains of New Hampshire called the Israel River Valley (Figure 1). As the Laurentide Ice Sheet receded across what is now New England at the end of the Last Glacial Maximum (LGM), a multitude of glacial lakes formed in front of the retreating ice margin. One of these lakes, Glacial Lake Israel, used to reside in what is now the Israel River Valley. Near the remnants of Glacial Lake Israel there was a locus of human occupation centered around a group of sites now termed the "Israel River Complex." There is evidence to suggest that humans moved into this area of New Hampshire around the onset of the Younger Dryas cold climatic period, (around 12.9 ka BP) following herds of migrating caribou. Through radiocarbon dating of a fragment of Alnisedi (eastern hemlock) found at the boundary of lake sediments from two stages of Glacial Lake Israel and mapping of these lake stages in ArcMap, this study aims to determine the timing and extent of two proposed postglacial lake stages and the relationship of this changing environment to the first humans of New Hampshire. A broader understanding of the glaciological history, archaeological research, and Indigenous knowledge of the region is necessary in understanding the dynamics of human occupation in this region; therefore, this paper will commence with a discussion of relevant background information.

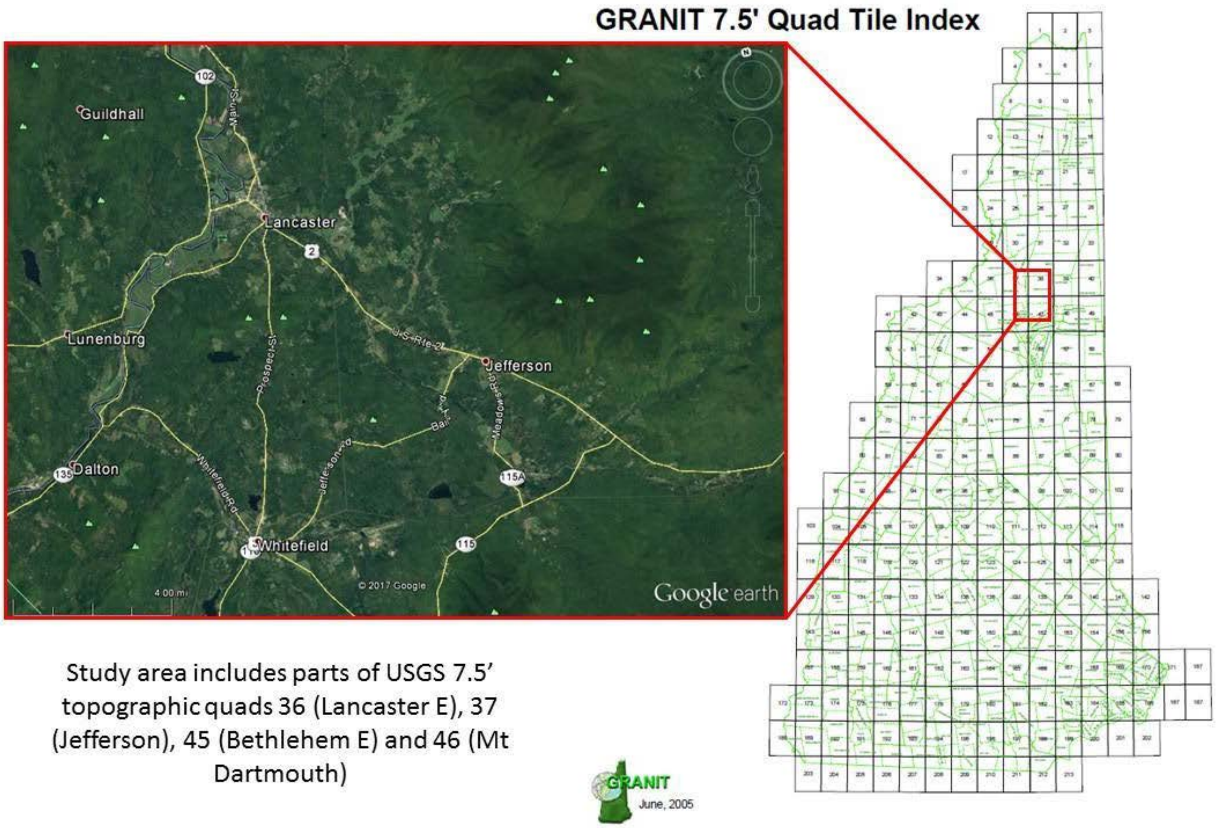



*Figure 1: Image of study area shown in relation to the Quad Tile Index of New Hampshire from the GRANIT online database.*

### The Intersection of Archaeology, Geology, and Indigenous Knowledge

Collaboration between archaeologists and geologists has been common since the beginning of the 19th century, and since the mid-1900s, an interdisciplinary approach to understanding past landscapes has become increasingly important (Bar-Yosef, 2001; Rapp and Hill, 2006). Equally important to the collaboration of these two disciplines is Indigenous knowledge, which is built on understandings of land and history in terms of traditional ecological knowledge (TEK) and cultural continuity between present day Indigenous peoples and Indigenous peoples of the past. This way of knowing is as equally valid and legitimate a system of knowledge as that used in traditional archaeology and western science. In fact, when the full history of interaction between Indigenous knowledge and western forms of knowledge is taken into consideration (this history being one of contact, variation, transformation, exchange, communication, and learning over several centuries) it becomes nearly impossible to consider western scientific knowledge systems without also considering Indigenous knowledge systems

(Agrawal, 1995). Thus, an integrated understanding of history in terms of archaeology, geology, and Indigenous knowledge can provide the opportunity to explore the human ecosystem in a more total way by considering the dynamics of human behavior in the natural environment, (Waters, 1992) and the history of people and land in the terms of those who are directly culturally descended from that history.

The Quaternary period is of particular interest in archaeology: Quaternary environments and environmental changes provided the backdrop for much of human evolution (Holliday, 2001). The Quaternary (a roughly 2 million year period) is one of three geologic periods that comprise the Cenozoic era, and is divided into the Pleistocene and Holocene epochs. The Quaternary is characterized by climatic cycles which impacted plant and animal communities, sea level, rivers, lakes, and glacial growth and recession; human history is inextricably linked to Quaternary environments (Holliday, 2001). This connection between people and land is also evidenced in Indigenous knowledge.

TEK is defined by Usher (2000) as "all types of knowledge about the environment derived from the experience and traditions of a particular group of people." Many authors have attempted to characterize TEK and western science in terms of their different ideologies, content, methods, epistemology, and context, but TEK and western science have a long history of interaction which undermines the legitimacy of this dichotomization (Usher, 2000). TEK promotes an understanding of the "stories, values, and social relations that reside in places as contributing to the survival, reproductions, and evolution" of Indigenous cultures and identities (Houde, 2007). TEK is "knowledge of the past and current uses of the environment that is transmitted through oral history," creating community and cultural identity surrounding relationship to the environment (Houde, 2007). Therefore, TEK cannot be overlooked in considerations of the relationship between humans and their environments, whether modern or occurring in the past.

Humans certainly occupied proglacial and periglacial environments at the end of the last glacial maximum in North America; all of the related glacial environmental settings have specific contexts that can be related to this occupation (Rapp and Hill, 2006). The proglacial and periglacial landscapes that existed at the end of the Pleistocene and beginning of the Holocene in what is now the northeast United States contained numerous glacial lakes, and this raises many important questions for geoarchaeologists: how did these environments influence their earliest human occupants? What happened to the record they left behind? What effect did the Younger Dryas (a cold climatic period lasting from roughly 12,900-11,600 BP) have on the relationship of peoples to the environment (Cremeens and Hart, 2003)? The deglaciation chronology of the northeast is well known through sediment records left by these lakes, and through positions of moraines, spillways, and meltwater channels--among other types of geological evidence. Additionally, TEK and Indigenous knowledge tell the histories of human relationships to land through time. These records are invaluable to reconstructions of past environments and the relationships of humans to those environments.

Geoarchaeologists attempt to answer these broad questions: Why did the people of this time period pick specific locations for their activities? And what has happened to the record of these peoples since they abandoned these sites (Cremeens and Hart, 2003)? The first question is largely behavioral, and the second deals with the importance of understanding site-specific formation processes that influence artifact patterning (Cremeens and Hart, 2003). Therefore, an understanding of past lifeways must be based on consideration of all that has happened to the landscape since the site was occupied; in this statement lies the key to understanding the importance of geoarchaeology.

This study focuses on the Israel River Valley, a valley situated just northwest of the White Mountains in New Hampshire. Once home to the different stages of Glacial Lake Israel, an ice-dammed glacial lake that formed as the Laurentide Ice Sheet receded northwards at the end of the Last Glacial Maximum, (LGM) the study area can be seen in Figure 1. A geological understanding of the area's landscape history involves deglaciation, lake formation, and finally human occupation around the onset of the Younger Dryas. This study provides an overview of Indigenous understandings of occupation history in the northeast from the time of deglaciation to the present and how these relate to archaeological understandings of this history.

This geoarchaeological project combines techniques of geological mapping, investigation of the area's archaeological research history, and incorporation of Indigenous knowledege in order to come to an understanding of the relationship between humans and Glacial Lake Israel. The following general questions frame the research: 1) How does the distribution of landscape types and lake shorelines relate to the distribution of occupation sites on the landscape? 2) Did humans coexist with any stages of the glacial lake? 3) If so, what does this mean in terms of past lifeways?

## Geological Background

### The LGM and Laurentide Ice Sheet Retreat

Many studies have suggested that humans occupied the regions around the margins of the continental ice sheet during and just after its recession from the northeast U.S. at the end of the Last Glacial Maximum. As a result, archaeological investigations have become increasingly interested in understanding the process of deglaciation, the chronology, and associated climatic change (Ridge, 2003; Boisvert, 1999). Proximity to the ice margin and to associated glacial lakes would have had considerable influence on settlement, migration patterns and food sources (Ridge, 2003). The North American Varve Chronology (NAVC) (Ridge et al., 2012) and paleomagnetic declination records have been used to correlate dates from varved glacial lake sediments across the region and formulate a deglaciation chronology for the entire northeast. This chronology has been calibrated using $^{14}C$ dating, and from there calibrated to calendar years (Ridge, 2003). Along the axes of the Connecticut and Merrimack River valleys, the age of deglaciation is defined where basal varve sections have been matched to the NAVC, and along with correlation to declination records, used to create a map showing deglaciation patterns across the northeast in calibrated (calendar) years by Ridge et al. (2003; 2012), which can be seen in Figure 2.

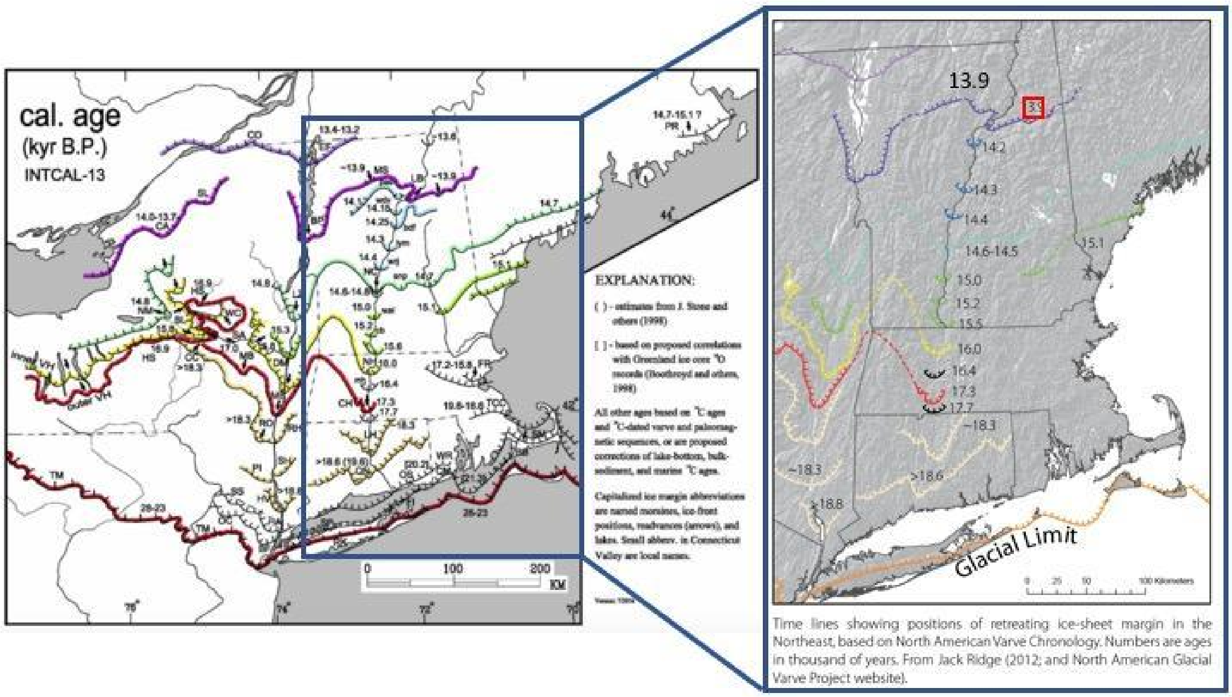



*Figure 2: Map showing calibrated ages of ice margins during recession of the Laurentide Ice Sheet from the Northeastern US. Ages shown in thousands of years before 1950 AD (cal ka BP). Enlarged map shows detail of New Hampshire, with the study area outlined in red. From the North American Glacial Varve Project Website, Tufts University Varve Project and The Geology of New Hampshire's White Mountains, Eusden and Thompson, 2013.*

Figure 3 shows Accelerator Mass Spectroscopy (AMS) radiocarbon dates from basal pond sediments collected from across the northern Northeast US, compiled by Thompson, (1999) exhibiting a pattern of older ages to the south and younger ages to the north. This pattern indicates northward recession of late Wisconsinan ice: ages in New Hampshire cluster around 13,000 radiocarbon yr BP, and ages in Quebec around 11,000 radiocarbon yr BP.

| Site | Lab No. | Age ($^{14}C$ yr BP) | Reference |
| --- | --- | --- | --- |
| 1. Cushman Pond | OS-7122 | 13,150 ± 50 | Thompson *et al.* (1996) |
| 2. Deer Lake Bog | QL-1133 | 13,000 ± 400 | Davis *et al.* (1980) |
| 3. Lost Pond | QL-985 | 12,870 ± 370 | Davis *et al.* (1980) |
| 4. Lake of the Clouds | I-10684 | 11,530 ± 420 | Spear (1989) |
| 5. Pond of Safety | OS-7125 | 12,450 ± 60 | Thompson *et al.* (1996) |
| 6. Surplus Pond | OS-7119 | 12,250 ± 55 | Thompson *et al.* (1996) |
| 7. Spencer Pond | AA-9506 | 11,665 ± 85 | C. Dorion (unpub. data) |
| 8. Columbia Bridge | WIS-961 | 11,540 ± 110 | Miller and Thompson (1979) |
| 9. Barnston Lake | GSC-420 | 11,020 ± 330 | McDonald (1968) |
| 10. Lower Black Pond | OS-7123 | 11,500 ± 50 | Thompson *et al.* (1996) |
| 11. Chain of Ponds | ? | 10,860 ± 160 | Borns and Calkin (1977) |
| 12. Lac aux Araignees | GSC-1353 | 10,700 ± 310 | Shilts (1981) |
| 13. Boundary Pond | GSC-1248 | 10,200 ± 200 | Shilts (1981) |
| 14. Lac à la Truite | GSC-1289 | 11,000 ± 240 | Shilts (1981) |
| 15. Lac Dufresne | GSC-1294 | 11,200 ± 160 | Shilts (1981) |

*Figure 3: AMS radiocarbon ages given by basal pond and lake sediments from across the northeastern U.S. as compiled by Thompson, 1999. All ages were calibrated using the IntCal 13 calibration curve.*

The most recent maximum advance of the Laurentide Ice Sheet occurred in the Late Wisconsinan during MIS 2, (marine isotope stage 2) which is one of many stages visible in the pattern of oxygen isotope variation recorded in the GISP2 and GRIP ice cores from Greenland (Ridge et al., 2012). These stages provide a proxy for temperature in the North Atlantic region. Retreat of the southeastern sector of the Laurentide Ice Sheet from the LGM began around 22,000 cal yr BP (Retelle et al., 2016; Ridge et al., 2002, 2012). At this time, the ice sheet extended out to George's Bank in the Gulf of Maine (Ridge, 2003). Cosmogenic nuclide exposure ages from boulders on Martha's Vineyard have shown that the margin of the LIS reached its maximum there around 23,200 cal yr BP (Balco et al., 2002). Ages from the Buzzard's Bay moraine near Woods Hole show that the ice margin left the area around 18,800 cal yr BP; together, these ages correlate with the terminations of cooling cycles recorded in Greenland ice cores (e.g., the termination of Heinrich event 2) which suggests that the ice margin position in this area was coupled to North Atlantic climate during the Late Wisconsinan; onset of ice sheet contraction began with rapid warming seen in the Greenland ice cores around 23,700 cal BP (Balco et al., 2002).

The glacial geology of Maine records northward recession of Late Wisconsinan Laurentide ice in the coastal moraine belt, much of which formed around 15,000 cal BP (Borns et al., 2004). Moraines in the coastal lowlands of Maine show morphology of deposits aligned along the former ice margin. The Cox Pinnacle Moraine (CPM) and the Waldoboro Moraine help delineate the position of the ice margin as it was pinned to the bedrock upland between the Androscoggin and Royal River valleys between 13.5-15.5 ka (Retelle at al., 2016). The Pineo Ridge Moraine complex and the Pond Ridge Moraine represent minor stillstands/readvances; the Pineo Ridge Moraine has been correlated to the latter half of the Oldest Dryas period by Kaplan, 2007. This period was followed by rapid recession of the ice across central and northern Maine between 13 and 11 cal ka BP in the warmer periods of the Bolling and Allerod interstadials (Borns et al., 2004, Kaplan, 2007).

By 11 cal ka BP, the ice may have separated into two large masses which stabilized or readvanced during the Younger Dryas (Borns et al., 2004). The Younger Dryas, which lasted approximately from 12,900-11,600 cal BP, was a global cool-climate event that appears as the Younger Dryas lithological zone in pond sediment cores from Northeastern Maine (Borns et al., 2004) and from cores in New Hampshire. Dates on peat from the Oxbow stratigraphy in northeastern Maine suggest deglaciation of the area by around 12,400 cal ka BP; this represents an area in which Younger Dryas readvance occurred before the ultimate disappearance of ice at the onset of the Holocene (Borns et al., 2004).

The Connecticut River valley presents a comparable story of ice sheet retreat. Multiple readvances are recorded; the oldest of these readvances is the Chicopee in southern Massachusetts, (dated by Ridge et al. 2002, 2012 at 17,921 cal ka BP) and is correlated to a cool event recorded in a Greenland ice core. The North Charlestown moraines (south-central New Hampshire) record another delay in ice recession and are dated at 14,731 cal ka BP. Following these four stillstands, ice retreat quickened until it was again interrupted by the Littleton-Bethlehem readvance (13,300 cal BP) which has been correlated to the Allerød/Greenland interstadial I using cosmogenic nuclide ages from the Androscoggin moraine complex on the Maine/NH border by Bromley et al., 2015. The Androscoggin moraine complex is related to the Littleton-Bethlehem moraine complex; the two moraine groups both have ages around 13,250 cal ka BP and represent the same readvance/stillstand (Bromley et al., 2015). However, Thompson et al. (2017) have suggested that the Littleton-Bethlehem readvance coincided with the Older Dryas cold interval and an equivalent cooling event in the Greenland Ice Core Chronology 2005 time scale. The final recession of ice from the Connecticut Valley occurred before 13,500 cal yr BP, as dated by terrestrial plant macrofossils in varves near the Canadian border (Ridge, 2002).

After about 13,400 cal yr BP LIS ice had completely receded from the northeast US except for the lingering ice masses in northern Maine, mentioned above (Ridge, 2002).

### Glaciation of the White Mountains

The existence of moraines in the White Mountains and the predominant mode of deglaciation there was debated continuously from the mid-1800's through the mid-1900's (Thompson et al., 2017). Most early investigations assumed that dynamic ice persisted in the White Mountains during deglaciation. Proponents for the post-ice sheet local ice model argued that the steep cirques and sharp arêtes in the White Mountains are evidence of cirque glacier erosion following recession of the Laurentide Ice Sheet, while others argued that continental ice was the most recent influence in the region (Allen et al., 2001). Geologists such as Charles Hitchcock and other workers found that continental glacial ice was the most recent dominant feature in the region, that the late Wisconsinan ice margin receded systematically in congruence with the active ice model, and that while small alpine glaciers did carve the cirque basins in the Presidential Range of the White Mountains, most of that activity happened before the onslaught of the most recent ice sheet and all the glacial activity discussed above (Thompson, 2000; Thompson et al., 2002; Thompson et al., 2017; Fowler et al., 2013).

However, new work by Fowler and Dulin (2017) and Davis (2017) explores the possibility that active cirque glaciers outlasted continental ice in the Presidential Range. A landform found below the Great Gulf during mapping of the surficial geology of the Mt. Washington East 7.5' quadrangle was hypothesized to be moraines deposited during active glaciation of the cirque after the departure of continental ice. Dulin (2012) concluded that the landform (discovered by Fowler) was deposited by ice moving out of the cirque, based on provenance data from clasts on the landform (Fowler and Dulin, 2017). Davis et al. (2017) obtained two $^{10}$Be exposure ages (13.0 ± 0.4, 12.7 ± 0.2 ka) from boulders at Pinkham Notch which are much younger than the age of deglaciation suggested by the Connecticut Valley varve chronology to the west (Davis et al., 2017). Although these boulder ages could be outliers, (Davis et al., 2017) it is interesting to note the possibility of active ice later than is suggested by the varve chronology shown in Figure 2, especially in terms of how it could have impacted species diversity and early human occupation of the region.

## Ice-Dammed Glacial Lakes in New Hampshire

Glacial lake deposits are among the most significant deglaciation features in the northern White Mountains (Allen et al., 2001). Richard Lougee defined and named many of the lakes in the Littleton - Jefferson - Lancaster area of New Hampshire in the 1930s (Thompson, 2013). These glacial lakes were dammed by the margin of the Laurentide Ice Sheet as it withdrew from west-sloping valleys and blocked drainage of meltwater coming off of them (Thompson, 2013). In other places, meltwater was dammed by accumulation of glacially-derived sediments; some of these drift-dammed lakes persisted into early postglacial time after the LIS had retreated fully from the region (Thompson., 2013). This model explains the two proposed postglacial stages of Glacial Lake Israel in this study.

End moraines and other deposits associated with ice-dammed glacial lakes in the Ammonoosuc and Israel River basins in the northwestern White Mountains help support the active-ice deglaciation model (Allen et al., 2001; Thompson et al., 1999). Ice-dammed lakes associated with moraines in what has been termed the “White Mountain Moraine Series” (WMMS) existed in the Ammonoosuc, Johns, and Israel river basins where drainage slopes between north and west; stages of these lakes shifted down their respective valleys as ice retreated and successively lower spillways opened, allowing lake levels to drop sequentially (Thompson et al., 2017; Thompson, 2000).

These lakes are important to understanding human habitation and migration in the newly deglaciated areas of the northeast, especially because they tended to form in long north-south corridors that are recognized as movement corridors for both humans and animals (Ridge, 2002). Lakes that persisted for millennia after deglaciation undoubtedly had an impact on food resources, as did the poorly drained flat surfaces left behind by them which eventually became wetlands and were able to support entirely different ecological regimes (Ridge, 2002). Figure 4 shows a map, compiled by Thompson et al. (2017), of the glacial lakes that existed in northern New Hampshire as ice receded northwards from its position at the LGM.

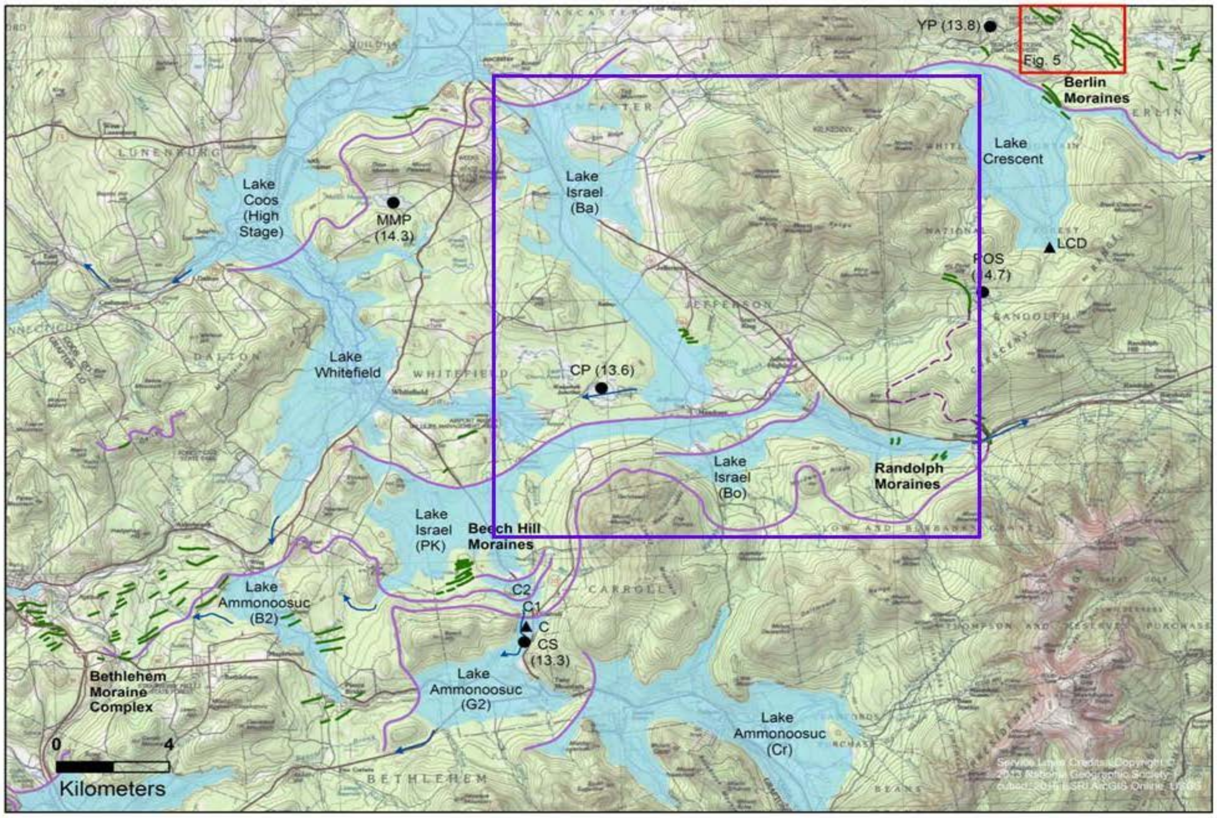



*Figure 4: Map of the northern White Mountains showing glacial lakes Ammonoosuc, Israel, Whitefield, Coos, and Crescent. Study area is outlined in purple. Moraine clusters are shown in green, lakes are shown in blue, and lake spillways are shown with blue arrows. Recessional ice-margin positions are shown by purple lines. Lake stages include the following: Crawford (Cr), Gale River 2 (G2), and Bethlehem 2 (B2) stages of Lake Ammonoosuc; Lake Carroll stages C1, C2; and the Bowman (Bo), Pine Knob (PK), and Baileys (Ba) stages of Lake Israel. Black dots show locations of radiocarbon ages in cal ka BP for Pond of Safety (POS), Carroll spillway (CS), Cherry Pond (CP), Martin Meadow Pond (MMP), and York Pond (YP). Black triangles show the Carroll delta (C) and Lake Crescent delta (LCD). (Figure modified from Thompson et al., 2017.)*

### *Glacial Lake Israel*

Glacial Lake Israel is the focus of this study. This glacial lake (as mapped by Thompson et al., 2017) had three successive ice-dammed stages, which formed as ice retreated down the Israel River valley towards Lancaster, New Hampshire (Thompson et al., 2017). The Bowman stage (into which the Older Dryas-age Randolph moraines, dated to ~14 cal ka BP, were deposited), was the oldest stage, which drained east across the divide at Bowman into the Moose River valley (Thompson et al., 2017, Figure 4). The Pine Knob stage then expanded west upon further ice retreat and ultimately drained into the Ammonoosuc valley; this stage was followed by the Baileys stage (Thompson et al., 2017). The Bailey's Stage was the third stage of Glacial Lake Israel, which formed as ice retreated yet further northwards and water spilled west across a low divide at Cherry Pond (in Jefferson, NH) into what would thenceforth be known as Glacial Lake Whitefield (Thompson et al., 2017). Glacial Lake Israel eventually merged with Glacial Lake Coos in the Connecticut River Valley as ice retreated north to Lancaster, NH (Thompson et al., 2017). This study modifies the history of Glacial Lake Israel to include two additional postglacial lake stages, named Alderbrook and Riverton.

There is much geological evidence to support the early stages of Glacial Lake Israel. End moraines in the headwaters of the Israel River valley provide evidence for a readvance in the Littleton-Bethlehem area, which has been correlated to Older Dryas cooling (Thompson, 2001, 2011). Moraines in the Israel River valley can be correlated with the Beech Hill and Bethlehem moraines; it is known that the ice margin which dammed the Bowman stage of Lake Israel also deposited these two moraine groups (Thompson, 1999). The Corrigan Pit is located next to the Israel River in Randolph, New Hampshire and exposes glaciolacustrine fan and delta deposits from the Bowman stage of Glacial Lake Israel (Thompson et al., 2002). The upper unit in the pit appears identical with the regional late Wisconsinan surface till, and some sand lenses show evidence of ice shove from the west. These deposits (especially the presence of till overlying lake sediments) are believed to record the eastward advance of a glacier margin into Glacial Lake Israel during the overall recession of the Laurentide Ice Sheet (Thompson et al., 2002; Thompson, 2000, 1999). Positions of moraines in this area indicate that they formed around the same time as the Bethlehem and Beech Hill moraines when the glacier margin ran up against the north side of Beech Hill and continued east around the north side of Cherry Mountain, damming the Bowman stage of Lake Israel (Thompson, 1999).

### *Glacial Lake Ammonoosuc*

Glacial Lake Ammonoosuc occupied the upper part of the Ammonoosuc river basin from Crawford Notch to Bethlehem, NH (Thompson et al., 2017). Most of the Bethlehem moraine complex was deposited in Lake Ammonoosuc, which had nine stages (defined by Thompson et al., 1999) and which formed as the Late Wisconsinan Laurentide Ice Sheet dammed the valley in the Littleton-Bethlehem area (Thompson et al., 2017; Allen et al., 2001). Figure 4 shows the spillways that drained Lake Ammonoosuc into the Gale River valley (after the Crawford stage) along with inferred positions of the Late Wisconsinan ice margin that correlate to this time period and have been determined from the orientation of moraines in the Bethlehem moraine complex as well as from extrapolation of the ice blockages needed in order to hold lake levels at elevations which correspond to existing deltas and spillways (Thompson et al., 2002). Lake Ammonoosuc ultimately disappeared when the ice margin receded from the Littleton-Bethlehem area (Allen et al., 2001). As ice receded northward from the Ammonoosuc valley, glacial lakes Carroll, Coos, and Whitefield formed.

### *Glacial Lakes Carroll, Coos and Whitefield*

Closely related to Glacial Lake Israel are glacial lakes Carroll, Coos, and Whitefield. These also developed as ice receded north from the Ammonoosuc valley (Thompson et al., 2017). Lake Carroll formed south of the Beech Hill moraines around the same time as Lake Israel, Lake Whitefield occupied the Johns river valley as the ice margin receded north and gradually drained and merged with Lake Coos (Thompson et al., 2017). Lake Coos was a drift-dammed lake north of glacial Lake Hitchcock that extended from Dalton, NH up the Connecticut Valley to North Stratford (Thompson et al., 2017; Thompson et al., 2011; Thompson et al., 2002). Lake Whitefield occupied the Johns River Valley and initially drained south into the Ammonoosuc River but, with further ice recession, merged with lake Coos (Thompson et al., 2017).

### *Glacial Lake Crescent*

Distinct from the Ammonoosuc River basin in the Upper Ammonoosuc River valley, the Berlin moraines suggest another glacial lake, Glacial Lake Crescent, that would have been dammed by the northeast-retreating ice lobe which deposited them (Thompson et al., 2017). Nine meltwater channels record a (probable) succession of lake spillways that opened as ice receded, and LiDAR imagery shows a delta complex built by incoming glacial meltwater at the head of the basin (Thompson et al., 2017).

## Climate in the Younger Dryas

Certain climatic conditions may have been favored over others for windows of habitation or migration, and rapid climatic changes marked by sudden changes in glacial recession/advance could have forced adaptation and movement (Ridge, 2002). The climatic instability of this glacial/deglacial climate is an important factor in considering human occupation of the region, and equally important is a consideration of related glacial landscape features such as lakes left in the wake of glacial ice (Ridge, 2002). The Younger Dryas cold reversal, which lasted from roughly 12,900-11,600 cal yr BP, immediately precedes the transition from the Pleistocene to the Holocene around 11,600 cal yr BP (Fiedel, 2011; Broecker, 2006). The period is bookended by two abrupt climate reversals; it began with a sharp cooling induced by the weakening of the Atlantic Meridional Overturning Circulation (AMOC), perhaps due to retreat of continental ice into Canada and shift of meltwater from the Mississippi drainage to the St. Lawrence (Broecker and Denton, 1989; Broecker, 2006) and ended with an equally sharp warming (Boisvert et al., 2017).

This climatic event is seen most clearly in Greenland ice core records, which indicate that it was cold and dry in the northern hemisphere- conditions approximating those at the LGM (Fiedel, 2011). The origins of the Younger Dryas climatic period remain a subject of debate, with workers suggesting that a flood of freshwater out of glacial Lake Agassiz (Broecker, 2006) could have disrupted ocean circulation, or an asteroid impact could have triggered the cold period due to alteration of the atmosphere (Fiedel, 2011). In North America, the drop in mean annual temperature during the Younger Dryas is estimated to be within the range of 2° to 6°C (Fiedel, 2011), with workers suggesting a lowering of average wintertime temperatures in the northeast United States by 5°C (Boisvert et al., 2017). It is reasonable to propose that during the Younger Dryas, Pleistocene caribou expanded into New Hampshire as the dramatic drop in mean annual temperature would have transformed New England into a climate more suited to their survival (Boisvert, 2013; Figure 5).

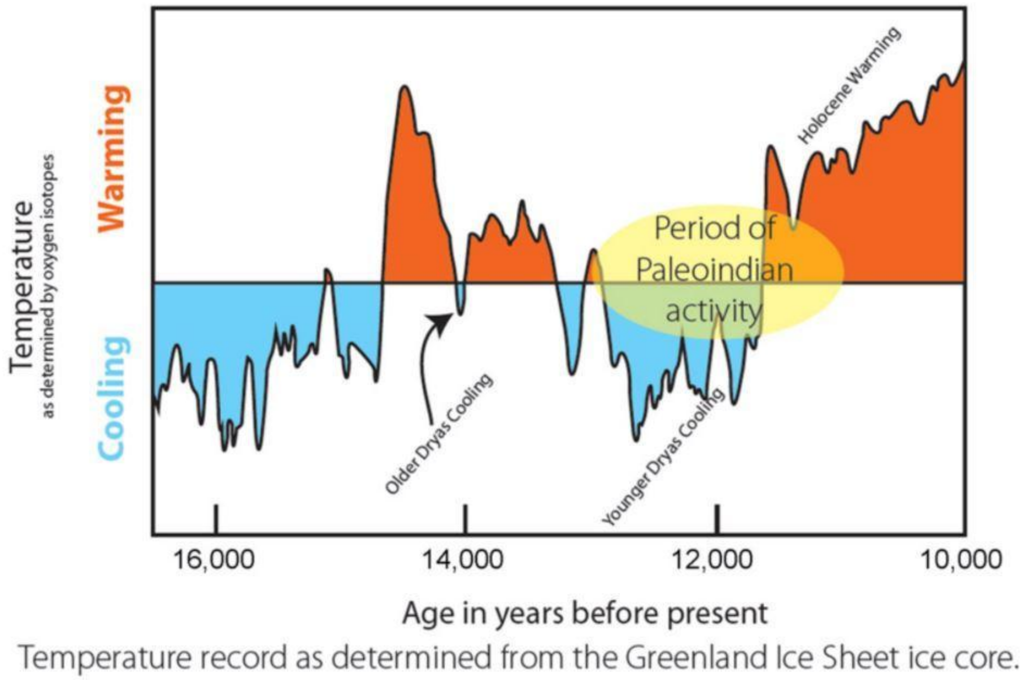



*Figure 5: Greenland ice sheet core temperature record showing time period of human activity in New Hampshire during the Younger Dryas (about 13 ka BP - 11 ka BP). Figure from Boisvert, 2013 (modified from Stuiver et al. 1995).*

## Archaeological Background

### Human Occupation of the White Mountains Region, New Hampshire

#### *Indigenous Knowledge*

Archaeology in New England has long focused on the idea that distribution of natural resources is the main factor controlling the location of human settlement, or more simply, that environmental factors are deterministic for settlement, subsistence, and technology (Bunker, 1994). While this method of interpretation works well in explaining observed archaeological site locations and correlates relatively well with ethnographic data for the New England region, people and their individual decisions are equally as responsible for past settlement patterns (Bunker, 1994). Therefore, an understanding of human history in New England and, more specifically, New Hampshire, should draw on both Indigenous knowledge and archaeological research (not that these are necessarily mutually exclusive).

Much of the classification of archaeological sites in New Hampshire throughout the prehistoric period is based on single artifact types, which while helpful in describing trends in tool manufacture, is unhelpful in that this classification scheme introduces a tendency to view past cultures in terms of the projectile points people made, a view which does not accommodate the rich diversity of past material and nonmaterial culture (Bunker, 1994). Often, archaeological periods come to represent people, despite the general consensus among academics that culture history periods are not meant to describe a people per se; “most archaeologists do not intend to alienate present-day indigenous people from their own understandings of the past in this manner…” (Julien et al., 2010).

Julien et al. (2010) argue that today, “First Nation people confront culture histories that disconnect present day people from the broader ideas of descent that lie at the heart of people’s understanding of who they are and what it means to be … Indigenous.” Important factors that fall outside of the realm of material culture include social or political boundaries, distance between occupied locations, and a consideration of resource conservation techniques; this means that often the full agency of populations is not visible in the archaeological record, which is important to keep in mind (Bunker, 1994). Incorporating both archaeological and ethnographic techniques in the investigation of lifeways during this time period can lead to consideration of conservation, tradition, adaptive/technological stability, resource availability, interaction, and chance. Perhaps the most important component of these studies, however, should be the history of those whose ancestors occupied the land.

In his book “A Time Before New Hampshire,” Michael J. Caduto, an “ecologist and student of Native peoples,” tells the story of the history of what is now New Hampshire from the perspective of those who lived it, tens of thousands of years ago. While his writing is informed by Abenaki traditional knowledge, archaeology, and anthropology, his presentation of stories ultimately reflects his own perspective and therefore must be considered as an interpretation, not as a direct portrayal of Indigenous knowledge. Relevant portions of his work are quoted here to illustrate the importance of synthesizing these different knowledge systems to create more comprehensive interpretations. His story begins in Jefferson, NH, 11,000 years ago: “High on a terrace above a mountain river, several families sit on the sandy ground hunched over their work. The staccato of stone against stone punctuates the steady rush of the roiling waters below. … An owl calls from the opposite bank [of the river] and another responds from a stunted spruce tree that protrudes from a swale amid the dusty expanse of grass, sedge, and juniper” (Caduto, 2003).

Caduto writes that these people “came to be near the large, streaming herds of caribou and to have access to sources of good stone that lay to the east and west.”

Beginning in the late Pleistocene, Caduto chronicles environmental change in the Israel River Valley and the arrival of the first groups of humans. He begins: “A long, ribbon-like copse of quaking aspens, balsam poplars, and white birches lines a sinuous, silty river that drains into a lake rich with shrubs and young trees along its shore where a stag-moose is feeding, belly-deep in a thick bed of aquatic plants.” In his account of late Pleistocene-early Holocene time, Caduto describes that “the ancient peoples of New Hampshire” encountered many diverse species (such as moose, white-tailed deer, beaver, elk, ducks and geese, squirrels and other small mammals, and trout) in addition to caribou, which were hunted occasionally, “to help their omnivorous communities survive” (Caduto, 2003). Caduto asks, “who were these ancient peoples whose lives and the world in which they lived still occupy a primal niche in our own ancient memories…?” While the earliest date of human presence in the Americas continues to be pushed further back within the scientific community, Caduto writes that “it is not likely, however, to bridge the gap between anthropological tenets and indigenous beliefs that these ancient peoples had their origins here, in this land.” It is important to note that this conception is challenged by Indigenous knowledge, and that archaeology has the capacity to be an important tool in establishing this continuity in the Northeast and elsewhere in the U.S.

### *Archaeology*

Thus far, archaeology has shown that the earliest human occupation of the Northeastern U.S. (and, more specifically, the White Mountains region) began around 11,000 $^{14}$C yr BP. This period is known within archaeology as the Paleoindian Period (Boisvert, 1999; 2013; Thompson et al., 2017). There are many challenges associated with the term “Paleoindian.” In their essay titled “Paleo is Not Our Word: Protecting and Growing a Mi’kmaw Place,” Donald M. Julien, Tim Bernard, and Leah Morine Rosenmeier, with review by the Mi’kmawey Debert Elders’ Advisory Council, write that “the vocabulary of Paleo Indians, Paleo Americans, and now even “Early Americans” grows out of assumptions of populations bounded by time,” contradicting Mi’kmaw beliefs that they come from the Mi’kmaw homeland in Nova Scotia in a way that non First Nation groups do not (Julien et al., 2010). They argue that this is “not to say that there is no change through time, but instead that the crux of being Indigenous is descending from human occupations in North America since the last glaciation, and potentially prior to the last glaciation" (Julien et al., 2010). In this way, terminology such as "Paleoindian" serves to disconnect populations through time and also through space, breaking the connections between people and homelands/ancestral places (Julien et al., 2010). It is important to acknowledge these critiques of the terminology, yet for the purposes of describing archaeological research around deglaciation of the northeastern U.S. the term will be used strictly to refer to the time periods described below.

The Paleoindian period is currently constrained by dates from the Whipple site in Southwestern NH, the Vail site in Western Maine, and the Debert site in Nova Scotia (Boisvert, 2013). The Paleoindian Period contains three subdivisions: Early (12,900-12,400 cal yr BP), Middle (12,400-11,600 cal yr BP), and Late (11,600-10,800 cal yr BP) which are defined slightly differently by various authors; these variations are summarized in Table 1 (Boisvert et al., 2017; Boisvert, 2013). (The Early and Middle sub-periods fall within the Younger Dryas chronozone.) This human occupation is evidenced within archaeology by a suite of stylistically and technologically distinctive stone artifacts (notably, a type of spear point called fluted points) that can be correlated with other assemblages across North America (Boisvert, 1999; 2013).

*Table 1: Age range interpretations of the early, middle, and late Paleoindian periods. Projectile point style associations for each period are described in Bradley et al., 2008.*

<table>
<tr><th>cal yr BP</th><th>Lothrop et al. 2016</th><th>Boisvert et al. 2017</th><th>Bradley et al. 2008</th><th>Projectile Point Styles in the NEM</th></tr>
<tr><td>10,000</td><td rowspan="3">late Paleoindian</td><td></td><td></td><td rowspan="3">Agate Basin-Related<br>Ste. Anne-Varney</td></tr>
<tr><td>10,800</td><td rowspan="2">late Paleoindian</td><td rowspan="2">late Paleoindian</td></tr>
<tr><td>11,600</td></tr>
<tr><td></td><td>middle Paleoindian</td><td>middle Paleoindian</td><td>middle Paleoindian</td><td>Michaud-Neponset<br>Crowfield-Related<br>Cormier-Nicholas</td></tr>
<tr><td>12,400</td><td rowspan="3">early Paleoindian</td><td rowspan="2">early Paleoindian</td><td rowspan="2">early Paleoindian</td><td rowspan="4">Kings Road-Whipple<br>Vail-Debert<br>Bull Brook-West Athens Hill</td></tr>
<tr><td>12,900</td></tr>
<tr><td>13,000</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>>13,400</td><td>pre-Clovis</td></tr>
</table>

The persistence and extent of human occupation in the White Mountains region is a testament to highly successful modes of adaptation in what was then a harsh and variable climate; human occupation in the region was most likely not possible until the last glacial ice was absent and flora and fauna had adequately colonized the landscape (Boisvert, 1999). As discussed above, radiocarbon dates from both terrestrial and marine sources have shown that New Hampshire was deglaciated between 14,000 and 13,000 $^{14}C$ yr BP; recession of the Laurentide Ice Sheet then continued into southeastern Quebec and was followed by marine transgression into the St. Lawrence Lowland shortly after 12,000 cal yr BP (Allen et al., 2001).

Systematic archaeological survey of New Hampshire does not currently exist; most of the known archaeological sites have been found through CRM surveys in advance of development (Boisvert, 2012). The sites that have been found are primarily dominated by lithics, with few faunal or floral archaeological materials (Boisvert, 2012). As of 2012, 16 sites had been partially excavated and 8 isolated groups of artifacts dating from this period had been documented (Boisvert, 2012). Figure 6 shows archaeological sites and isolated finds in New Hampshire. Although the body of knowledge on the human history of New Hampshire during this time period is small, it is important to strive for an understanding of sites in the broader context of change over time and of intergroup relationships; only then can the history of human occupation in the region be fully understood (Boisvert, 2012).

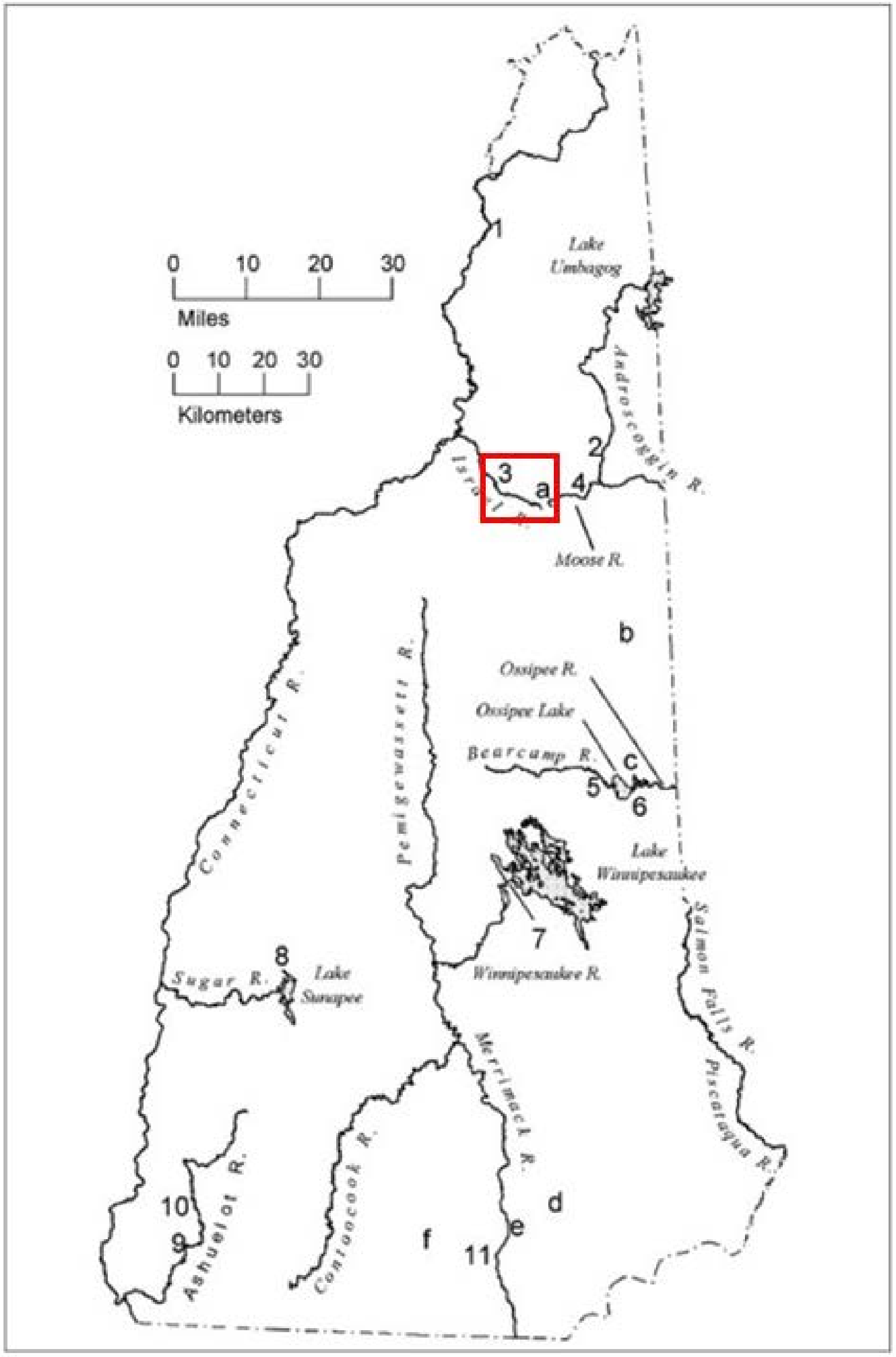



*Figure 6: Map of Paleoindian sites and isolated finds in New Hampshire. Study area, outlined in red, includes the Israel River Complex sites. Sites: 1: Colebrook Site, 2: Mount Jasper lithic source (Berlin), 3: Israel River Complex, 4: Potter Site (Randolph), 5: Stone's Throw Site (Tamworth), 6: Thorne Site (Effingham), 7: Weirs Beach Site (Laconia), 8: George's Mills (Sunapee), 9: Whipple Site (Swanzey), 10: Tenant Swamp Site (Keene), 11: Thornton's Ferry and Hume Sites (Merrimack). Isolated finds: a: Lowe biface (Randolph), b: Intervale point (Conway) c: Ossipee Lake point (Freedom), d: Massabesic Lake point (Auburn), e: Smyth, Neville, and Manchester points (Manchester), f: New Boston point (New Boston). Figure from Boisvert, 2012.*

## History of Archaeological Research in New Hampshire

In his publication titled "The Paleoindian Period in New Hampshire," (2012) a chapter of the summary book "Late Pleistocene Archaeology and Ecology in the Far Northeast," Richard Boisvert gives a history of archaeological research in New Hampshire, summarized here. The discovery of the Israel River Complex sites (see Figure 6, 7, 8) in 1995 marked the beginning of a rapid increase in the amount of excavations, culminating in 15 by 2003. Before then, the only well-documented site was the Whipple Site, which was identified in the mid-1970s and in some ways launched the trajectory of future archaeological research in the state; the Thorne, Thornton's Ferry, Hume, and George's Mills Sites, as well as a handful of isolated finds, were also known. Early research focused on the resolution of the internal chronology of the period based off of variations in projectile point characteristics and lithic sources.

In the fall of 1995, the discovery of a fluted point at the Israel River Complex sites in Jefferson began a series of investigations by the New Hampshire Division of Historical Resources through SCRAP, the State Conservation and Rescue Archaeology Program. This program first identified the Jefferson I, II, (which was eventually purchased for preservation by the Archaeological Conservancy) and III sites. Later, the Jefferson IV, V and VI sites were discovered and field investigations are still ongoing. Most recently, the discovery of another Israel River Complex site, Jefferson VII, has prompted investigation.

The geographic and temporal range of the sites (16 known, plus the Jefferson IV site, see Figures 7 and 8) is broad, yet a few trends can be seen in site character. These have been identified by Boisvert as "quarry-lithic extraction sites, lithic workshops, small-scale hunter-forager transient camps, and aggregated base camps" (2012, pg. 81). Determination of site "function" has been primarily based off of lithic data, which introduces bias and presents problems in terms of site preservation and limited field sampling (Boisvert, 2012).

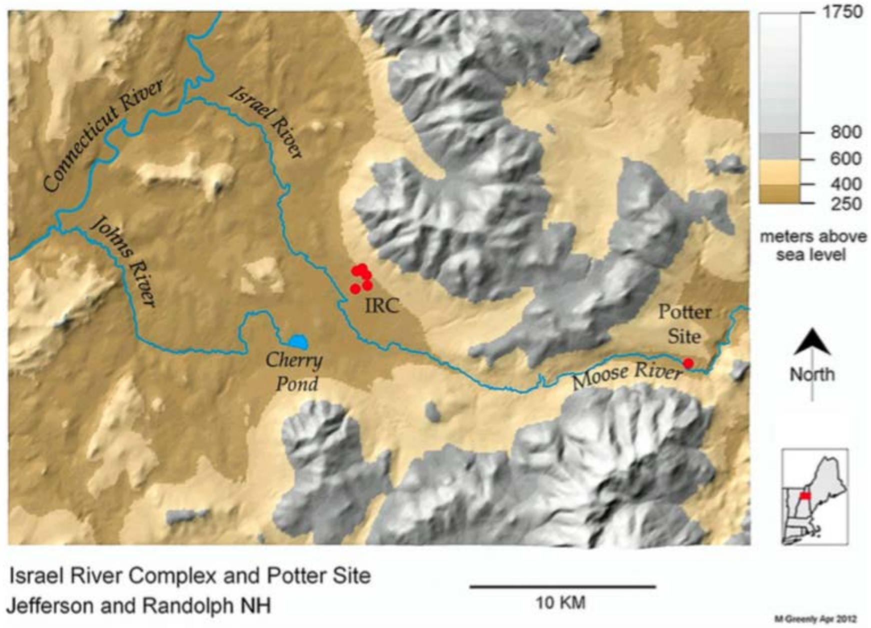



*Figure 7: LiDAR image showing location of Israel River Complex sites (near Jefferson, NH) in relation to the Potter Site in Randolph, NH. Small inset shows location within the state of New Hampshire, and coloring indicates meters above sea level. Figure from Boisvert et al., 2017.*

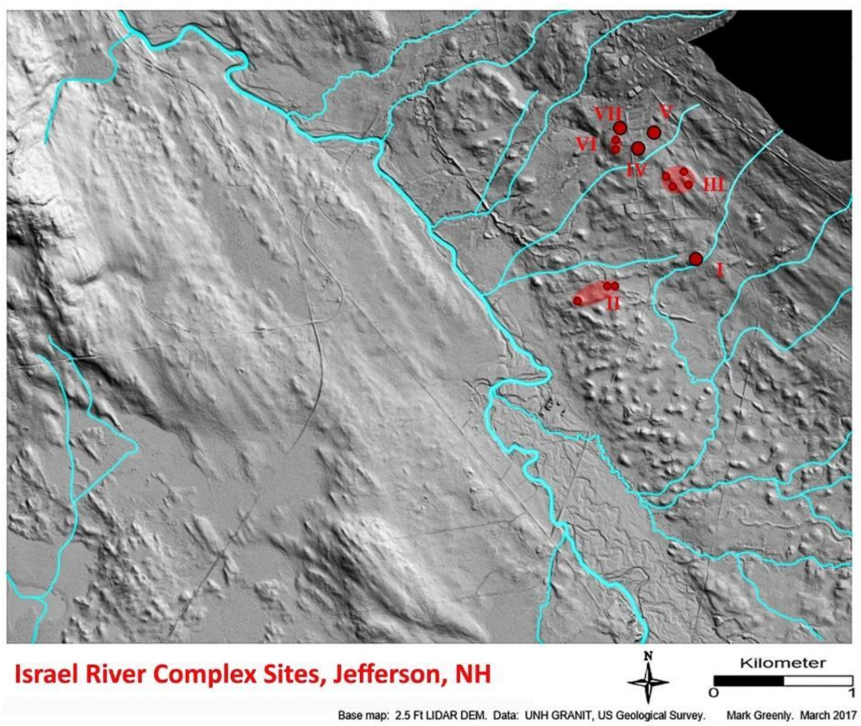



*Figure 8: LiDAR image showing specific locations of the Israel River Complex sites (Boisvert, pers comm.).*

## Study Area

The area of focus sits on the border of four USGS 7.5 minute topographic quadrangles, the Lancaster E, Jefferson, Bethlehem E and Mt Dartmouth quads (Figure 9). Surficial geologic maps of the Jefferson and Mt Dartmouth quadrangles show that the study area is characterized by stream alluvium and related features associated with the Israel River, overlying till (see Appendix B). In regards to bedrock geology, the study area falls within the Bronson Hill Anticlinorium, a feature extending through New Hampshire and Connecticut, and was produced through the collision of the Bronson Hill Volcanic arcs with Laurentia during the third stage of the Taconic Orogeny (Baker, 2016; Cargill, 2016). The Jefferson dome (Oliverian in age) then intruded along the axis of the anticlinorium (Baker, 2016; Cargill, 2016).

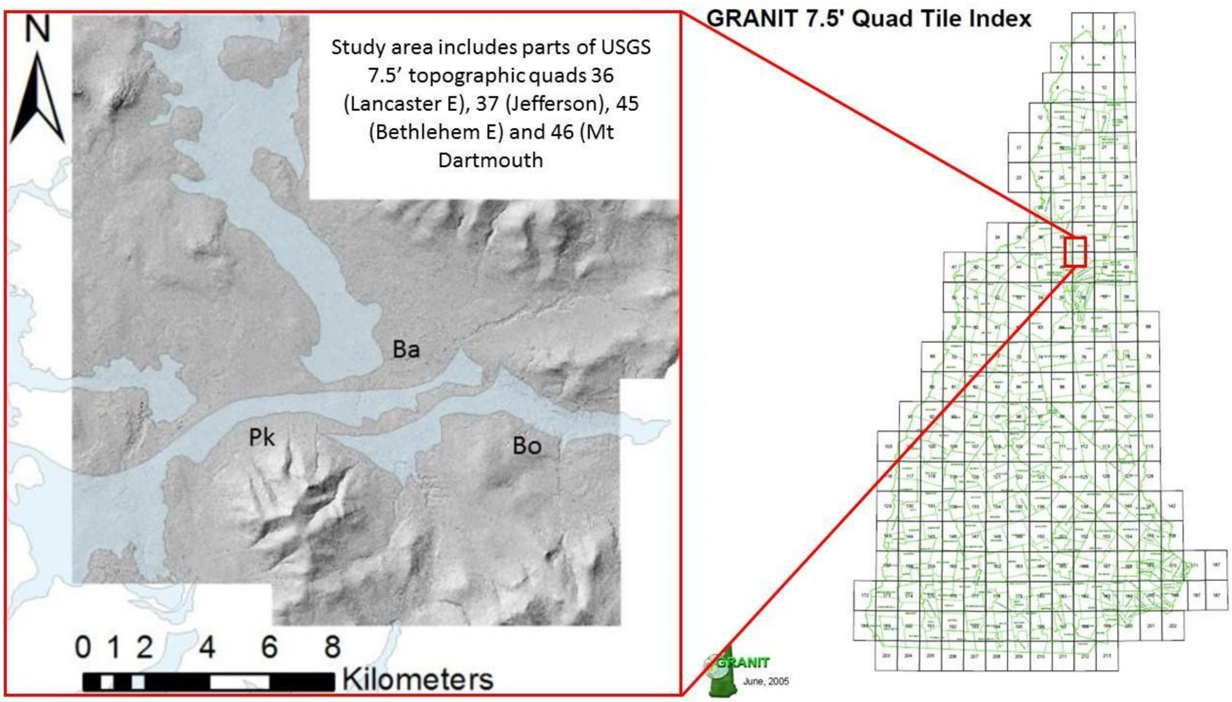



*Figure 9: LiDAR image of study area shown in relation to the GRANIT 7.5' quad index of New Hampshire. Study area falls within quads 36, 37, 45 and 46, which are the Lancaster E, Jefferson, Bethlehem E and Mt Dartmouth quads, respectively.*

### The Israel River Complex Sites

The Israel River Complex (IRC), one of the larger groups of sites that has been excavated in the White Mountains, significantly adds to the body of data on the early human presence in the region (Boisvert, 1999) and provides a unique opportunity to study the relationship of human settlement to the changing climatic and environmental conditions immediately following (or concurrent to) deglaciation. Figures 7 and 8 show the group of individual IRC sites (Boisvert et al., 2017) situated on the north flank of the lower Israel River, which serves as a corridor between the Connecticut and Androscoggin Rivers. Figure 10 shows the same group of sites overlain on a LiDAR image of the study area, in relation to the Bailey's stage of Glacial Lake Israel (Thompson et al., 2017).

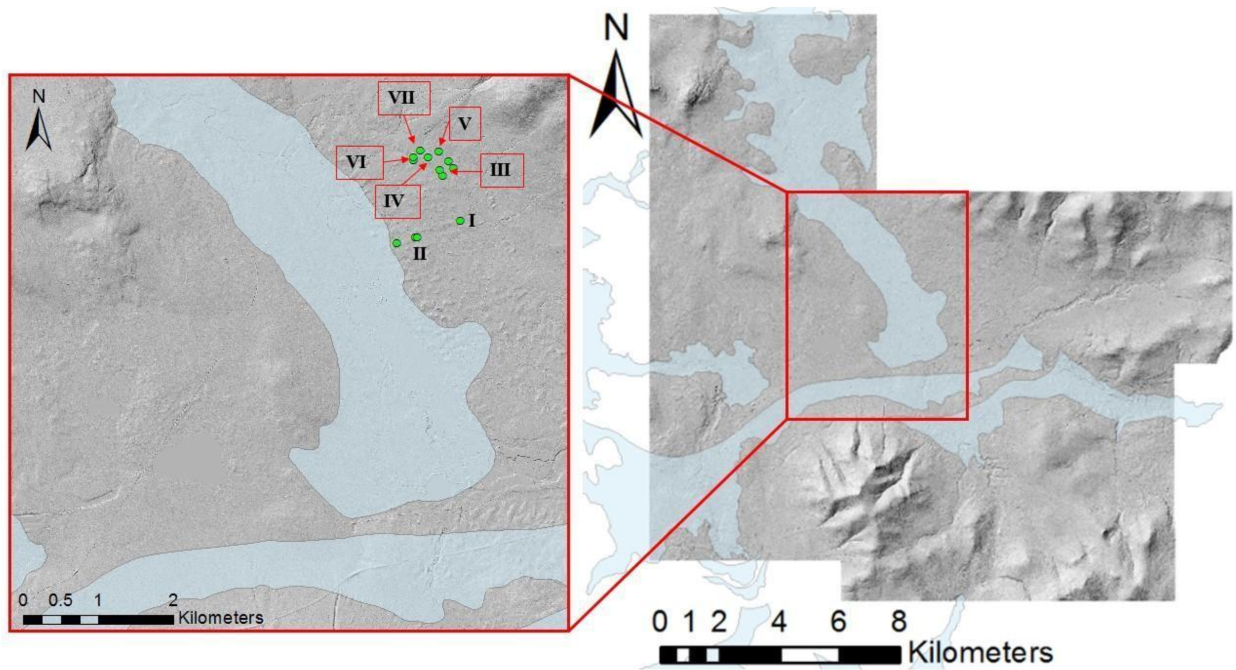



*Figure 10: LiDAR image of study area showing location of IRC sites (numbered 1-7) in relation to the Bailey's stage of Glacial Lake Israel as mapped by Thompson et al., 2017. IRC sites are shown as green circles, lake level shown as a blue polygon.*

The ages of the IRC sites are determined on the basis of diagnostic artifacts such as fluted projectile points, channel flakes, and spurred end scrapers, as well as on the relative abundance of Munsungun chert, a lithic material recognized to be highly associated with sites of the same age (Boisvert et al., 2017). At the Jefferson II site, radiocarbon dates of 8,590 ± 60 C yr BP (9,580 cal BP) and 8,090 ± 90 C yr BP (8,900 cal BP) were obtained, and being uncharacteristically young, interpreted as mixing of young charcoal into older deposits by natural disturbance (Boisvert, 2012). Similarly, a date of 7,930 C yr BP (8800 cal BP) obtained from the Jefferson III site was interpreted as being too young (Boisvert, 2012). Just over a third of the excavated sites in New Hampshire have been radiocarbon dated, and out of these only two or three can be considered confidently dated (Boisvert, 2012). The radiocarbon date of 11,140 cal BP obtained as a part of this study adds to this body of knowledge, providing further evidence for site occupation during the Younger Dryas.

More than half of the IRC sites reflect both Early and Middle Paleoindian period occupation (Boisvert et al., 2017; Boisvert, 2012). Vail/Debert points (see points B, C, and D in Figure 11) found at the Jefferson II and III sites are considered to be Early Paleoindian (see Table 1) by association with sites where many early dates have been reported (Boisvert, 2012). Additionally, a Bull Brook-West Athens Hill point from the Jefferson IV site (E in Figure 11) can be dated to the Early Paleoindian period (Table 1). Michaud-Neponset points and point bases recovered from the Jefferson I, II, and III sites (G, I, and J in Figure 11) indicate occupation in the Middle Paleoindian period (Table 1). It is clear that the IRC area was repeatedly occupied over a long time period, and this raises the question of the factors that could have drawn people to the same locality as well as the consistency of those factors through time (Boisvert et al., 2017). There is evidence to indicate that caribou hunting played a role in subsistence during this time period (Boisvert et al., 2017; Boisvert, 2013).

At the end of the Younger Dryas, the fluted point tradition (Figure 11) appears to have ceased; succeeding styles show a diminution of fluting and were smaller (Boisvert, 2013). The lack of Late Paleoindian period sites in northern New Hampshire makes it tempting to conclude that peoples left the White Mountains region to follow caribou herds northward, or changed subsistence focus to other sources, although there is no evidence to support this hypothesis (Boisvert, 2013). The only conclusion that can be drawn is that there is a change in artifact type visible in the archaeological record. As time progressed, use of the Mt. Jasper rhyolite became confined to a smaller area around the lithic source, and use of the Jefferson rhyolite seems to have stopped completely (Boisvert, 2013).

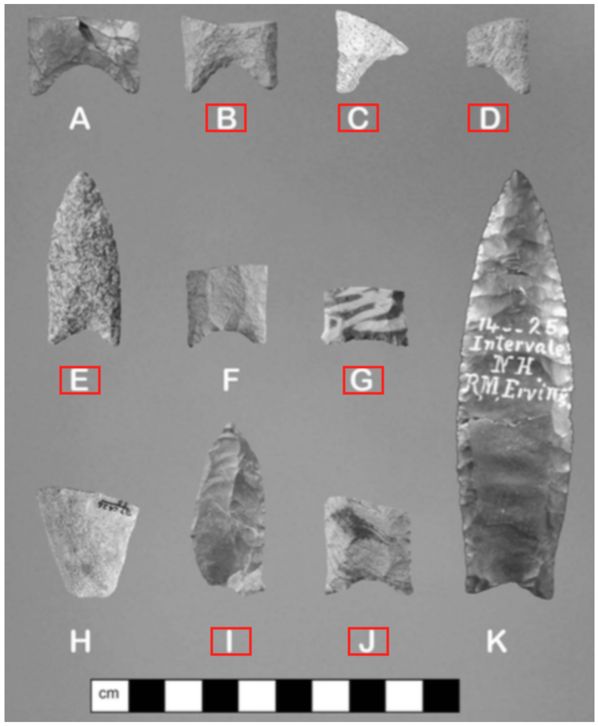



*Figure 11: Points from sites in New Hampshire used in relative dating; points found at IRC sites highlighted in red. A: Kings Road/Whipple point base, (Whipple site) B: Vail/Debert point base, (Jefferson III site) C: Vail/Debert point base, (Jefferson II site) D: Vail / Debert point base, (Jefferson II site) E: Bull Brook / West Athens Hill point, (Jefferson IV site) F: Bull Brook/West Athens Hill point base, (Potter site) G: Michaud / Neponset point base, (Jefferson II site) H: Agate Basin–related point base, (Thorne site) I: Michaud / Neponset point base, (Jefferson III site) J: Michaud / Neponset point base, (Jefferson I site) K: Michaud / Neponset point, (Intervale site). Figure from Boisvert, 2012.*

Site investigations have shown a set of functionally distinct sites and subareas, along with what appears to be a pattern of occupation (Boisvert et al., 2017). Intensely used spaces approximately 40-50 square meters large have a wide variety of implements made from diverse rock types, in contrast to smaller subareas (also termed “loci”) with more narrow ranges of tool forms; this pattern suggests household areas flanked by tool manufacturing areas, fluted point finishing areas, and/or meat and hide processing areas (Boisvert et al., 2017; Boisvert, 1999, 2012).

## Lithic Assemblages at the Israel River Complex Sites

Characteristic of the IRC sites are artifacts and flakes of flow-banded rhyolite (Figure 12) emplaced as dikes associated with the White Mountain Plutonic series; this type of stone has been found throughout the northeast, indicating that it was transported great distances from the source location in New Hampshire (Figures 13 and 14). Often exhibiting spheroidal textures, artifacts made of this New Hampshire rhyolite have also been found in southeastern Quebec (Pollock et al., 2008). The rhyolite is vitreous and flint-like, and was used to make projectile points knives, scrapers, and other chipped stone implements (Boisvert and Pollock, 2009; Boisvert et al., 2017). Figure 12 shows images of the Mt Jasper and Jefferson rhyolites, which have the characteristics described above and are named for their source locations.

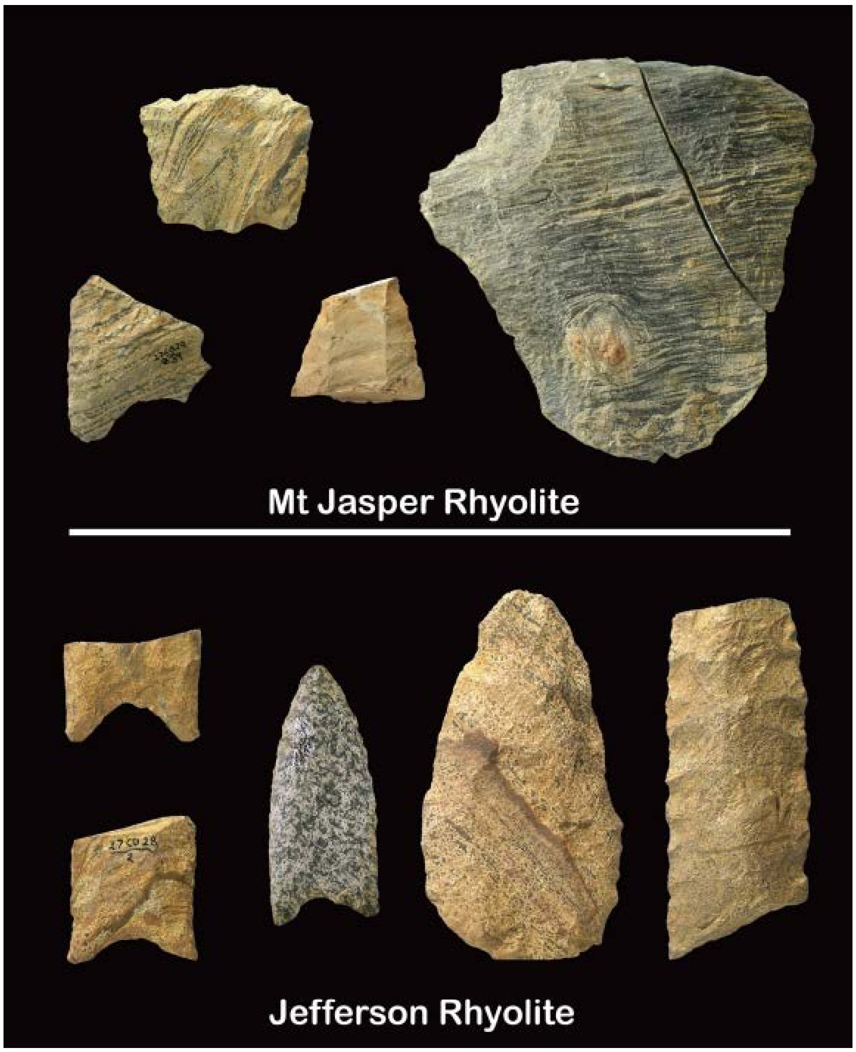



*Figure 12: Images of the Mt Jasper and Jefferson rhyolites (Boisvert and Pollock, 2009).*

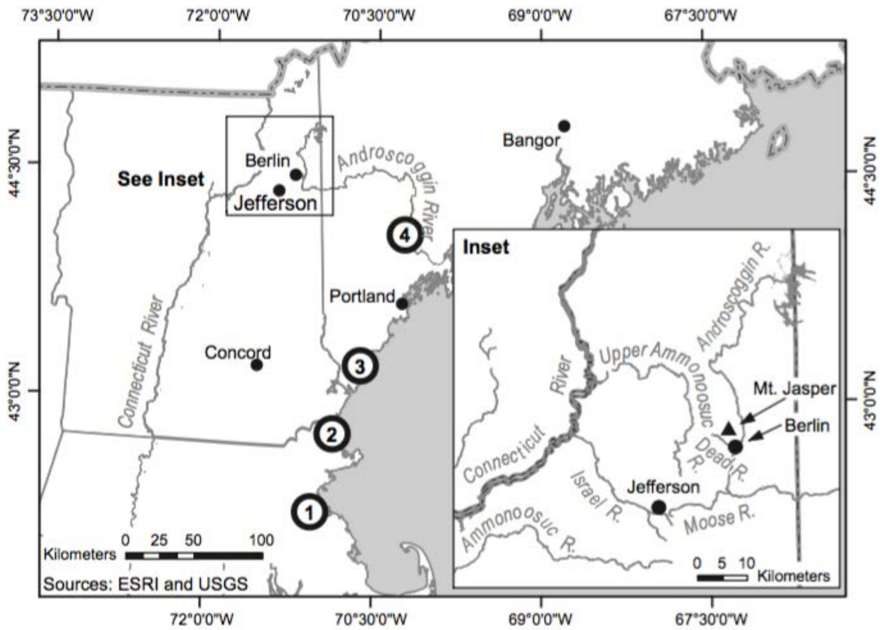



*Figure 13: Locations where New Hampshire spherulitic flow-banded rhyolites have been found at archaeological sites in Massachusetts, New Hampshire, and Maine. Inset shows the Mt Jasper dike near Berlin, NH (from Pollock et al., 2008).*

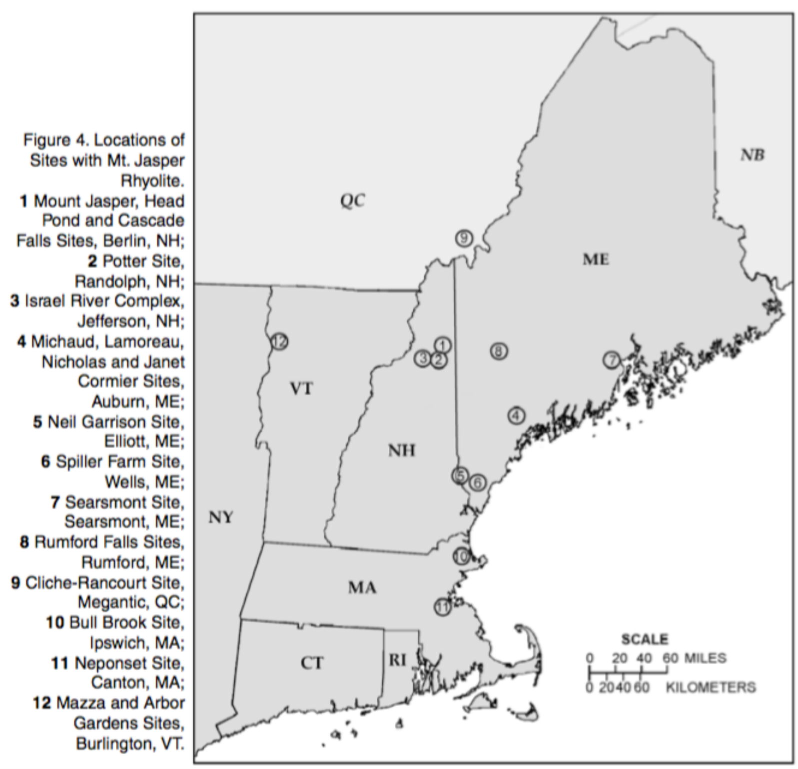



*Figure 14: Locations of sites at which Mt Jasper rhyolite has been found across the northeast; fragments of the rhyolite were carried at least 250 km (from Boisvert and Pollock, 2009).*

There are three major known occurrences of rhyolite suitable for use as stone tool material: the Mt Jasper lithic source, (a dike near Berlin, NH) blocks of the Jefferson rhyolite incorporated within glacial deposits near Jefferson, NH, and dikes recently discovered by Baker and colleagues in 2016, (a hand sample of which can be seen in Figure 15) which appear to be related to the source for the blocks of Jefferson rhyolite mentioned above (Pollock et al., 2008; Baker, 2016; Boisvert et al., 2017).

Additionally, another rhyolite dike was found (Niiler, 2018) near Randolph, New Hampshire, during the summer of 2017. Jefferson rhyolite has also been found near the IRC, at the Potter site in Randolph, NH (Figure 7; Boisvert et al., 2017). Much work has been done to articulate the macroscopic criteria for differentiating between the Mt Jasper and Jefferson rhyolites; a summary of their differentiating characteristics can be found in Boisvert and Pollock, 2009. Evidence for this limited range of artifact/lithic fragment sources comes from comparison of dike samples to artifacts on the basis of thickness and continuity of flow bands, and spherule characteristics (Pollock et al., 2008). The distribution of this characteristic rhyolite (much like the Munsungun chert) allows conclusions to be drawn about the cultural patterns of people who used it (Pollock et al., 2008).


*Figure 15: Image of Jefferson Rhyolite found near Pliny Mountain by Baker (2016), showing flow banding. Image from Jefferson Quadrangle Bedrock Geology map, 2017.*

The two main sources (the Mt Jasper lithic source and the outcrop of the Jefferson rhyolite described by Baker, 2016) can be characterized as rhyolite dikes associated with the White Mountain Plutonic series, a group of Jurassic granitic intrusives (Pollock et al., 2008). These are located along prominent east-west routes between the east-flowing Androscoggin

River and the south-flowing Connecticut River; travel between the two rivers would have taken a route directly beneath Mt Jasper (Pollock et al., 2008; Boisvert et al., 2017).

The Mt Jasper rhyolite dike intruded into Ammonoosuc Volcanics as the youngest dike out of the four types of dikes present at Mt Jasper (Pollock et al., 2008). Out of the 8 rhyolite dikes found on Mt Jasper, the Mt Jasper lithic source dike is the only one to show evidence of alteration by humans (Pollock et al., 2008; Boisvert et al., 2017). It is thought that the use of this dike as a lithic source continued for at least 11,500 years (Boisvert and Pollock, 2009; Boisvert et al., 2017).

The rhyolite dikes found by Baker (2016) in Jefferson are likely related to the Conway granite that outcrops in the Jefferson 7.5' quadrangle (Boisvert et al., 2017). It is possible that the Conway granite acted as a feeder magma for the rhyolite, (both were emplaced during the Jurassic) an idea which is supported by the intrusive character of the rhyolite as observed in the field (Baker, 2016; Cargill, 2016). The Jefferson rhyolite, emplaced during cone-sheeting associated with caldera collapse, may represent a final surge in magmatism before volcanic activity ceased in the Pliny Range Caldera Complex (Boisvert et al., 2017; Cargill, 2016).

## Landscape and Early Human Occupation of the Israel River Valley

### Caribou, Glacial Lake Israel, and Human Occupation

Three sediment cores obtained from Cherry Pond in 1999 show varves deposited into Glacial Lake Israel, the earliest of which possibly provide a limiting date for the beginning of human occupation (Thompson et al., 2017). The cores also show the onset of the Younger Dryas chronozone around 10,700 cal yr BP as a transition from gyttja to barren gray muds, and it is during this abrupt climate event that humans moved into the area (Thompson et al., 2017). Caribou require cold climates, and it is suggested that the shift in mean temperature during the Younger Dryas allowed movement of herds in to the northeast US; subsequently, the abrupt end to the Younger Dryas extirpated those herds as climate warmed (Boisvert et al., 2017; Boisvert, 2013). Direct evidence for caribou is scant; however, caribou bone has been identified at the Whipple and Tenant Swamp sites in southwestern New Hampshire and the Michaud site in western Maine, while cervid protein (most likely caribou) was found on a flake at the Jefferson IV site in the IRC (Boisvert, 2013).

Environmental change in the Israel River valley undoubtedly had an impact on human lifeways there, as did independent trajectories of cultural change and agency. There is evidence to suggest that caribou hunting played an important role in human occupation of the region, along with use of numerous other plant and animal populations living in the fertile valleys surrounding glacial and postglacial lakes. Situated on the northeast flank of the Israel River valley with vantage over the valley floor, the Israel River Complex sites would have been in a prime location for observing herds migrating through the Connecticut and Androscoggin drainages (Boisvert et al., 2017; Boisvert, 2013). Migrating herds may have funneled up the Israel River valley, across the drainage divide at Bowman (near Randolph, New Hampshire) and down the Moose River to the Androscoggin River valley (Boisvert, 2013). The positions of the Jefferson I, IV, and VI sites (Figure 10), all situated on south/southwest facing knolls, would have provided an exceptional view of this migration area (Boisvert, 2013). These sites have been interpreted as having short-term/seasonal occupations, in contrast to the Potter site in Randolph which has been interpreted as more of a multi-component site (Boisvert, 2013).

As a prey species for humans, caribou present both advantages and disadvantages. They migrate in large numbers, migration routes are not easily predictable, and they usually travel too fast to be directly followed (Boisvert et al., 2017). However, they are comparatively easy to kill once found, and they do tend to travel along the edges of water bodies or along a single elevation contour (Boisvert et al., 2017). Ethnohistoric accounts of caribou hunters from Alaska and Arctic Canada contain evidence of caribou being funneled into bodies of water and then killed; (Boisvert et al., 2017) it may be true that similar tactics were used in New Hampshire with remnant postglacial stages of Glacial Lake Israel.

Viewsheds of the Israel River valley from IRC sites, conducted by Boisvert et al. (2017) capture large amounts of land along the contemporary river channel; the study posits five locations in the IRC cluster as vantage points, which are contrasted against household areas and special function areas. (One of these viewsheds was replicated as part of this study—see Figure 73.) These viewsheds (in addition to tools found at the sites) support the interpretation of the IRC sites as positioned purposefully to obtain views of what would have been prime caribou migration areas: i.e., what is now the valley floor containing the Israel River (Boisvert et al., 2017). Based on this information, Boisvert et al. argue that “caribou hunting… served as the principal reason for the existence and arrangement of the places that were occupied and used”

(Boisvert et al., 2017, pg. 7). However, the existence of the postglacial Alderbrook and Riverton stages undoubtedly provided access to numerous other resources that were just as important to the occupants of the Israel River Complex.

## Study Purpose

Previous research on both the glaciological and archaeological history of the Israel River Valley is extensive. Interdisciplinary research abounds, with much collaboration between geologists (of all kinds) and archaeologists, producing evaluations of the history of this dynamic region approached from nearly all angles. However, more remains to be done. This study focuses on the importance of environmental change in evaluating past human lifeways through the revision of mapped shorelines of the three known stages of Glacial Lake Israel (the Bowman, Pine Knob, and Bailey's stages) and new mapping of the two proposed postglacial stages (Alderbrook and Riverton). Landscape type mapping and shoreline elevation modeling, in addition to a radiocarbon date from a fragment of Alnisedi (eastern hemlock) at the boundary of Bailey's and Alderbrook Stage lake sediments, confirms the coexistence of the postglacial Alderbrook Stage with the occupation of the IRC sites and investigates the relationship of the changing postglacial environment to the region's earliest occupants. Research is guided by these questions:

-Can the existing maps of the shorelines of Glacial Lake Israel be further improved?
-Can the two proposed postglacial stages be mapped and confirmed by evidence found in the field?
-How (and why) do the IRC sites relate to the boundaries of the different stages of the paleo-lake?
-Can this new data help determine the relationship between the earliest human occupants of the Israel River Valley and the extremely variable environment they inhabited?
-How do existing archaeological interpretations relate to Indigenous histories and knowledge of the region?

In continuing the investigation of environmental change in the Israel River Valley, this study will contribute to an understanding of the relationships of humans to the land, and to an understanding of the importance of glacial and postglacial lakes in shaping the environment and lifeways of the earliest human occupants of New Hampshire.

## Methods

This section will commence with a discussion of the methodological framework used in approaching the interaction of Indigenous knowledge and archaeological data. Following is a discussion of the methods used to collect data during fieldwork, which included digging test pits, collecting samples for radiocarbon dating, and visiting an active excavation at the Jefferson VI site. Presented next is a discussion of lab methods used in radiocarbon dating. The section ends with a summary of the process of LiDAR acquisition and the modeling techniques used in the creation of shorelines and landscape polygons, viewsheds, and elevation profiles.

### Methodological Framework

Archaeology is informed by theory, which provides a lens through which to approach understandings of cultures and lifeways. Theoretical positions, even if presented as objective, ultimately reflect the prerogatives of the archaeologist (Bentley and Maschner, 2007) and promote/reify one mode through which to understand the world. It is important to consider the impact that theory has on the findings of archaeological research, how those findings are presented, and who they affect. Some theory focuses on methods of western science and uses these modes, presented as objective, to understand past people. Theory as such often overlooks the importance of Indigenous knowledge, which is the basis for Indigenous archaeology theory. It is important, therefore, to not overlook the relevance and importance of Indigenous knowledge regardless of the archaeological theory being used.

While this study does not make use of a fully Indigenous framework in its analysis, it does attempt to incorporate Indigenous knowledge, so a brief discussion of Indigenous archaeology is justified. In his essay titled “Indigenous Archaeologies: A Worldwide Perspective on Human Materialities and Human Rights,” H. Martin Wobst writes that Indigenous archaeologies “probe the material record, past and/or present, to understand the materiality of particular places, … and to learn what that materiality may add to our knowledge of human materiality in general” (Wobst, 2010). Wobst argues that Indigenous archaeology makes it easier for others to understand a given place and time, highlighting the deep importance of place in Indigenous archaeology theory (Wobst, 2010).

This study strives, where possible, to integrate Indigenous knowledge in to an interpretation of the archaeological understanding of New Hampshire and the Israel River valley around the late Pleistocene/early Holocene, although does not claim to use an exclusively

Indigenous archaeological framework. The positionality of the researcher and an awareness of their habitus, which Maggie Walter and Chris Andersen describe as directing action "largely unconsciously through beliefs that, while internalized, are nonetheless derived from external social forces," is important in considering what knowledge is being reproduced through research (2013). Additionally, an attempt was made to avoid the positioning of Indigenous methodology and knowledge as in opposition to western frameworks (Walter and Andersen, 2013) and instead to draw attention to the history of interaction between the two ways of knowing. In this context, some modes of the Indigenous Research Paradigm were integrated into analysis of the archaeological and paleoenvironmental records; these include community/Indigenous epistemology and ontology, (accepting other ways of knowing) ethics and respect, and community collaboration and permission (Lambert, 2018). These modes of the Indigenous research paradigm were adapted to the study with the goal of acknowledging Indigenous knowledge as another legitimate way of knowing about the world, alongside the archaeological, geological, and paleoenvironmental understandings of the region, and to show that these frameworks are not incompatible.

To begin a consideration of Indigenous epistemology and ontology, oral histories are presented as evidence for cultural continuity of Indigenous peoples in the northeastern U.S. since the last glaciation; these histories and other resources discussing cultural continuity and Indigenous knowledge are of primarily Indigenous authorship, where possible. All species names used in discussion of paleoenvironmental conditions are listed first with the Abenaki names and with English following in parentheses. Traditional uses for these species are also listed; these names and traditional uses were sourced from the Native American Ethnobotany Database (http://naeb.brit.org/) and the Cowasuck Band of the Pennacook Abenaki People ethnobotany webpage (http://www.cowasuck.org/herbal.cfm). Additionally, the resources provided in Appendix A are exclusively Indigenous resources. The inclusion of resources created/maintained exclusively by Indigenous peoples in the northeastern U.S. is intentional and deliberate, and emphasizes the fact that there is a wide range of Indigenous knowledge resources that cannot be overlooked.

Additionally, and with the purpose of engaging in community collaboration, information about this study was sent to Indigenous groups throughout the northeast U.S.--specifically to representatives (of federally recognized tribes and tribal groups) in the states of New Hampshire, Maine, and Massachusetts. In an email, the project was described and representatives were asked if they knew anything of Indigenous history in New Hampshire or of the relationship between archaeology and Indigenous knowledge. Comment, critique, or engagement with the project (at whatever level the participants were able or interested to contribute) was welcomed. This email was sent with the purpose of engaging in collaboration with Indigenous communities that may have an interest in the Israel River valley or in New Hampshire's history more generally. These actions were all taken to foreground ethics and respect for Indigenous knowledge and peoples.

## Field Methods

### Test Pits and Exposures of Stratigraphy

Fieldwork was completed over the month of July in 2017. Funding was provided by a Hoffman Research Support Grant obtained through Bates College. Within the study area, field data collection focused on locations providing visibility of possible lake sediments and/or till. Cut banks along the shores of the Israel River generally provided the best exposures of stratigraphy. Test pits were also dug to confirm the character of certain landscape features, notably till hummocks and meltwater channels/spillways in some instances. Features resembling wave-cut shorelines were also mapped. Site locations were concentrated in the area once covered by the Bailey's stage of Glacial Lake Israel, as can be seen in Figure 16. Sites will be discussed in more detail in results. Navigation in the field was assisted by a large printout of the study area LiDAR, as well as by use of a handheld Trimble GPS device loaded with both LiDAR imagery and a topographic basemap of the study area. Before going out into the field, site locations were chosen through LiDAR analysis and inspection of imagery on Google Earth, and picked based on the probability of good stratigraphy exposure or the presence of distinctive landscape types.

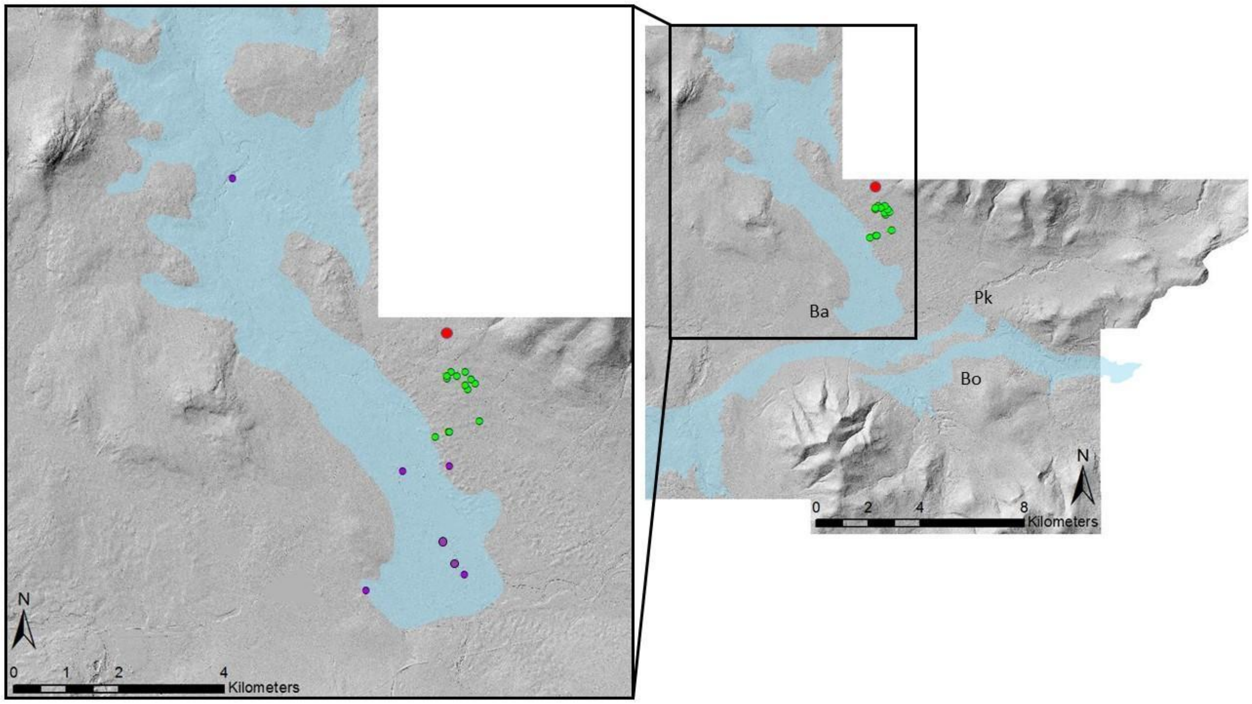



*Figure 16: Field site locations are shown as purple circles. Blue polygon shows the Bailey's Stage (Ba) of Glacial Lake Israel (Thompson et al., 2017) overlain on a (315, 45) hillshade of the study area. (Other stages are labeled Bo for Bowman and Pk for Pine Knob.) Green circles show IRC sites and red circle shows the location of Jefferson, NH.*

## Data Collection and Sampling

At each site location, GPS coordinates and stratigraphic data were digitally recorded using a Trimble Juno SD handheld GPS device, as well as by hand in a Rite-in-the-Rain field notebook. Both a LiDAR image and a topographic basemap of the field area were loaded onto the Trimble device prior to fieldwork to assist with navigation in the field. At each site location, a test pit was dug as deep as possible until either the water table was reached or digging was obstructed by clasts/roots, etc. In the case of sites with cut banks, exposures were cleaned off using a shovel and dug down as far as possible, usually to near the water line. From here, detailed notes were taken of stratigraphy and location, (including a sketch of a stratigraphic column with appropriate symbols and unit numbers) and sediment samples were collected from each identifiable layer present. These samples were labeled with location, unit number, and date and kept throughout fieldwork in a refrigerator. Features recorded at each site included grain size, sediment texture and color, clast size (if clasts were present in the matrix) and bedding/lamination.

## Sampling for Radiocarbon Dating

Three sets of samples were collected from locations within the study area, with the goal of investigating the postglacial environment of the Israel River Valley and the relationship of the IRC sites to this landscape. These samples included wood and organic material from a cut bank of the Israel River on the Ingerson property, wood from between two layers of lake sediments (obtained from Mr. Neil Gross) and bone fragments from the Jefferson VI site in the IRC obtained from Dr. Richard Boisvert. Figure 17 shows the locations of these three sample types in relation to the larger study area.

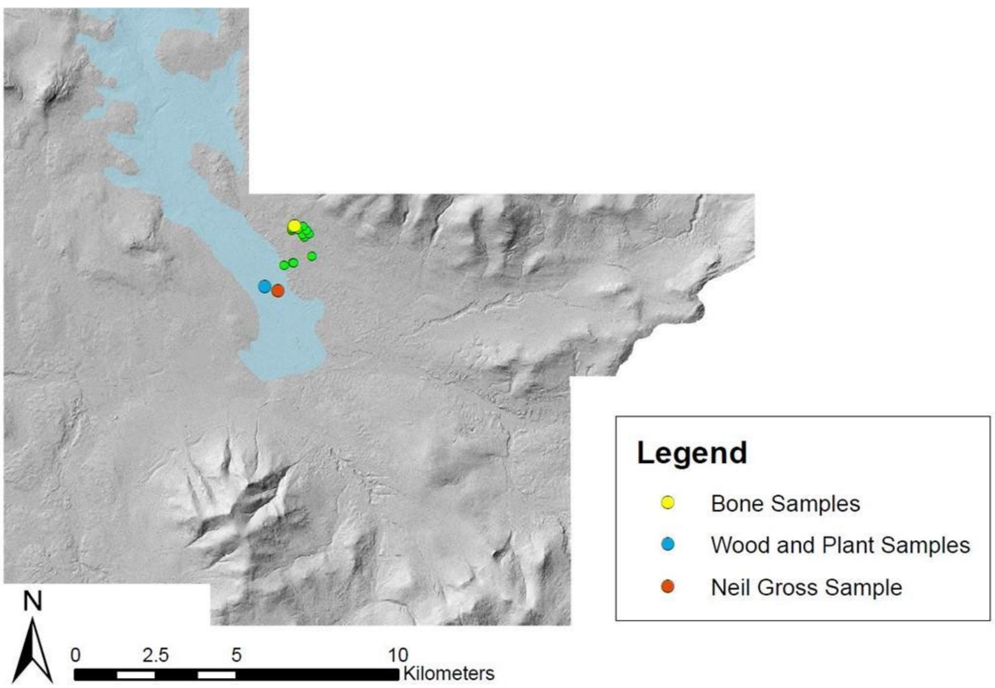



*Figure 17: Radiocarbon sample locations in the study area. Blue polygon shows the Bailey's Stage of Glacial Lake Israel (Thompson et al., 2017) overlain on a (315, 45) hillshade and green circles mark the locations of the IRC sites.*

During an additional visit to the Site 2 cut bank (Figure 18) at the Ingerson Transportation property on October 20th 2017, samples for radiocarbon dating were collected. Four samples of organic material were collected from the interface between the possible varved lake sediments (or a flood deposit) and overlying gravel alluvium (Figure 19). These were collected between 4-6 ft (1.2-1.8 m) below the surface of the flood plain/field, to date the transition from the Bailey's stage to postglacial stages of Glacial Lake Israel. These samples were identified by Brett Huggett using an Olympus SZ-6045 microscope (Huggett, pers comm). Of these four samples, one was selected for radiocarbon dating based on its identification as a woody stem. This sample (numbered two in Figure 19) was obtained from the transition between Units 1 and 2. This woody stem was determined to be more likely to represent the age of the sediments in which it was preserved, compared to a root which could have intruded into the sediments after deposition.

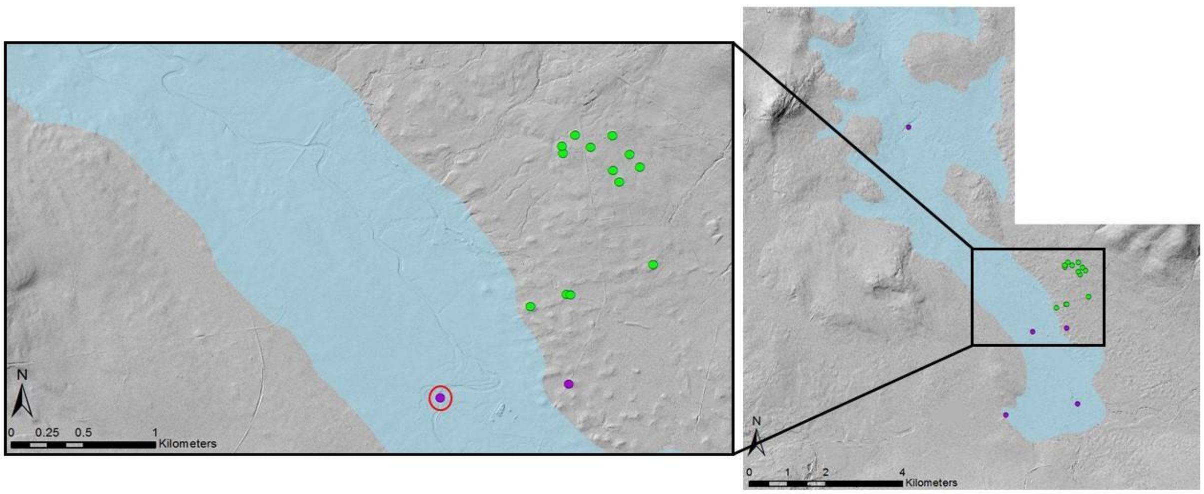



*Figure 18: Site 2, (highlighted in a red circle) a cut bank along the Israel River on the Ingerson property.*

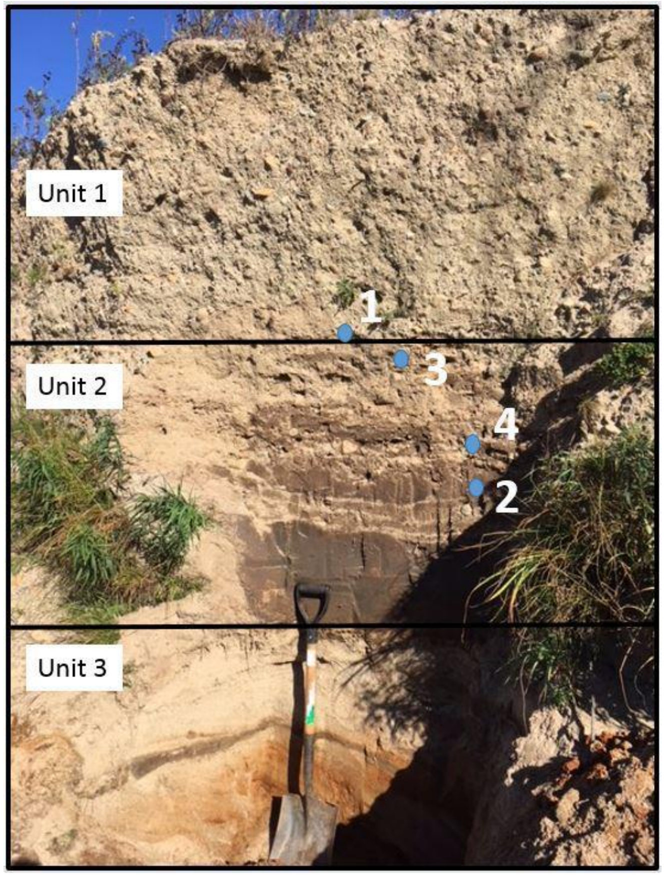



*Figure 19: Cut bank at the Ingerson property. Stratigraphic units are labeled 1-3. Samples (numbered 1-4) were collected for radiocarbon dating from Unit 2 (lake sediments or a floodplain deposit) and the boundary between units 1 and 2.*

### Visit to the Jefferson VI Site in the Israel River Complex

Field work also included visiting an active dig site in the study area. During the month of July, Dr. Richard Boisvert (the NH state archaeologist) and volunteers for SCRAP (the New Hampshire State Conservation and Rescue Archaeology Program) conducted investigations at the Jefferson VI site in the Israel River Complex, which coincided with the fieldwork period for this study. A visit to this dig site was made to observe the methods of excavation and the artifacts being investigated, as well as to talk with Dr. Boisvert about the archaeological work being done and to give a presentation on this study to the volunteer archaeologists, many of whom have been working in the area for multiple years. Additional conversations were had with Dr. Boisvert throughout the fieldwork period about the history of SCRAP investigations at the Israel River Complex sites, about the lithic types present at these sites, and about the relation of these sites to the former lakeshore of the Bailey's stage of Glacial Lake Israel.

Additionally, 20 bone fragments (identified tentatively as cervid, based on data from the neighboring Jefferson IV site where cervid protein was identified on a fragment of bone) were obtained from Dr. Boisvert for radiocarbon dating. These bone fragments were excavated from an area called the “Salvage Block” at the Israel River Complex site 27-CO-74, also called the Jefferson VI site, in October of 2013 (Figure 20). This area was excavated before construction of a septic system which would have destroyed any archaeological evidence (Boisvert, pers comm). These bone fragments were chosen for dating based on their mass (most fragments are around 0.5 grams) and their association with diagnostic artifacts at the site (Boisvert, pers comm). The bone fragments were sent out for radiocarbon dating in three bags, grouped by depth at which they were uncovered within a square meter excavation area.

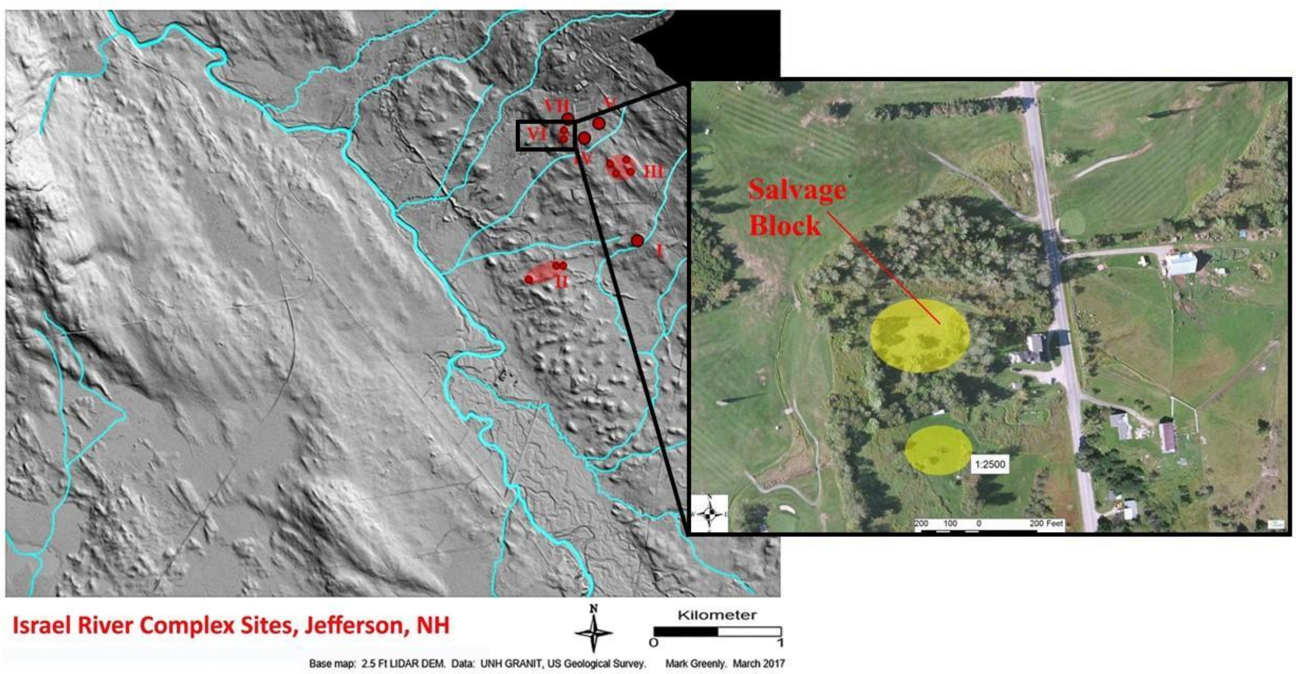



*Figure 20: Aerial image of the Jefferson VI site showing the area from which the 20 bone fragments were excavated (the Salvage Block). The Jefferson VI site is shown on a hillshade with the other IRC sites (Boisvert, pers comm).*

### Alnisedi (Eastern Hemlock) Fragment from Below Alderbrook and Riverton Stage Lake Clays

On December 1, 2017, another visit was made to the study area to collect a sample of wood from Mr. Neil Gross. The sample was part of a larger log unearthed in 2004 during construction of a garage on the Ingerson property along route 115a. The log was found about 8 ft below the ground surface, underneath approximately 2 ft of topsoil, 3 ft of brown clay, and 3 ft of blueish gray clay, and sitting on top of “hardpan” (Ingerson, pers comm.). The log was between 8-10 ft long and 5-6 inches in diameter. The log was overturned and not in a growth position when found (Gross and Ingerson, pers comm). The clay layer is interpreted as Alderbrook Stage lake sediments, while the “hardpan” is interpreted as Bailey’s Stage lake sediments. The log was identified by Brett Huggett (using an Olympus SZ-6045 microscope) as Alnisedi (eastern hemlock).

## Laboratory Methods

### Radiocarbon Dating

Radiocarbon dating is particularly useful in archaeology and Quaternary geology because of its ability to date materials up to 40,000 years old-- relatively young materials in geological terms (Beta Analytic, 2017). Carbon 14 or $^{14}C$ (also called radiocarbon), the unstable and radioactive heavy isotope of carbon, is an isotopic chronometer, meaning it essentially records the passage of time (Beta Analytic, 2017). $^{14}C$ is continually formed in the upper atmosphere through a process called spallation, when cosmic rays bombard atoms and shatter the nuclei into smaller pieces -in this case, neutrons- which then slow down during collisions with other atoms and are absorbed by the nuclei of Nitrogen 14 (Figure 21). This absorption kicks out a proton, transforming the atom of Nitrogen 14 to one of $^{14}C$ (Beta Analytic, 2017).

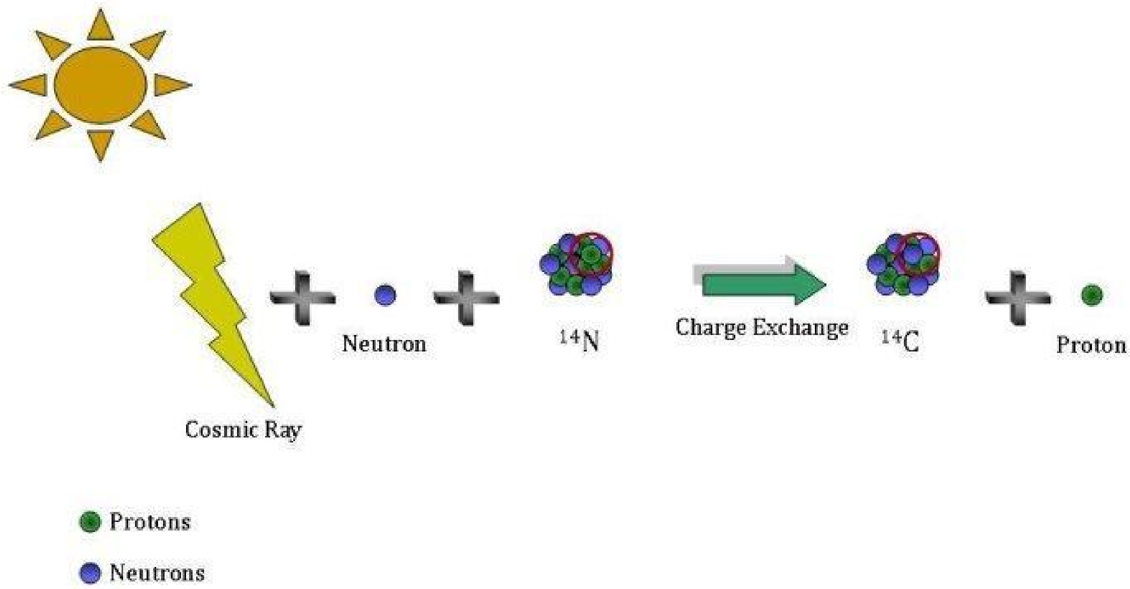



*Figure 21: Spallation in the upper atmosphere, the process by which $^{14}C$ is produced as cosmic rays bombard atoms. (Image from https://www.esrl. noaa.gov/gmd/ccgg/isotopes/decay.html)*

$^{14}C$ is then oxidized to $CO_2$ in the atmosphere, and enters the global carbon cycle where it is taken up by plants and animals (Beta Analytic, 2017). Upon the death of an organism, carbon exchange stops and no more $^{14}C$ is assimilated; the $^{14}C$ content of the organism then begins to decrease at a rate determined by the half life of $^{14}C$, which is 5,730 years. During Beta Decay, (the radioactive decay of $^{14}C$) atoms of $^{14}C$ decay into atoms of $^{14}N$ as neutrons in the nuclei of carbon atoms become protons and change the atomic structure from carbon to nitrogen, releasing electrons and antineutrinos in the process (Beta Analytic, 2017; Figure 22). Radiocarbon dating measures the residual radioactivity of a sample; knowing the amount of $^{14}C$ in a sample can indicate the age of the organism at death, when new radiocarbon stopped being assimilated.

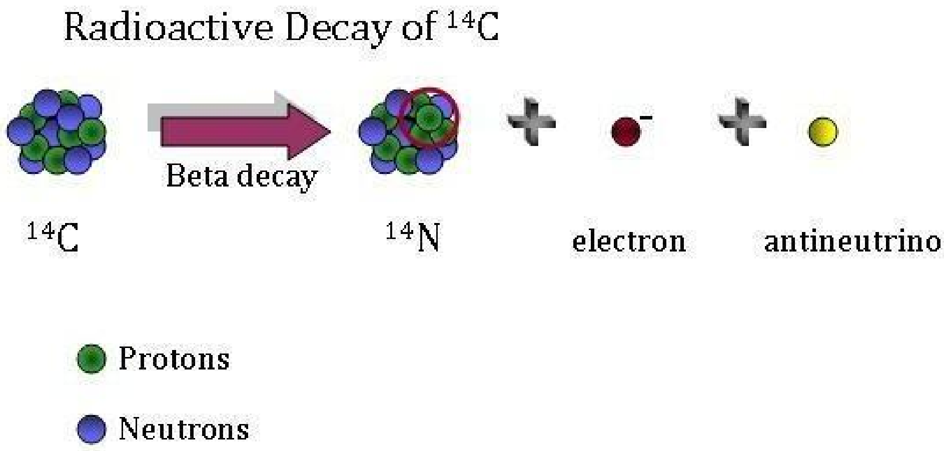



*Figure 22: The process of Beta Decay, where $^{14}C$ decays to $^{14}N$, releasing an electron and an elementary particle called an antineutrino. (Image from https://www.esrl.noaa.gov/gmd/ccgg/isotopes/decay.html)*

All samples were sent to the National Ocean Sciences Accelerator Mass Spectrometry (NOSAMS) facility at the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, Massachusetts, for radiocarbon dating.

### *Sample Preparation and Pretreatment*

Before being sent to the NOSAMS lab at WHOI, the wood/plant sample from the interface of Units 1 and 2 at the Site 2 cut bank was rinsed first with tap water, then with deionized water, and finally cleaned of loose debris and dirt with an ultrasonic probe. The sample was given a sample name of IR10202917A. A portion of this sample was retained for records and named IR10202917B. The sample of wood obtained from Mr. Gross was given a sample name of NG1212017 and was sent to the NOSAMS lab without being rinsed. Part of this sample was also retained for records. The bone fragments were sent as is, in bags marked with numbers 6526, 6533, and 6611, indicating the layers from which they were excavated within the 1m x 1m excavation area at site 27-CO-74.

In the sample preparation lab at WHOI, all natural carbon samples are treated and processed into graphite for Accelerator Mass Spectrometry (AMS) analysis. An outline will be provided here for the specific processing of the wood, plant, and bone samples collected in this study. First, organic materials in the samples were isolated; for plant and wood samples, a series of acid-base-acid leaches was used, and for bone samples, collagen was extracted using the

EDTA (ethylenediaminetetra-acetic acid) method (WHOI, 2017). This method was performed by Noreen Tuross in the Harvard University Center for the Environment Department of Human Evolutionary Biology. (For EDTA decalcification, small bone chunks were soaked and swirled in an EDTA solution for periods of up to several weeks; decalcification was complete when the bone pieces became translucent and at this time, the collagen from the fragments was floating in solution (Tuross, 2012). The amount of collagen extracted was not, however, large enough to provide a radiocarbon date.) The remaining samples (Sample 2 and the Alnisedi fragment) were then converted to $CO_2$ through organic combustion, and finally converted to graphite (WHOI, 2017).

### *Accelerator Mass Spectrometry Analysis*

Once samples were converted to graphite (solid carbon), they were analyzed using the Continuous-Flow AMS System (CFAMS), which counts atoms of the three isotopes of carbon ($^{12}C$, $^{13}C$, and $^{14}C$) directly. For a schematic of the CFAMS apparatus used at the NOSAMS lab, see Figure 23. A brief description of the AMS process is given below.

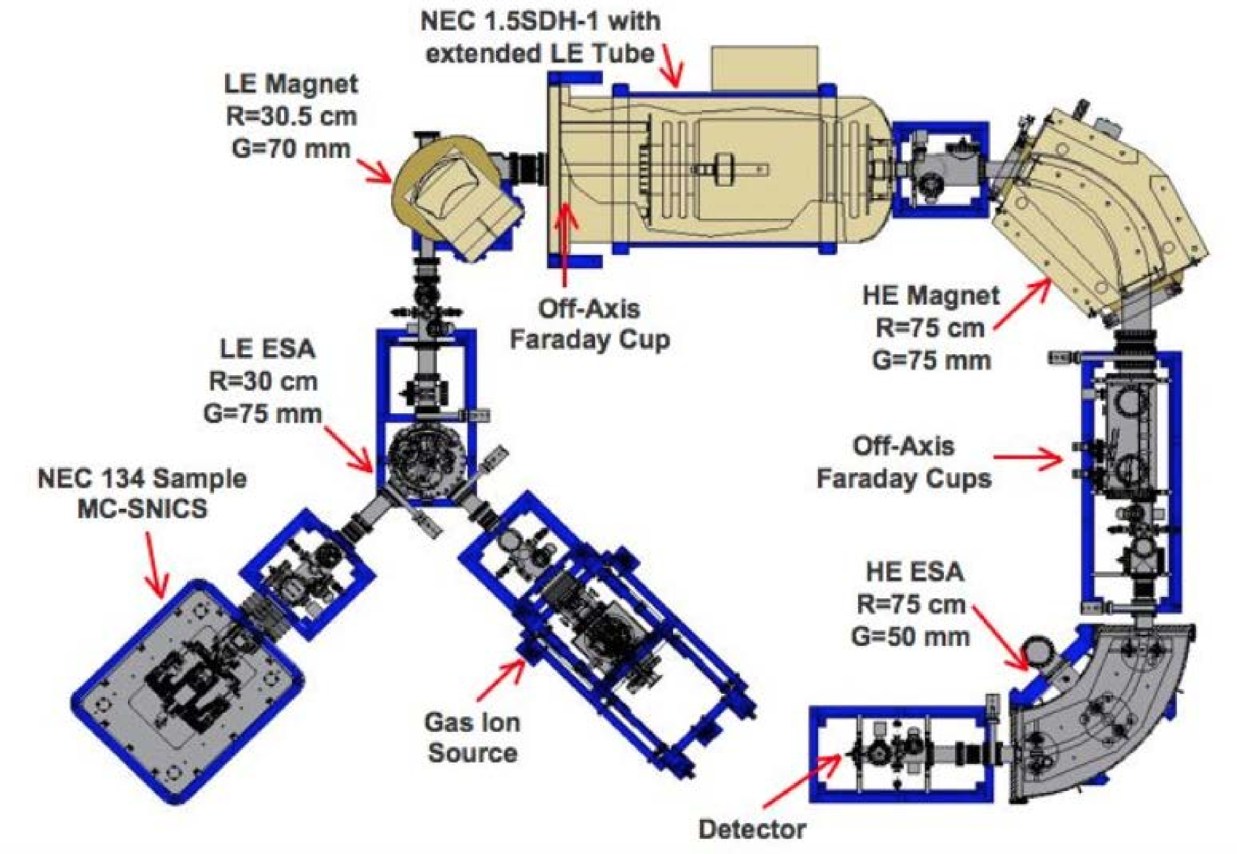



*Figure 23: Plan view of the Continuous-Flow AMS System at the NOSAMS lab; the system is constructed around a 500kV pelletron accelerator. Shown on the left are a bounced injection system with a modified SNICS solid sputter ion source and a microwave gas ion source. Shown on the right are the high energy mass spectrometer and particle detection system (from Woods Hole Oceanographic Institution, 2017).*

Graphite produced during sample prep is compressed into a small cavity in an aluminum target, and is made to emit $C^-$ ions by being sputtered with heated, ionized cesium. These ions are then injected into an accelerator. The accelerator directs them through a stripper, removing electrons and transforming the $C^-$ ions into $C^+$ ions. $C^+$ ions then pass through a magnet which magnetically separates them by mass, curving their paths to differing degrees based on the weights of the different isotopes of carbon. At the exit of the analyzing magnet, two Faraday cups count the lighter isotopes of carbon ($^{12}C^+$ and $^{13}C^+$) by measuring the electric current generated by their ion streams. The ion stream of $^{14}C^+$ ions is curved least, (because $^{14}C$ is the heaviest isotope of carbon) and these ions are counted by a solid-state, silicon-surface-barrier detector (WHOI, 2015).

Once the samples were analyzed using the method described above, a process blank (radiocarbon-free material prepared using the same methods as the samples) was put through the apparatus to quantify the amount of contamination introduced during the sample preparation process. Additionally, a machine background blank was also processed to measure the amount of contamination introduced during the process of AMS itself. These contamination amounts were then subtracted from the final counts of $^{14}C$, and this count was used in the calculation of the radiocarbon ages of the samples (WHOI, 2017).

### *Calculation of Radiocarbon Ages*

The results of AMS radiocarbon analysis were ratios of $^{12}C$ to $^{14}C$ in each sample. At NOSAMS, these ratios were compared to the ratio in the international standard in order to obtain the Fraction Modern (Fm). Fm is a measurement of the deviation of the $^{14}C/^{12}C$ ratio in the sample from "modern," which is defined as 95% of the amount of $^{14}C$ of NBS Oxalic Acid I (WHOI, 2017). This Fraction Modern is then corrected for isotopic fractionation by using the $^{12}C/^{13}C$ ratio given by the AMS system to convert the value it would be if the original $\delta^{13}C$ were -25‰ (the $\delta^{13}C$ value to which all radiocarbon measurements are normalized). The radiocarbon ages of the samples were then calculated from the $\delta^{13}C$-corrected Fraction Modern according to this formula:

$$\text{Radiocarbon Age} = -8033\ln(\text{Fm})$$

Ages at the NOSAMS lab are calculated using the Libby half life of radiocarbon, which is 5,568 years (different from the more accurately known half life of 5,730 years) with errors given as 8033 times the relative error in the Fm. Calibration curves, which convert radiocarbon years to calendar years, include a correction which accounts for the use of the Libby Half life instead of the more accurate half life of 5,730 years. Calibration of radiocarbon years to calendar years is necessary because the proportion of $^{14}C$ in the atmosphere has varied by a few percent over time; this change is recorded in the tree ring record (up to 12.5 ka) where the concentration of $^{14}C$ in the atmosphere each year is recorded in individual rings of known ages (Beta Analytic, 2017). Beyond 12.5 ka, coral and varve records show the changing concentration of $^{14}C$ (Beta Analytic, 2017). Datasets of these types from across the world have been compiled to create the IntCal13 radiocarbon calibration curve, part of which is seen in Figure 24. Conversion of radiocarbon years to calendar years was done using the online conversion tool Calib 7.1, developed by Stuiver, Reimer, and Reimer, (2017) which uses the IntCal13 curve to calibrate ages of nonmarine samples from radiocarbon years to calendar years (see Figure 24).

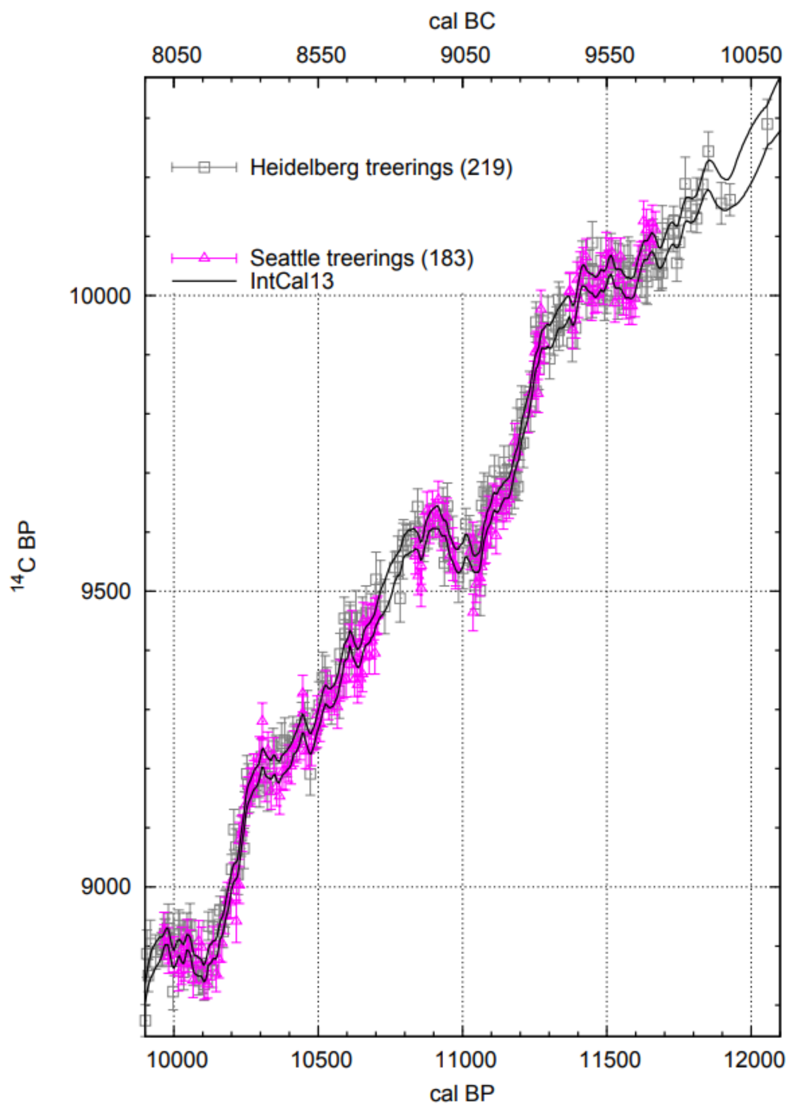



*Figure 24: IntCal13 radiocarbon calibration curve from 10,000-12,000 cal BP, constructed from data in the Heidelberg and Seattle tree ring records. (Image from http://www.radiocarbon.org/IntCal13%20files/intcal13.pdf)*

## Spatial Analysis: ArcGIS

After fieldwork was completed, data files from the Trimble GPS unit were uploaded to a Dell laptop computer using a program called GPS Pathfinder Office. These data were then exported as ESRI shapefiles, and added as a layer in ArcMap version 10.5. All modeling was done using LiDAR (Light Detection and Ranging) data, which was downloaded from the NH Granit online database.

### LiDAR Acquisition

Airborne LiDAR has only been recognized as a new archaeological tool since the turn of the century, but interest in the technique is increasing and the use of LiDAR is becoming widespread throughout the archaeological world (Crutchley, 2010). LiDAR is a remote sensing technique that uses a near-infrared laser to produce highly accurate x,y, and z measurements in the form of mass point cloud datasets (arcMap, 2017). These can be analyzed in different ways to produce information about the surface of the earth (ArcMap, 2017).

To produce LiDAR data, an active optical LiDAR sensor is mounted on an aircraft and this sensor transmits laser beams toward the ground while the aircraft moves along a specific survey route and detects the precise time from when the laser pulse left the system to when it returns. Laser pulses reflect from objects on and above the ground surface; the amount of returns equals the amount of reflective surfaces (tree branches, buildings, etc.) that the laser light encounters as it travels towards the ground (Figure 25). The last return will be of the ground surface, and this is the return used to produce bare earth terrain models (Figure 26).

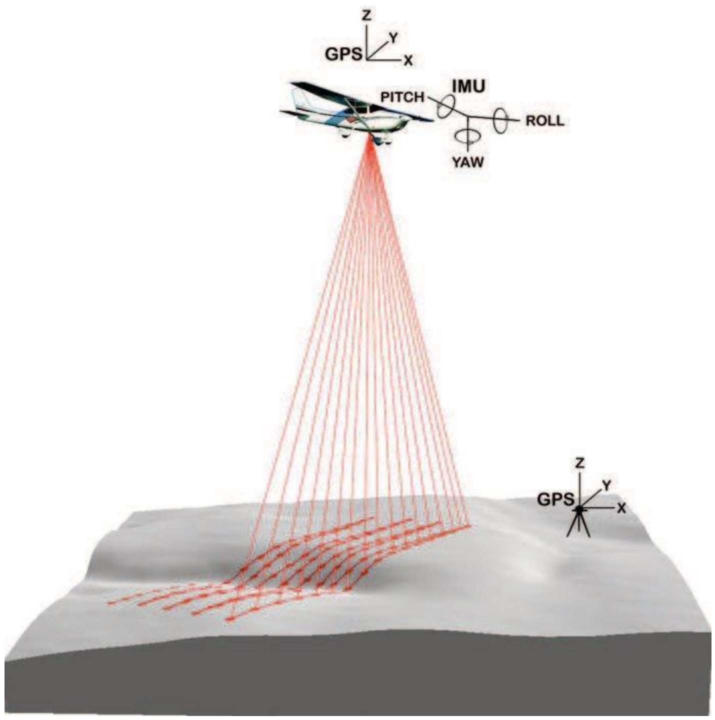



*Figure 25: Schematic showing collection of LiDAR data and the roles of the GPS and INS/IMU systems. Red lines indicate laser light (Reutebuch et al., 2005).*

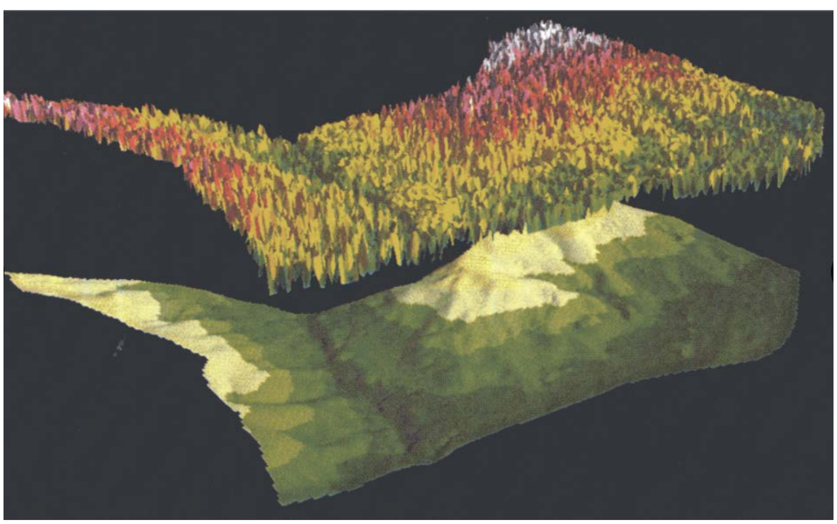


*Figure 26: Bare earth and first return (forest canopy top) LiDAR surfaces (Chormann, 2015).*

The return time is used to calculate the range distance between the sensor and the target, and when combined with measurements from GPS and INS (inertial navigation system, also called an IMU) measurements, the distance measurements are transformed to three dimensional points of the ground surface (ArcMap, 2017). The INS determines the attitude of the aircraft recorded in degrees of roll, pitch, and yaw (LiDAR-UK, 2017). Analysis of laser time range, laser scan angle, GPS position, and INS information then transforms the point data into highly accurate georeferenced x,y,z (latitude, longitude, and elevation) coordinates, known as a point cloud (ArcMap, 2017; Figure 27).

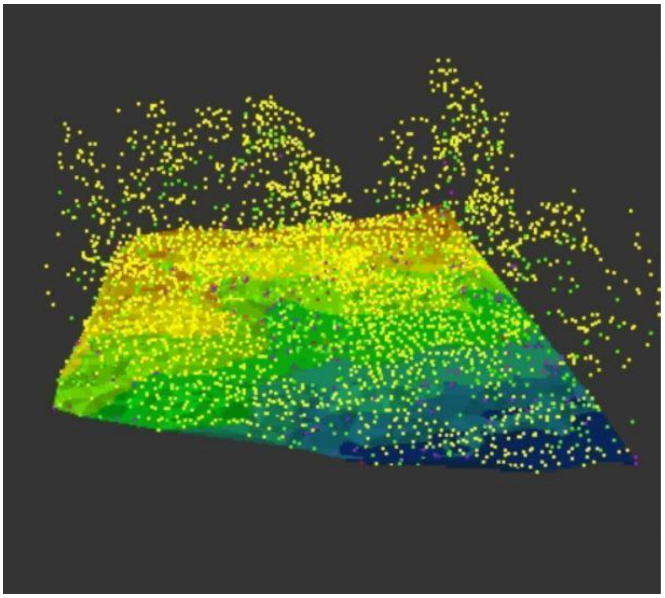


*Figure 27: LiDAR point cloud (Chormann, 2015).*

LiDAR was downloaded from the NH Granit online database through the LiDAR Data Distribution tool. The DEM (digital elevation model) data for the Connecticut River Watershed flyover (conducted in 2015, see Figure 28) is used in this study. In this dataset, each pixel (1m x 1m) represents the elevation of the bare earth with all vegetation removed from the surface. The CT River flyover was conducted by the New Hampshire Geological Survey (NHGS) and the New Hampshire Department of Environmental Services (NHDES) and was funded by the NHGS and the White Mountain National Forest (WMNF); this flyover encompassed 181 square miles (NH Granit, 2017). LiDAR was then mosaicked to bring together all the tiles in the study area using the Mosaic to New Raster tool.

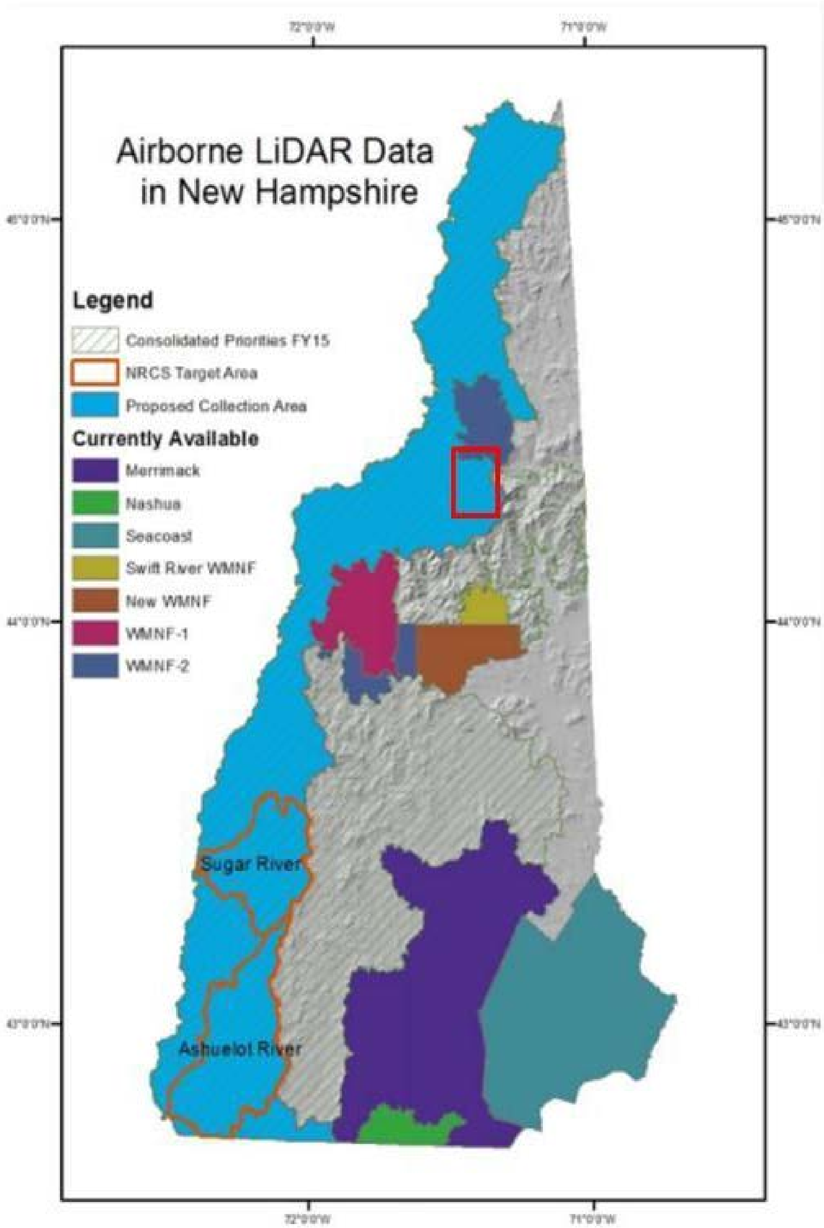



*Figure 28: Airborne LiDAR flyovers in New Hampshire; the proposed collection area includes the LiDAR used in this study as part of the CT River 2015 flyover (Chormann, 2015). Study area outlined in red.*

## Modeling Using LiDAR

### *Hillshading*

After the LiDAR data was downloaded, hillshading was done to illuminate different landscape features. The Hillshade tool in ArcMap allows the user to adjust the altitude of the sun (angle of the sun above the horizon, from 0-90 degrees) and the azimuth of the sun (angle of the sun's relative position along the horizon, where 0/360 degrees is north and 180 degrees is south) in order to illuminate different features on the bare earth DEM (Figure 29). See Figure 30 for examples of different landscape illuminated using hillshading.

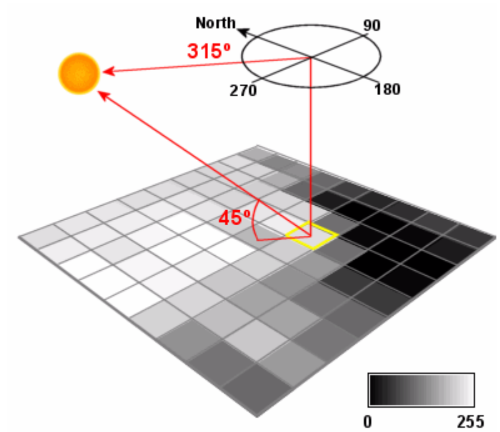



*Figure 29: Schematic of an azimuth of 315 and an altitude of 45, illustrating the direction of sunlight on a hillshade with these parameters (image from http://www.geography.hunter.cuny.edu/~jochen/GTECH361/lectures/lecture11/concepts/Hillshade.htm).*

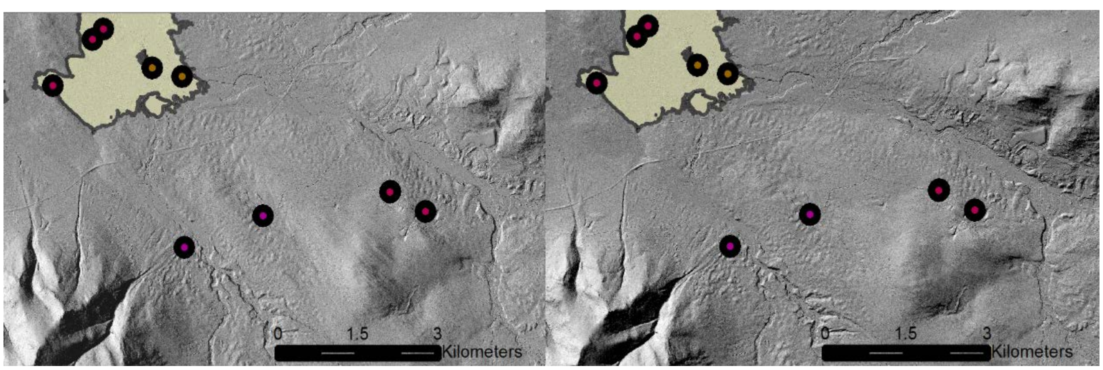



*Figure 30: Images of a (290, 45) hillshade (left) and a (315, 45) hillshade (right) illustrating the difference in appearance of the LiDAR. An azimuth of 290 illuminates more linear features, while an azimuth of 315 illuminates more circular features, and thus was used to map regions of hummocky till.*

### Shoreline Modeling: Landscape Polygons

Landscape features (hummocky till, smooth till, lake bottom, and bedrock) were identified from LiDAR hillshades based on characteristic sets of surface conditions such as slope, elevation, and texture, from the method outlined by Koe (2016). Examples of characteristic landscape morphology for each of these features can be seen in the results section (Figures 52 through 55).

Polygons of landscape features were created in ArcMap (using the freehand tool) based on analysis of LiDAR and field mapping, and compiled into the landscape type map seen in Figure 51. Polygons were drawn, as best as possible, along boundaries between the four landscape types of hummocky till, smooth till, lake bottom, and bedrock. Additionally, the Slope tool (in the 3D Analyst toolbar, under Raster Surface) was used to clarify changes in elevation, and to assist with determining boundaries between the different landscape types as seen in LiDAR. The Slope tool measures the maximum rate of change in elevation from one cell to its neighbors, and colorizes the LiDAR to show highest rates of change in red and lowest rates of change in green (this colorization depends on the color ramp used).

These landscape types were then compared to results of spillway elevation modeling (by overlaying shoreline models on various landscape type maps in ArcMap) to determine the agreement or disagreement between the two lake level modeling approaches. Landscape type and spillway elevation model comparison maps are described in the results section, along with the landscape type map including all four units.

### *Shoreline Modeling: Spillway Elevation Method*

Modeling of the different stages of Glacial Lake Israel was done to compare to existing shorelines as mapped by Thompson et al., 2017. Using the elevations of known spillways obtained from the literature (Thompson et al., 2017) and from ArcMap, the shorelines of the five stages of Glacial Lake Israel were mapped through the classification of break values. The spillways used were the Cherry Pond spillway, elevation 1,110 ft/338 m, (for the Bailey's stage), the Pine Knob spillway, elevation 1,269 ft/387 m, (for the Pine Knob stage), the spillway at Bowman, elevation 1,500 ft/457 m, (for the Bowman stage), and the spillway for the Alderbrook and Riverton stages where the Israel River crosses under Route 2 in Jefferson, NH, elevation 1,080 ft/329 m and 1,044 ft/318 m, respectively.

Spillway elevations were then classified as the break values for the LiDAR (Figure 31) and the raster was reclassified for each lake level (using the Raster Reclassify tool in the Spatial Analyst toolbar in ArcMap) to a binary where each cell held only one of two possible values: a value above the specified break value or a value below the break value. After the rasters were reclassified in binary, the raster to polygon tool was used to convert the reclassified raster for each lake stage to a polygon representing the shoreline of that stage. Before modeling the Riverton Stage shoreline by classifying break values based on spillway elevations, a unit of alluvium deposited by the Israel River (identified during fieldwork as being about 4 ft thick) was removed from the DEM. This was done by creating a raster from the Bailey's Stage shoreline model (using the Feature to Raster tool in the Conversion Tools toolbar) and then adding a field of 4 to this raster. First, the cells with no data in the new raster, which had a field of 4 in every cell, were told to have values of 0 in the code written in the raster calculator. This created a new raster, and the raster calculator was then used to subtract this raster from the study area DEM, which created a DEM simulating the removal of a 4 ft thick gravel layer from the selected area.

These shoreline polygons were then edited by deleting individual vertices and the Generalize and Smooth tools were used to delete areas of higher elevation that appear on the modern landscape and would have in fact been underwater when the lake existed. This technique was also applied to smooth any complications of the lakeshore introduced by modern drainages, etc. which were below the classified break value but would also have not existed concurrently with the lake.

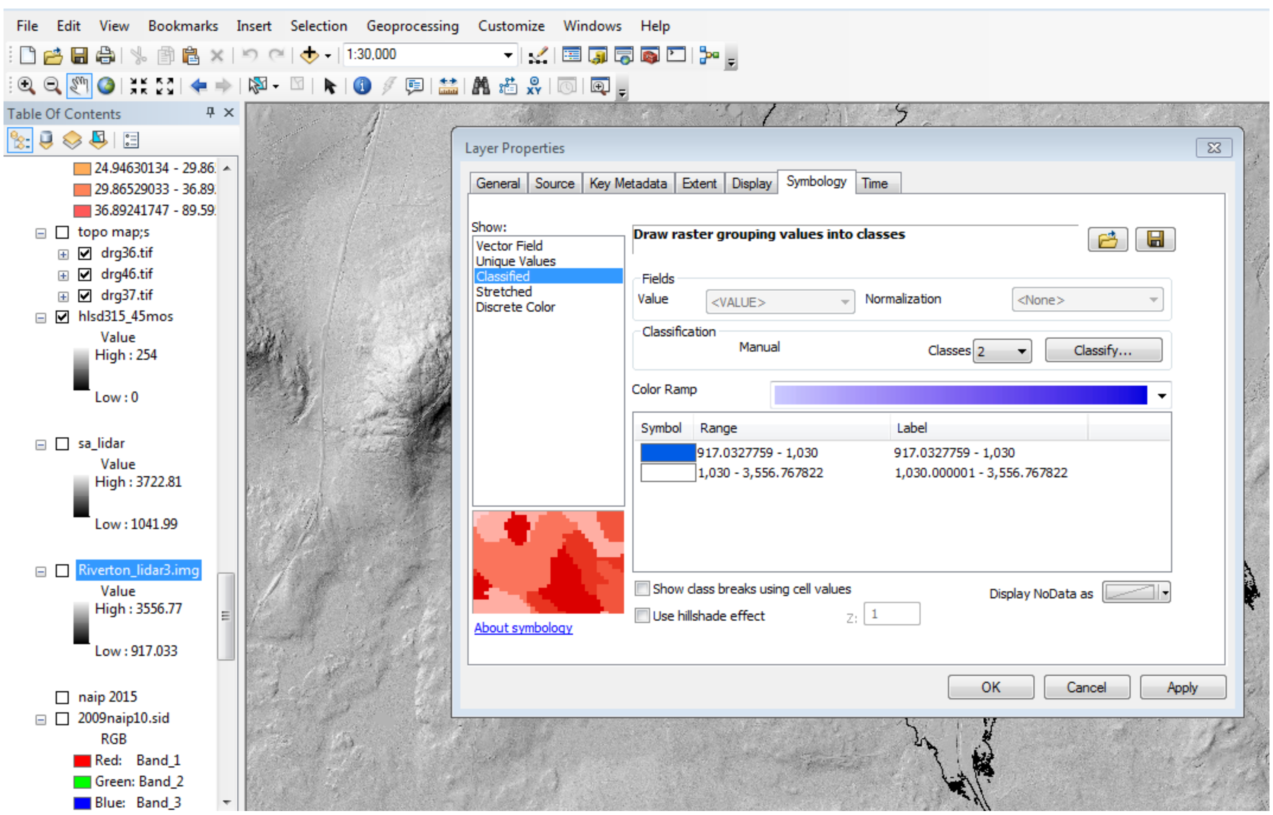



*Figure 31: Classification of break values for the Riverton stage spillway, which has an elevation of 1,044 ft/318 m. Break values were classified as the minimum elevation of the study area (about 917 ft) to the elevation of the spillway at 1,044 ft, and then from the spillway elevation to the maximum elevation on the study area LiDAR, about 3,556 ft. The class of values above the*

*spillway elevation was given no color, and the class below, which was reclassified and then converted to a polygon to represent the lake level, was given a blue color. This process was repeated for all five lake stages.*

### Elevation Profiles

Elevation profiles were created across four transects in the study area: through the Bailey's Stage and into the Jefferson II site, from the Cherry Pond spillway to the wave cut island feature in the Bailey's Stage, longitudinally through this wave cut island feature, and across the Alderbrook and Riverton spillway. (See results section for individual profiles.) These elevation profiles were constructed from 3D lines drawn on the surface of the study area hillshade using the Profile Graph tool in the 3D Analyst toolbar. The profiles were analyzed for evidence of wave cut shoreline features, and used to verify spillway elevations to further confirm the accuracy of the spillway elevation modeling method.

### Viewshed from the Jefferson II Vantage Point Site

A Viewshed was made (using the Viewshed tool in the Spatial Analyst toolbar) from the area identified as the "Jefferson II Vantage Point" site by Boisvert et al., 2017. This site is a till hummock to the west of the main Jefferson II site, seen in the results section (Figure 72). For the observation point, which is the point from which the viewshed is calculated, fields were added in the attribute table called OFFSETA and OFFSETB (with values of 5 ft and 3 ft, respectively) to set the height of the observation points and the height of target points, after the method described by Boisvert et al., 2017. This viewshed was compared to the Alderbrook Stage spillway elevation model.

## Results

### Overview

The results presented below include descriptions of relevant sample sites, radiocarbon dates, and maps made through modeling and analysis of LiDAR. Presented first are descriptions of geomorphology and stratigraphy at all relevant site locations visited during fieldwork, interspersed with descriptions of materials collected for radiocarbon dating and the dates obtained. Following these descriptions are explanations of maps, including lake level models with ice cover positions and landscape type maps. Following this is a comparison of modeled shorelines to mapped landscape types and explanations of elevation profiles taken throughout the study area.

### Site Locations and Descriptions

A description of each site is given, (including stratigraphy, geomorphology, etc.) along with descriptions of materials collected for radiocarbon dating, if applicable. Site locations can be seen in relation to lake stages and the IRC sites in Figure 32.

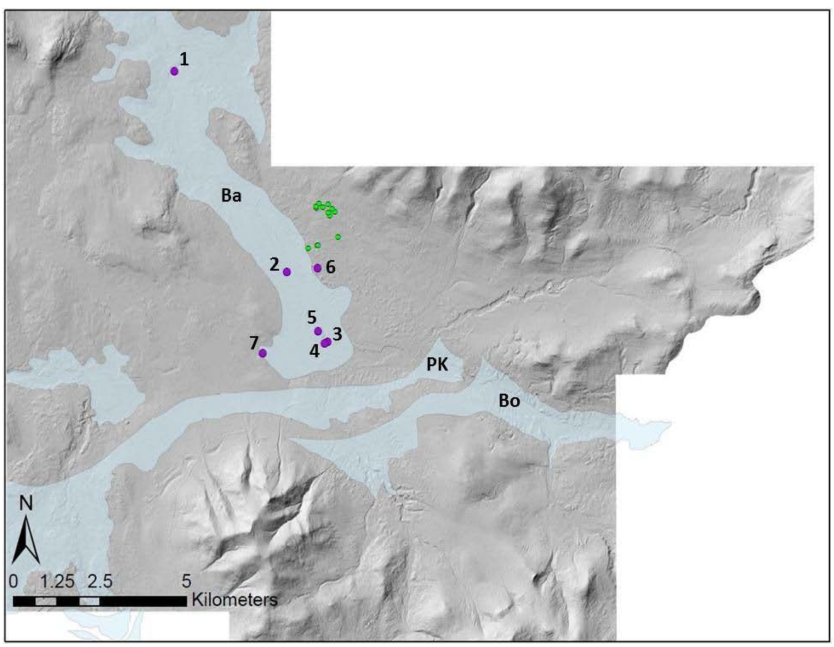



*Figure 32: Hillshade of study area (azimuth 315, altitude 45) showing site locations (purple dots) numbered by the order in which they are discussed below. Green dots show the locations of the Israel River Complex sites. Blue polygons show the Bowman, (Bo) Pine Knob, (PK) and Bailey's (Ba) stages of Glacial Lake Israel as mapped by Thompson et al., 2017.*

## Site 1- Proposed Alderbrook and Riverton Spillway

Test pit at the proposed spillway for the two postglacial stages of Glacial Lake Israel showed layered deposits of sand under finer claylike material. The two units were separated by a layer of oxidized sand.

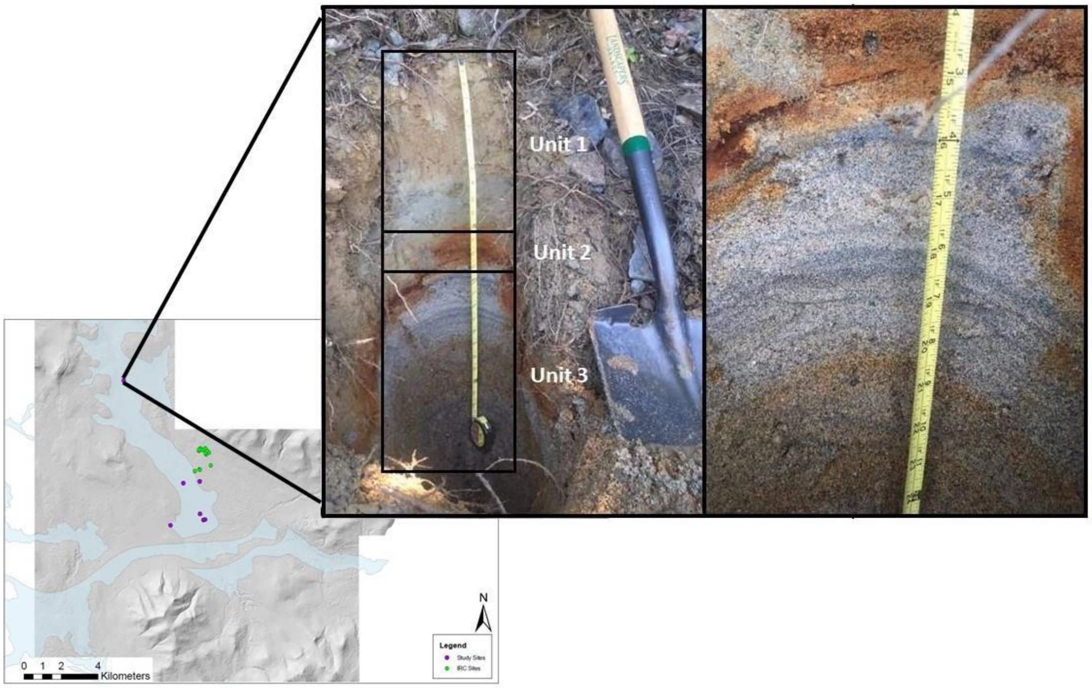



*Figure 33: Site 1, (elevation 1,010 ft, 308 m) test pit from the proposed spillway at Riverton, which drained the fourth and fifth stages of Glacial Lake Israel. Unit 1 (12 in, 30.5 cm) is silty fine/claylike sand, gray brown in color. Unit 2 (3 in, 8 cm) is a layer of oxidized sand, medium to coarse grain size. Unit 3 (12 in, 30.5 cm) is layered sand, medium to coarse grain size, gray in color with interspersed purpleish layers.*

## Site 2 - Cut Bank on the Ingerson Property

Test pit at a cut bank of the Israel River on the property of Ingerson Transportation. Three stratigraphic units were identified: alluvium, a possible floodplain deposit, and bedded sands.

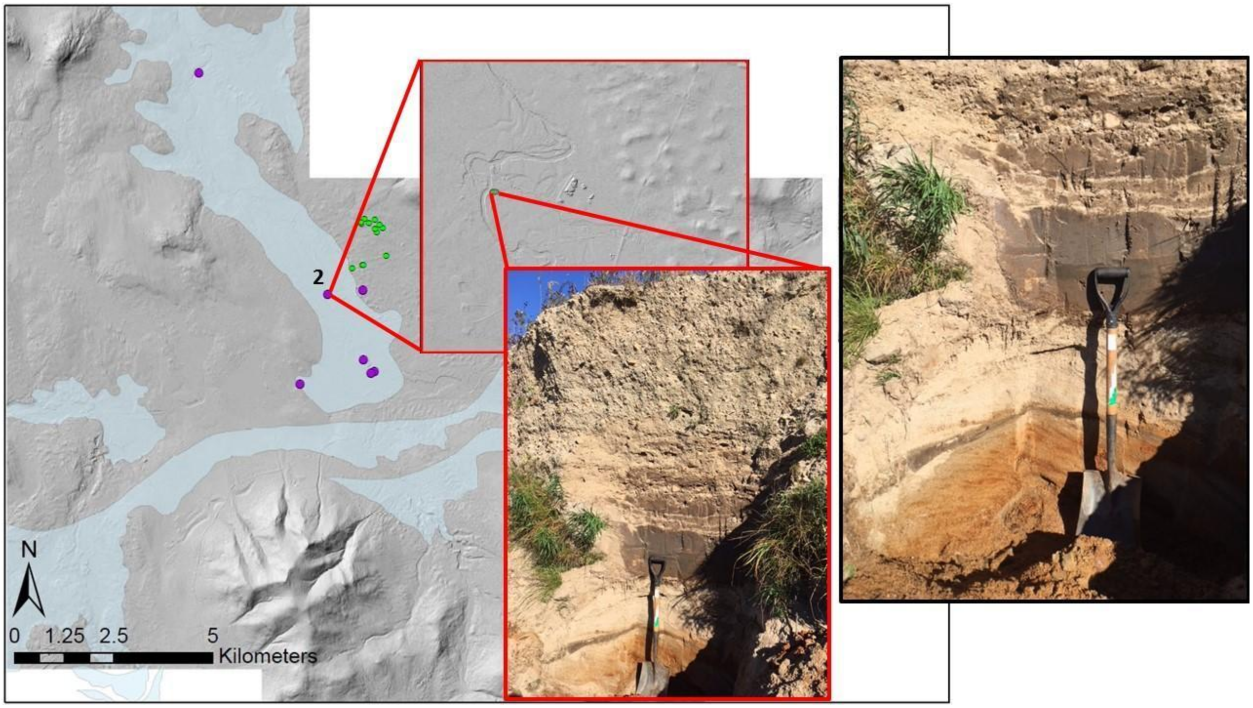



*Figure 34: Site 2, (elevation 1,062 ft, 324 m) a cut bank exposure of the Israel River on the Ingerson mulch farm property. Stratigraphy was broken up into three general units, described below in Figure 35.*

### *Samples Collected from Site 2 for Radiocarbon Dating*

Samples were collected from Site 2 in the field in October 2017. See figures 37 and 38 for detailed images. Sample 1 is a wood fragment identified as some type of woody root, measuring 7.8 x 1.5 cm. Sample 2 is also a wood fragment, identified as some type of woody stem, broken into three fragments measuring 8 x 1.2 cm, 9.5 x 1.2 cm, and 1.5 x 1.2 cm. Sample 3 is some type of fibrous plant material measuring 10 x .5 cm, and Sample 4, measuring 4.5 x .5 cm, is similar to Sample 3 and appears to be a bit woodier (Huggett, pers comm.). Sample locations in situ can be seen in Figure 36. Sample 2 was sent to the NOSAMS lab at the Woods Hole Oceanographic Institution for radiocarbon dating, yet returned a date of >modern and was therefore not useable (see Table 2).


*Figure 35: Israel River cut bank exposure on the Ingerson property. Samples were collected from the contact of units 1 and 2 to obtain a date for the transition from a lacustrine/post lacustrine marsh to a fluvial environment. Sample 1 was identified as some type of woody root, Sample 2 was identified as some type of woody stem, and Samples 3 and 4 were identified as fibrous plant material.*

Unit 1, approximately 4 ft (1.2 m) thick, was composed of coarse, poorly sorted sand and gravel. No stratification or alignment of clasts was identified. Clasts were gravel to cobble sized, and ranged from subangular to rounded. This unit is interpreted to be alluvium deposited by the early Israel River. Unit 2, approximately 3.5 ft (1.1 m) thick, was composed of interbedded sand and dark silty fine material. In the upper layers of the unit, some gravel was incorporated from Unit 1. The lower layer of the unit was exclusively composed of dark organic rich silt, interpreted as floodplain deposits (Thompson, pers comm.). Unit 3, visible above the water table for about 4 ft, ( 1.2 m) graded from coarse tan sand with some lenses of gravel and darker fine sand to layers of crossbedded medium sand showing evidence of oxidation, also including lenses of coarser material and dark fine material. Below this oxidized sand was a layer of coarser sand, also red in color, mixed with some gravel and pebble size clasts. This layer could be interpreted as foreset beds deposited in a braided stream environment during the recession of the Laurentide Ice Sheet before the formation of Glacial Lake Israel.

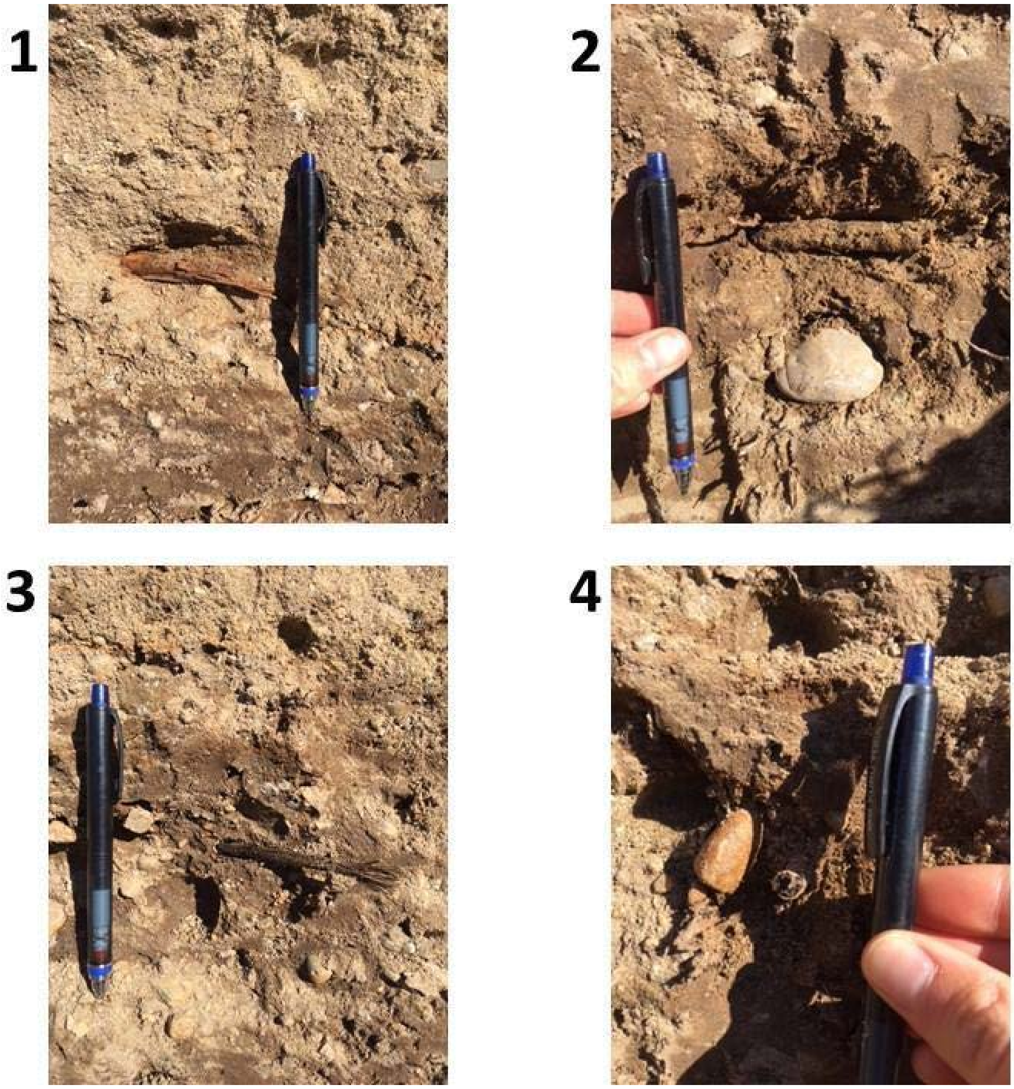



*Figure 36: Samples in situ, Site 2. Sample 1: woody root. Sample 2: woody stem. Samples 3 and 4: fibrous plant material.*


*Figure 37: Detailed images of samples from Site 2.*


*Figure 38: Images of samples 1, 2, and 3, taken with an Olympus SZ-6045 microscope. These images were used to identify samples as fragments of woody stem, (Sample 2) root, (Sample 1) or fibrous plant material (Sample 3).*

## Site 3 - Rhythmically Bedded Sediments

Rhythmically bedded sediments found in a cut bank of the Israel River towards the southern limit of the Bailey's Stage were interpreted as bedded stream deposits, based on the presence of small lenses of gravel and darker, finer grained layers (Thompson, pers comm.).

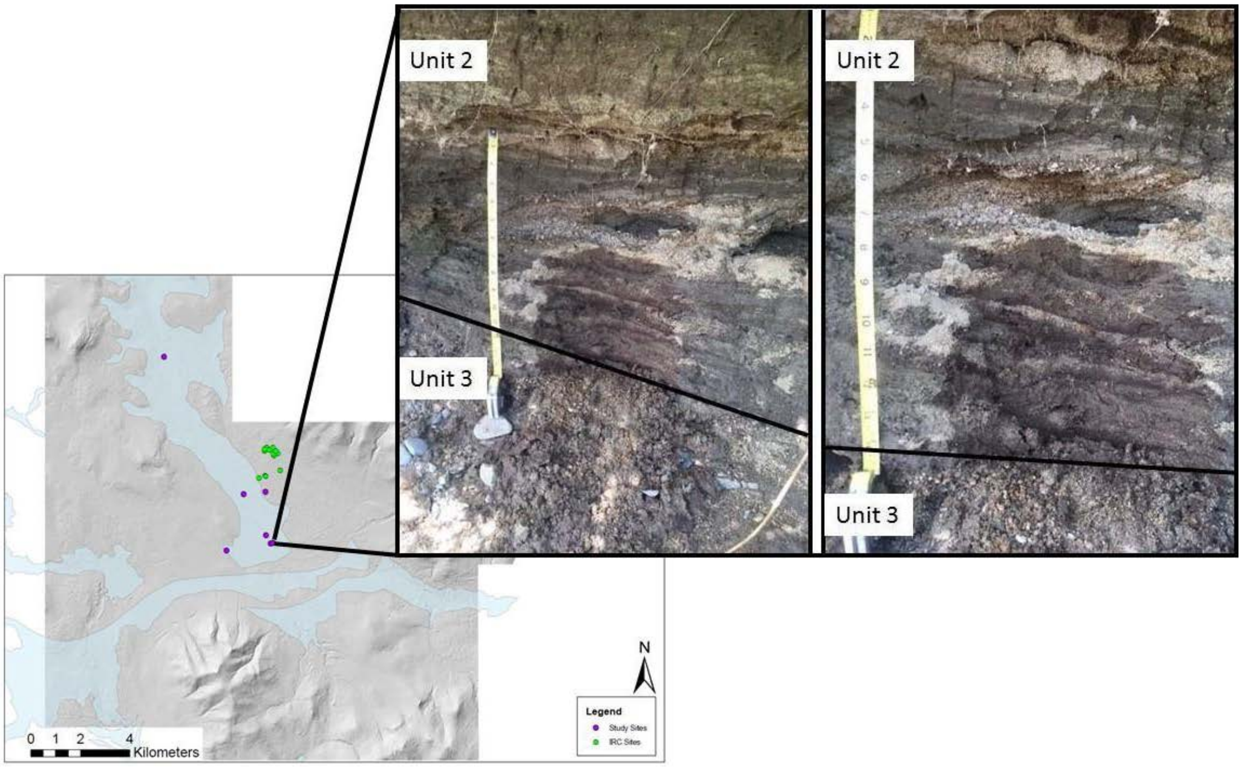



*Figure 39: Site 3, (elevation 1,085 ft, 331 m) bedded sediments visible in a cut bank of the Israel River towards the southernmost limit of the Bailey's stage of Glacial Lake Israel. Unit 1 (not pictured) is ~2.5 ft (0.8 m) of fine silty/sandy brown topsoil. Unit 2, ~17 in (0.4 m) thick, is layered light and dark silty fine sand. Intermixed in these layers were lenses of medium sand including pebble size subangular clasts. Unit 2 at this site is interpreted as similar to Unit 2 from Site 2. Unit 3, about 2 ft (0.6 m) of which was visible above the river, was composed of a tan medium sand matrix with gravel to cobble size rounded clasts.*

## Sites 4 and 5 - Wave Cut "Island"

The elevation of the "island" feature seen in a (315,45) hillshade (middle) was found to be consistent with the elevation of the Bailey's Stage spillway at Cherry Pond, indicating that the top of this feature was likely above the Bailey's Stage water level and was created by the carving action of waves on the lake surface.

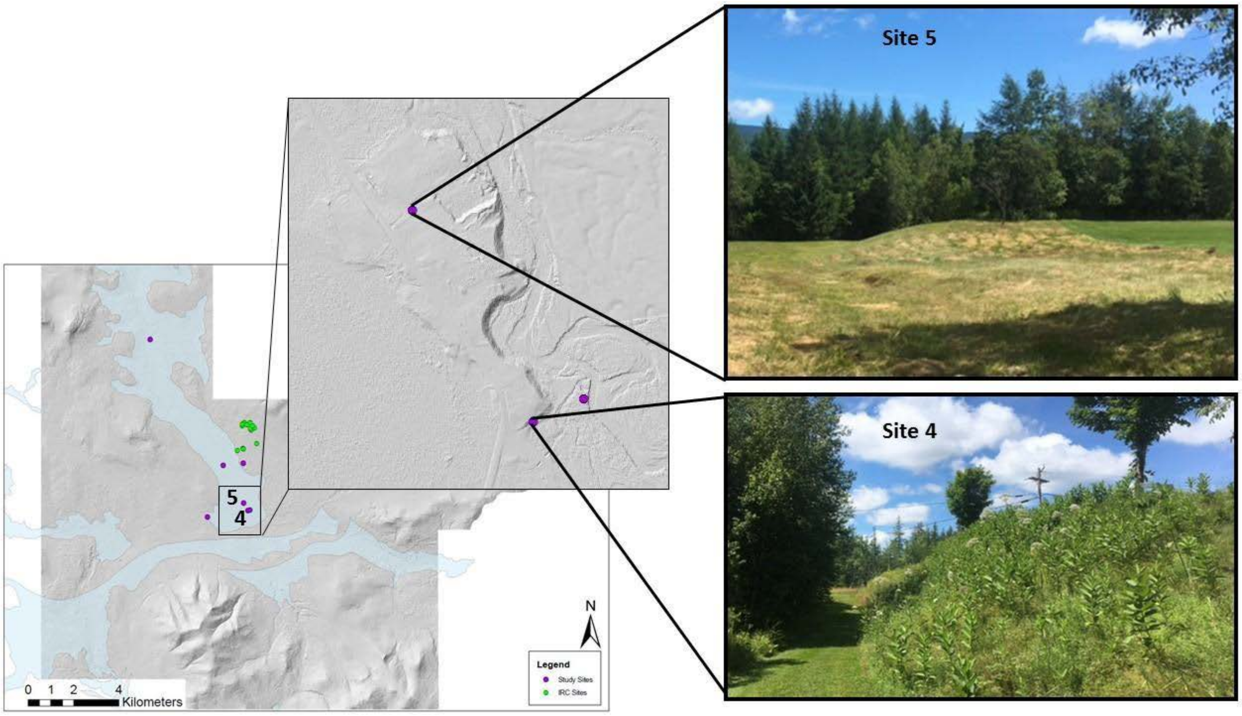



*Figure 40: Sites 4 and 5: wave-cut shorelines visible on property directly west of the Israel River (elevations 1,110 ft, 338 m). The dramatic relief of this figure stands out against the surrounding even lake bottom.*

### Site 6 - Till Hummock

A test pit in a till hummock next to route 115a confirmed the existence of tan silty, sandy till with clasts of pebble to boulder size. These hummocks border the shoreline of the Bailey's, Alderbrook, and Riverton stages and are the location of the IRC sites.

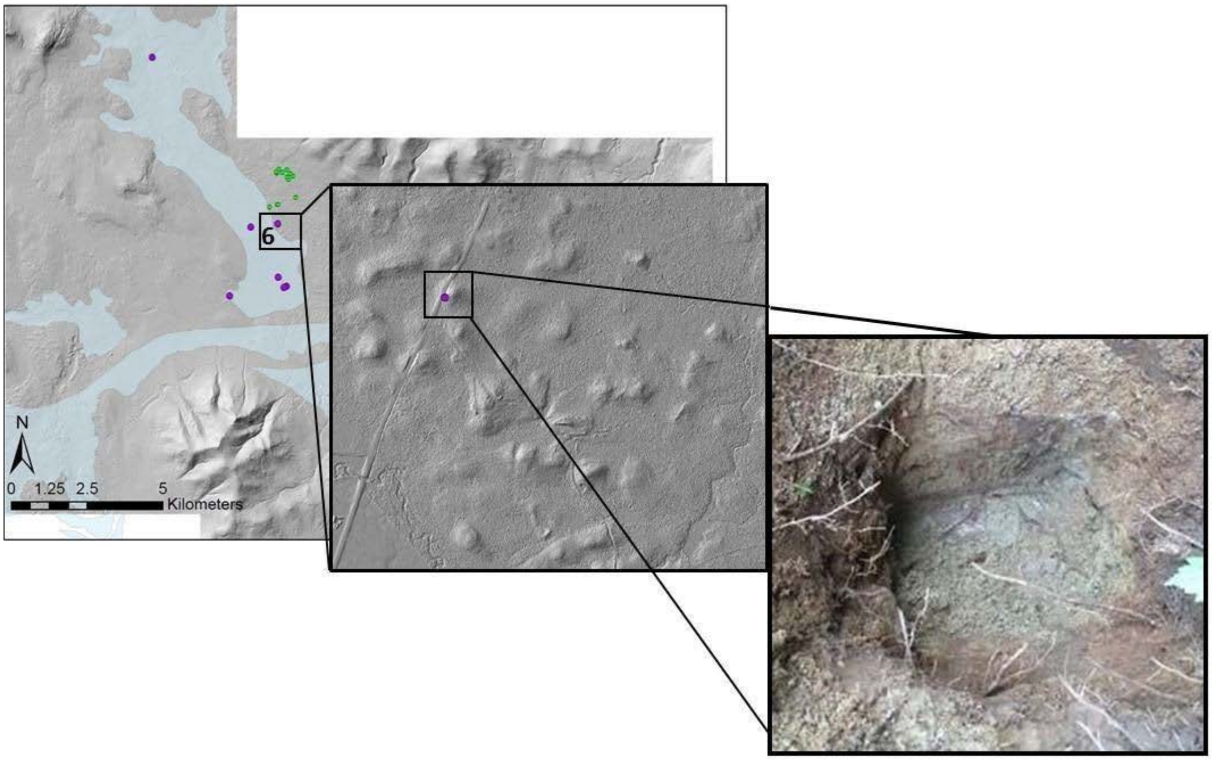



*Figure 41: Site 6, (elevation 1,116 ft, 340 m) test pit in a till hummock just outside of the Bailey's Stage shoreline of Glacial Lake Israel, across route 115a from the Israel River Complex sites. Till (farthest right image) was composed of a tan silty, sandy matrix with angular clasts of pebble to boulder size. Above the till was ~2.5 ft (0.8 m) of topsoil.*

### Site 7 - Bailey's Stage Spillway at Cherry Pond

The elevation of this spillway was found to be consistent with the elevation of the wave-cut features identified at sites 4 and 5 (see Figure 40), confirming the spillway elevation for the Bailey's Stage. A test pit in the Cherry Pond spillway showed till overlain by bog moss.

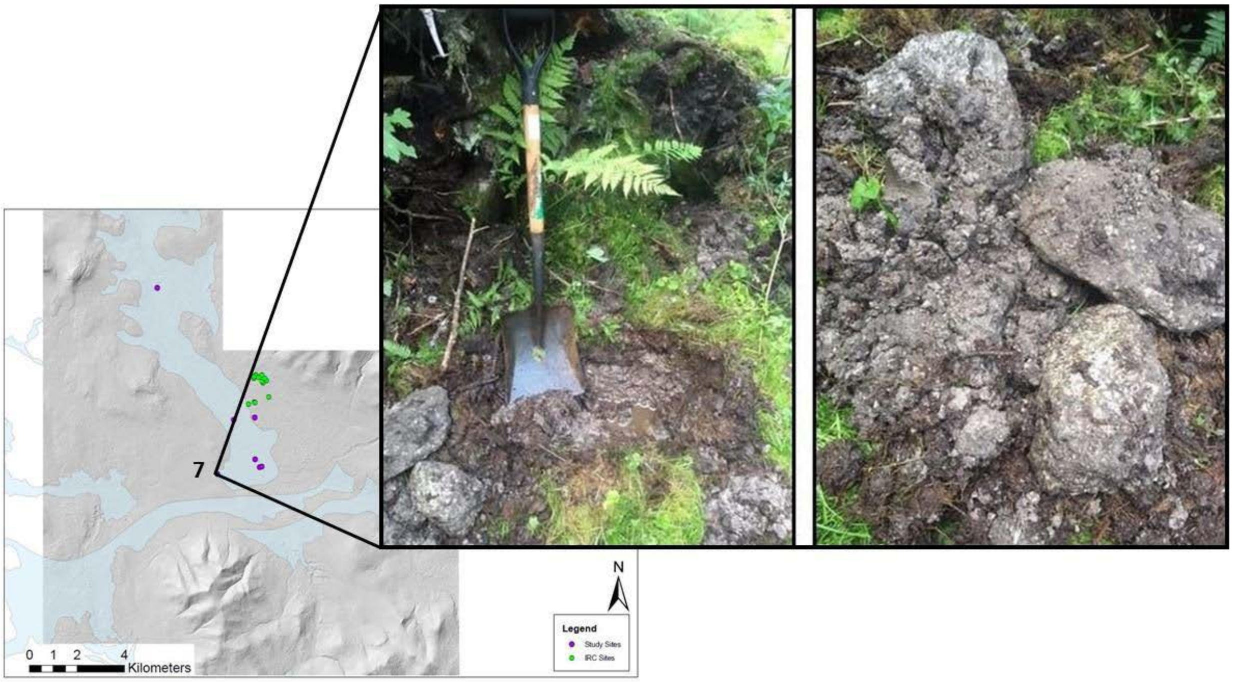



*Figure 42: Test pit in the spillway of the Bailey's Stage of Glacial Lake Israel, near Cherry Pond, accessed by way of the Jefferson Rail Trail in Pondicherry Reserve (elevation 1,110 ft, 338 m). Test pit showed gray sandy, gravelly, till with angular gravel to boulder size clasts, overlain by bog moss.*

## Additional Radiocarbon Samples

In addition to samples collected from the cut bank at Site 2, a sample of wood was obtained from Mr. Neil Gross and fragments of calcined bone were obtained from Dr. Richard Boisvert for radiocarbon dating at the NOSAMS lab. The date on the wood fragment, identified as Alnisedi, (eastern hemlock) was 9,730 +/- 80 radiocarbon years or 11,140 cal BP (Huggett, pers comm.; Table 2) while the bone fragments were not able to be dated due to inadequate collagen. The locations of these samples can be seen in Figure 17.

### Bone Fragment Samples

20 bone fragments (Figure 43) were obtained for dating from Dr. Boisvert with the goal of further constraining the occupational period of the IRC sites. These fragments were excavated from Site 27-CO-74 (the Jefferson VI site) in 2013 from an area called the Salvage Block, before it was destroyed in the construction of a septic system. See Figure 20 for an aerial image and site plan of the Salvage Block. These bone fragments were determined to contain only a minimal

amount of collagen by the collagen extraction service used at the NOSAMS lab at Woods Hole, where the fragments were sent for dating. Thus, no dates from the fragments were obtained.


*Figure 43: Bone fragments, excavated from Israel River Complex site 27-CO-74 (the Jefferson VI site) in October of 2013, obtained from Dr. Richard Boisvert during fieldwork. Bag numbers correlate to the depth from which the fragments were excavated. All samples came from between 237-247 cm below the surface, which correlates to Zone II levels 3 and 4 of the SW quadrant of the 1m x 1m excavation block shown in Figure 44, below (highlighted in red).*

The bone fragments were excavated from the roughly 0.5 x 1 m area highlighted with a red square in Figure 44; this quadrant contained the majority of the faunal assemblage excavated from the Salvage Block. The inset in Figure 44 shows all artifacts excavated from the area, with the chipped stone assemblage marked by gray dots and further differentiated into Munsungun Chert, Normanskill Chert, Mount Jasper Rhyolite, Undifferentiated Chert, Undifferentiated Rhyolite, Indeterminate stone, and FCR (fire cracked rock) by different colored dots. See figure legend for color codes.

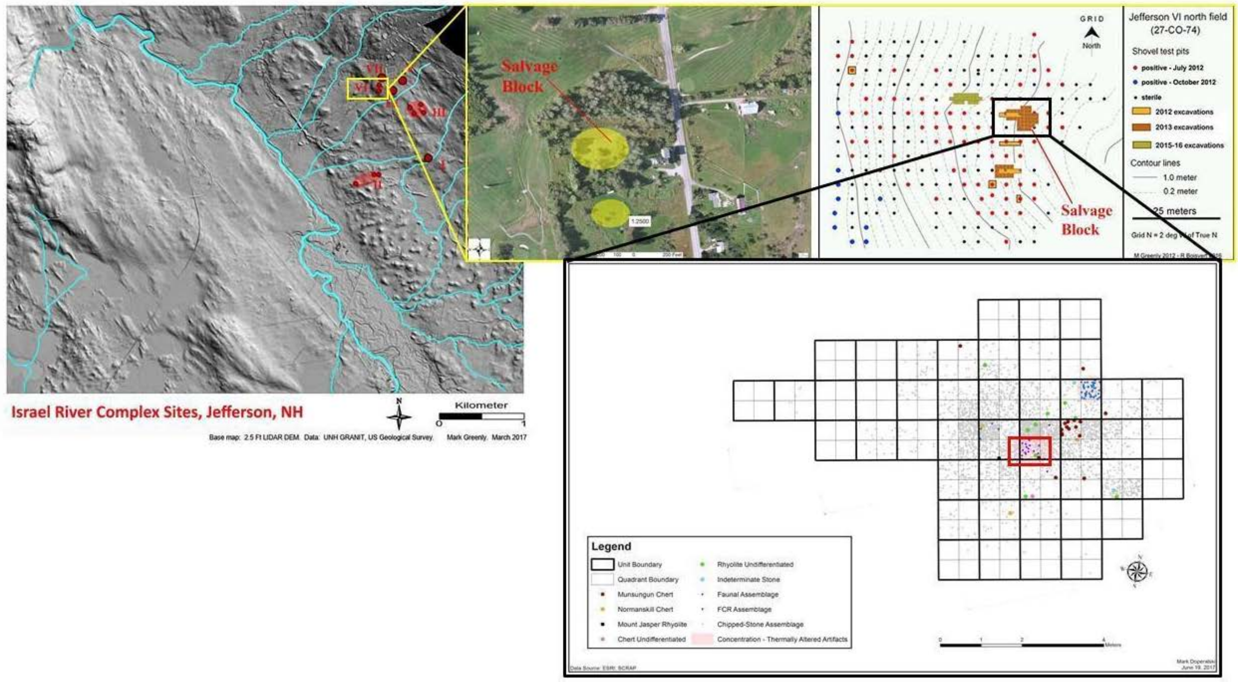



*Figure 44: Hillshade showing the IRC sites with inset of an aerial photo and site plan of the Jefferson VI site (top right). Bone fragments obtained from Dr. Boisvert for radiocarbon dating were excavated from the Salvage Block at the Jefferson VI site in 2013. The Salvage Block is highlighted in yellow in the aerial photo (middle) and in dark orange on the site plan (top right). An inset of the Salvage Block (bottom right) shows the entire faunal assemblage excavated from the site as purple dots. (All images from Boisvert, pers comm.)*

## Additional Wood Sample

In addition to the organic samples collected from Site 2, a wood fragment (measuring 23.3 cm x 4.5 cm) was obtained from Mr. Neil Gross, who collected the fragment from the Ingerson property in 2004 (Ingerson, pers comm.). The fragment was dated to an age of 9,730 +/- 80 radiocarbon years, or 11,140 cal BP (Table 2). Images of this fragment can be seen in Figure 45. The fragment (identified as Alnisedi (eastern hemlock)) was part of a larger piece of wood (probably a portion of a tree trunk) found during construction of a garage on the Ingerson property. This piece of wood was found buried approximately 8 ft (2.4 m) below the ground surface, on top of hardpan, (although this layer is interpreted as Bailey's Stage lake sediments) and overlain by a layer of clay approximately 5 ft (1.8 m) thick (Gross and Ingerson, pers comm.). This clay layer is interpreted as glacial sediment deposited into the Alderbrook Stage of Glacial Lake Israel.

Table 2: *Radiocarbon data (NOSAMS, 2018) for Sample 2 (woody stem) and fragment of Alnisedi (eastern hemlock) obtained from the Ingerson property. The Alnisedi fragment (upper row in table) returned a date of 9,730 +/- 80 radiocarbon years, while Sample 2 (bottom row in table) returned a modern date.*

| Receipt # | Date Reported | Submitter Identification | Type | Process | Accession # | F Modern | Fm Err | δ13C Corr | Age | Age Err | δ13C | δ13C Source | Δ14C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 149419 | 2/2/2018 | NG1212017 | Plant/ Wood | (OC) Organic Carbon | OS-138289 | 0.2979 | 0.0030 | * | 9,730 | 80 | -26.5 | Measured | -704.53 |
| 149420 | 2/2/2018 | IR 10202917A | Plant/ Wood | (OC) Organic Carbon | OS-138290 | 1.0877 | 0.0024 | * | >Modern | | -27.03 | Measured | 78.9 |

* The asterisks indicate that the radiocarbon result was corrected for isotopic fractionation using unreported d13C values measured on the accelerator.
The Fraction Modern reported requires no further correction for fractionation.
Stable isotope d13C results reported in column 12 should not be used to post-correct.

Figure 45: *Left: Inner side of the Alnisedi fragment. Right: Outer (bark) side of the fragment. A small portion of this larger fragment was dated at the NOSAMS lab.*

## Lake Level Modeling

The results of lake level modeling in ArcMap were compiled into maps and combined with approximations of ice cover positions taken from Thompson et al., 2017. See Appendix C for high quality versions of all maps. All lake level polygons shown are overlain at 50% transparency on a (315, 45) hillshade, and all ice cover polygons are shown with a stippled white pattern at 0% transparency. Lake level maps are for the most part limited to the boundaries of the study area; where stages extend beyond the study area a description is provided.

### Bowman Stage Model

The Bowman Stage is the first and oldest stage of Glacial Lake Israel, dating to approximately 14 cal ka (Thompson, pers comm.). This age is bracketed by the approximate age (~14 cal ka BP) of the Randolph moraines, seen in Figure 4 (Thompson et al., 2017). These moraines give an upper age estimate for the beginning of the Bowman Stage. The total area of the Bowman Stage given by the model is ~4 square miles; the model gives lake dimensions of ~0.6 miles in length and ~8 miles in width. The Bowman Stage model extends beyond the study area to the southeast and southwest, wrapping around the base of Cherry Mountain in the southern half of the study area. The ice cover margin damming the lake was approximated from Thompson et al., 2017, while the northeast margin of the ice front was approximated based on elevations of the northeast valley wall taken from LiDAR as well as from linear features indicating scour by glacier ice.

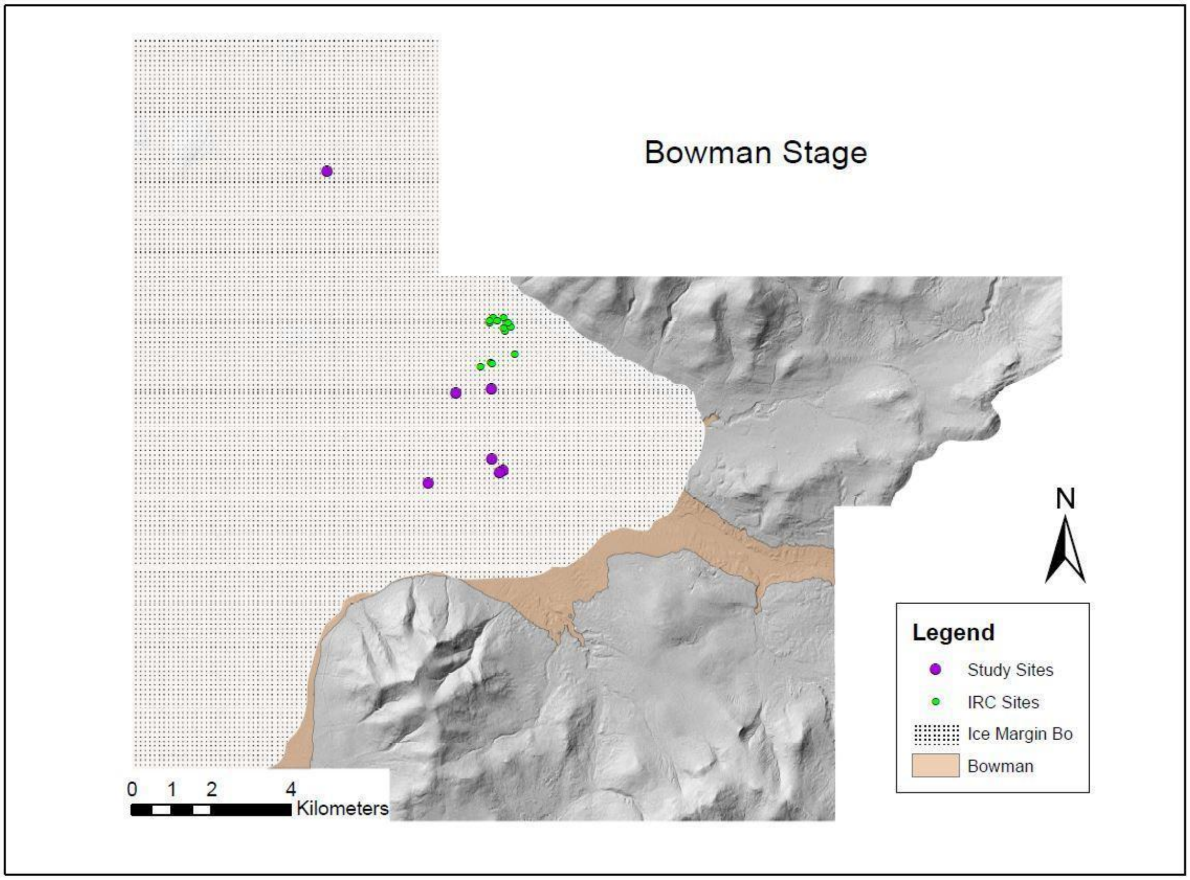



*Figure 46: Results of lake level modeling for the Bowman Stage of Glacial Lake Israel. A spillway elevation of 1,500 ft (457 m) was used to model this stage.*

### Pine Knob Stage Model

The Pine Knob Stage model extends beyond the study area towards Carroll and Bethlehem in the southwest (Thompson et al., 2017). The Pine Knob Stage is the second stage of the lake, dating to somewhere around 13.9 cal ka (Thompson, pers comm.). The total area of the Pine Knob Stage given by the model is ~5 square miles; the model gives lake dimensions of ~0.5 miles in length and ~9 miles in width. Visible retreat measuring ~1 mile is observed from the Bowman Stage model in the direction of southwest to northeast, following retreat of the ice front. For purposes of consistency, the ice cover damming the lake was approximated from Thompson et al., 2017 in an identical fashion to that of the Bowman Stage. This method may not, however, be the most accurate representation of actual ice sheet retreat.

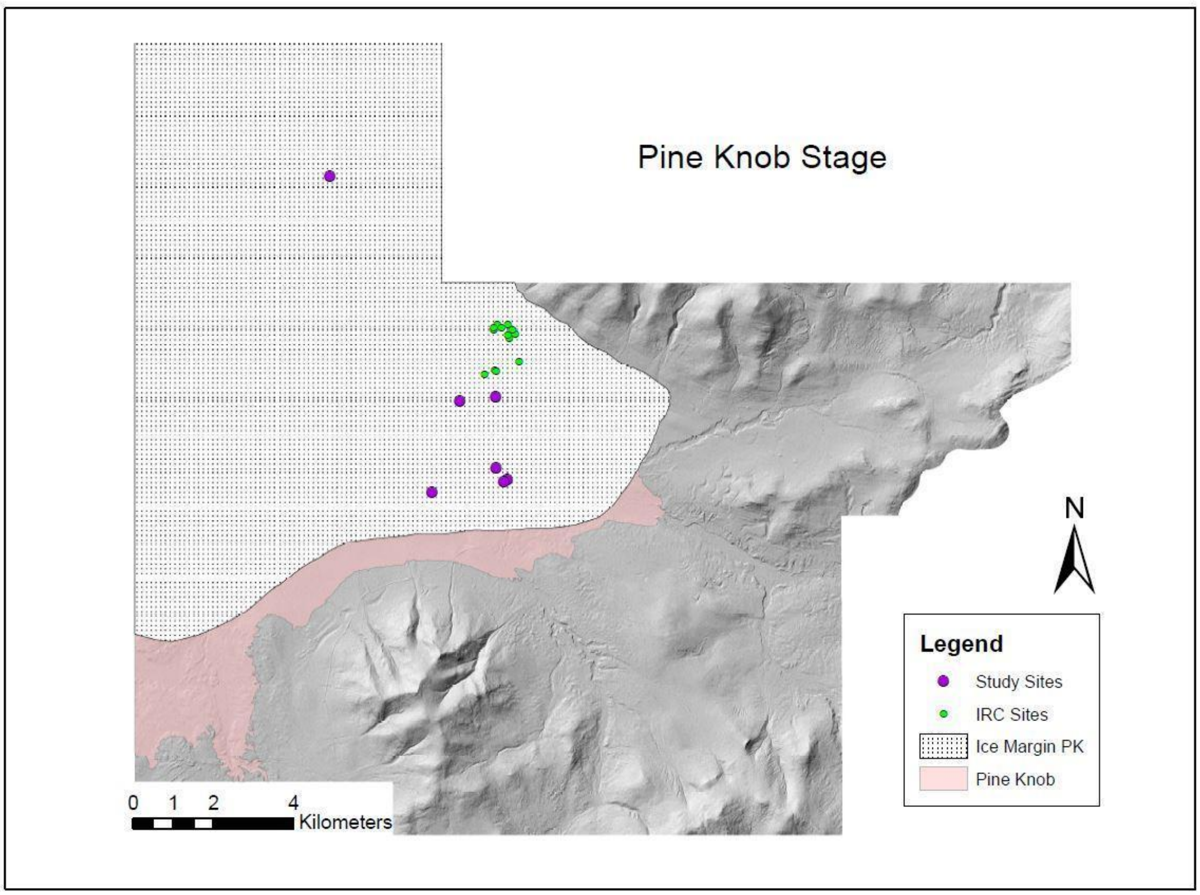



*Figure 47: Results of lake level modeling for the Pine Knob Stage of Glacial Lake Israel. A spillway elevation of 1,269 ft (387 m) was used to model this stage.*

### Bailey's Stage Model

The Bailey's Stage is the third stage of Glacial Lake Israel, the timing of which is constrained by a basal radiocarbon age of 13.6 cal ka from a core taken at Cherry Pond (Thompson et al., 2017). This age marks the minimum estimate for the end of the Bailey's Stage, meaning that the collective duration of the Bowman, Pine Knob, and Bailey's stages is roughly 400 years (Thompson et al., 2017; Thompson, pers comm.). The total area of the Bailey's Stage given by the model is ~12.5 square miles; the model gives lake dimensions of ~8.3 miles in length and ~1.3 miles in width. Recession of the lake shoreline from the southwest to northeast in the amount of ~0.9 miles was measured, following retreat of the ice front. The Bailey's Stage model extends beyond the study area to the north. The ice cover damming the lake was approximated from Thompson et al., 2017 and shows the ice front extending from the ice dam of Lake Whitefield (the westernmost edge of the ice front, from Thompson et al., 2017) eastwards to the Bailey's Stage ice dam.

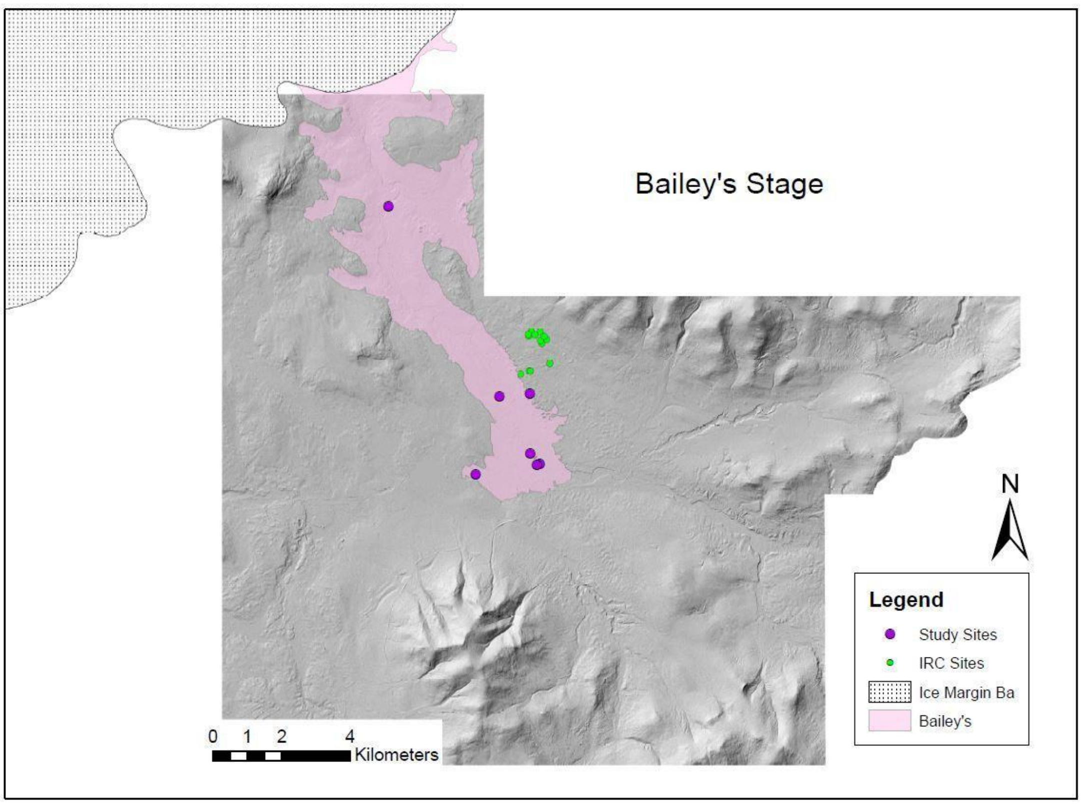



*Figure 48: Results of lake level modeling for the Bailey's Stage of Glacial Lake Israel. The Bailey's Stage is the third stage of the lake, timing of which is constrained by a basal radiocarbon age of ~13.6 cal ka from the Cherry Pond Spillway (Thompson et al., 2017). A spillway elevation of 1,110 ft (338 m) was used to model this stage.*

## Alderbrook Stage Model

The Alderbrook Stage is the fourth stage of Glacial Lake Israel, the timing of which is constrained by the radiocarbon age of the Alnisedi (eastern hemlock) fragment, 11,140 cal BP. The Alderbrook Stage model is shown dammed by a till ridge extending across what is now the channel where the Israel River crosses under US Highway 2 in Riverton, NH. This ridge-like till feature is inferred to have dammed residual water from the Bailey's Stage at this location, creating this fourth stage before the subsequent Riverton Stage. The total area of the Alderbrook Stage given by the model is ~2.9 square miles; the model gives lake dimensions of ~5.0 miles in length and ~0.4 miles in width. Reduction of the lake area towards the center of the valley measuring ~0.2 miles along the eastern shoreline and ~0.3 miles along the western shoreline is visible from the Bailey's Stage model in addition to northward recession measuring ~1.0 mile and southward recession to the location of the till dam, measuring ~1.4 miles from the northernmost extent of the preceding Bailey's Stage.

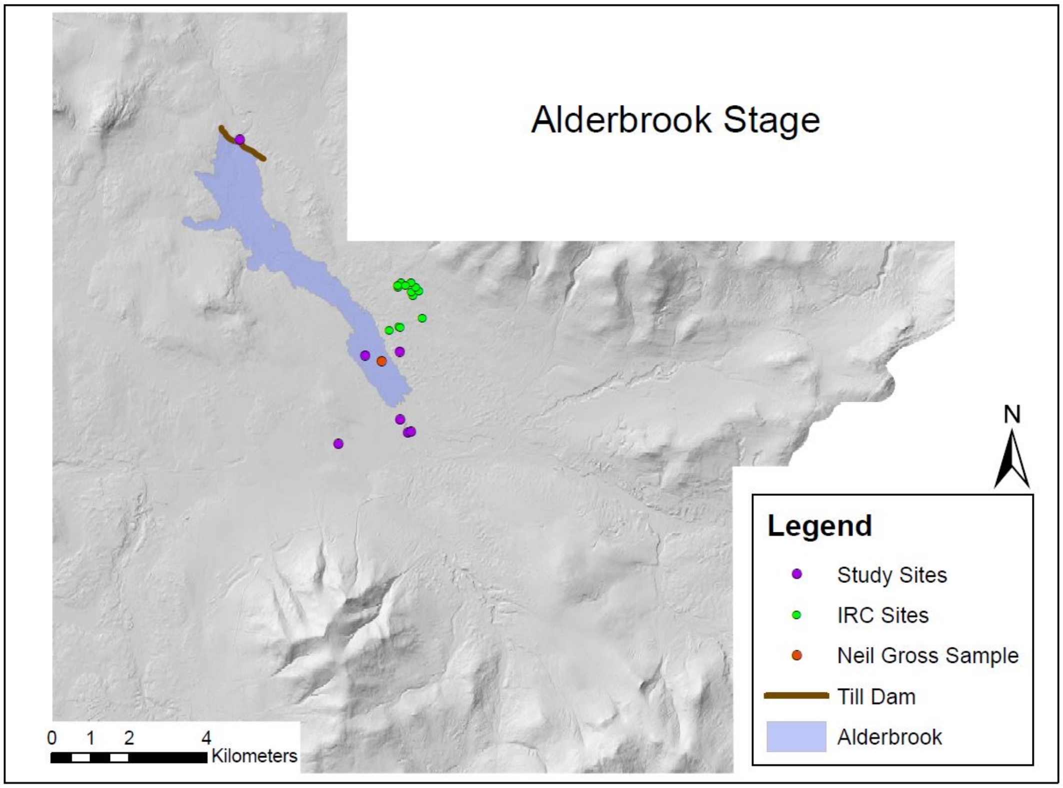



*Figure 49: Results of lake level modeling for the Alderbrook Stage of Glacial Lake Israel. The Alderbrook Stage is the fourth stage of the lake, timing of which is constrained by a radiocarbon age of ~11 cal ka from a fragment of Alnisedi (eastern hemlock) found between Bailey's and Alderbrook lake sediments. A spillway elevation of 1,080 ft (329 m) was used to model this stage.*

### Riverton Stage Model

The Riverton Stage is the fifth and youngest stage of the lake, dating to younger than ~11 cal ka BP. The Riverton Stage model is shown dammed by a till ridge extending across what is now the channel where the Israel River crosses under US Highway 2 in Riverton, NH. This location exhibits characteristics of a spillway, namely the consistent elevation of 1,044 ft (318 m) across both banks of the channel (Thompson, pers comm.). This ridge-like till feature is inferred to have dammed residual water from the Alderbrook Stage at this location, creating this final Riverton Stage. The total area of the Riverton Stage model is ~0.8 square miles; the model gives lake dimensions of ~2.0 miles in length and ~0.4 miles in width. Reduction of the lake area towards the center of the valley measuring ~0.18 miles along the eastern shoreline and ~0.14 miles along the western shoreline is visible from the Alderbrook Stage model in addition to northward recession measuring ~3.0 miles.

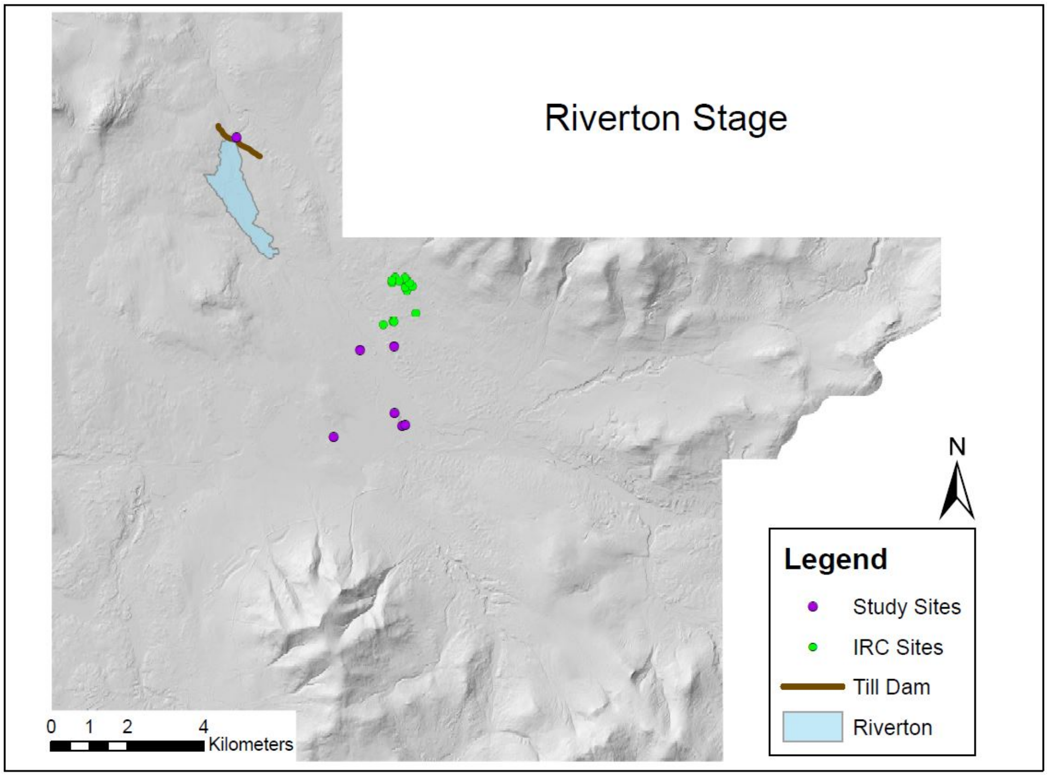



*Figure 50: Results of lake level modeling for the proposed Riverton Stage of Glacial Lake Israel. A spillway elevation of 1,044 ft (318 m) was used to model this stage.*

## Landscape Classification Mapping

Landscape classification was performed through analysis of LiDAR and polygons were drawn with the objective of delineating landscape types and determining general distribution patterns of these types. Lake bottom polygons were drawn at the transition from hummocky till to smooth valley floor along the extent of the Israel River valley, and color-coded based on lake stage (Figure 51). These lake bottom polygons were then compared to the lake levels obtained through spillway elevation modeling. Transitional lake bottom marks periods between the mapped Bowman, Pine Knob, and Bailey's stages where lake levels were falling as the ice cover moved from southeast to northwest. No transitional lake bottom was mapped for the transition from the Bailey's to Alderbrook or the Alderbrook to Riverton Stage because of the complete overlap of the Alderbrook, Riverton and Bailey's lake bottom polygons.

Lake bottom covers approximately 17 square miles (15% of the study area), and sits at elevations ranging from ~1,000 ft to ~1,100 ft. Hummocky till covers approximately 46 square miles (39% of the study area), and sits adjacent to lake bottom areas at elevations ranging from ~1,100 ft to ~1,500 ft. Smooth till borders hummocky till at higher elevations (ranging from ~1,200 ft to ~2,300 ft) and covers 39 square miles -- approximately 33% of the study area. Finally, bedrock was mapped at the highest elevations ranging from 1,700 ft to 3,600 ft, and covers the smallest fraction of the study area: 15 square miles, or 13%.

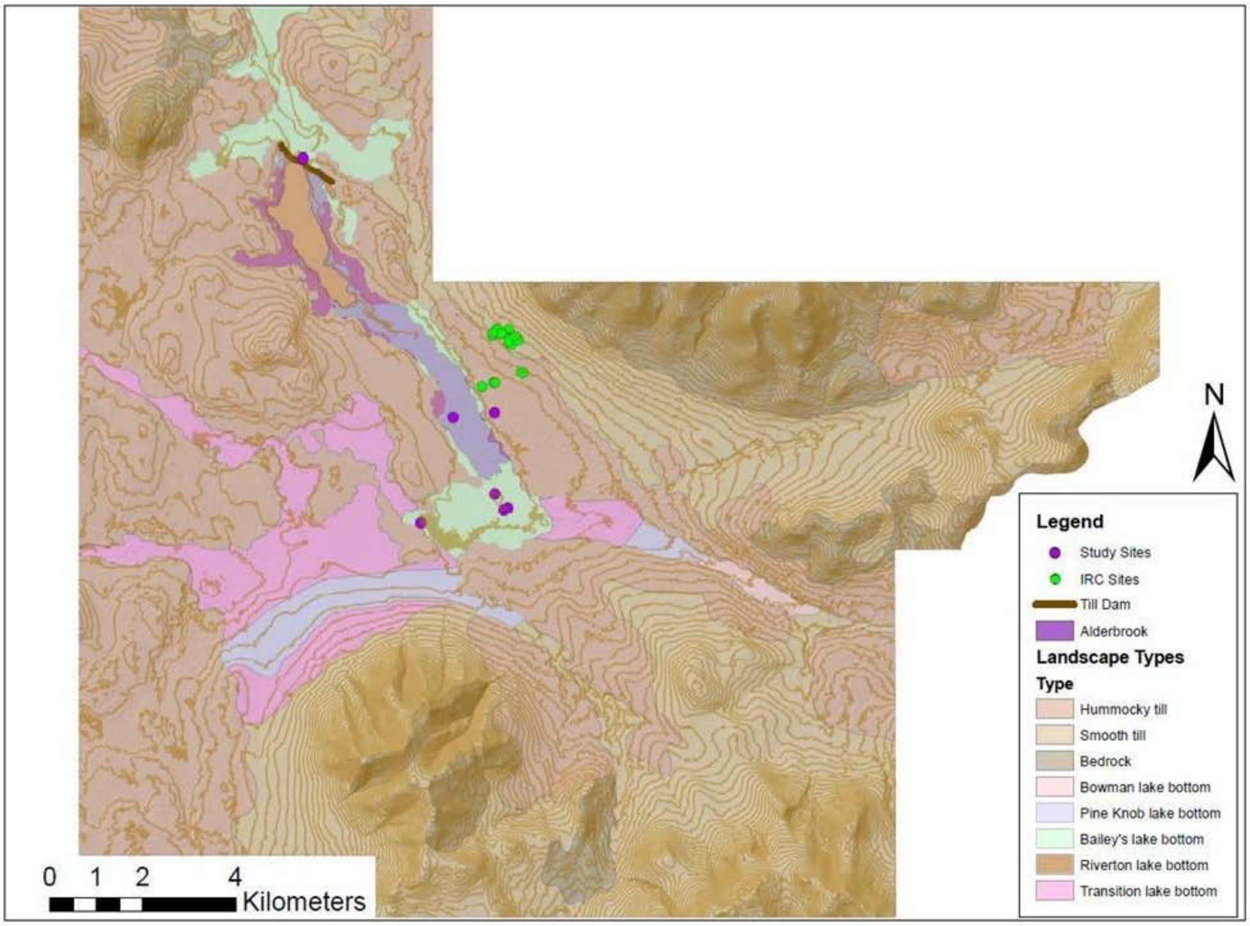



*Figure 51: Results of landscape type mapping for the extent of the study area. Contour interval is 50 ft. A general pattern can be seen in the distribution of landscape type polygons. Bordering lake bottom on nearly all sides is hummocky till, while hummocky till is in turn bordered at higher elevations by smooth till. Bedrock was identified at the highest elevations where till was unable to be deposited, and/or on steeper gradients. See Figures 52-55 for images of these landscape types as they appear in LiDAR. Landscape type polygons are shown overlain on the Alderbrook Stage lake bottom model.*

## Landscape Classification Units

Examples of landscape units (bedrock, smooth till, hummocky till, and lake bottom) are shown, with 50 ft contours, to emphasize the different elevation gradients at which the landscape types are found. Descriptions are given of the appearance of the different landscape types on LiDAR.

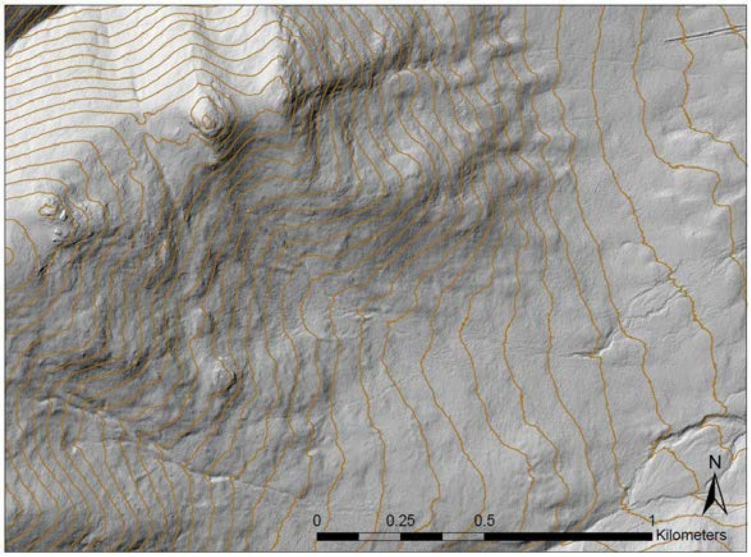



*Figure 52: Example of a bedrock outcrop as seen in LiDAR. Image is shown with a (315, 45) hillshade at 0% transparency. Bedrock appears as a roughly textured surface on areas of high elevation and/or steeper gradient. Contours show high relief.*

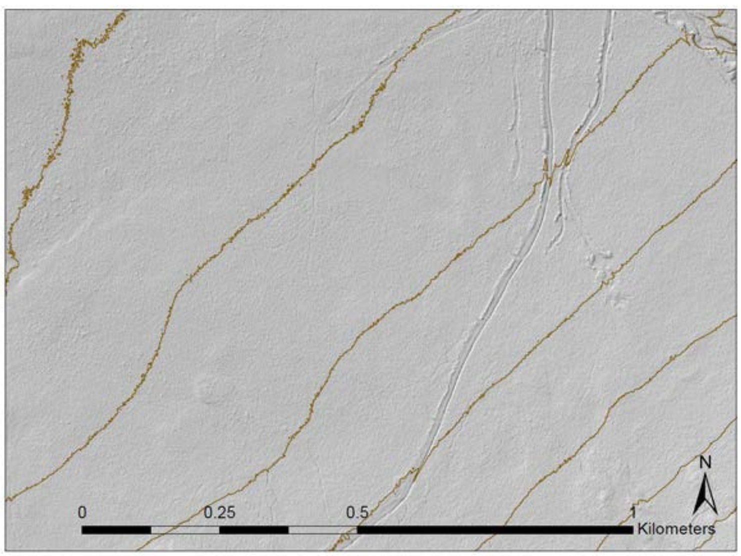



*Figure 53: Example of the "smooth till" landscape type as seen in LiDAR. Hillshade shown is (315, 45) at 0% transparency. Smooth till such as this can be described after Koe, 2016 as glacial nondissected till, smooth in texture with a rounded relief. Smooth till was found on areas of mid elevation on the walls of the Israel River Valley, between bedrock and hummocky till. Contours show medium relief.*

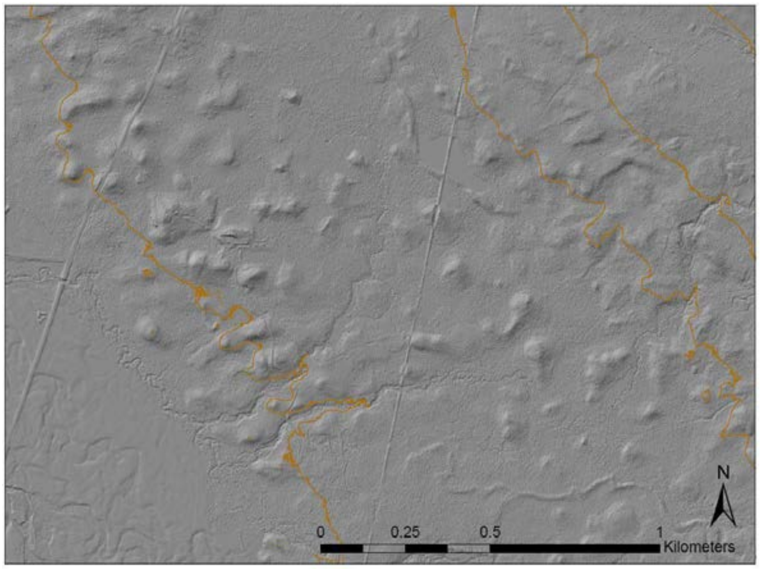



*Figure 54:* *Example of the "hummocky till" landscape type as seen in LiDAR. Hillshades shown are (45, 45) at 0% transparency with 10% contrast overlain by (290, 20) at 50% transparency. Hummocky till appears as an otherwise smooth surface peppered with sharply delineated round till mounds, approximately ranging from 150 ft to 670 ft in diameter throughout the study area. The transition to lake bottom can be seen on the left side of the figure, sharply delineated by the boundary of the hummocky and contrastingly smooth landscapes. Contours show medium to low relief.*

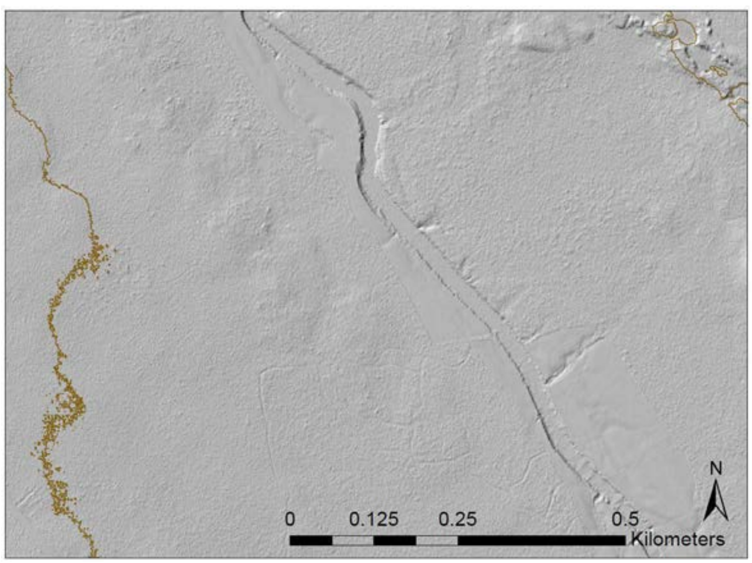



*Figure 55:* *Example of the "lake bottom" landscape as seen in LiDAR. Image shown with a (315, 45) hillshade at 0% transparency. Lake bottom appears similar to smooth, nondissected till but can be distinguished by its existence between regions of hummocky till and its presence only in the floor of the Israel River Valley at the lowest elevations. Image shows the active channel of the Israel River and an otherwise uniform, even landscape. Contours show low relief.*

### Comparison of Lake Bottom Polygons to Lake Level Models

Lake level models of the Bailey's, Alderbrook, and Riverton stages were overlain on maps showing relevant lake bottom polygons in order to compare the results of these two mapping approaches. In all three cases, lake bottom polygons fall mostly within the limits of the modeled lake levels. However, the Bailey's Stage lake bottom area underestimates the model significantly; this indicates that the boundary between smooth lake bottom and hummocky till does not accurately approximate lake levels given by modeling. The Alderbrook Stage, however, closely approximates the smooth till-hummocky till boundary.

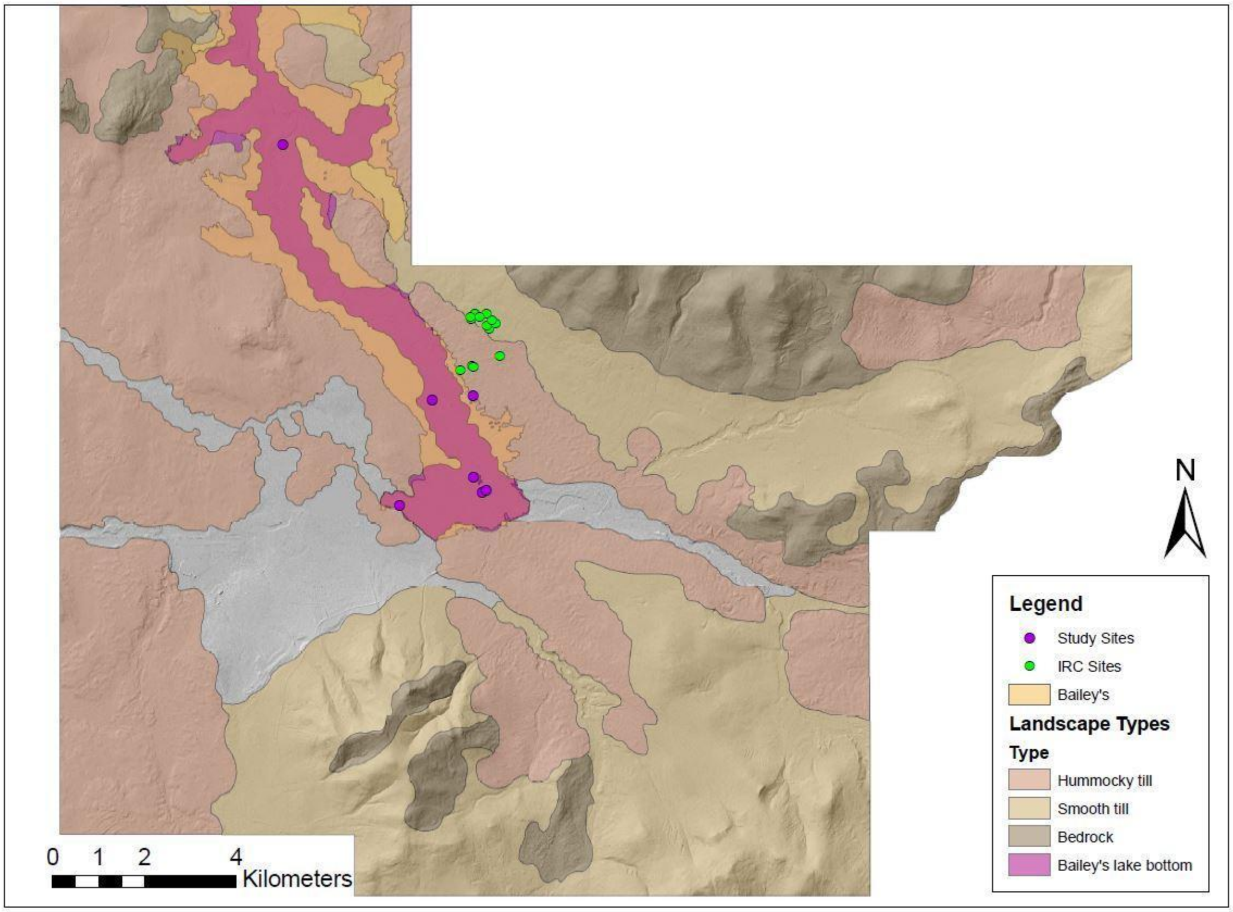



*Figure 56: Comparison of Bailey's Stage lake bottom area (pink polygon) to Bailey's Stage area (orange polygon) obtained through modeling in ArcMap. All but some peripheral areas of the lake bottom polygon overlap with the Bailey's Stage lake level modeled through the spillway elevation of 1,110 ft. However, the lake bottom polygon significantly underestimates the lake area covered by the model. This shows that the Bailey's Stage model does not follow the boundary between smooth lake bottom and hummocky till for its shoreline; if this was the case, the lake bottom polygon would not underestimate the model. Overlap of the Bailey's Stage model and areas of smooth till is also visible in the northeast corner of the study area.*

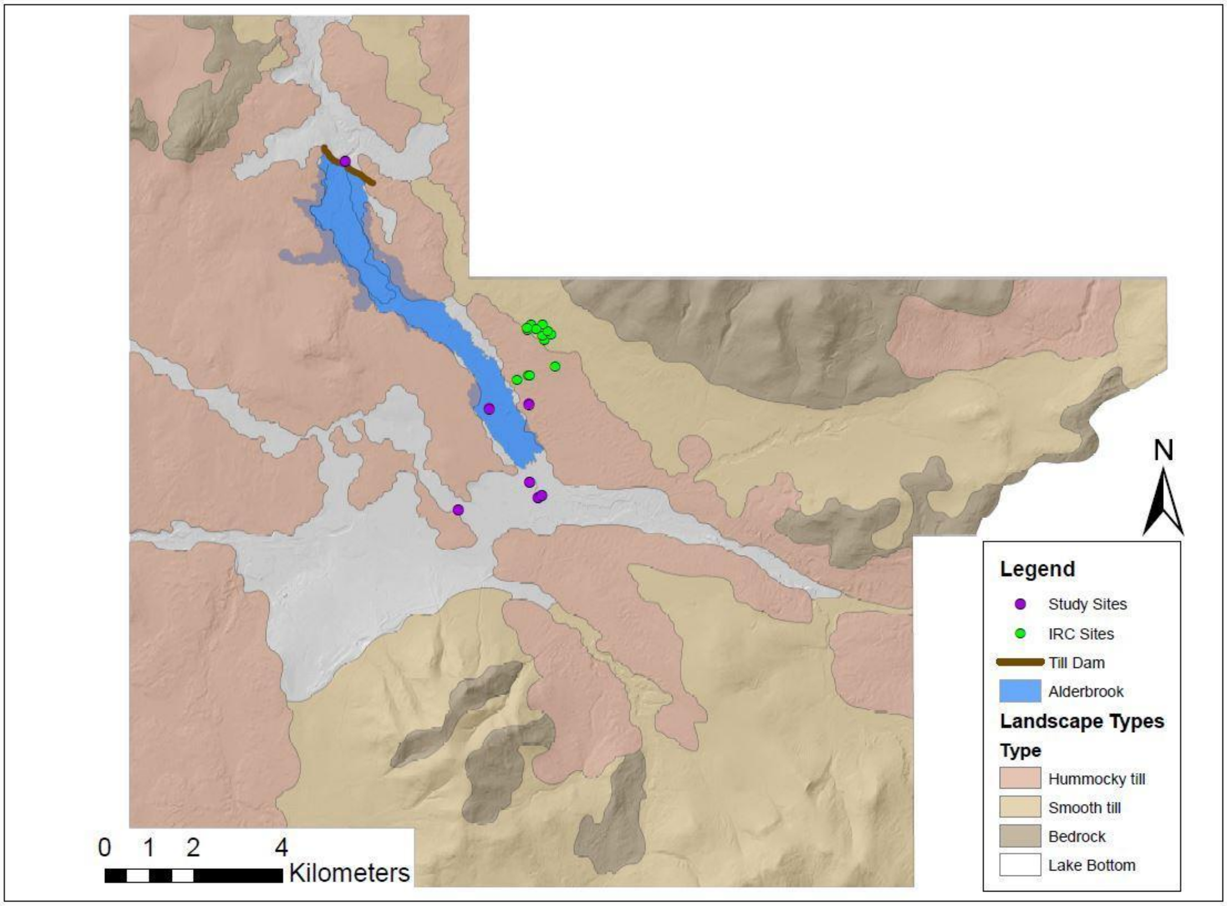



*Figure 57: Comparison of Alderbrook Stage shoreline model created in ArcGIS (blue polygon) to Bailey's Stage lake bottom area (no polygon, symbolized with (315,45) hillshade) obtained through landscape type mapping. All but some peripheral areas of the model polygon overlap with the Bailey's Stage lake bottom. The lake bottom does not significantly underestimate the lake area covered by the Alderbrook model. This shows that the Alderbrook Stage model does approximately follow the boundary between smooth lake bottom and hummocky till for its shoreline. (Riverton Stage shown outlined under the Alderbrook polygon.)*

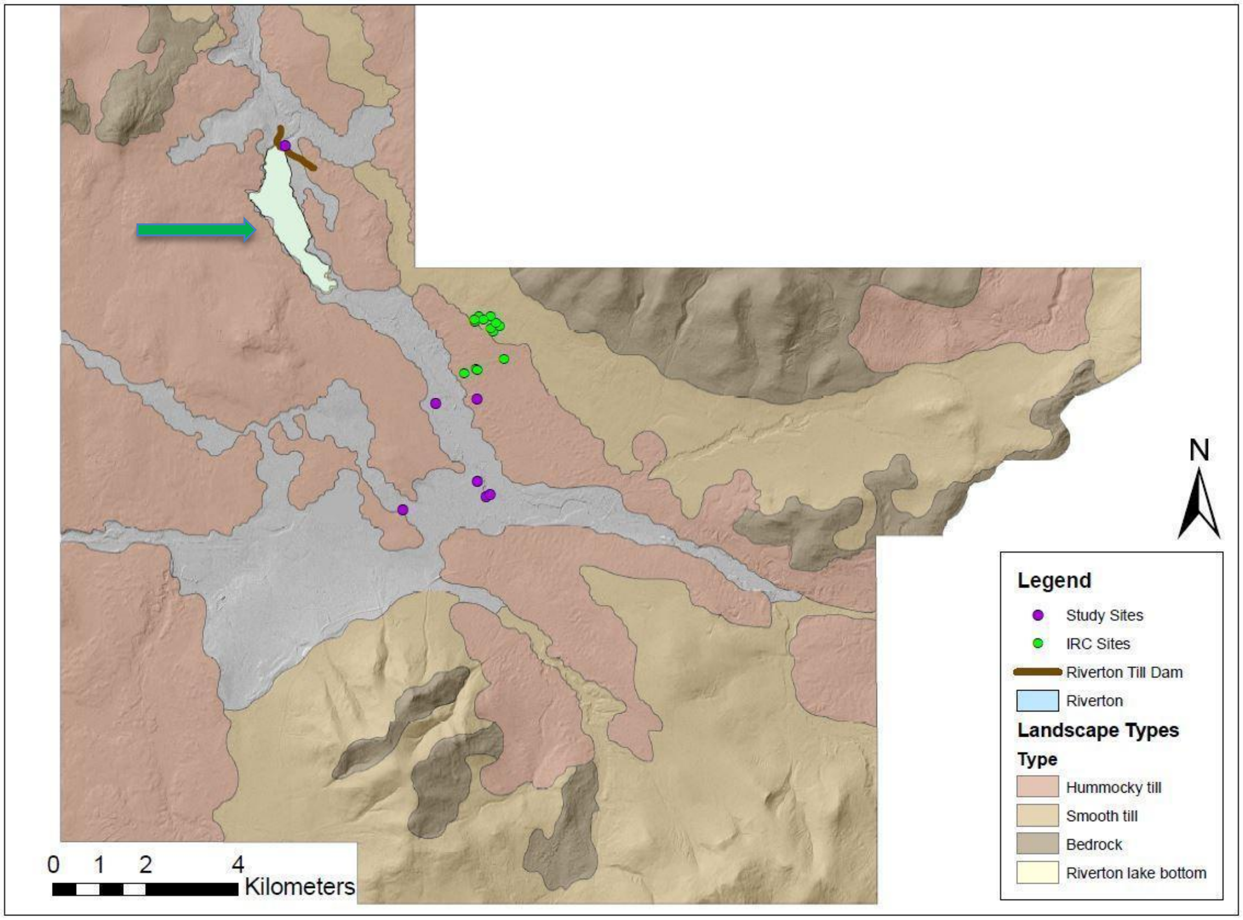



*Figure 58: Comparison of Riverton Stage lake bottom area (yellow polygon) to Riverton Stage area (blue polygon) obtained through modeling in ArcMap. The light green polygon (denoted with a green arrow) created by complete overlap of the yellow and blue polygons shows that both fall within the limits of the Bailey's Stage lake bottom (represented as a (315,45) hillshade).*

**Elevation Profiles**

Elevation profiles were drawn at key locations throughout the study area to assist in describing landscape features and evidence of changes in lake level, ice position, etc. All distances are in feet. Locations of the profiles are shown on a (315, 45) hillshade with the Bailey's Stage model overlain where appropriate.

### Bailey's Stage and Jefferson II Profile

Profile shows a transect beginning in hummocky till on the western side of the Bailey's Stage model and ending at one of the sites in the Jefferson II group in hummocky till on the eastern side of the Bailey's Stage model. Till hummocks are visible in the profile on both sides of the lake, while a pronounced dip in elevation at approximately 5,800 ft across the transect marks the active channel of the Israel River. Evidence of the Bailey's Stage shoreline is visible at ~2,800 ft and ~7,400 ft as terraces that mark the transition from hummocky till to gently sloping lake bottom. Similarly, Alderbrook Stage shorelines are visible at ~4,800 ft and ~6,900 ft across the profile.

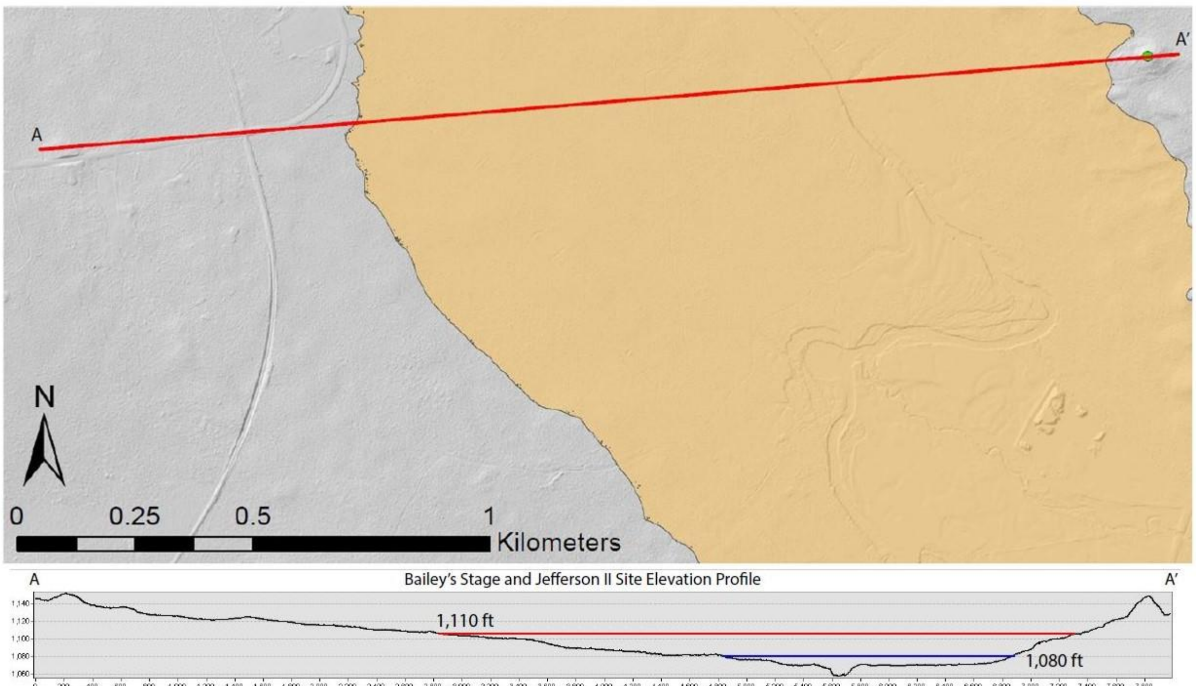



*Figure 59: Bailey's Stage and Jefferson II elevation profile and transect. Top: transect location; Bailey's Stage model shown in orange overlain on a (315, 45) hillshade. Elevation profile transect marked with a red line. Jefferson II IRC site shown as a green dot. The transect is 8,000 ft long and passes through a site in the Jefferson II group on the eastern side of the Bailey's Stage. The profile begins in hummocky till on the western side of the lake and ends in hummocky till on the eastern side, crossing through gently sloping, smooth lake bottom. Red line on profile shows shorelines of the Bailey's Stage, blue line shows shorelines of the Alderbrook Stage, and the elevations of the shorelines are labeled.*

## Bailey's Spillway and "Island" Elevation Profile

Profile shows a transect beginning in the Cherry Pond spillway on the western side of the Bailey's Stage model and ending on the eastern side of a wave cut feature in the Bailey's Stage. The elevation of the spillway matches the elevation of the top of the wave cut feature, confirming the spillway elevation as a reliable elevation for use in lake level models.

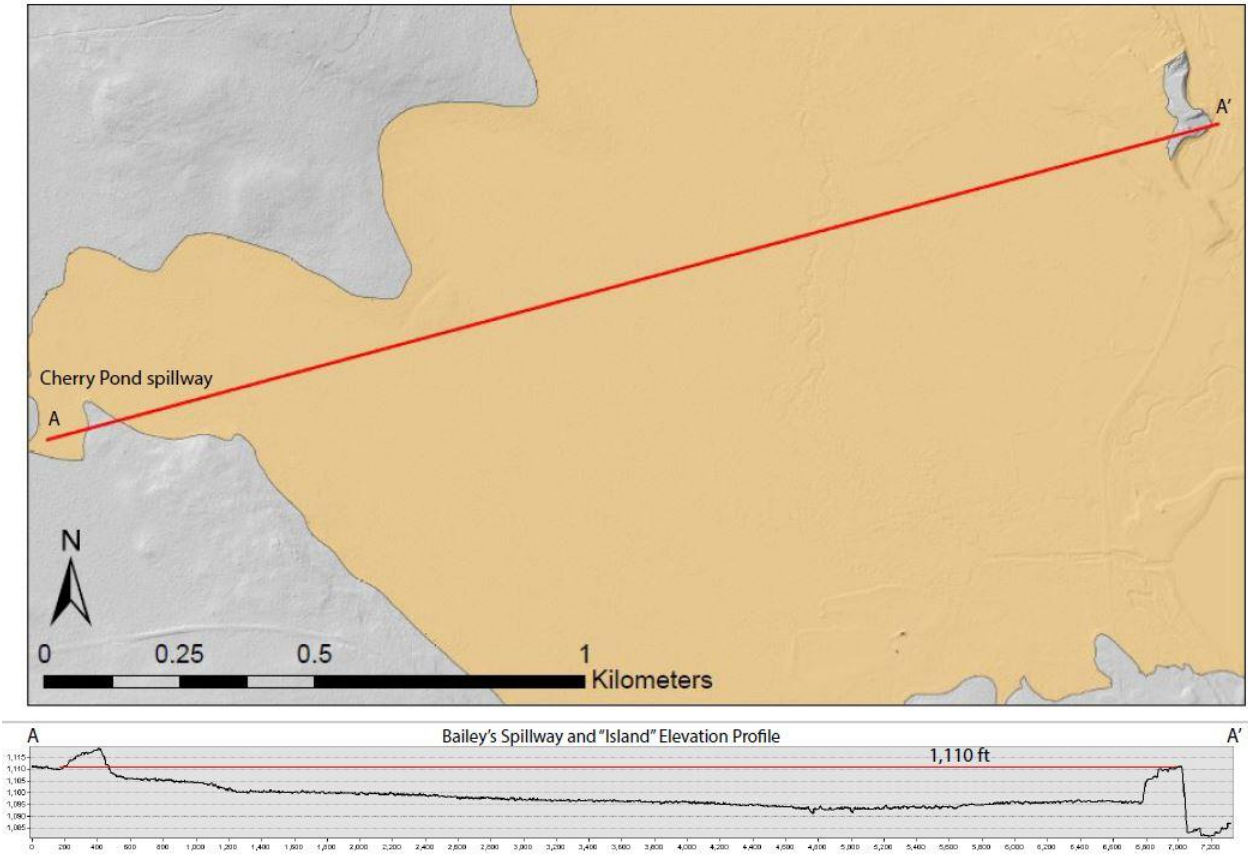



*Figure 60: Bailey's spillway and wave cut "island" elevation profile and transect. Top: transect location; Bailey's Stage model shown in orange overlain on a (315, 45) hillshade. The transect is 7,400 ft long and passes through the wave cut feature in the middle of the Bailey's Stage. The profile begins in the Cherry Pond spillway on the western side of the lake and ends on Bailey's Stage lake bottom. Red line on profile shows that the elevations of the Cherry Pond spillway and the top of the wave cut feature are equivalent, at 1,110 ft (338 m).*

## Bailey's "Island" Elevation Profile

Profile shows a transect running from north to south across the wave cut feature. The profile illustrates the shaping of this feature by the high water level of the Bailey's Stage, evidenced in the elevation of the uppermost surface of the "island" at 1,110 ft (338 m).

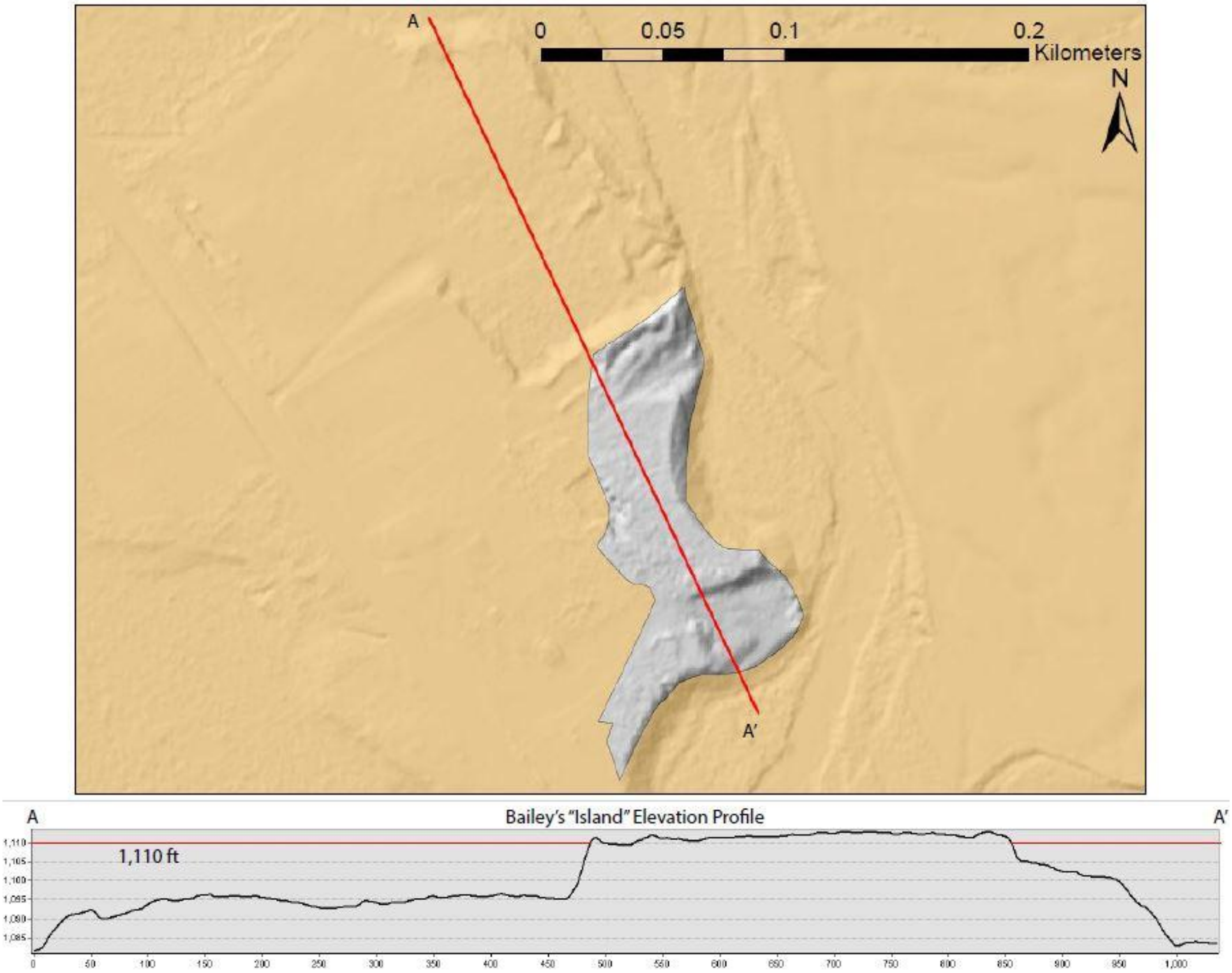



*Figure 61: Wave cut "island" elevation profile and transect. Top: transect location; Bailey's Stage model shown in orange overlain on a (315, 45) hillshade. Elevation profile transect marked with a red line. The transect is 1,050 ft long and passes longitudinally through the wave cut feature in the middle of the Bailey's Stage. The profile shows the top of the wave cut feature at an elevation of 1,110 ft, (338 m) the same elevation as the Cherry Pond spillway.*

## Alderbrook and Riverton Spillway Elevation Profile

Profile shows a transect beginning on the north side of the spillway and ending on the south side. The elevation of the spillway today is 1,044 ft (318 m) which is taken as the spillway elevation for the Riverton Stage. A higher elevation till ridge is visible at 1,080 ft (329 m) and this is taken as the spillway for the Alderbrook Stage.

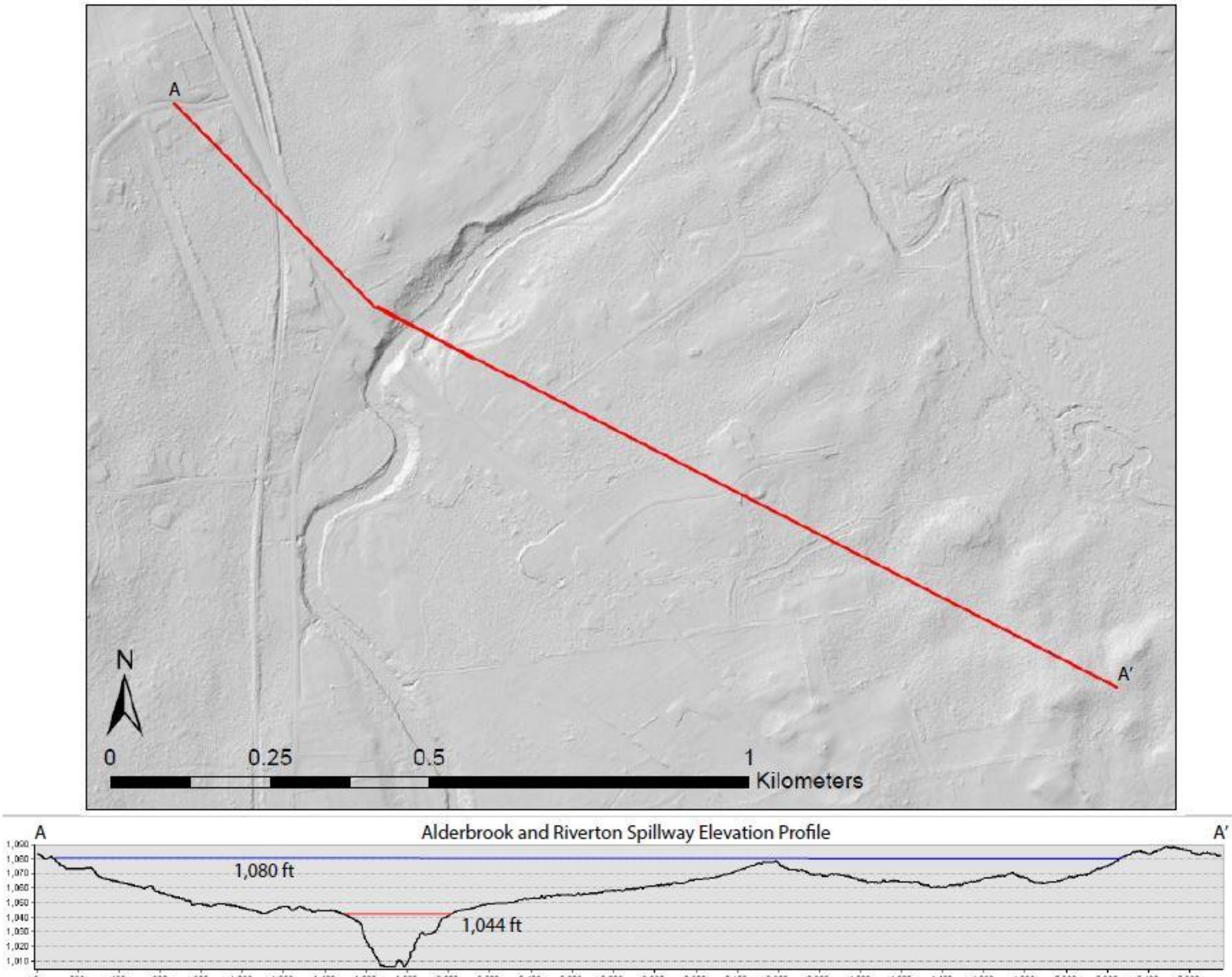



*Figure 62: Alderbrook and Riverton spillway elevation profile and transect. Top: transect location; hillshade is (315, 45). Elevation profile transect marked with a red line. The transect is 6,000 ft long and shows the higher elevation (1,080 ft/329 m, blue line) of the till ridge that dammed the Alderbrook Stage and the eroded till dam of the Riverton Stage (1,044 ft/318 m, red line).*

## Discussion

### Overview

Incorporating knowledge gained from archaeology, TEK and Indigenous knowledge, paleoclimate data, and the modeling and mapping described above, this study investigates the environmental changes that took place in the Israel River Valley after the drainage of the Bailey's Stage of Glacial Lake Israel through the spillway at Cherry Pond and how this history of environmental change is reflected in Indigenous knowledge. (The timing of Bailey's Stage drainage has been constrained by a basal radiocarbon date from the Cherry Pond core, placing drainage at 13.6 cal ka BP (Figure 63, Thompson et al., 2017).) The environmental changes taking place in the postglacial Israel River Valley were not unique for their time; complex histories characterized glacial and postglacial lakes at the front of the receding Laurentide Ice Sheet across the Northeast. Proglacial lake footprints were governed by changing ice margins, differential isostatic rebound, changing elevations of glacial lake outlets/spillways, and topography south of the ice sheet margin (Lothrop et al., 2016). Ice-dammed lakes which existed during deglaciation gave way to drift and/or stagnant ice dammed lakes which existed into the Holocene, hundreds if not thousands of years after deglaciation (Lowell, 1985). This pattern applies to the Israel River Valley and the numerous stages of Glacial Lake Israel; the new stages described here were postglacial lakes that may have lasted into the early Holocene, certainly impacting the valley's environment and earliest known human populations through their influence on local climate, animal, and plant resources.

### Indigenous Knowledge and Cultural Continuity

"Although it is impossible," Caduto writes, "to show a direct linear archaeological and cultural connection through time, peoples of this vast region evolved, like their environments--with fits and starts." This statement is directly contradicted by Indigenous knowledge. Early peoples in New Hampshire were only the beginning of a "cultural continuum" that stretches all the way back to deglaciation (Caduto, 2003). The Koasek Traditional Band of the Koas Abenaki Nation website states that "Native Americans have occupied northern New England for at least 10,000 years. There is no proof these ancient residents were ancestors of the Abenaki, but there is no reason to think that they were not."

Historical narratives in the northeast (and in much of America) often neglect the significance and complexities of the land's Indigenous cultures, as explained on the Indigenous

New Hampshire website, a collaboration between the University of New Hampshire's Anthropology Department, and Paul and Denise Pouliot of the Cowasuck Band of the Pennacook Abenaki People (Indigenous New Hampshire, 2018). These narratives, intentionally or not, perpetuate the idea that North America was sparsely inhabited before European arrival and that the land's original inhabitants have since disappeared (Indigenous New Hampshire, 2018). On the contrary, and despite the profound injustices that Indigenous peoples have endured, Indigenous cultures prevail and extend much further back in to the history of the land than many interpretations would have us believe. As the website of the Cowasuck Band of the Pennacook Abenaki People states: "there is a growing effort to bring history back into focus and to correct many misconceptions" (www.cowasuck.org, 2011) about the history of Indigenous peoples in this country, a history which stretches from the time of Laurentide Ice Sheet recession to the present day. The use of oral traditions can demonstrate the cultural complexity of Indigenous cultures through time, through periods of tens of thousands of years (Watkins, 2003).

The connection between oral narratives and environmental events provides some of the strongest evidence for this deep history. Bonnie Newsom, in a report prepared for Acadia National Park titled "Ancient Ones and Cultural Affiliation: An Examination of the Evidence from Maine," links Wabanaki oral narrative with paleoclimate data, illustrating cultural affiliation stretching back tens of thousands of years (Newsom, 2010). A story about the opposing forces of Summer and Winter, in which Summer travels north to the land of the Snow and becomes weakened, eventually being rescued by the Winds and returning to her former beauty, can be interpreted as representing the opposing climate forces related to glacial cycles (Newsom, 2010). Newsom argues that this interpretation connects the Wabanaki people to major climatic events in the northeast, likely the retreat of the Laurentide Ice Sheet; these connections support Wabanaki claims of deep antiquity in the northeast (Newsom, 2010; Julien et al., 2010).

In a similar case, another narrative tells of a giant beaver dam blocking the water on the St. John River, and Gluskap (an important figure in Wabanaki and Mi'kmaw oral history) throws two giant rocks at the beaver to kill him so the people downstream can have water again. The rocks miss the giant beaver but eventually it dies and turns to stone on the shores of the river. This narrative is cited by Beck (1972) as evidence of a fossil memory of the Pleistocene giant beaver, *Castoroides ohioensis* (in Newsom, 2010; Julien et al., 2010). Newsom (2010) describes

Beck's interpretation: that the tale of the giant beaver was passed through generations and originated from a time prior to the extinction of the species at approximately 12,000 cal BP.

Another source of evidence for the depth of Indigenous history in the northeast is linguistics. The distribution of Indigenous languages in North America is related to biogeographic zones associated with the end of the Wisconsinan glaciation (Newsom, 2010). Newsom explains how Algonquin languages are linked to a specific faunal province which occurred in the northeastern U.S. concurrent to the Wisconsinan, evidenced by the fact that the distribution of the languages matches Wisconsinan geographic features that must have existed prior to the Holocene. This supports a correlation between the age of the Wisconsinan glaciation and the deep history of these language families.

"If there is one shared sentiment across Mi'kma'ki, it is that people share a homeland--we come from this place," write Donald M. Julien, Tim Bernard, and Leah Morine Rosenmeier, with review by the Mi'kmawey Debert Elders' Advisory Council (2010). As was discussed previously, they argue that to disconnect populations through time means breaking people from homelands and ancestral places as well. The authors describe that the Mik'mawey Elders' Council rejects the term "Paleo American" because it has come to indicate that people living in North America more than 10,000 years ago are not Native American. However, they argue that life since the last glaciation "after 11,000 years of shared historical experiences--has been the basis for defining Native American or First Nation" (Julien et al., 2010).

## The Alderbrook and Riverton Stages of Glacial Lake Israel

Evidence is provided here for two additional postglacial stages of Glacial Lake Israel; the Alderbrook Stage, which directly followed the Bailey's Stage, and the Riverton Stage, the final stage of Glacial Lake Israel. Basis for the existence of the Alderbrook Stage comes from a log found between Bailey's and Alderbrook Stage lake sediments, a fragment of which returned an AMS date of 11,140 cal BP (9,730 +/- 80 radiocarbon years). Species identification on the fragment suggests Alnisedi (eastern hemlock, *Tsuga canadensis*), based on the abrupt transition from early to late wood in the tracheids (compared to the more gradual transition seen in Kokokhôakw (balsam fir)) and the absence of resin canals, which would be seen in Pasaakw (pine) (Huggett, pers comm.).

The location of the wood fragment as it was found in situ can be seen in Figure 63. It is hypothesized that the wood was carried from the uplands by meltwater and deposited during or directly after the transition from the Bailey's to Alderbrook stages, then subsequently covered by sediments deposited in the Alderbrook Stage. This hypothesis is based on the stratigraphic context of the wood, which was found between "hardpan" and clay (Ingerson and Gross, pers comm.). The overlying clay was described as roughly 5 ft thick, and may be postglacial sediments deposited in the Alderbrook Stage. It is possible that the "hardpan" on which the wood fragment was found is actually some type of gravelly mixture deposited during drainage of the Bailey's Stage, rather than lodgement till. However, this interpretation would require the full drainage of the Bailey's Stage. It is more likely that the sediments are the uppermost layer of Bailey's Stage sediments onto which the log dropped through the new lower water level of the Alderbrook Stage, because spillway elevations do not support full drainage between the Bailey's and Alderbrook stages. This sequence is supported by the age of the wood fragment; if the log was deposited directly on till left by the receding icefront, the age would have to roughly approximate the age of deglaciation. In fact, the age given by the wood fragment falls about 2-3,000 years after ice retreat northwards to Lancaster and the deglaciation of the Israel River Valley, (Thompson et al., 2017) thus suggesting the post-Bailey's Alderbrook stage. The depositional environment in this stage would have been capable of accumulating a significant layer of fine clay-like sediment over glacial lake sediments and gravels left behind by the previous stages of Glacial Lake Israel, which in turn overlie till.

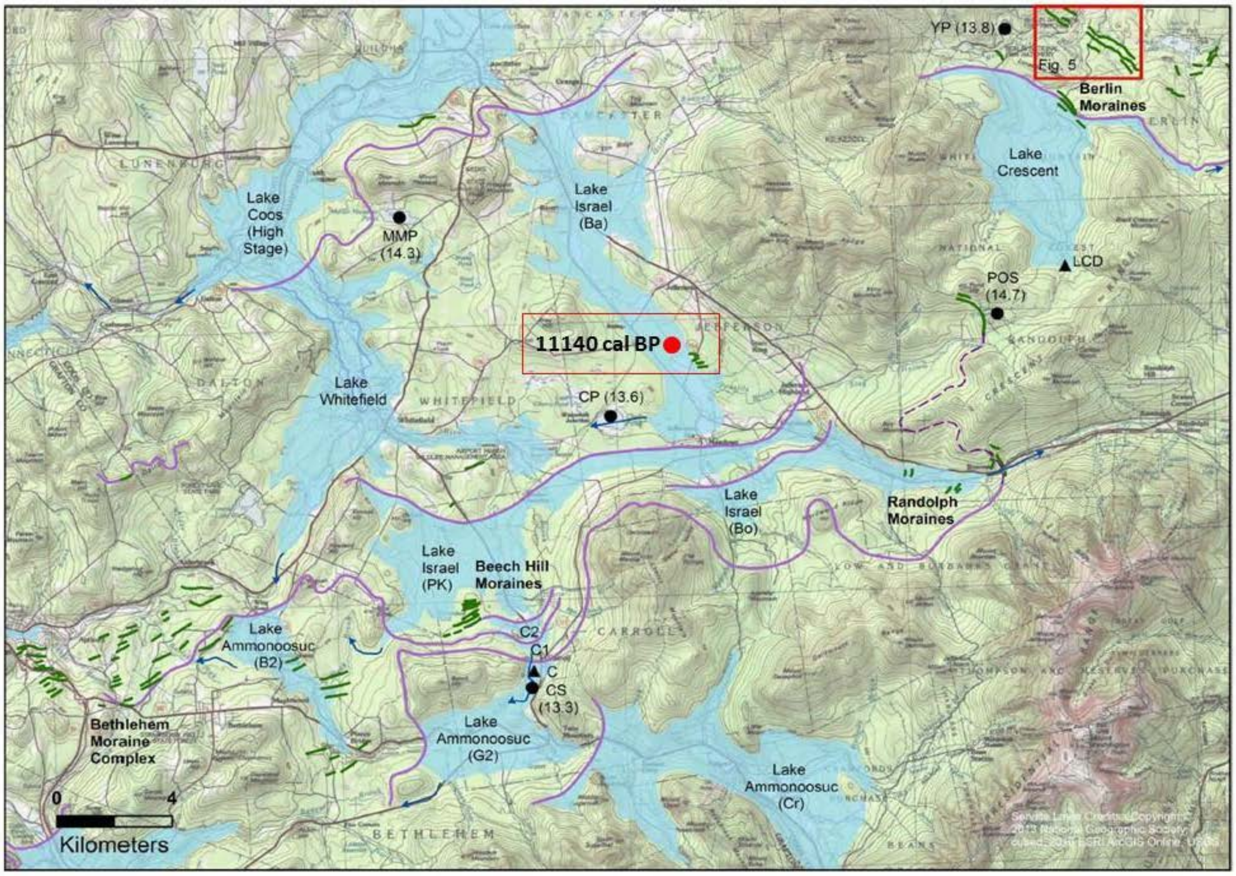



*Figure 63: Map of the Bowman, Pine Knob, and Bailey's stages of Glacial Lake Israel as mapped by Thompson et al. (2017) showing the date obtained from the wood sample on the Ingerson property (11,140 cal ka BP). The basal radiocarbon date marking drainage of the Bailey's Stage is denoted by a black dot labeled "CP (13.6)."*

Further evidence for the existence of the Alderbrook Stage is seen in an elevation profile through the valley floor (Figure 59). The profile shows wave-cut shorelines of the Alderbrook Stage at an elevation of approximately 1,080 ft on either side of the active channel of the Israel River, with breaks in slope at 4,800 ft and 6,900 ft across the profile from west to east. Similar evidence for the Bailey's Stage shoreline appears on the profile, with slope breaks at 2,800 ft and 7,400 ft across the profile from west to east. These shoreline features are at an elevation of 1,110 ft (Figure 59).

Multiple interpretations can explain this post-Bailey's, pre-Riverton depositional environment. The interpretation proposed here places the dam of the Alderbrook Stage in the same location as the Riverton Stage dam, where the Israel River crosses under Route 2 in

Riverton, NH. It is proposed that the Alderbrook stage was dammed by a till ridge (elevation 1,080 ft) at this location and subsequent erosion--most likely by meltwater, as the landscape at this time would still have been easily erodible due to lack of full colonization by forest--brought the till dam down to approximately 1,044 ft to dam the Riverton Stage. The location of this till ridge is the best candidate for a spillway in the area; (Thompson, pers comm.) LiDAR analysis has shown it to be the point of lowest elevation in the valley to which the water had access.

However, it is possible that the Alderbrook Stage could have been dammed by a more ephemeral feature such as a stagnant ice dam or a temporary dam created by landslide debris coming off of nearby hills, perhaps similar to the landslide that has been documented at Cherry Mountain. Cosmogenic nuclide ages collected to constrain deglaciation of Mount Washington by Davis et al. (2015) show deglaciation of Tuckerman Ravine and Pinkham Notch at 12.6 cal ka BP and 12.7 cal ka BP, respectively. These ages support the possibility of remnant stagnant ice in the valleys around the Mount Washington area at the onset of the Younger Dryas, during the presence of the Alderbrook and Riverton stages. Therefore, it is reasonable to assume that these postglacial stages could instead have been dammed by remnant ice. The Alderbrook Stage is shown modeled in Figure 49 using the spillway elevation of 1,080 ft.

The main source of evidence for the Riverton Stage (of which no absolute date has been obtained) is the spillway at Riverton, which appears as a well-defined channel incised into a ridge of till running parallel to Route 2 in Riverton, NH. This till dam is illustrated as a brown line in Figure 64, which shows models of the Bailey’s, Alderbrook, and Riverton stages in relation to the IRC sites and the location of the dated wood sample (termed “Neil Gross Sample,” after the original owner of the wood fragment). The elevations of the ground surface on either side of this channel are approximately 1,044 ft; this elevation is taken to approximate the elevation of the till dam as it held back the Riverton Stage. The elevation of the till dam as it appears today is lower than that of the dated wood sample, which, at 8 ft below the ground surface, had an elevation of approximately 1,063 ft when buried (Ingerson, pers comm.). This provides further evidence for the existence of the Alderbrook Stage, supporting the interpretation that the till dam at Riverton was eroded down from its higher level of 1,080 ft by postglacial flooding/erosion (Thompson, pers comm.).

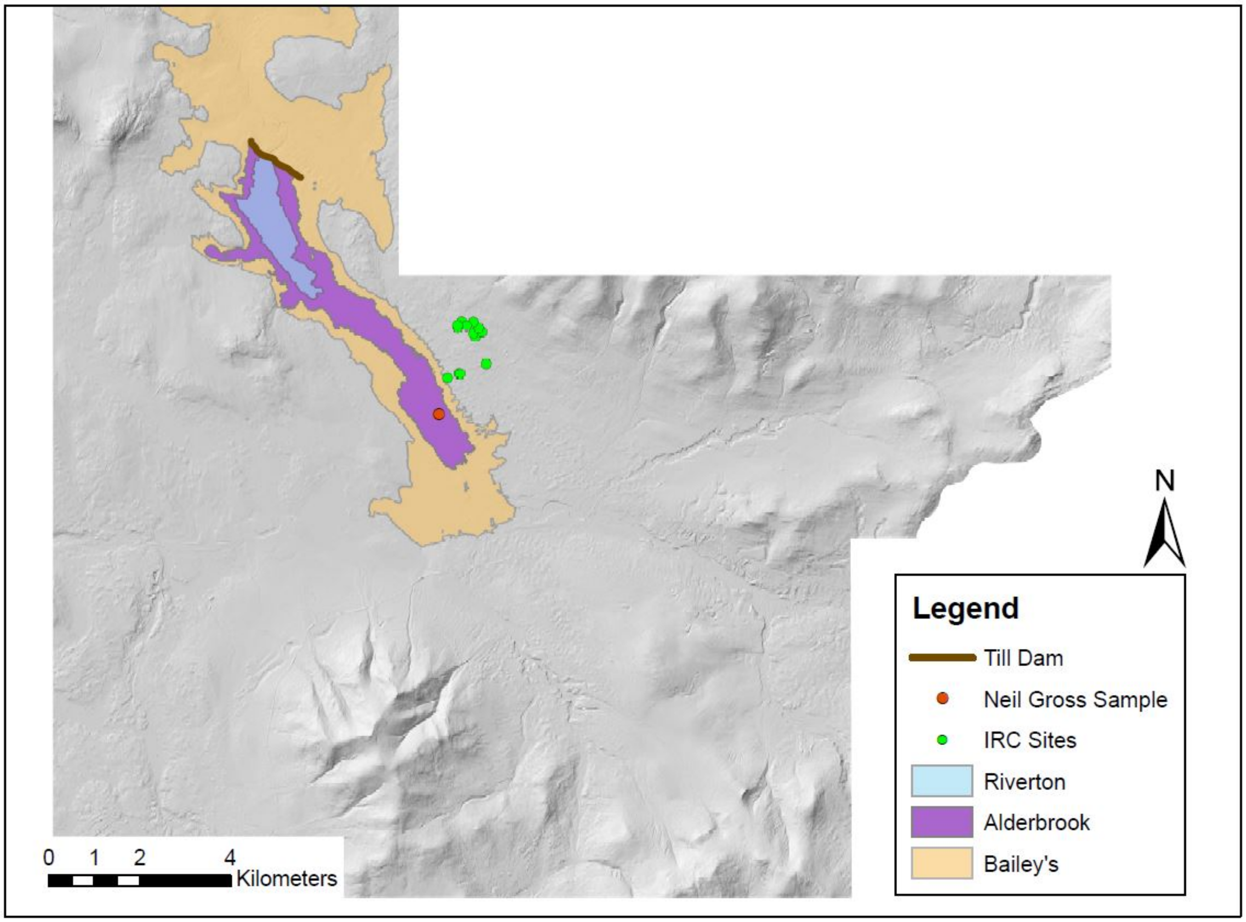



*Figure 64: Models of the Bailey's, Alderbrook, and Riverton stages shown in relation to the IRC sites and the location of the dated wood fragment. Hillshade of study area is (315,45).*

Figure 65 shows deglaciation of the Israel River Valley and changes in lake stages through time. By the time that the Bailey's Stage drained, the study area was deglaciated (except for possible remnant stagnant ice) and ice cover had moved north to Lancaster. Within the next 2,000 years, the IRC sites were occupied (Boisvert et al., 2017; Lothrop et al., 2016) and remaining postglacial lake stages occupied the valley. Regardless of the precise form of the Alderbrook and Riverton stages, the impact to environment and lifeways of the IRC occupants was significant because of the proximity of these lakes to the sites and the impact they had on resource availability and hunting strategies.

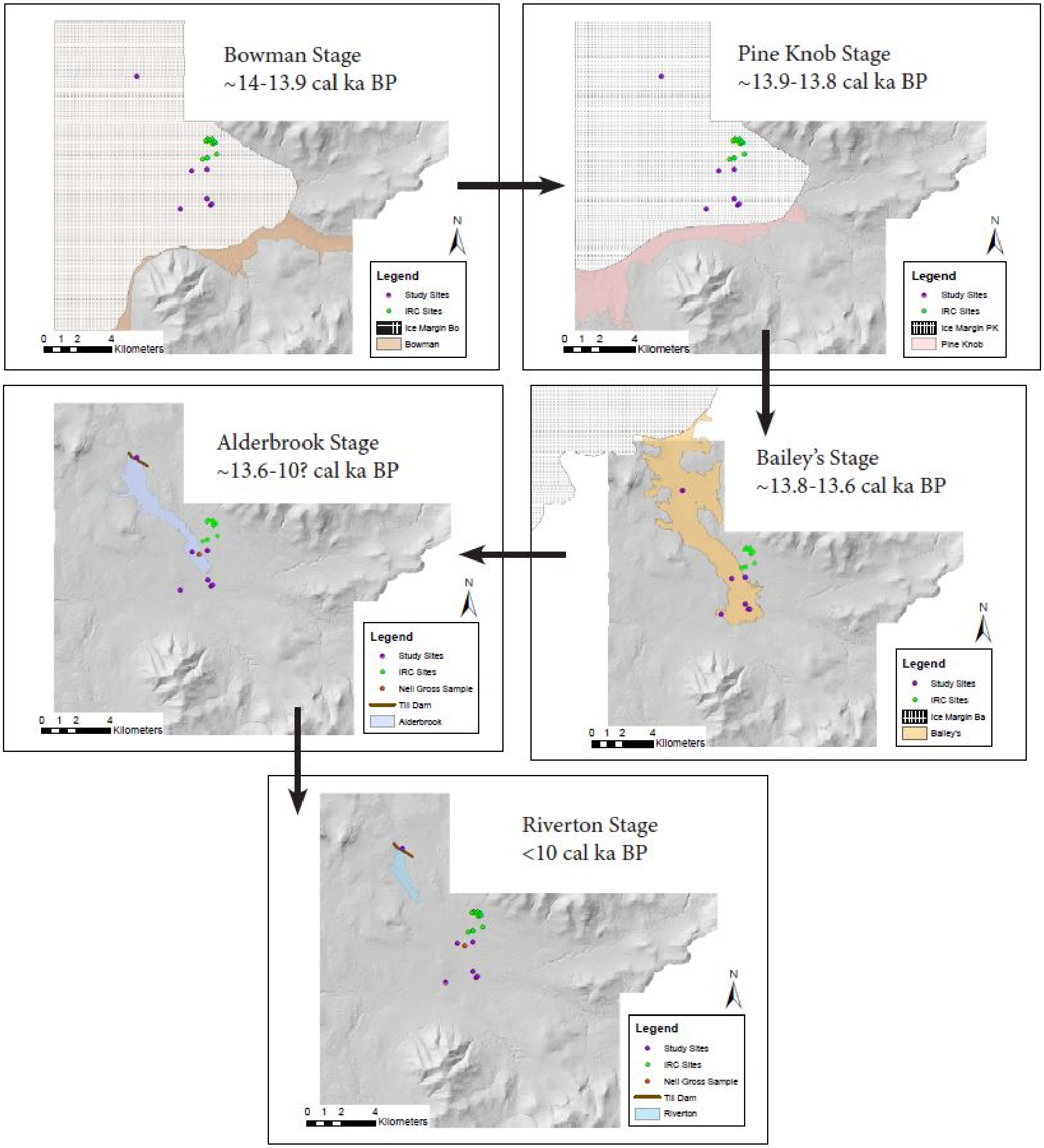



*Figure 65: Progression of lake stage and ice cover models through time, overlain on (315,45) hillshades. (For a higher quality image, see Appendix C.) Approximate temporal ranges are given for each stage. Green dots denote locations of the IRC sites, purple dots denote locations of study sites, and lake models are colored polygons. Ages for the Pine Knob stage are inferred from bracketing ages of the Randolph moraines (dated to 14 cal ka BP) and the drainage of the Bailey's Stage (Thompson et al., 2017). The Alderbrook stage age is from the Neil Gross sample, dated to 9,730 +/- 80 radiocarbon years (11,140 cal yr BP).*

### Regional Paleoenvironment

Climate proxy data from Greenland ice sheet cores provide evidence that in addition to orbitally driven warming after the LGM, abrupt climate oscillations in the North Atlantic had major effects on environments in the recently deglaciated Northeast (Lothrop et al., 2016; Alley, 2000; Steffenson et al., 2008). These climate oscillations included the Older Dryas, Bolling-Allerod, and Younger Dryas. The Younger Dryas was the most pronounced of these and lasted longest, from approximately 12,900 to 11,600 cal BP (Lothrop et al., 2016; Carlson, 2013).

Vegetation changes in the northeast/New England Maritimes (NEM) have been widely researched for this time period. Table 3 lists all species mentioned in the texts, with Abenaki, English, and Latin names, as well as traditional uses by Indigenous groups in the northeast where available. Davis and Jacobson (1985) used percentages and accumulation rates of modern pollen of selected species near present northern range limits in eastern North America to present a mapped history and description of vegetation change for the late glacial and early Holocene periods. From this analysis, Davis and Jacobson constructed a series of physiognomic vegetational zones from 14,000 cal BP to 9,000 cal BP. Patterns in their research show bands of tundra, woodland, and forest following the receding ice front northward, with lowlands serving as corridors for early spread of tree taxa.

*Table 3: Abenaki, Latin, and English names for plant species mentioned in the text. Column on the far right lists traditional plant uses for Indigenous groups in the northeast, not exclusively Abenaki traditional uses. Abenaki names and traditional uses are sourced from the Native American Ethnobotany Database (http://naeb.brit.org/) and the Cowasuck Band of the Pennacook Abenaki People ethnobotany webpage (http://www.cowasuck.org/herbal.cfm).*

| Abenaki Name | English Name | Latin Name | Traditional Use |
|---|---|---|---|
| Alnisedi | Eastern Hemlock | Tsuga canadensis | antirheumatic (Abenaki, Algonquin) |
| Maskwamozi | Birch | Betula | |
| Anaskemezi | Oak | Quercus | |
| Msazesso (white spruce) and Mskak (black spruce) | Spruce | Picea | dermatological aid (Penobscot), urinary aid (white spruce, Abenaki) |
| | Sedge | Carex | |
| | Bog Blueberry | Vaccinium uliginosum | |
| Pasaakw (Red Pine) | Pine | | cough medicine (white pine, Abenaki) |
| Wdopi | Alder | Alnus | analgesic, antirheumatic, hemostat (Mi'kmaq) |
| Wawabibagw | Poplar | Populus | antidiarrheal (Chickasaw) |
| Kokokhôakw (fir) | Balsam Fir | Abies balsamea | antiseptic, dermatological aid, panacea (Abenaki), heart health, cold remedy, laxative (Algonquin) |
| Senomozi | Maple | Acer | respiratory aid (striped maple, Abenaki) |
| | Larch | Larix | |
| Anibi | Elm | Ulmus | |
| Kanozas | Willow | Salix | eye medicine (Abenaki) |

Lothrop et al. (2016) summarize work by Newby et al., (2005) through the early Holocene. Pollen records show the period from deglaciation through 14,600 cal BP as dominated by sedge, Msazesso, (spruce) and Kanozas; (willow) these vegetation types reflect open environments. During the warmer Bolling-Allerod period pollen assemblages reflect Msazesso, (spruce) Pasaakw, (pine) Maskwamozi, (birch) Anaskemezi, (oak) and Wawabibagw (poplar) (Lothrop et al., 2016). At 13,000 cal BP, after the drainage of the Bailey's Stage, most of northern New Hampshire was vegetated by tundra, (characterized by sedges, Kanozas, (willows) grasses, sage, Wdopi (alder) and Maskwamozi (birch) with encroachment of Wawanonagw (poplar) beginning in southern NH and a mixed woodland environment characterizing northern Massachusetts (Davis and Jacobson, 1985). In a pollen and macrofossil analysis of a core taken from Crider's Pond in southeastern Pennsylvania, Watts (1979) found that Pasaakw, (pine) Maskwamozi, (birch) Kokokhôakw, (fir) and Wdopi (alder) were abundant around 13,000 BP, occurring after the Msazesso (spruce) woodland/boreal forest recorded there for the glacial period.

These vegetation changes resemble pollen records from other sites in northern New England, with a compositional shift at approximately 13,000 cal BP (attributed to the Younger Dryas) from open Pasaakw (pine) and Msazesso (spruce) woodland to denser forest including Pasaakw, (pine) Alnisedi, (eastern hemlock) Wdopi, (alder) larch, and Kokokhôakw (fir) (Oswald and Foster, 2011). The onset of the Younger Dryas (lasting in total from 12,900-11,600 cal BP) correlates to a regional temperature decline of up to 5° C, with a vegetation shift to tundra (open spruce parklands and sedge landscapes) in northern regions and closed spruce forest in the southern NEM (Lothrop et al., 2016; Boisvert et al., 2017; Newby et al., 2005). Here, the contrasting regimes of open landscapes in the north and boreal forests in the south provided ideal summer and winter habitats for long-distance migratory caribou herds (Newby et al., 2005 in Lothrop et al., 2016).

By 12,000 cal BP, major land areas were open to colonization by plants, with significant ice coverage only remaining in northern Maine and adjacent Canada (Davis and Jacobson, 1985). At this time northern New Hampshire was still a tundra environment, but woodlands were creeping farther north and had reached what is now the central portion of the state (Davis and Jacobson, 1985; Figure 11). Vegetation zone maps by Davis and Jacobson (1985) indicate that Wawabibagw, (poplar) Msazesso, (spruce) and Maskwamozi (birch) arrived in northern New Hampshire by around 11 ka radiocarbon years BP (approximately 12,900 cal BP) and were followed by Kokokhôakw (balsam fir) around 12,400 cal BP and Anaskemezi (oak) around 11,500 cal BP. Similarly, results from a macroflora analysis at Columbia Bridge, VT, show abundances of Msazesso, (spruce) Pasaakw, (pine) and sedges around 11,500 cal BP, which are interpreted as a tundra assemblage (Watts, 1979). By 11,000 cal BP, reconstructions by Davis and Jacobson (1985) show both mixed woodland and tundra in northern NH, (Figure 66) here, Wawabibagw (poplar) and Msazesso (spruce) were abundant, with a transition to forest dominated by Msazesso, (spruces) Kokokhôakw, (balsam fir) Maskwamozi, (birches) and Wawabibagw (poplars) in the mideast and southern portions of the state (Davis and Jacobson, 1985). The woodland areas to the south existed as an intermediate zone between tundra and forest, with Wawabibagw, (poplars) Msazesso, (spruces) and Pasaakw (pines).

Oswald and Foster (2011) conducted an analysis of pollen in a core from Long Pond in Mansfield, VT, which showed low percentages of Msazesso (spruce) after 11,500 cal BP, with Maskwamozi (birch) pollen peaking around 11,200 cal BP. From 10,200-8,400 cal BP Pasaakw (pine) was found to remain abundant, while Alnisedi (hemlock) pollen increases to reach a maximum around 8,400 cal BP (Oswald and Foster, 2011). By 10,000 cal BP, reconstructions by Davis and Jacobson show nearly all of NH colonized by forest, with some remnant patches of mixed woodland in the northern half of the state; tundra occupied areas of Canada just north of Maine and the deglaciated area north of the Champlain Sea. By this time, nearly all of Vermont, NH, part of southern Quebec, and all but the northern third of Maine was a mixed forest including Wawabibagw, (poplar) Msazesso, (spruce) Pasaakw, (pine) Maskwamozi, (birch) Anibi, (elm) larch, ironwood, ash, Kokokhôakw, (balsam fir) Anaskemezi, (oak) and Senomozi (maple) (Davis and Jacobson, 1985).

As the forest group continued to colonize the landscape and Kokokhôakw (fir) became more abundant, nonarboreal taxa characteristic of the tundra period (such as sedges) continued to decrease in abundance, reaching minimum concentrations around 9,000 cal BP. Wawabibagw, (poplar) Msazesso, (spruce) and Kokokhôakw (fir) continued at minimal levels for thousands of years (Davis and Jacobson, 1985). The temporal transition from tundra to woodland to forest in the northeast throughout this time period is broadly similar to the spatial transition that occurs today from north to south in eastern Canada (Davis and Jacobson, 1985). By the Early Holocene, (roughly 11.6 - 10 cal ka BP) vegetation had again changed to Pasaakw (pine) forest, reflecting warming temperatures (Lothrop et al., 2016). During the early Holocene, when warmer, drier conditions prevailed, eastern white pine and Anaskemezi (oak) were abundant and Alnisedi (eastern hemlock) expanded gradually after 10,000 cal BP with a decrease in influence of the Laurentide Ice Sheet (Oswald and Foster, 2011). Similarly, Watts (1979) found an increase in Alnisedi (eastern hemlock) and Anaskemezi (oak) around 10,000 cal BP, which they use to mark the beginning of the Holocene.

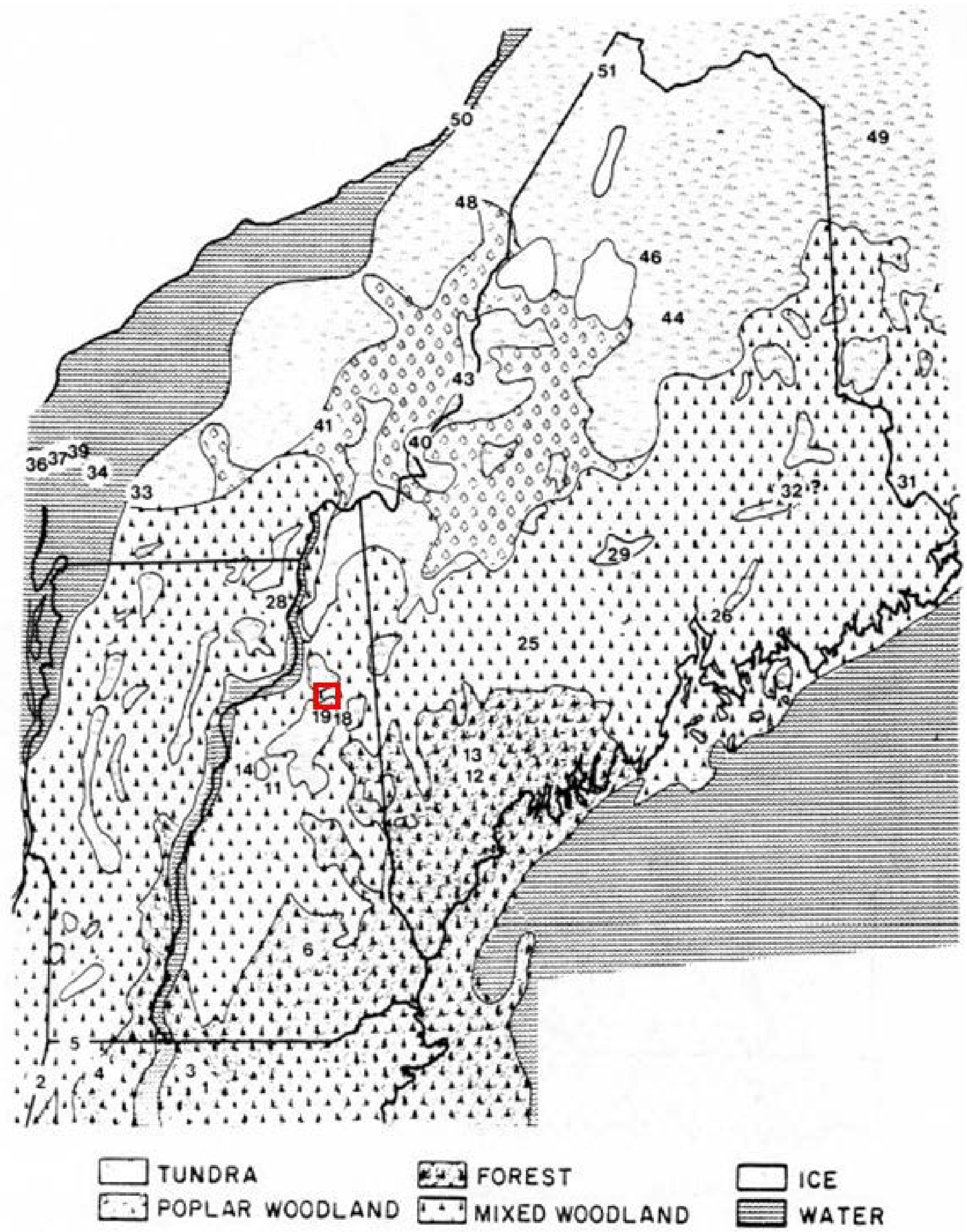



*Figure 66: Davis and Jacobson, (1985) Figure 12: landscape reconstruction for 11,000 cal BP. Study area highlighted in red. Surrounding the study area is tundra and mixed woodland.*

### Paleoclimate Data Specific to the Study Area

Paleoclimate data and radiocarbon dates from a core taken in Cherry Pond, the spillway for the Bailey's Stage, show that around the end of the Younger Dryas and the beginning of the Holocene, vegetation species in the Israel River Valley align with interpretations discussed above. At a depth of 965 cm below pond surface in the Cherry Pond core, a shift from a band of massive silt and clay (interpreted as the sedimentological signature of Younger Dryas cooling) to banded gyttja marks the transition to the Holocene (Thompson et al., 2017; Figure 67). At this transition, a radiocarbon date on organic material (11,294-11,978 cal BP) indicates the presence of Msazesso, (spruce) sedge, Maskwamozi, (birch) and bog blueberry in the Israel River Valley (Thompson et al., 2017; Figure 68). The dated fragment of Alnisedi (eastern hemlock) falls near this age range, in accordance with research discussed above associating the spread of Alnisedi (eastern hemlock) to the onset of the Holocene. In Figure 69, vegetation change during the time period around 11,140 cal BP is highlighted. Core data from Echo Lake shows peaks in Kokokhôakw (fir) and Msazesso (spruce) which decline at the onset of the Holocene, in addition to spikes in Maskwamozi, (birch) Pasaakw, (pine) and Alnisedi (eastern hemlock) pollen at/extending into the early Holocene (Shuman et al., 2005). The dated Alnisedi (hemlock) fragment (at 11,140 cal BP) may suggest that Alnisedi (hemlock) was present in the study area earlier than the Echo Lake pollen data shows. However, the presence of Maskwamozi (birch) and Msazesso (spruce) pollen in the Echo Lake core in addition to the Cherry Pond core confirms the presence of these species in the region in the late Pleistocene/early Holocene.

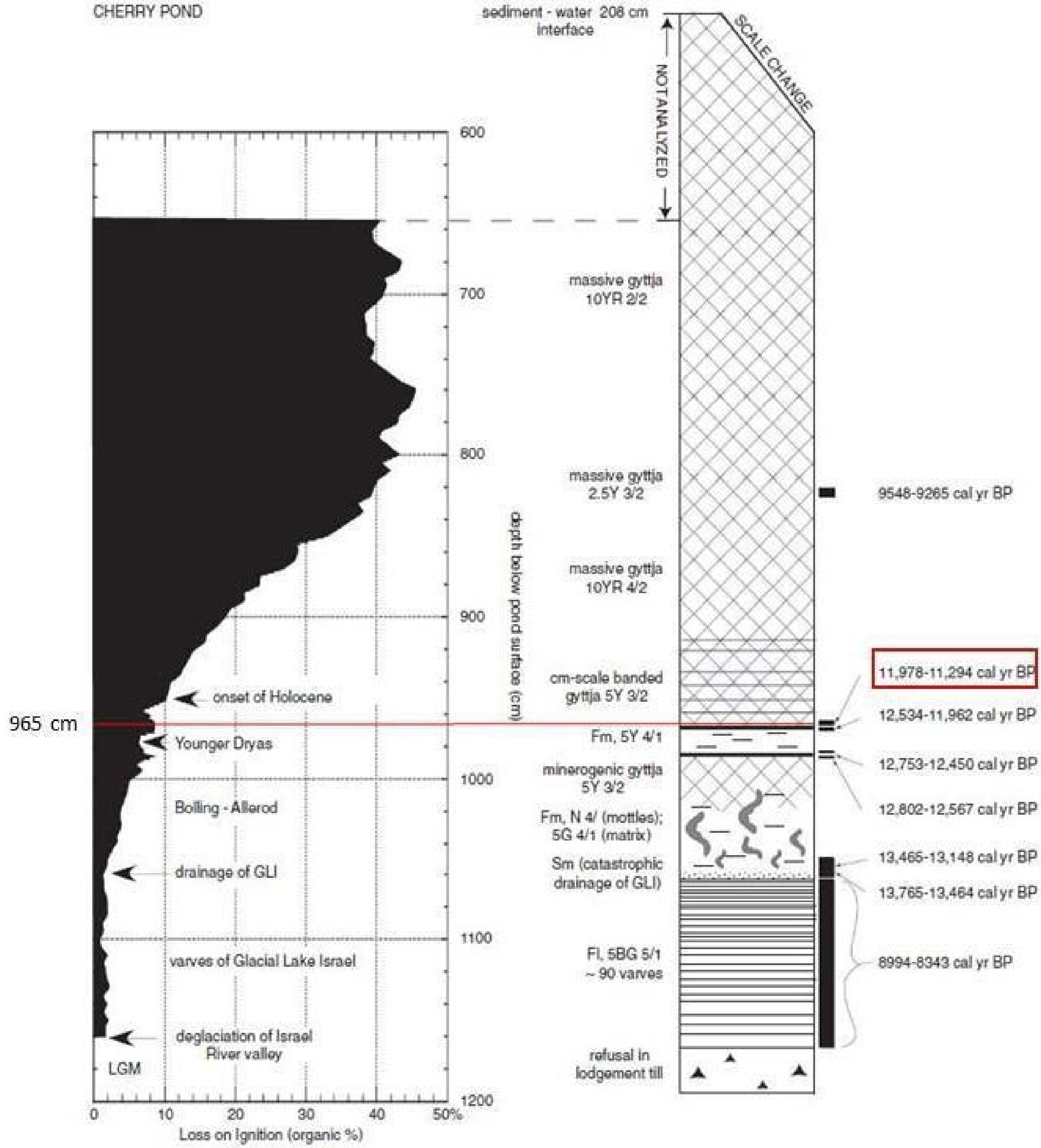



*Figure 67: Cherry Pond core log showing transition from Younger Dryas massive silt and clay to early Holocene banded gyttja at 965 cm below pond surface (modified from Thompson et al., 2017). Highlighted in red is the age range in which the dated hemlock fragment falls.*

The presence of bog blueberry and sedge at a depth of 965 cm in the core suggest moist to wet environments, possibly wetlands, (NRCS Plants Database, 2018) which may provide evidence for a shallow lacustrine environment surrounding the Alderbrook Stage on the valley floor. The presence of Msazesso, (spruce) Maskwamozi, (birch) and Alnisedi (hemlock) indicate woodland environments with high and medium palatability for animal browsing (NRCS Plants Database, 2018). Around the existence of the Alderbrook stage, then, it is reasonable to propose a mixed woodland environment with some (edible) species of tundra vegetation preferring marshy or wetland-like environments in addition to woodland vegetation useable as a food source by animals and humans. (See Table 3 for traditional uses of these species.)

| | Coring site | Event | Laboratory number | Age ($^{14}C$ yr BP) | $\delta^{13}C$ ‰ | Calibrated age, cal yr BP ($2\sigma$) | Sample material |
|---|---|---|---|---|---|---|---|
| | Carroll Spillway | Abandonment of Carroll Spillway and termination of meltwater drainage to glacial Lake Ammonoosuc | PL-0000890A | 11,430 ± 80 | −26.0 | 13,113–13,434 | Insect parts, wood fragments, *Dryas integrifolia* leaves, *Scirpus* and Cyperaceae achenes, *Hypericum* seeds, *Vaccinium oxycoccos* leaves, Juncaceae seeds |
| | Cherry Pond | Glacial Lake Israel varves; deglaciation of Cherry Pond basin | PL-0000483A | 7760 ± 140 | −25.9 | 8343–8994 | *Dryas integrifolia*, insect parts, *Picea* seed, Cyperaceae achenes, *Daphnia* sp. |
| | Cherry Pond | Glacial retreat to Lancaster; glacial Lake Israel drainage | PL-0000496A | 11,480 ± 80 | −23.6 | 13,148–13,465 | Insect parts, *Daphnia* sp., woody twigs, seeds |
| | Cherry Pond | Glacial retreat to Lancaster; glacial Lake Israel drainage | PL-0000489A | 11,800 ± 80 | −22.9 | 13,464–13,765 | *Dryas integrifolia* leaves, insect parts, *Daphnia* sp., *Vaccinium oxycoccos* leaf, *Betula* bract |
| | Cherry Pond | Termination of Bølling-Allerød | PL-0000485A | 10,780 ± 80 | −26.9 | 12,567–12,802 | Insect parts, *Daphnia* sp., *Picea* needles |
| | Cherry Pond | Onset of Younger Dryas lithic zone | PL-0000488A | 10,720 ± 80 | Not determined | 12,450–12,753 | Insect parts, *Daphnia* sp., *Betula* bract |
| | Cherry Pond | Termination of Younger Dryas lithic zone | PL-0000486A | 10,370 ± 80 | −27.2 | 11,962–12,534 | Insect parts, *Daphnia* sp., *Picea* seeds and needles, *Larix* needle, woody twigs, *Betula* bracts, *Salix* twig, *Vaccinium uliginosum* leaves |
| 11140 cal BP | Cherry Pond | Onset of Holocene | PL-0000484A | 10,070 ± 80 | −27.1 | 11,294–11,978 | Insect parts, *Picea* needles, woody twigs, *Betula* bracts, *Vaccinium uliginosum* leaves, *Carex* sp. achenes |
| | Cherry Pond | Peak organic productivity in pond | PL-0000487A | 8440 ± 80 | −24.8 | 9265–9548 | Gyttja |
| | Martin Meadow Pond | Deglaciation of Martin Meadow Pond basin | PL-0000491A | 12,360 ± 80 | Not determined | 14,079–14,852 | Insect parts, *Daphnia* sp., *Dryas integrifolia* leaves, woody twigs, *Salix herbacea* leaves |
| | Martin Meadow Pond | Deglaciation of Martin Meadow Pond basin | PL-0000889A | 10,920 ± 80 | −26.0 | 12,697–12,990 | Insect parts, *Daphnia* sp., *Dryas integrifolia* leaves, conifer needle, woody twigs, Cyperaceae achene, *Brasenia schreberi* seed |
| | Pond of Safety | Deglaciation of Pond of Safety basin | OS-7125 | 12,450 ± 60 | −18.2 | 14,218–14,983 | *Dryas integrifolia* leaves, moss parts, *Carex* sp. achene, *Daphnia* sp., insect parts, *Salix herbacea* leaves, Characeae oospores |
| | Pond of Safety | Onset of Younger Dryas lithic zone | OS-7121 | 11,300 ± 80 | −26.4 | 13,032–13,309 | Bulk accelerator mass spectrometry (AMS) on minerogenic gyttja |
| | Pond of Safety | Termination of Younger Dryas lithic zone | OS-7120 | 10,650 ± 45 | −27.2 | 12,554–12,705 | Bulk AMS on minerogenic gyttja |
| | York Pond | Deglaciation of York Pond basin (varved interval) | PL-0000494A | 11,980 ± 90 | −28.0 | 13,582–14,058 | Insect parts, *Daphnia* sp., *Picea* needles and seeds, woody twigs, *Vaccinium uliginosum* leaves, *Carex* sp. achenes |
| | York Pond | Cessation of glacial meltwater input | PL-0000495A | 10,900 ± 80 | −25.6 | 12,689–12,981 | Insect parts, *Dryas integrifolia* leaves, woody twigs |
| | York Pond | Onset of Younger Dryas lithic zone | PL-0000490A | 10,650 ± 80 | −27.5 | 12,516–12,723 | Insect parts, *Picea* needles and seeds, woody twigs, Cyperaceae achene |
| | York Pond | Termination of Younger Dryas lithic zone | PL-0000493A | 10,090 ± 80 | −26.6 | 11,325–12,002 | Insect parts, *Picea* needles and seeds, woody twigs, *Vaccinium* sp. leaves, *Betula* seed |
| | York Pond | Peak organic productivity in pond | PL-0000492A | 8180 ± 80 | −26.3 | 8989–9415 | *Picea* needles and seeds, *Pinus strobus* needles, *Betula* seeds, conifer bracts |

*Figure 68: Radiocarbon dates and associated sample material from pond cores around the Israel River Valley and adjacent areas (Thompson et al, 2017). Red text shows date from Ingerson property, red box shows approximate range within which this new date falls and associated vegetation sample material.*

Another important factor in the paleoenvironmental equation is moisture availability and its impact on vegetation. Shuman et al. (2005) summarize vegetation change patterns over the early Holocene (which they define as 11,500-8,000 cal BP) in the White Mountains based on temporal variations in moisture availability. They argue that the shift from Msazesso (spruce) to

Pasaakw (pine) populations in the region around 11,000 cal BP corresponds with a transition to warmer and drier conditions. As time progressed, conditions in the White Mountains became still drier and warmer; this is evidenced in the abundance of white pine pollen found in cores across the region with increasing time. However, the subsequent rise in beech and Alnisedi (hemlock) supports the interpretation that conditions again shifted towards the wetter end of the spectrum near the end of the early Holocene, around 8,000 cal BP (Shuman et al., 2005). This change may have been due to the declining influence of the Laurentide Ice Sheet and the collapse of the Hudson Bay ice dome around 8,000 cal BP. These factors combined to allow additional advection of subtropical moisture into New England, which allowed populations of Maskwamozi (birch) and beech to expand (Shuman et al., 2005). In this way, a consideration of moisture availability (which is controlled by local lake levels, among other factors) helps show that climate conditions influenced long-term regional vegetation trends in the Holocene (Shuman et al., 2005).

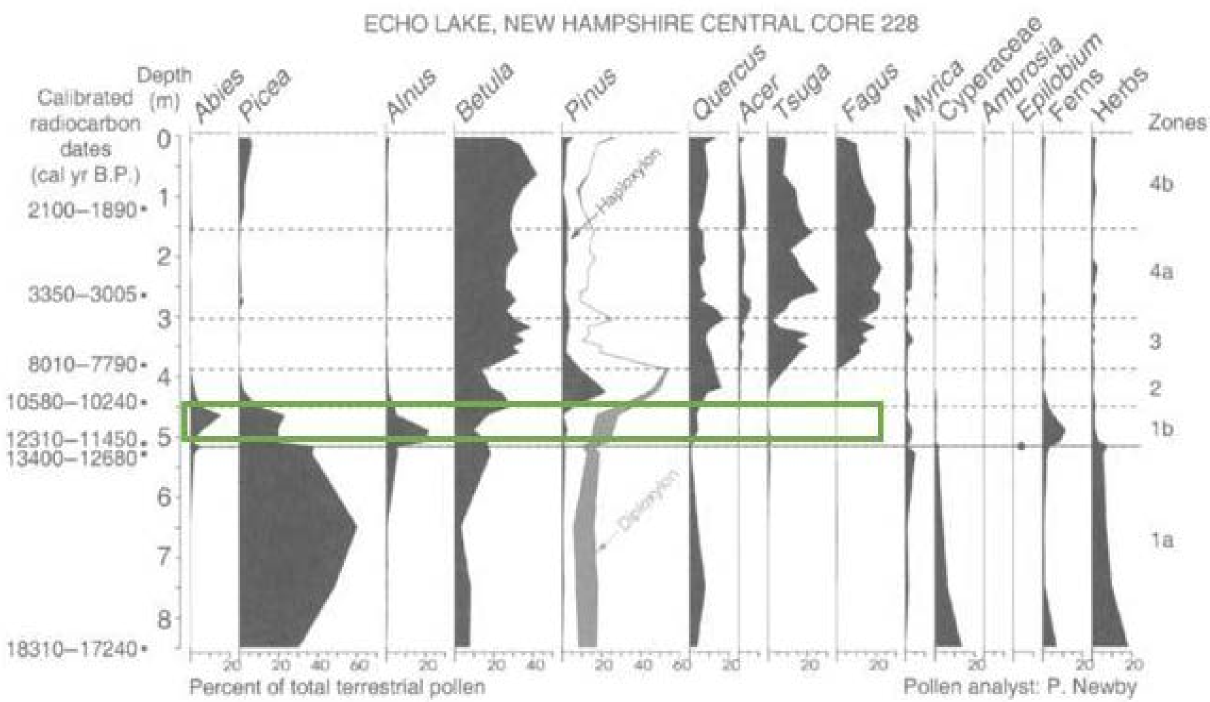



*Figure 69: Pollen analysis results from a core at Echo Lake, NH, correlated to calibrated radiocarbon dates (modified from Shuman et al., 2005). Green rectangle highlights species mentioned in the text at/around 11,140 cal BP: abies (fir), picea (spruce), betula (birch), pinus (pine), and tsuga (hemlock).*

## Paleoclimate and the Israel River Complex Sites

### Relative Dating of the IRC

The Israel River Complex sites have not been absolutely dated; the occupational period is constrained by diagnostic artifacts and based on a chronology of projectile point styles defined by radiocarbon dates from other sites in the northeast. The chronology of the Paleoindian Period is described by Bradley et al., 2008 (in Boisvert et al., 2017) and summarized by Lothrop et al. (2016) and includes three divisions: early, (approximately 13,000-12,200 cal BP) middle, (12,200-11,600 cal BP) and late, (11,600-10,000 cal BP). Age range interpretations for these periods, with their associated projectile point styles, are listed in Table 1. Analysis of calibrated radiocarbon ages from the middle Paleoindian period has shown that dates for sites with points in the Michaud-Neponset forms fall predominantly within the latter portion of the Younger Dryas, (with some dates suggesting overlap into the early Holocene) while early Paleoindian Period forms fall predominantly within the first half of the Younger Dryas period (Lothrop et al., 2016). Fluted projectile points, channel flakes, spurred end scrapers, and the presence of significant amounts of Munsungun chert have all been used to relatively determine the ages of the sites (Boisvert et al., 2017; Boisvert, 1999, 2012).

Sites in the IRC fall within the early and middle Paleoindian Periods, and according to investigations conducted thus far, (with the exception of late 19th and early 20th century debris in plow zones) show no evidence of later occupation by Indigenous peoples (Boisvert et al., 2017; Boisvert, 2012; Thompson et al., 2002). This is not to say, however, that Indigenous groups have no connection to the land in the Israel River Valley.

### Paleoclimate and Early Human Populations in the NEM

Caribou have long been thought to play a role in the interpretation of regional subsistence patterns during this period. It has been suggested that sites dating to the Paleoindian period may represent social aggregations similar to those of the contemporary arctic and subarctic (Pelletier and Robinson, 2005; Curran 1984). In the period from 12,000-11,000 cal BP the receding margin of the Laurentide Ice Sheet was separated from New Hampshire and Maine by the Champlain Sea (Figure 70) and in northern NH the environment consisted of a transitional zone between tundra and mixed woodland, as discussed above (Davis and Jacobson, 1985; Pelletier and Robinson, 2005; Lothrop et al., 2016). Pelletier and Robinson (2005) propose a tundra/mixed forest ecotone extending through southern Canada just north of NH and VT at 11,000-10,500 cal

BP (Figure 71). However, the landscape reconstructions of Davis and Jacobson (1985) show tundra extending into northern NH; this reconstruction would bring the tundra/mixed woodland ecotone far enough south to cross through the study area during the existence of the Alderbrook Stage and the occupation of the IRC.

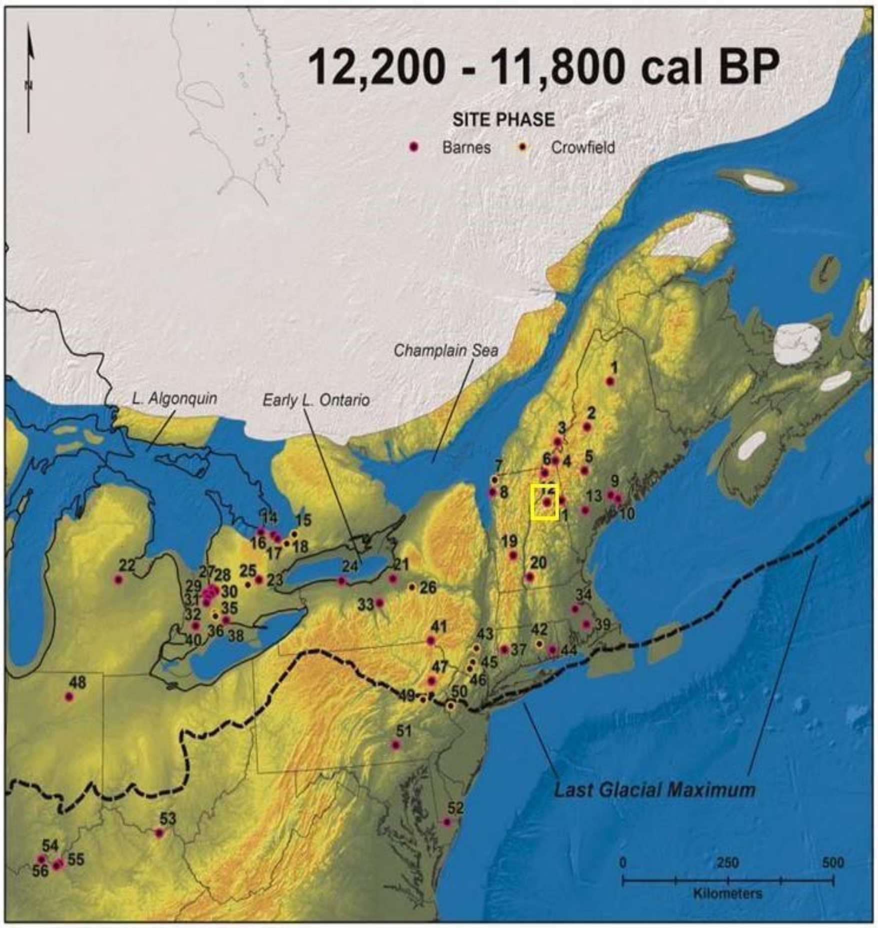



*Figure 70: Schematic showing retreat of the LIS in the Late Pleistocene and locations of middle Paleoindian period sites in the northeast. The IRC is highlighted in yellow (figure modified from Lothrop et al., 2016).*

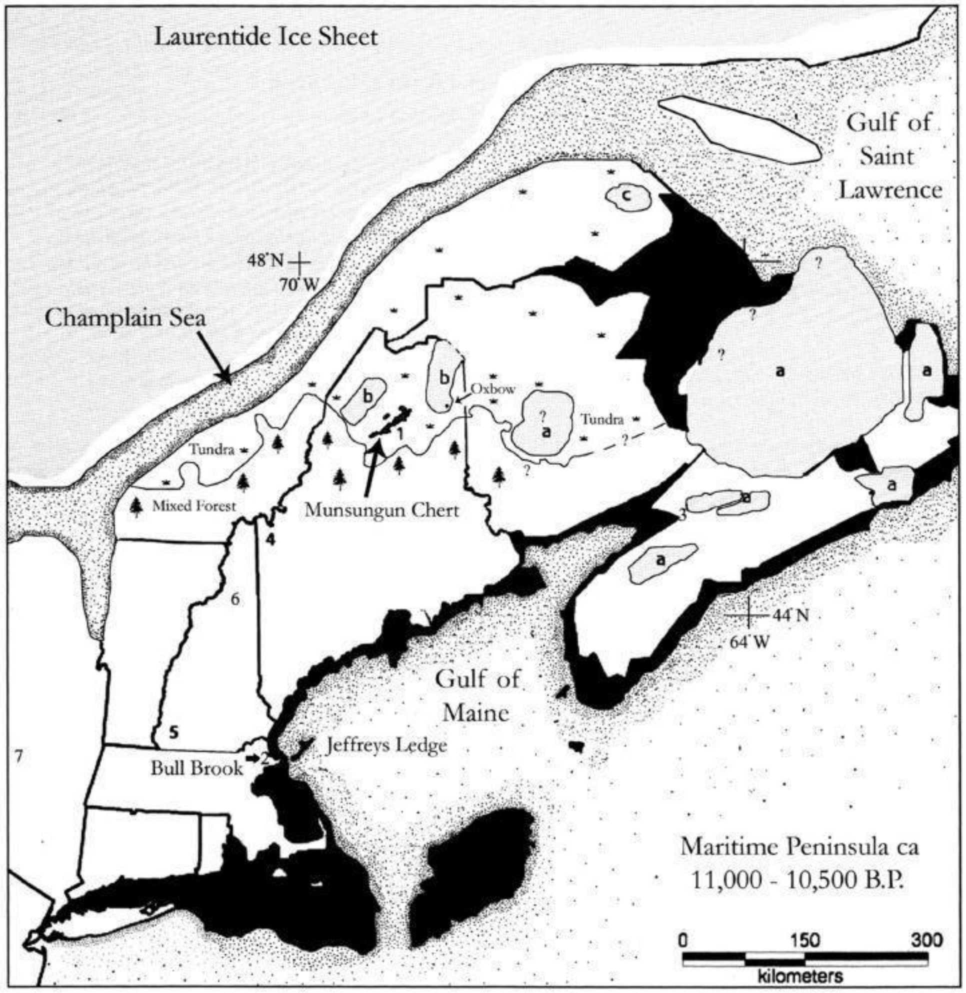



*Figure 71: Tundra-mixed forest ecotone at 11,000-10,500 cal BP (Pelletier and Robinson, 2005). Landscape reconstructions from Davis and Jacobson (1985) extend the tundra/mixed woodland boundary further south, with tundra existing in northern NH and Wawabibagw (poplar) woodland reaching north into southern Canada. Combining the two models puts the ecotone in the study area at the time that the IRC was occupied and the Alderbrook/Riverton stages existed in the Israel River Valley. (Study area marked with a 6).*

Pelletier and Robinson (2005) argue that caribou concentrations may have been influenced by summer use of glacial ice near the Munsungun quarries in northern Maine (Figure 71). These workers propose remnant ice patches existing in the upland regions of Nova Scotia, Maine and possibly New Hampshire, with wide areas of tundra and ice contact being ideal environments for the summertime aggregation of caribou herds (Pelletier and Robinson, 2005). Based on this idea of seasonal caribou migration, Newby et al. (2005) and Pelletier and Robinson (2005) propose seasonal movement of humans between tundra environments in the north (summer) and mixed forest environments in the south (fall/winter). Pelletier and Robinson cite modern analogs of Alaska and the Canadian Yukon where wood and bone artifacts have been found melting from ice margins and have returned dates older than 8,000 cal BP as evidence for this pattern. Boisvert et al. (2017) argue that caribou hunts would be most successful in the late summer and early autumn when caribou congregate around these tundra/ice contact areas. Human movements could also have been determined by locations of lithic raw materials, such as Munsungun chert (Pelletier and Robinson, 2005).

## The Importance of Location for the IRC Sites: Vantage and Caribou

Evidence suggests that the IRC was repeatedly occupied over a considerable length of time. What factors would have made this place attractive to people? Would those factors have stayed consistent over time (Boisvert et al., 2017)? Thompson et al. (2002) suggest that the presence of the Mt Jasper and Jefferson rhyolites may be a contributing factor in the location and occupational history of the IRC. Evidence for movement throughout ME, NH, northern VT and eastern MA can be seen in the presence of raw materials (such as Munsungun chert from northern Maine) at the IRC sites and the recovery of flow-banded Jefferson-like rhyolites at other sites in the northeast; the sphere of interaction was quite wide (Thompson et al., 2002).

Additionally, the Israel River and the Moose River to the east serve as a corridor between the Connecticut and Androscoggin Rivers and form one of only a few corridors of east-west travel in Northern NH (Thompson et al., 2002). The Israel River is a tributary to the Connecticut River 15km to the Northwest, while the drainage divide at Bowman separates the head of the Israel River from the Moose River, which joins the Androscoggin about 25 km to the east near Gorham, NH. The location of the IRC therefore supports the idea of mobile populations.

Archaeological evidence from the IRC suggests a mixture of domestic spaces and specialized activity areas, (characterized by bifacial tool manufacturing areas and hide processing areas) which is interpreted as evidence of a caribou hunting culture (Boisvert 1999, 2004, 2012, Boisvert et al., 2017). These determinations have been made based on the presence of bone and antler tool manufacturing equipment, delicate retouched flakes suggesting clothing manufacture, and projectile points suggestive of large mammal hunting (Thompson et al., 2002). A detailed intra-site analysis of the Jefferson VI site conducted by Doperalski (in press) showed a large amount of debitage and channel flakes, interpreted as evidence for final shaping of projectile points on site, meat processing, hide preparation, clothing manufacture, and working of bone, antler, and wood. Activity areas were determined based on concentrations of debitage, with separate areas for tool manufacture and maintenance and bone/antler/wood processing and hide preparation (Doperalski, in press). The artifact distributions at many of the IRC sites have been interpreted as evidence of repeated seasonal occupation by small, potentially household level groups (Thompson et al., 2002).

A similar analysis was conducted for the Tenant Swamp site near Keene, NH. There, loci were characterized as having relatively clear demarcations between dense artifact deposits and empty spaces. These well-defined loci were interpreted as locations of structures or tents (Doperalski, in press; Goodby et al., 2014). In the same vein of speculation, the distribution patterns of the locus analyzed at the Jefferson VI site suggests a central hearth area around which tool manufacture took place, with hide processing taking place further from this center area (Doperalski, in press). At the IRC, however, the density of chipped stone artifacts gradually drops off and lacks the well-demarcated zone of the Tenant Swamp loci. This could suggest (with great speculation) that activities were completed outdoors rather than within a structure, which might indicate occupation during the warmer months of the year (Doperalski, in press).

The evidence of hunting, combined with the artifact distribution analysis, is suggested by Doperalski to confirm a late summer/early autumn seasonal occupation focused on preparations for winter when caribou hides would be at the highest quality (Doperalski, in press; Boisvert et al., 2017). Perhaps the location of the IRC along a proposed caribou movement corridor supports the interpretation of the sites as a staging zone for hunting operations that could have taken place as caribou moved south from the tundra zone at the end of summer to the woodlands in the southern NEM ca. 11,000 cal BP. Or, this proposed late summer/early autumn occupation could have been focused around hunting caribou attracted to remnant ice in the valleys of the White Mountains, (in agreement with the remnant ice model of Pelletier and Robinson, 2005) in addition to use of the abundant resources present in the postglacial Alderbrook Stage environment.

A recent viewshed analysis of four locations within the IRC conducted by Boisvert et al. (2017) provides evidence that the habitation sites either have good viewsheds of potential caribou travel routes through the Israel River Valley (and, consequently, the postglacial lakes there) or have vantage points nearby that have good viewsheds. Although no species identification has been successfully performed on faunal remains from any of the IRC sites, the broader archaeological context as well as discovery of cervid protein on a Munsungun chert flake from the Jefferson IV site indicates that caribou or related species were hunted (Thompson et al., 2002). Small low density sites and loci with artifacts limited to channel flakes, point fragments, and sparse debitage with strategic views of the Israel River Valley are characterized as vantage points to facilitate observation of migrating caribou herds (Boisvert et al., 2017). The Jefferson I site is a good example of such a location, as well as the till hummock adjacent to the Jefferson II site (Boisvert et al., 2017). This pattern has been described in other areas, notably by Ellis and Deller (2000) with the Parkhill site in Ontario and Spiess, Cowie, and Bartone (2012) with the Beacon Hill site in western Maine.

The presence of water sources such as the Alderbrook stage along the floor of the Israel River Valley may have provided another advantage in hunting caribou. There is evidence to show that caribou often travel along natural boundaries such as lakeshores or contours (Boisvert et al., 2017; Boisvert, 2012; Spiess, 1979). The viewsheds performed by Boisvert et al. in 2017 show that extensive areas of the Alderbrook stage would have been visible from these vantage point sites; Figure 72 shows the Jefferson II site and highlights the vantage point site on a till hummock to the west, as defined by Boisvert et al. (2017). Figure 73 is a replicated viewshed of the valley from the vantage point site, illustrating the good vantage over the Alderbrook Stage and the floor of the Israel River Valley.

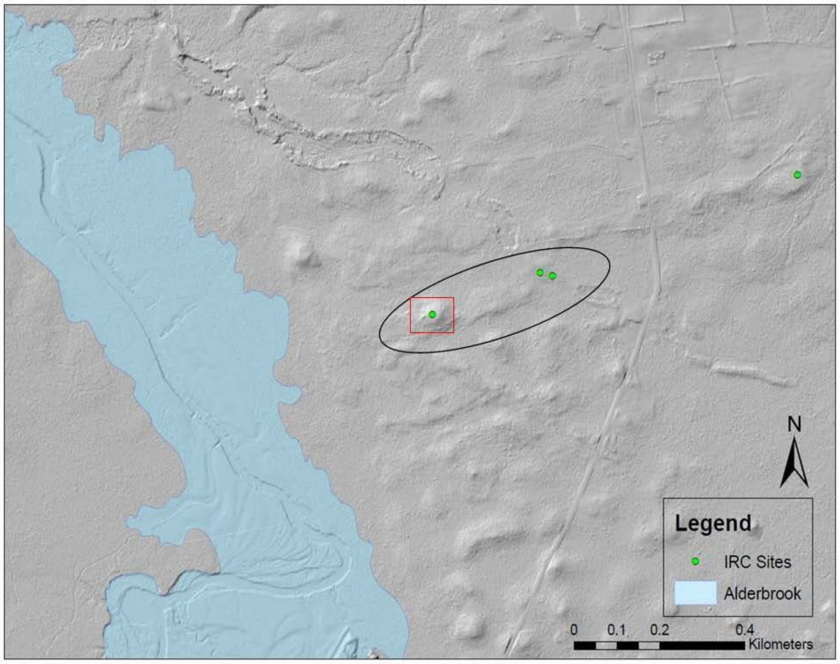



*Figure 72:* *Vantage point (outlined in red) at the Jefferson II site (outlined in black) from Boisvert et al., 2017. This vantage point was used to make the viewshed seen overlying the Alderbrook stage in Figure 73.*

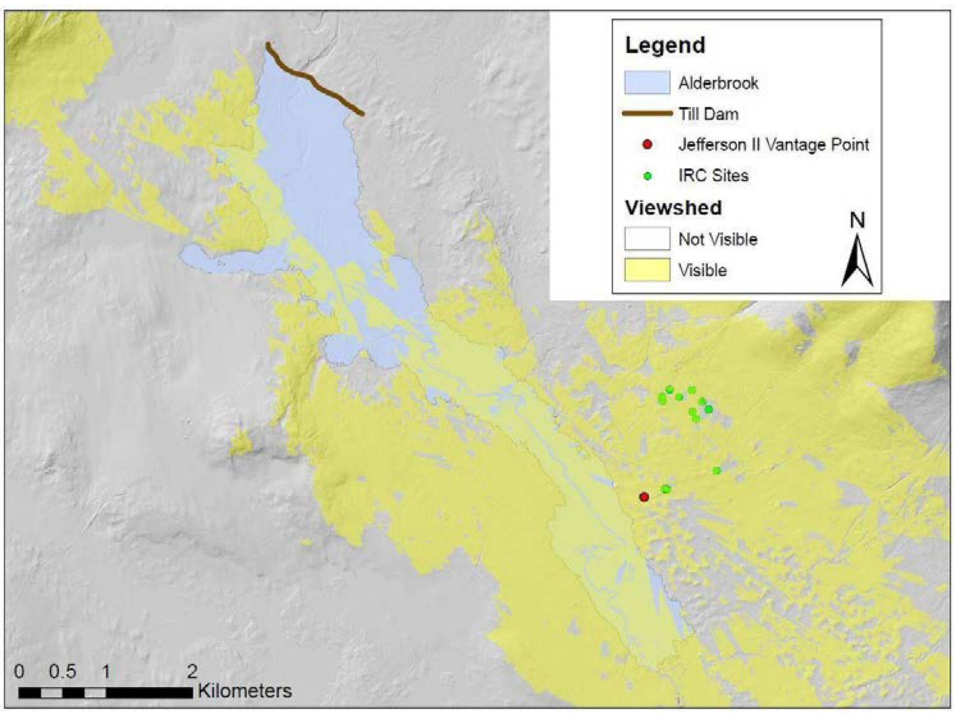



*Figure 73:* *Viewshed from what Boisvert et al. (2017) defined as the Jefferson II vantage point site, a till hummock adjacent to the main Jefferson II site. More than half of the Alderbrook lake area is visible from the site, supporting the idea that sites were located in areas with good vantage of waterways/caribou movement pathways.*

Boisvert et al., (2017) propose that this site configuration was an adaptation to the cooler climate of the Younger Dryas and related caribou behavior. Spiess (1979) summarizes several ethnohistoric accounts of caribou hunting from across Alaska and arctic Canada, where strategies focused on driving caribou along lines of cairns, brush piles, and low fences into bodies of water where they could be more easily targeted. These tactics integrated knowledge of animal behavior with knowledge of the local landscape and would have been as applicable in the late Pleistocene/early Holocene as they are today.

## A Wider Range of Subsistence and Social Models

There is much more to the story than caribou, however. The patterns observed in northern NH are in no way representative of all areas in the northeast at this time period; in fact, they may represent seasonal adaptations different from sites farther south in NH but still regionally comparable, such as the Tenant Swamp site (Boisvert et al., 2017). It has been suggested that the caribou hunted by people at this time did not in fact occur in large herds migrating great distances across bare ground (Dincauze, 1993a; Pelletier and Robinson, 2005). These claims encourage the search for subsistence interpretations drawing on a wider range of resources and social models.

The generalist approach, summarized by Dincauze (1983), focuses on increased productivity and species diversity in late Pleistocene forests and shallow water/marshy environments where caribou were instead most likely hunted on an encounter basis (Pelletier and Robinson, 2005). This approach focuses on the concept of ecotonal area exploitation, shifting this focus from the tundra/Msazesso (spruce) parkland ecotone to an ecotone farther south: that of the Msazesso (spruce) parkland/Msazesso (spruce) woodland. In a study on Glacial Lake Hitchcock, Curran and Dincauze (1977) propose that the woodland ecotone would've been considerably biotically richer than the tundra ecotone, which was traditionally favored as the area most likely to have been utilized by humans. They argue that the rapidly changing late-glacial environment could have expanded environmental transition zones, enriching the biota and allowing species found today at higher arctic/subarctic latitudes to be found at lower latitudes- an interpretation supported by the lower average temperatures of the Younger Dryas (Curran and Dincauze, 1977).

Curran and Dincauze (1977) also describe the importance of bog and grassland environments; Boisvert (2012) agrees and argues that the Connecticut River Valley would've been most attractive to humans directly after the drainage of Glacial Lake Hitchcock because of the attractiveness of the remnant marshland. These claims have been supported by cases such as the archaeological site found on the bed of Glacial Lake Ashuelot, which now sits on the margins of Tenant Swamp near Keene, NH (Boisvert, 2012; Goodby et al., 2014). The Tenant Swamp site sits on a terrace overlooking the Ashuelot River, and would have provided a good vantage point for observation of caribou as well as access to smaller mammals such as beaver and otter; in fact, bone fragments identified as otter were found at the site, along with cervid fragments identified as caribou (Goodby et al., 2014).

In total, these arguments suggest a strong relationship between late Pleistocene/early Holocene wetlands/postglacial lakes and sites of human occupation around this time period, (Boisvert, 2012) and emphasize the importance of the Alderbrook and Riverton stages of Glacial Lake Israel to the environment and to the lifeways of the Israel River Complex occupants.

## Conclusions

Through an analysis of archaeological data and partial use of the Indigenous Research Paradigm outlined by Lambert, (2018) this study works towards a more complex understanding of lifeways in the postglacial Israel River valley, and approaches this analysis in terms of the postglacial Alderbrook and Riverton stages of Glacial Lake Israel. Evidence for these stages is seen in elevation profiles, mapping of landscape types and their correlation to lake stage models, shoreline and wave-cut features seen in the field, and in the presence of a visible spillway through which both stages drained. The existence of these postglacial stages, especially the Alderbrook stage which has been dated to 11,140 cal BP, (confirming overlap with human occupation of the Israel River Complex sites) undoubtedly had implications for life in the Israel River Valley around the late Pleistocene/early Holocene.

The presence of a postglacial lake on the valley floor probably allowed caribou to be funneled through the valley and hunted efficiently. Just as importantly, however, a postglacial lake would have supported numerous other species such as beaver, stag moose, otter, and a wide variety of edible plants. In this way, the late Pleistocene/early Holocene environment and occupants of the Israel River Complex were connected on a deeper and more complex level than what has been argued in much archaeological work (which tends to focus most heavily on the importance of big game hunting). Research on this human/environment relationship should work to further understand the role of these postglacial lakes in this environment and in doing so should incorporate data from all available sources. These include Indigenous knowledge and archaeology, paleoclimate studies, and geology, among others.

Further work should continue to integrate Indigenous knowledge with archaeological research in the area, working towards a deeper understanding of human history in the region from the Pleistocene to the present. There is ample evidence to support the deep history of human occupation in the area, indicating that this human/environment relationship is one that stretches thousands of years back to the recession of the Laurentide Ice Sheet. Indigenous knowledge in the form of oral histories illustrate this deep history and should be considered alongside archaeological data; both tell the same story from different angles and can enrich each other. Additionally, traditional ecological knowledge (TEK) further illustrates the deep history of human/environment interaction in New Hampshire. In conjunction with paleoclimate research and archaeological work, TEK can illuminate the complex interactions of Indigenous peoples and the environment into the deep past.

Archaeology at the Israel River Complex is ongoing, and there is certainly more to be discovered in collaboration with Indigenous peoples in New Hampshire and throughout the northeast U.S. The relationship between the post-glacial occupants of New Hampshire and the environment in post-glacial valleys such as the Israel River valley is by no means fully known. Consideration of paleoclimate data, archaeology, and Indigenous knowledge will certainly lend insights into this rich history and will expand our understanding of human/environment relationships to include the perspectives of those who have direct cultural continuity with the people who lived in postglacial New Hampshire.

## References

Agrawal, A., 1995, Dismantling the Divide between Indigenous and Scientific Knowledge: Development and Change, v. 26, p. 413-439.

Allen, T., Creasy, J., Davis, P. T., Eusden, J., Fowler, B., & Thompson, W., 2001, The Notches: Bedrock and Surficial Geology of New Hampshire's White Mountains: Geological Society of America Annual Meeting (Guidebook for Geological Field Trips in New England), p. 1-33.

Alley, R. B., 2000, Ice-core evidence of abrupt climate changes: Proceedings of the National Academy of Sciences of the United States of America, v. 97, p. 1331-1334.

Baker, S., 2016, Bedrock Geology of the Southern Half of the Jefferson 7.5' Quadrangle, New Hampshire [Undergraduate thesis]: Bates College, Lewiston, Maine.

Baker, S., Boisvert, R., Eusden, J. D., Hamilton, N., & Pollock, S., 2017, The New Hampshire Spherulitic Rhyolites: Rocks of Importance to Prehistoric Native Americans in Guidebook for Field Trips in Western Maine and Northern New Hampshire: New England Intercollegiate Geological Conference, Bates College, 11 p. doi:10.26780/2017.001.0017

Balco, G., Stone, J., Porter, S., & Caffee, M., 2002, Cosmogenic-nuclide ages for New England coastal moraines, Martha's Vineyard and Cape Cod, Massachusetts, USA: Quaternary Science Reviews v. 21, p. 2127-2135.

Bar-Yosef, O., 2001, A Personal View of Earth Sciences' Contributions to Archaeology in Goldberg, P., Holliday, V., & Reid Ferring, C., ed., Earth Sciences and Archaeology, New York: Kluwer Academic/Plenum Publishers.

Beck, J., 1972, The Giant Beaver: A Prehistoric Memory?: Ethnohistory, v. 19, p. 119-122.

Bentley, R. A., & Maschner, H. D. G., 2007, Introduction: On Archaeological Theories in Bentley, R. A., Maschner, H. D. G., and Chippendale, C., ed., Handbook of Archaeological Theories, New York: AltaMira Press, 774 p.

Beta Analytic, 2017, Radiocarbon Dating: An Introduction: https://www.radiocarbon.com/about-carbon-dating.htm (accessed November 2017).

Boisvert, R., 1999, Paleoindian occupation of the White Mountains, New Hampshire: Géographie physique et Quaternaire, v. 53, p. 159-174.

Boisvert R., 2004, Clovis Era Archaeology in Northern New Hampshire: The Israel River Complex in Lepper, B., and Bonnichsen, R., ed., New Perspectives on First Americans Studies, College Station: Texas A&M University Press.

Boisvert, R., 2012, The Paleoindian Period in New Hampshire in Chapeldaine, C., ed., Late Pleistocene Archaeology and Ecology in the Far Northeast, College Station: Texas A&M University Press.

Boisvert, R., 2013, The First Geologists: Late Pleistocene Settlement of the White Mountains: in The Geology of New Hampshire's White Mountains: Lyme, New Hampshire, Durand Press.

Boisvert, R., & Pollock, S., 2009, Archaeology and Geology of the Mount Jasper Lithic Source: The New Hampshire Archeologist, v. 49, p. 37-48.

Boisvert, R., Krajcik, T., & Greenly, M., 2017, Paleoindian Adaptation to the Landscape of Northern New Hampshire: PaleoAmerica. doi:10.1080/20555563.2017.1380483

Borns, H., Doner, L. J., Dorion, C., Jacobsen, G. J., Kaplan, M., Kreutz, K., & Weddle, T., 2004, The deglaciation of Maine, USA: Quaternary Science Reviews, v. 2, p. 89-109.

Bradley, J. W., Spiess, A. E., Boisvert, R. A., & Boudreau, J., 2008, What's the Point?: Modal Forms and Attributes of Paleoindian Bifaces in the New England-Maritimes Region: Archaeology of Eastern North America, v.36, p. 119-172.

Broecker, W., 2006, Was the Younger Dryas Triggered by a Flood?: Science, v. 312, p. 1146-1148.

Broecker, W., & Denton, G., 1989, The role of ocean-atmosphere reorganizations in glacial cycles: Geochimica et Cosmochimica Acta, v. 53, p. 2465-2501.

Bromley, G., Hall, B., Thompson, W., Kaplan, M., Garcia, J., & Schaefer, J., 2015, Late glacial fluctuations of the Laurentide Ice Sheet in the White Mountains of Maine and New Hampshire, USA: Quaternary Research v. 83, p. 522-530.

Bunker, V., 1994, New Hampshire's Prehistoric Settlement and Chronology in Piotrowski, T., ed., The Indian Heritage of New Hampshire and Northern New England: North Carolina, McFarland & Company, Inc., 221 p.

Caduto, M., 2003, A Time Before New Hampshire: University Press of New England, 265 p.

Cargill, J. L., 2016, Structure and Geochronology of the Jurassic Pliny Range Caldera Complex: 7.5' Jefferson Quadrangle, Northern New Hampshire [Undergraduate thesis]: Bates College, Lewiston, Maine.

Carlson, A., 2013, The Younger Dryas Climate Event: The Encyclopedia of Quaternary Science, v.3, p. 126-134. doi:10.1016/B978-0-444-53643-3.00029-7

Chormann, R., 2015, The Emerging LiDAR Landscap: NRCS State Technical Committee Meeting.

Cremeens, D., & Hart, J, 2003, Introduction in D. Cremeens & J. Hart, ed., Geoarchaeology of Landscapes, New York: The University of the State of New York.

Crutchley, S., 2010, The Light Fantastic: Using Airborne Lidar in Archaeological Survey: ISPRS TC VII Symposium, v. XXXVIII, p. 160-164.

Curran, M., & Dincauze, D., 1977, Paleoindians and Paleo-lakes: New Data from the Connecticut Drainage: Annals of the New York Academy of Sciences, p. 333-348.

Curran, M., 1984, The Whipple Site and Paleoindian Tool Assemblage Variation: A Comparison of Intrasite Structuring: Archaeology of Eastern North America, v.12, p. 5-40.

Davis, P. T., Koester, A. J., Shakun, J. D., Bierman, P. R., & Corbett, L. B., 2017, Applying the Cosmogenic Nuclide Dipstick Model for Deglaciation of Mt. Washington in Guidebook for Field Trips in Western Maine and Northern New Hampshire: New England Intercollegiate Geological Conference, Bates College, 30 p. doi:10.26780

Davis, R.B. & Jacobson, G.L., 1985, Late glacial and early Holocene landscapes in northern New England and adjacent areas of Canada: Quaternary Research, v. 23, p.341-368.

Dincauze, D. F., 1993a, Fluted Points in the Eastern Forests in From Kostenki to Clovis: Upper Paleolithic-Paleo-Indian Adaptations, ed., New York: Plenum Press.

Dincauze, D. F. & M. L. Curran, 1983, Paleoindians as Generalists: An Ecological Perspective: Paper presented at the 48th Annual Meeting, Society for American Archaeology, Pittsburgh.

Doperalski, M., 2018, A GIS-Based Spatial Analysis of a Paleoindian Chipped-Stone Assemblage at the Jefferson VI Site in Northern New Hampshire (in press).

Dulin, I.T., Fowler, B. K., & Cook, T. L., 2012, New Evidence of a Post-Laurentide Local Cirque Glacier on Mount Washington, New Hampshire [Undergraduate thesis]: Lewiston, Bates College, 75 p.

Ellis, C., & Deller, D. B., 2000, An Early Paleo- Indian Site near Parkhill, Ontario: Quebec: Canadian Museum of Civilization, 313 p.

Eusden, D., & Thompson, W., 2013, Forces that Shaped the White Mountains in The Geology of New Hampshire's White Mountains, ed., Lyme, New Hampshire: Durand Press.

Eusden, D., Hillenbrand, I., Baker, S., & Cargill, J., compilers, 2017, Bedrock Geology map of the Jefferson Quadrangle, New Hampshire: U.S. Geological Survey and N.H. Geological Survey.

Fiedel, S. J., 2011, The mysterious onset of the Younger Dryas: Quaternary International, v. 242, p. 262-266. https://doi.org/10.1016/j.quaint.2011.02.044

Fowler, B., Barker, G., and Chormann, F., Surficial Geologic Map of the Mount Dartmouth 7.5' Quadrangle, New Hampshire: USGS, scale 1:24,000.

Fowler, B., & Dulin, I., 2017, Possible Post-Laurentide Cirque Glaciation in the Great Gulf Presidential Range, New Hampshire in Guidebook for Field Trips in Western Maine and Northern New Hampshire: New England Intercollegiate Geological Conference, Bates College, 13 p. doi:10.26780/2017.001.0005

Fowler, B., Thompson, W., & Davis, T., 2013, Glaciers Shape the Mountains in The Geology of New Hampshire's White Mountains, ed., Lyme, New Hampshire: Durand Press.

Goodby, R. G., Bock, P., Bouras, E., Dorion, C. A., Evans, G., Largy, T., Pollock, S., Rockwell, H., & Spiess, A., 2014, The Tenant Swamp Site and Paleoindian Domestic Space in Keene, New Hampshire: Archaeology of Eastern North America, v.42, p. 129-164.

Holliday, V., 2001, Quaternary Geoscience in Archaeology in P. Goldberg, V. Holliday, & C. Reid Ferring, ed., Earth Sciences and Archaeology, New York: Kluwer Academic/Plenum Publishers.

Houde, N., 2007, The Six Faces of Traditional Ecological Knowledge: Challenges and Opportunities for Canadian Co-Management Arrangements: Ecology and Society, v. 12.

Indigenous New Hampshire, an Exploration of the Cultural Heritage of New England: https://indigenousnh.com/about/ (accessed March 2018).

Julien, D., Bernard, T., & Rosenmeier, L. M., with review by the Mi'kmawey Debert Elders' Advisory Council, 2010, Paleo is Not Our Word: Protecting and Growing a Mi'kmaw Place in Bruchac, M., Hart., S. M., & Wobst, H. M., ed., Indigenous Archaeologies: a reader on decolonization, New York: Routledge, 436 p.

Kaplan, M., 2007, Major ice sheet response in eastern New England to a cold North Atlantic region, ca. 16-15 cal ka BP: Quaternary Research v. 68, p. 280-283.

Koasek of the Koas, 2015, Language: http://www.koasekofthekoas.org/new%20%207.html (accessed March 2018).

Koe, S., 2016, Applications of LiDAR in the study of landscape geomorphology, Sandwich Range, White Mountain National Forest [Undergraduate thesis]: Bates College, Lewiston, Maine.

Lambert, L., 2018, Indigenous Research Paradigm: A Conceptual Model: American Indigenous Research Association: https://www.americanindigenousresearchassociation.org/wp-content/uploads/2013/01/LL-spider-conceptual-model-lg-2.jpg (accessed March 2018).

Lothrop, J., Lowery, D. L., Speiss, A. E., & Ellis, C. J., 2016, Early Human Settlement of Northeastern North America: PaleoAmerica, v. 2, p. 192-251.

Lowell, T.V., 1985, Late Wisconsin ice-flow reversal and deglaciation, north-western Maine, in Borns, H.W., Jr., LaSalle, & Thompson, W.B., eds., Late Pleistocene history of north-eastern New England and adjacent Quebec: Geological Society of America, Special Paper 197, p. 71-83.

Native American Ethnobotany Database: http://naeb.brit.org/ (accessed March 2018).

Newby, P., Bradley, J., Spiess, A., Shuman, B., & Leduc, P., 2005, A Paleoindian Response to Younger Dryas Climate Change: Quaternary Science Reviews, v.24, p.141-154.

Newsom, B., 2010, Ancient Ones and Cultural Affiliation: An Examination of the Evidence from Maine: Report Prepared for Acadia National Park, National Park Service, Bar Harbor, Maine.

NH Granit, 2017, Topographic LiDAR in New Hampshire: http://www.granit.unh.edu/resourcelibrary/specialtopics/lidar/ (accessed July 2018).

Niiler, K., 2018, Bedrock mapping of the Southern Portion of the 7.5' Mt. Crescent Quadrangle, New Hampshire [Undergraduate thesis]: Bates College, Lewiston, Maine.

NOAA, 2017, The Technical Details: Radioactive Decay: Global Monitoring Division: https://www.esrl.noaa.gov/gmd/ccgg/isotopes/decay.html (accessed November 2017).

Oswald, W.W., & Foster, D. R., 2011, Middle-Holocene dynamics of Tsuga canadensis (eastern hemlock) in northern New England, USA: The *Holocene,* v. 22, p. 71-78.

Oxford Radiocarbon Accelerator Unit, 2017, Why radiocarbon measurements are not true calendar ages: Radiocarbon Calibration: https://c14.arch.ox.ac.uk/calibration.html - conventions_timescale (accessed November 2017).

Pelletier, B., & Robinson, B., 2005, Tundra, Ice and a Pleistocene Cape on the Gulf of Maine: A Case of Paleoindian Transhumance: Archaeology of Eastern North America, v. 33, p. 163-176.

Pollock, S., Hamilton, N., & Boisvert, R., 2008, Archaeological geology of two flow-banded spherulitic rhyolites in New England, USA: their history, exploitation and criteria for recognition: Journal of Archaeological Science, v. 35, p. 688-703. doi:10.1016/j.jas.2007.05.020

Rapp, J., & Hill, C., 2006, Geoarchaeology: the Earth-Science Approach to Archaeological Interpretation, Second Edition ed., New Haven: Yale University Press.

Retelle, M., Weddle, T., & Eckert, S., 2016, Guidebook for Field Trips along the Maine Coast from Maquoit Bay to Muscongus Bay: Middlebury College Geology Department, Maine Geological Survey.

Reutebuch, S., Andersen, H., & Mcgaughey, R., 2005, Light Detection and Ranging (LIDAR): An Emerging Tool for Multiple Resource Inventory: Journal of Forestry- Washington, v. 103, p. 286-292.

Ridge, J., 2003, The Last Deglaciation of the Northeastern United States: A Combined Varve, Paleomagnetic, and Calibrated 14C Chronology in Cremeens, D. & Hart, J., ed., Geoarchaeology of Landscapes, New York: The University of the State of New York.

Ridge, J., North American Glacial Varve Project: The NAVC and Deglaciation of the Northeastern U.S.: http://eos.tufts.edu/varves/NAVC/navcdeglac.asp

Ridge, J., Balco, G., Bayless, R., Beck, C., Carter, L., Dean, J., Voytek, E., and Wei, J., 2012, The New North American Varve Chronology: A Precise Record of Southeastern Laurentide Ice Sheet Deglaciation and Climate, 18.2-12.5 Kyr BP, and Correlations with Greenland Ice Core Records: American Journal of Science, v. 312, p. 685-722.

Shuman, B., Newby, P., Donnelly, J. P., Tarbox, A., & Webb III, T., 2005, A Record of Late-Quaternary Moisture-Balance Change and Vegetation Response from the White Mountains, New Hampshire: Annals of the Association of American Geographers, v. 95, p. 237-248.

Spiess, A. E., 1980, Reindeer and Caribou Hunters: An Archaeological Study: Reviews, p. 370-374.

Spiess, A. E., Cowie, E., and Bartone, R., 2012, Geographic Clusters of Fluted Point Sites in the Far Northeast, in Chapeldaine, C., ed., Late Pleistocene Archaeology and Ecology in the Far Northeast, College Station: Texas A&M University Press, p. 95–112.

Steffensen, J. P., Andersen, K., Bigler, M., Clausen, H. B., Dahl-Jensen, D., Fischer, H., Goto-Azuma, K., Margareta Hansson,5 Sigfús J. Johnsen,1 Jean Jouzel,6 Valérie Masson-Delmotte,6 Trevor Popp,7 Sune Rasmussen, O., Röthlisberger, R., Ruth, U., Stauffer, B., Siggaard-Andersen, M., Sveinbjörnsdóttir, A. E., Svensson, A., & White, J. C., 2008, High Resolution Greenland Ice Core Data Shows Abrupt Climate Change Happens in Few Years: Science, v. 321, p. 680-683. DOI: 10.1126/science.1157707

Stuiver, M., Reimer, P. J., & Reimer, R. W., 2018, Calib 7.1: http://calib.org/ (accessed February 2018).

The Cowasuck Band of the Pennacook Abenaki People, 2002-11, http://www.cowasuck.org (accessed March 2018).

The Cowasuck Band of the Pennacook Abenaki People, 2002-11, Ethno-botany: http://www.cowasuck.org/herbal.cfm (accessed March 2018).

The Cowasuck Band of the Pennacook Abenaki People, 2002-11, Abenaki Language: http://www.cowasuck.org/language/lesson16.htm (accessed March 2018).

Thompson, W., 2013, The Laurentide Ice Sheet in The Geology of New Hampshire's White Mountains, ed., Lyme, New Hampshire: Durand Press.

Thompson, W., Baker, S., Barker, G., & Chormann, F., Surficial Geology of the Jefferson 7.5' Quadrangle, New Hampshire: USGS StateMap, scale 1:24,000.

Thompson, W., & Barker, G., 2017, Glacial Deposits and Late-Glacial to PostGlacial Alluvial Fans in the Northwestern White Mountains, New Hampshire in Guidebook for Field Trips in Western Maine and Northern New Hampshire: New England Intercollegiate Geological Conference, Bates College, 13 p.

Thompson, W., Dorion, C., Ridge, J., Balco, G., Fowler, B., & Svendsen, K., 2017, Deglaciation and late-glacial climate change in the White Mountains, New Hampshire, USA: Journal of Quaternary Research, p. 1-25. doi:10.1017/qua.2016.4

Thompson, W., Hildreth, C., Boisvert, R., Dorion, C., & Fowler, B., 2002, Glacial Geology and Archaeology of the Northern White Mountains, New Hampshire: Guidebook for the 65th Annual Reunion of the Northeastern Friends of the Pleistocene, p. 1-37.

Thompson, W., Ridge, J., & Springston, G., 2011, Glacial Geology of the Upper Connecticut River Valley, Littleton-Lancaster, NH, and Barnet-Guildhall, VT: Geological Society of New Hampshire & Vermont Geological Society Summer Field Trip, p. 1-23.

Tuross, N., 2012, Comparative decalcification methods, radiocarbon dates, and stable isotopes of the VIRI bones: Radiocarbon, v. 543, p. 837-844.

UK LiDAR, 2017, What is Lidar?: http://www.lidar-uk.com/what-is-lidar/ (accessed November 2017).

USDA Natural Resources Conservation Service, 2017, Plants Database: https://plants.usda.gov/core/profile?symbol=vaul (accessed February 2018).

Usher, P., 2000, Traditional Ecological Knowledge in Environmental Assessment and Management: Arctic Institute of North America, v. 53, p. 183-193.

Walter, M., & Andersen, C., 2013, Indigenous Statistics: A Quantitative Research Methodology: California, Left Coast Press, 159 p.

Waters, M., 1992, Principles of Geoarchaeology: A North American Perspective, Tucson: The University of Arizona Press.

Watkins, J., 2003, Beyond the Margin: American Indians, First Nations, and Archaeology in North America: American Antiquity, v. 68, p. 273-85.

Watts, W. A., 1979, Vegetational History of the United States 25,000 to 10,000 Years Ago: in Wright, H. E., Porter, S. C., ed., Late Quaternary Environments of the United States: The Late Pleistocene: University of Minnesota Press.

Wobst, H. M., 2010, Indigenous Archaeologies: A Worldwide Perspective on Human Materialities and Human Rights in Bruchac, M. M., Hart, S. H., & Wobst, H. M., ed., Indigenous Archaeologies: A Reader on Decolonization: New York, Routledge, 436 p.

Woods Hole Oceanographic Institution, 2017, General Statement of 14C Procedures at the National Ocean Sciences AMS Facility: Radiocarbon Data and Calculations: http://www.whoi.edu/nosams/general-statement-of-14c-procedures (accessed November 2017).

## Appendix A: List of Resources

### Abenaki Groups

Abenaki Nation of New Hampshire:
Rhonda Besaw, Speaker
TEL: 603-837-3381
Kcicasco@aol.com

Cowasuck Band – Pennacook/Abenaki People:
Paul Pouliot, Council Chief and Speaker
TEL: 603) 776-1090
FAX: 603) 776-1091
cowasuck@cowasuck.org
www.cowasuck.org

Koasek Abenaki of the Koas:
Council of Chiefs : Amy Therrian, Carrie Gendreau, John Prescott, Shirly Hook
www.koasekofthekoas.org
www.voicesofthekoas.com

Koasek Traditional Abenaki Nation:
Chiefs Paul Bunnell and Nathan Pero
bunnellloyalist@aol.com
www.cowasuckabenaki.com

Nulhegan Band of the Coosuk - Abenaki Nation:
Don Stevens, Chief
TEL: (802) 985-2465
donald_stevens@myfairpoint.net
www.abenakitribe.org

Sovereign Abenaki Nation of Missisquoi:
St. Francis/Sokoki Band
Chief Eugene Rich
Debra Bergeron, Repatriation Coordinator
TEL: 802-868-2559
FAX:  802-868-5118
sogomo@comcast.net

### New England Groups

Eastern Pequot Reservation:
Eastern Area Office
Roy Sesbastian, Chairperson
North Stonington, CT 06359

Golden Hill Indian Reservation:
Golden Hill Paugussett 3 Chief Government
TEL: (203) 377-4410
FAX: (203) 738-2051

Paucatuck Eastern Pequot Tribe:
Eastern Area Office
Roy Sebastian, Chairperson
935 Lantern Hill Rd.
Ledyard, CT 06339

Schaghticaoke Tribal Nation of Kent:
Schaghticoke Tribal Council
Richard Velky, Chairperson
TEL: (203) 459-2531
FAX: (201) 459-2535

Gedakina, Inc.
Native American Experiential Outdoor Education and Leadership Development
http://gedakina.org/index.php/about-gedakina/

### Intertribal Organizations

Laconia Indian Historical Association:
Cliff Williamson, President
TEL: 603-934-4819 (Gerald Dulac, Land Trust)

NH Intertribal Native American Council:
Peter Newell, Council Chief
9 Durrell Mountain Road
Belmont NH 03220

### Federally Recognized Tribes of Maine

Aroostook Band of Micmacs:
Jennifer Pictou, THPO
TEL: 207.764.1972, 207.764.7667
Email: jpictou@micmac-nsn.gov
Website: www.micmac-nsn.gov

Passamaquoddy Tribe:
Donald Soctomah, THPO
TEL: 207.796.5533
CELL: 207.214.4051
Email: Soctomah@gmail.com
Website: www.wabanaki.com

Penobscot Nation:
Christopher Sockalexis, THPO
TEL: 207.817.7471
FAX: 207.817.7450
Email: chris.sockalexis@penobscotnation.org
Website: www.penobscotculture.com

## Appendix B: Surficial Geology of the Jefferson and Mount Dartmouth 7.5' Quadrangles

Portions of the surficial geology maps that fall within the study area. The maps do not cover the whole study area, but show the more southern portion of the Israel River valley. The Jefferson quadrangle surficial geology map covers part of the northern half of the study area, while the Mount Dartmouth quadrangle surficial geology map covers part of the southern half of the study area.

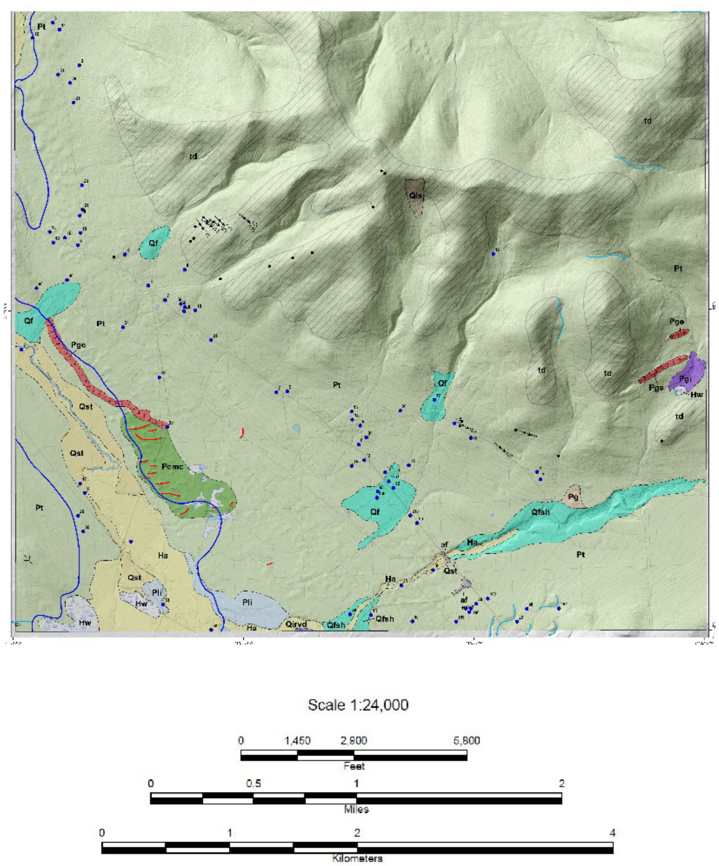
**Surficial Geology of the**
**Jefferson 7.5' Quadrangle, New Hampshire**

Surficial Geology by Woodrow B. Thompson
Digital Compilation by Sarah W. Baker and Gregory A. Barker
New Hampshire State Geologist: Frederick H. Chormann

Surficial Geologic Map Open-File Series GEO-037-024000-SMOF

*This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under StateMap award number G15AC00504*

**New Hampshire Geological Survey**
**NH Department of Environmental Services**
**29 Hazen Drive, P.O. Box 95**
**Concord, NH 03302-0095**
**Phone: 603-271-1976**
**E-mail: geology@des.nh.gov**




### DESCRIPTION OF MAP UNITS

**Stream or lake**

af — **Artificial fill**— Earth material of various sorts, used as road fill. Shown only where thick enough to alter the topographic map contours.

HOLOCENE DEPOSITS

Ha — **Stream alluvium** Sand, gravel, and silt deposited on the flood plains of streams. Unit may include some wetland areas.

Hw — **Wetland deposits**—Peat, muck, silt, and clay. Deposited in poorly drained areas.

QUATERNARY DEPOSITS

Qirvd — **Israel Valley deposits** — Unclassified glacial to postglacial sand and gravel in the Israel River valley. Most of this unit occurs in the adjacent Mount Dartmouth quadrangle to the south (Fowler and Barker, 2015).

Qst — **Stream terraces** — Sand and gravel deposited on former flood-plain surfaces along the Israel River and other streams.

Qf — **Fan deposits (undifferentiated)** Alluvial fans formed along the mid to lower reaches of streams that drain the steep mountain slopes which occur over much of the map area. Typically composed of very coarse, poorly-sorted pebble-boulder gravel and minor sand.

- Qfb2 — Younger fans deposited by Bunnell Brook.
- Qfb1 — Older fans deposited by Bunnell Brook.
- Qfg — Garland brook fan.
- Qfsh — Stag Hollow Brook fan.

Qls — **Landslide areas**—Zone of single or multiple slope failures, including: (1) cluster of several very steep debris avalanche tracks on the south face of the ridge between Mount Starr King and Mount Waumbek in Jefferson; and (2) zone of slump movements with arcuate headscarps along the upper part of Bunnell Brook in Lancaster and Kilkenny; and (3) a rockslide or debris avalanche on the southeast end of Terrace Mountain in Kilkenny. Avalanche deposits may include variable proportions of reworked till and colluvium together with bedrock blocks from local outcrops. Slump deposits may include reworked till, colluvium, stream gravel, and fine-grained sediments deposited in ice-dammed ponds. Additional landslides are likely to occur in remote mountainous terrain of the White Mountain National Forest.

PLEISTOCENE DEPOSITS

Pli — **Glacial Lake Israel deposits** Glacial Lake Israel deposits. Sand and gravel deposited into Lake Israel, which existed when the lower Israel River valley was dammed by the receding glacial ice margin. The upper surfaces of these deposits were at least partly terraced as the lake level dropped and the postglacial Israel River began to rework and cut down through the glacial lake sediments.

Pg — Small areas of sand and gravel of probable glacial origin, but whose depositional environments are unknown.

Pgi — **Ice-contact deposits** Sand and gravel deposited by glacial meltwater streams in contact with remnant masses of stagnant ice. Occurs along Big Ledge Brook in Randolph.

Pge — **Eskers** — Ridges of gravel and minor sand deposited by meltwater streams in subglacial ice tunnels. Eskers occur in the Israel River valley in Jefferson, and on the lower southeast slope of Pliny Mountain in Randolph.

Pemc — **End moraine complex** — Area of short moraine ridges and till hummocks deposited at the margin of the Laurendtide Ice Sheet as it receded north-northwest from the Israel River valley. In this area, many ridges and hummocks of stony till are interspersed with low areas including patches of wet ground.

Pt — **Till** — Loose to very compact, poorly sorted, massive to weakly stratified mixture of sand, silt, and gravel-size rock debris. Deposited directly from glacial ice. May include lensesm of waterlaid sand and gravel.

td — **Thin-drift areas** "td" indicates areas where outcrops are common and/or surficial sediments are inferred to be generally less than 10 ft thick. Mapped partly from air photos and LiDAR imagery, especially in remote areas, where thin-drift areas are likely more extensive than shown here.

**Surficial Geologic Map of the Mount Dartmouth, New Hampshire**

By Brian K. Fowler and Gregory A. Barker
New Hampshire State Geologist: Frederick H. Chormann

Surficial Geologic Map Open-File Series GEO-046-024000-SMOF

This geologic map was funded by the New Hampshire Geological Survey, New Hampshire Department of Environmental Services and by the 2014 USGS National Cooperative Geologic Mapping Program Award No. G14AC00427

**New Hampshire Geological Survey**
**NH Department of Environmental Services**
**29 Hazen Drive, P.O. Box 95**
**Concord, NH 03302-0095**
**Phone: 603-271-1976**
**E-mail: geology@des.nh.gov**

## Legend

### Map Symbols

- Well Location
- bedrock

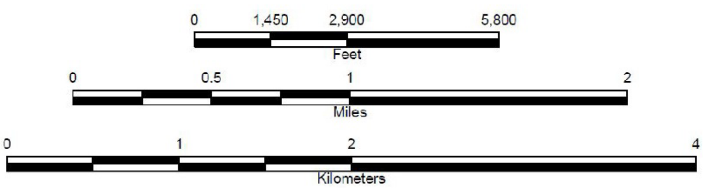
### Type

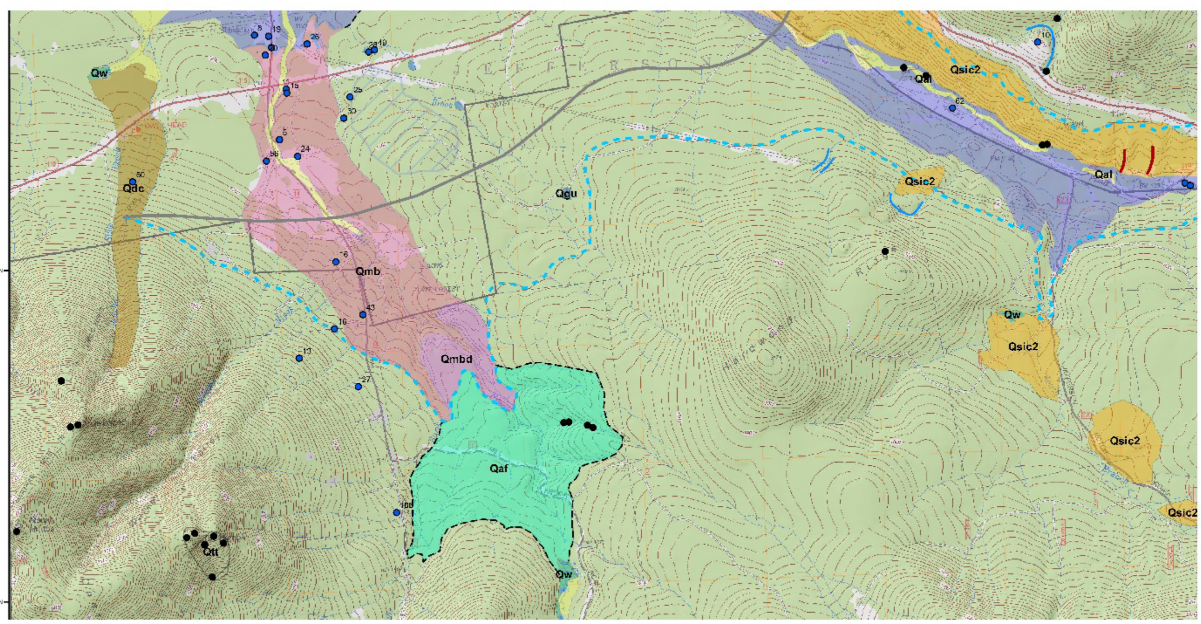
- Inferred Contact
- Glacial lake level
- Ice Front Position
- Meltwater channel
- Meltwater spillway
- Moraine ridge
- Esker

### Surficial Units

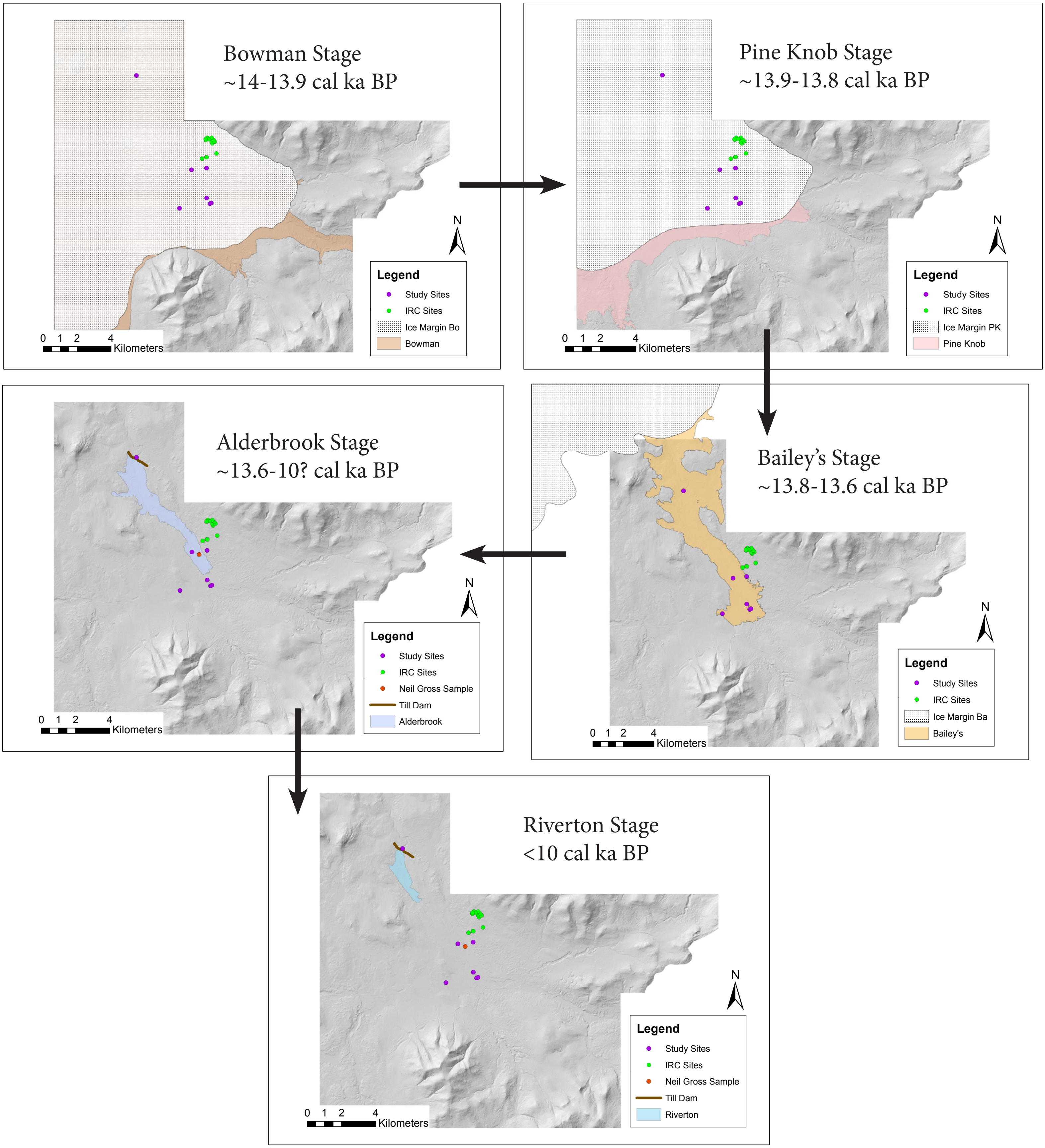
- Qfgz - Upper Zealand River Valley Deposit
- Qsic1 - Ice Contact Deposit
- Qsic2 - Ice Contact Deposit
- Qag - Ammonoosuc River Valley Deposit
- Qtt - Thin Till
- Qirvd - Israel River Valley Deposit
- Qmbd - Mill Brook Valley Delta
- Qmb - Mill Brook Valley Deposit
- Qgu - Uncorrelated Glacial Deposit
- Qaf - Alluvial Fan
- Qal - River Alluvium
- Qdc - Colluvial Diamict
- Qt - Till
- Qw - Wetland
- Water
- Area of Massive Boulders

Scale 1:24,000

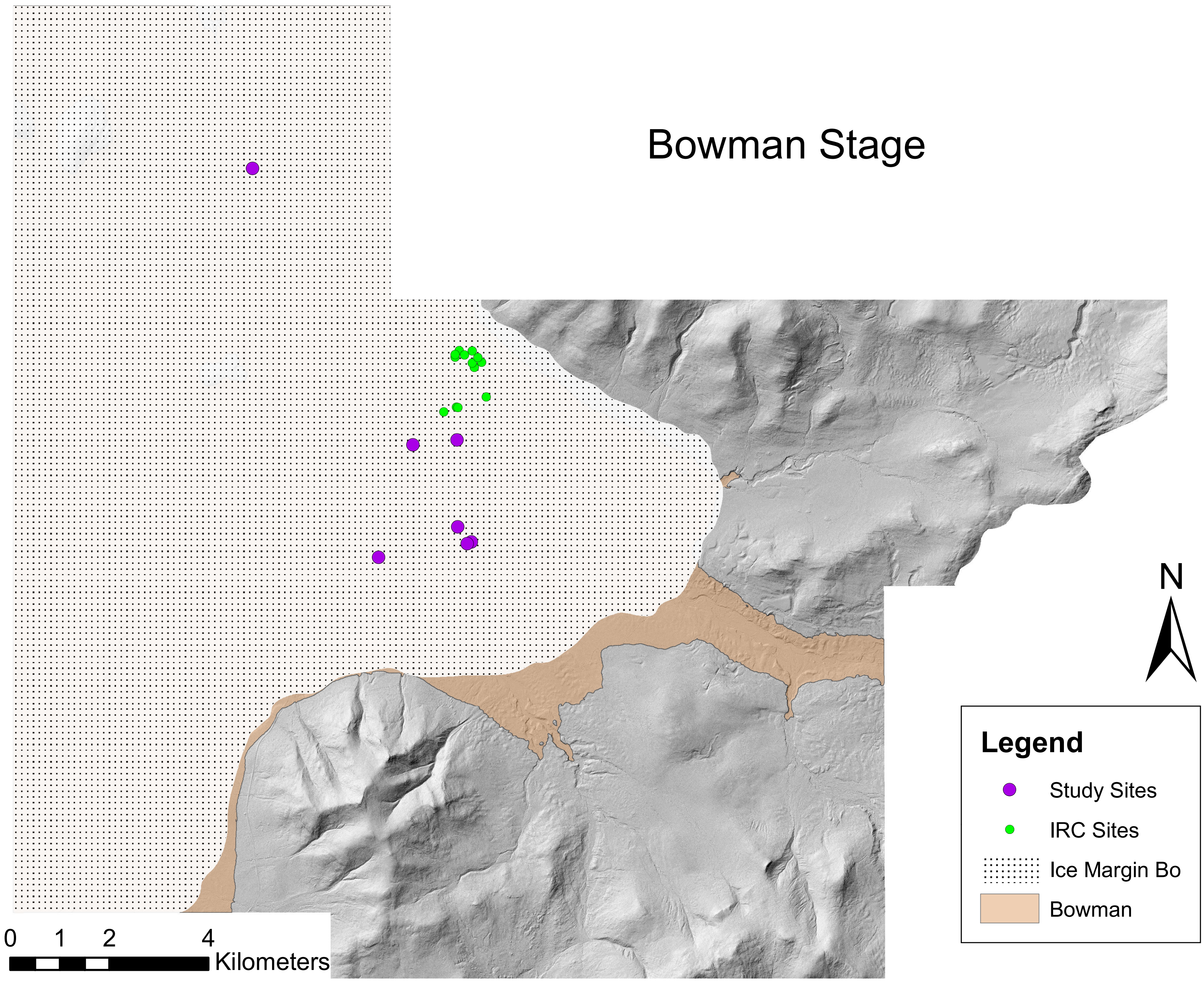


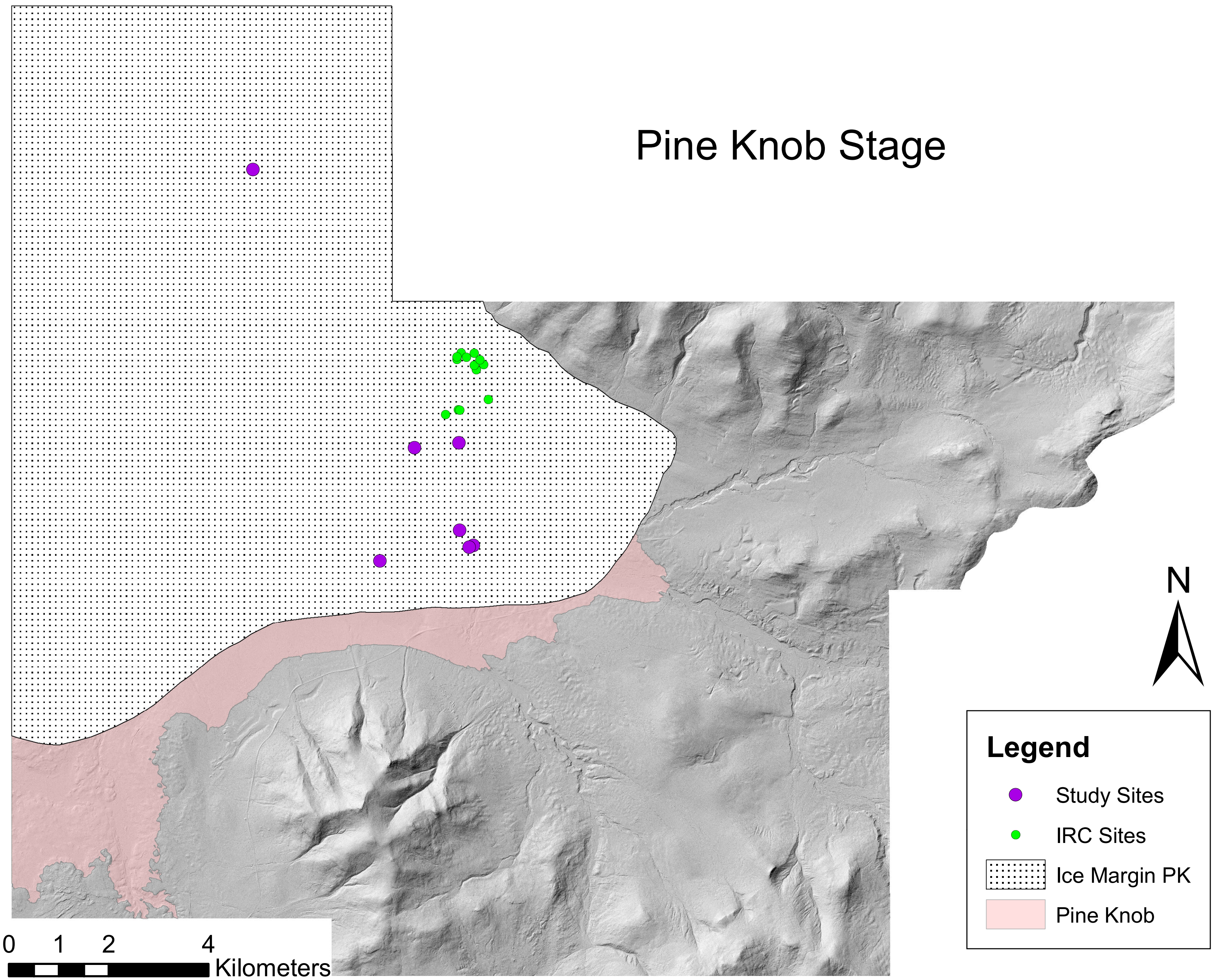
# Appendix C: Higher Quality Lake Stage Maps

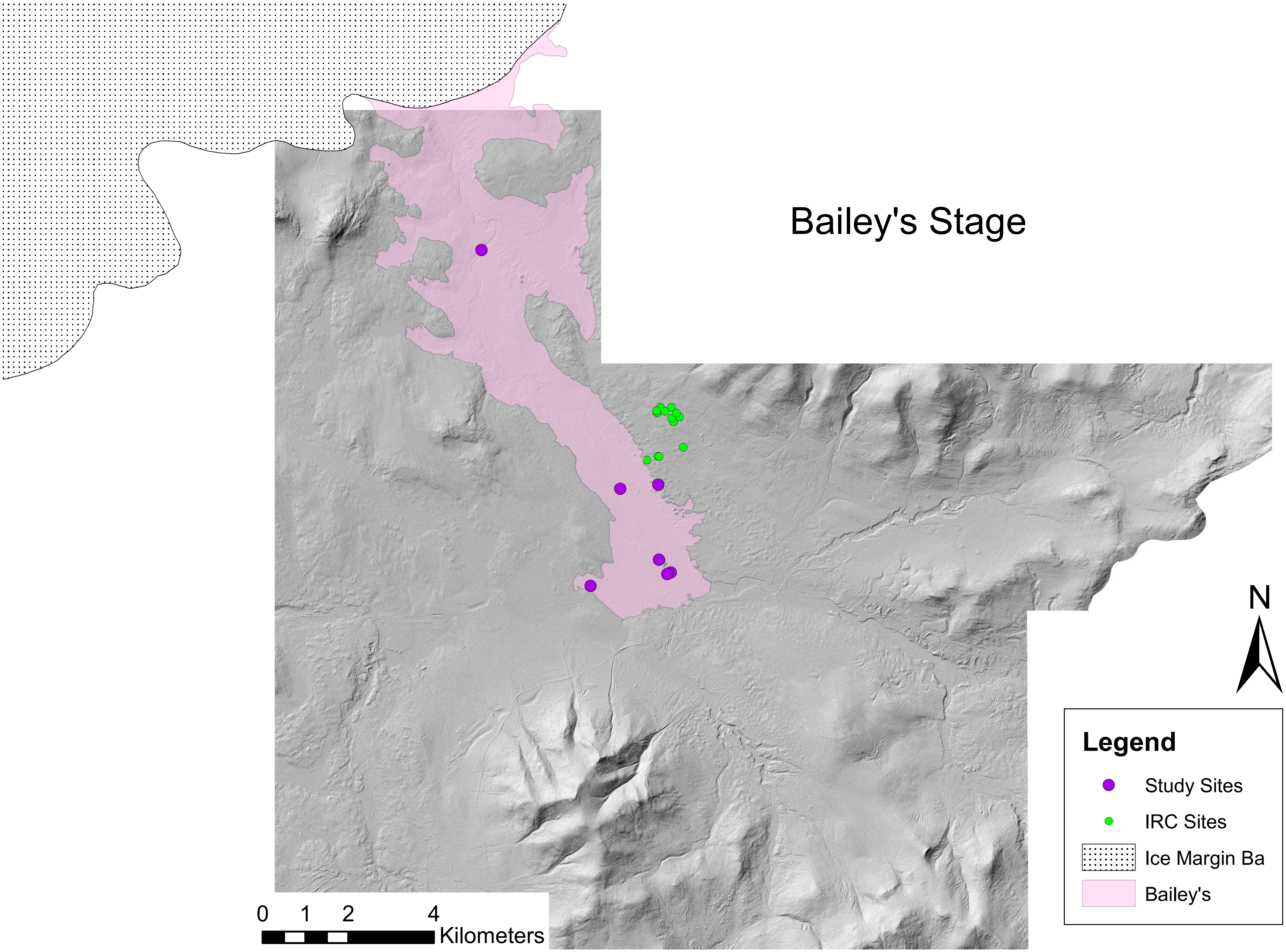


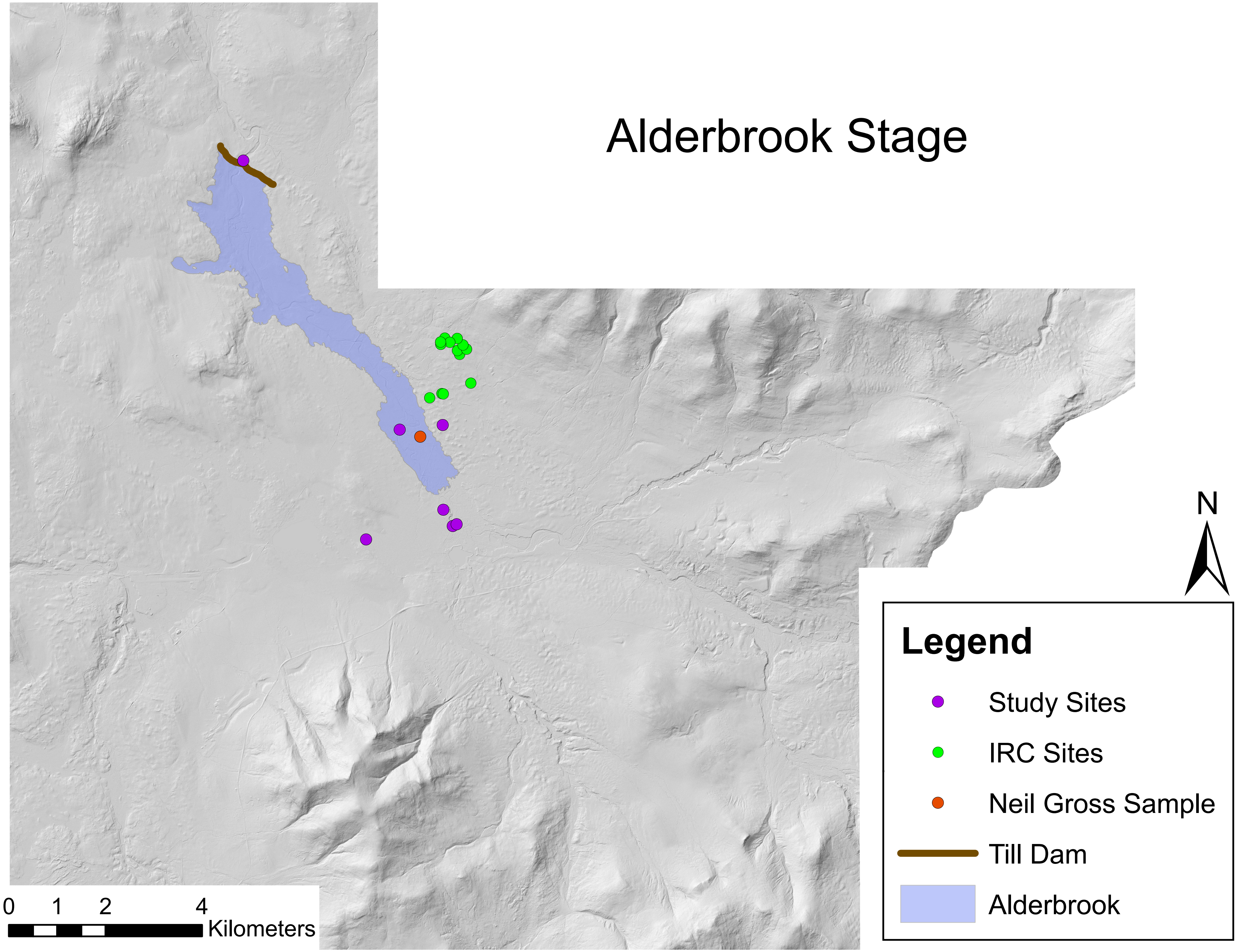
Bowman Stage
~14-13.9 cal ka BP
N
Legend
Study Sites
IRC Sites
Ice Margin Bo
Bowman
0 1 2 4
Kilometers
Pine Knob Stage
~13.9-13.8 cal ka BP
N
Legend
Study Sites
IRC Sites
Ice Margin PK
Pine Knob
0 1 2 4
Kilometers
Alderbrook Stage
~13.6-10? cal ka BP
N
Legend
Study Sites
IRC Sites
Neil Gross Sample
Till Dam
Alderbrook
0 1 2 4
Kilometers
Bailey's Stage
~13.8-13.6 cal ka BP
N
Legend
Study Sites
IRC Sites
Ice Margin Ba
Bailey's
0 1 2 4
Kilometers
Riverton Stage
<10 cal ka BP
N
Legend
Study Sites
IRC Sites
Neil Gross Sample
Till Dam
Riverton
0 1 2 4
Kilometers



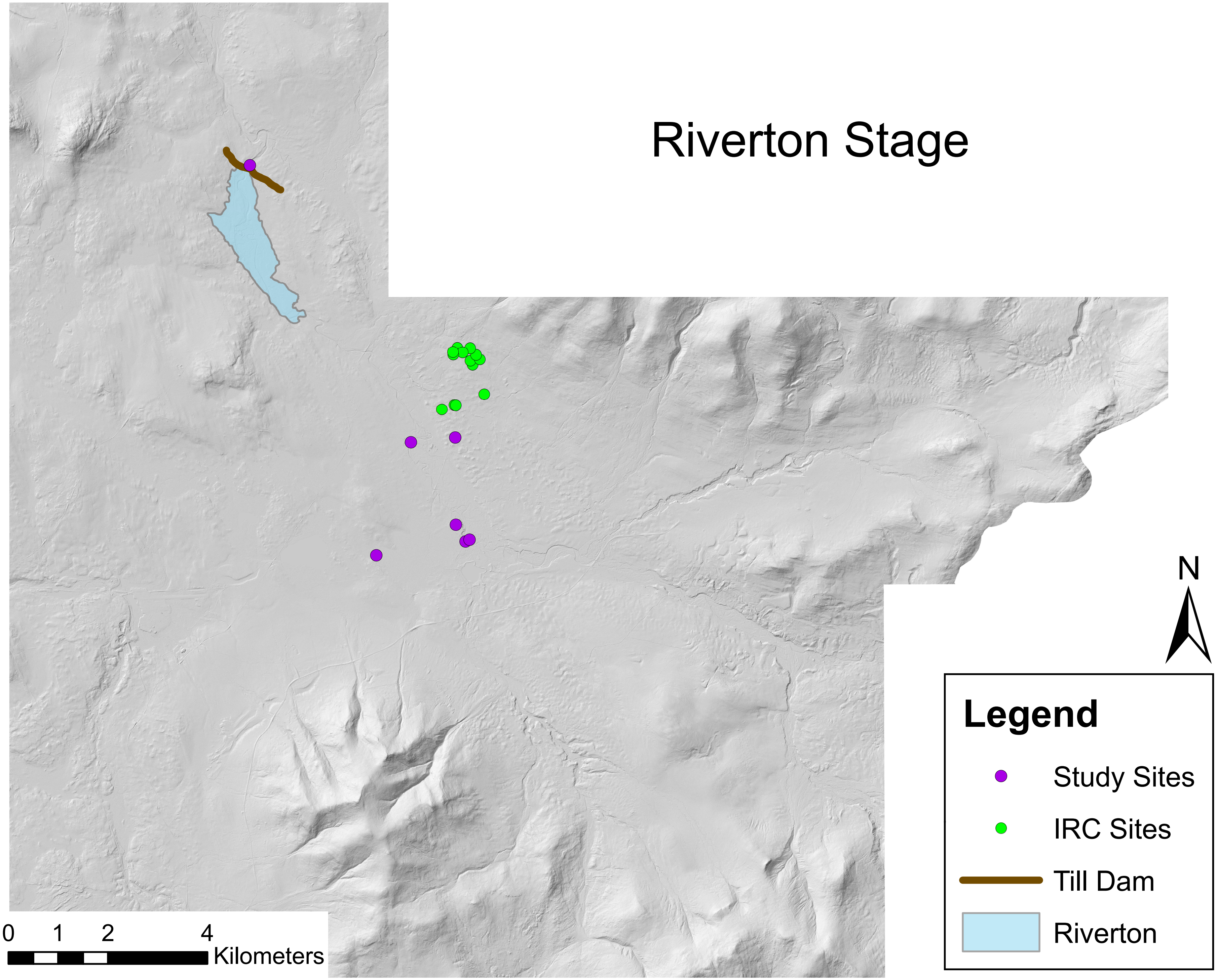
Bowman Stage
N
Legend
Study Sites
IRC Sites
Ice Margin Bo
Bowman
0 1 2 4
Kilometers


Pine Knob Stage
N
Legend
Study Sites
IRC Sites
Ice Margin PK
Pine Knob
0 1 2 4
Kilometers


Bailey's Stage
Legend
Study Sites
IRC Sites
Ice Margin Ba
Bailey's
N
0 1 2 4
Kilometers



Alderbrook Stage
N
Legend
Study Sites
IRC Sites
Neil Gross Sample
Till Dam
Alderbrook
0 1 2 4
Kilometers


Riverton Stage
N
Legend
Study Sites
IRC Sites
Till Dam
Riverton
0
1
2
4
Kilometers