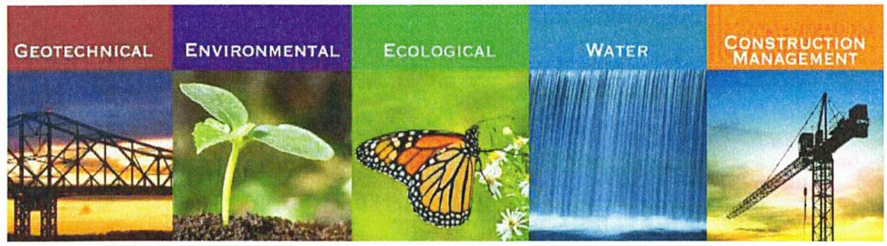

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GROUNDWATER RESOURCE ASSESSMENT
PHASE I GROUNDWATER INVESTIGATIONS REPORT

NEW LONDON, NEW HAMPSHIRE

May 30, 2023
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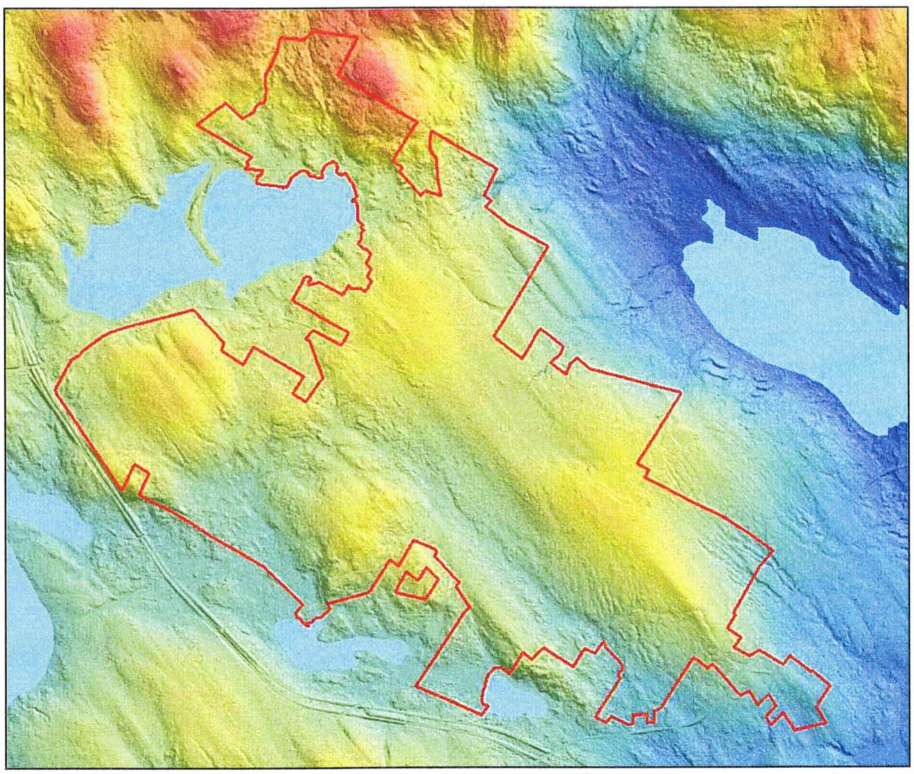

PREPARED FOR:
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May 30, 2023
Project No.: 33.0083192.00

Mr. Peter Pitsas, P.E.
Underwood Engineers, Inc.
99 North State Street
Concord, NH 03301-4334

Re: Groundwater Resource Assessment – Phase I Groundwater Investigations Report
New London, New Hampshire

Dear Peter,

Emery & Garrett Groundwater Investigations (EGGI), a Division of GZA, is pleased to present this Phase I groundwater investigations report designed to assess the potential to develop additional groundwater resources in the Town of New London, New Hampshire.

We hope you find the information contained herein responsive to your needs. If you have any questions concerning this material, please do not hesitate to contact us.

Very truly yours,

EMERY & GARRETT GROUNDWATER INVESTIGATIONS, A DIVISION OF GZA

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TABLE OF CONTENTS

FIGURES

1.0 INTRODUCTION

Emery & Garrett Groundwater Investigations (EGGI), a Division of GZA GeoEnvironmental, Inc. (GZA) has completed a groundwater investigation in the Town of New London, New Hampshire. This report presents the results of this assessment. EGGI was a subcontractor to Underwood Engineers (UE), the primary contractor for the investigation entitled, "Additional Water Supply Capacity Investigation" which was authorized on December 5, 2022, by the New London – Springfield Water System Precinct (NLSWSP). The primary components of EGGI's investigation included:

- Consideration of various alternatives for increasing the groundwater withdrawal capacity of the existing Colby Point Wellfield (**Figure 1**), and
- An evaluation of potential locations for developing additional groundwater supplies from sand & gravel or fractured bedrock aquifers, primarily focused within the water precinct boundaries (**Figure 1**).

The NLSWSP is almost wholly within New London, but a small portion of the distribution system and the water storage tank is located in the southeast corner of Springfield. The Precinct boundary was the primary area of investigation and a 1,000-foot buffer around the Precinct constituted the Study Area. However, reconnaissance-level investigations regarding potential sand & gravel aquifers were completed in some specific areas outside the Study Area (**Figure 1**).

New London straddles a major watershed divide with surface waters on the northwest side of the Precinct draining towards Sunapee Lake, those in the eastern end flowing into the Upper Blackwater River watershed, and the south central portion draining southwards into the Lane River (**Figure 2**).

The existing distribution system for both public water and sewer within the Precinct is shown on **Figure 3**. A small portion of another small public distribution system for the Slope & Shore Development lies within the designated Study Area.

2.0 EVALUATION OF THE POTENTIAL TO INCREASE GROUNDWATER WITHDRAWALS FROM THE COLBY POINT WELLFIELD

2.1 <u>DESCRIPTION OF THE COLBY POINT WELLFIELD</u>

The Colby Point Wellfield is situated on a narrow peninsula projecting out from the north shore of Little Lake Sunapee (**Figure 4**). The morphology of the peninsula suggests that it is an esker that was deposited at the base of the last continental glacier that covered the area. Eskers are generally formed in a subglacial tunnel when flowing meltwater erodes upwards into the ice and deposits sinuous ridges of coarse-grained material that can provide for highly productive aquifers. The internal distribution of the sediments at the Colby Point Wellfield, however, shows fairly extensive fine-grained material and only a limited area of transmissive sand & gravel deposits suitable for a wellfield. Therefore, it is possible that although the surface morphology suggests the peninsula is an esker, it may in fact have been formed as a subaerial deposit of material laid down in a gap between stagnant ice blocks. Such a deposit is less likely to have experienced the high-energy glacial meltwater characteristic of eskers, which may account for the abundance of fine-grained deposits.

The exact genesis of the peninsula is not of great consequence, but the distribution of fine-grained deposits does play a primary role in limiting the hydraulic communication between Little Lake Sunapee and the Colby Point Wellfield. As is well documented in earlier reports (D.L. Maher, 1984, 1994, and 1995; and Wagner, Heindel, and Noyes, Inc., 1988), the transmissive sand & gravel deposit within which the six production wells are installed is limited in geographic extent and is not continuous beneath the peninsula, thereby restricting where production wells can be located. Effective production wellfields need both efficient wells that are well connected to transmissive deposits and access to available groundwater recharge. Little Lake Sunapee provides an obvious source of recharge to the groundwater system of the Colby Point Wellfield, but the availability of recharge is restricted by both the relatively shallow depth of the Production Wells and the hydraulic restriction presented by the fine-grained material/deposits that exist between the Lake and the Aquifer. These two characteristics of the Colby Point Wellfield both influence the available options that the Precinct has to increase the total groundwater production.

Groundwater movement through an aquifer is largely controlled by the inherent properties of the material through which groundwater flows and the gradient of the water table that allows gravity-driven groundwater migration. Therefore, a shallow Production Well is limited in its ability to create a steeper groundwater flow gradient because the well cannot lower the water table below the top of the shallow well screen. As mentioned earlier, the fine-grained materials that lie between the Colby Point Production Wells and the Lake restrict groundwater flow and the only way to increase flow through those deposits is to increase the groundwater flow gradient, which is restricted by the limited available drawdown in the Production Wells. With that context in mind, the next section will evaluate various alternatives that might be considered to increase groundwater withdrawals from the Wellfield.

2.2 <u>POTENTIAL ALTERNATIVES TO INCREASE GROUNDWATER WITHDRAWALS</u>

The Precinct specifically requested that we provide opinions regarding possible alternatives to increase the Town's ability to withdraw groundwater resources from the Colby Point Wellfield. These alternatives are addressed in each of the following sections: Options #1 through #4. Two additional options (supplementing groundwater recharge through the application of Artificial Recharge (AR) and deep bedrock wells) are also discussed.

2.2.1 <u>Option #1: Over-drilling of One or More of the Existing Wells</u>

Over-drilling of Production Wells is essentially a type of well replacement where the new well is constructed at the exact same location as the old. To accomplish this, a steel casing with a larger diameter than the existing well is driven down around the well, allowing the old well to be removed in its entirety. A new well of the same depth can then be installed as desired inside the larger casing. No undisturbed samples can be recovered during the over-drilling process, so the selection of a well screen slot size would be based on the original production well construction. Over-drilling is particularly useful if a well is inefficient and a larger-diameter well or modified screen size is desired.

Well efficiency is generally calculated by observing water level changes under pumping conditions in both the Production Well and another monitoring well immediately outside the Production Well. A more efficient well will show similar water levels inside and outside the Production Well. However, in the case of the Colby Point Wellfield, there are no monitoring wells in close proximity to the Production Wells, so an assessment of well efficiency is not possible. Given what is known about the Production Well construction and the nature of the geologic deposits, it is most likely that the restriction of groundwater flow through the fine-grained deposits overlying the Aquifer has the greater impact on overall groundwater production capacity. Therefore, it is anticipated that the installation of larger-diameter Production Wells at the same locations of the existing 10-inch-diameter Wells will result in only nominal increases in withdrawal capacity.

If the Town elected to install monitoring wells in close proximity to the six Production Wells, well efficiency testing could be performed to confirm whether or not pumping well efficiency is a major concern in the Wellfield, but in the absence of those data, this option would not appear to be cost-effective.

2.2.2 Option #2: Installing a Replacement Well or Wells Near the Existing Wells

Similar to the over-drilling option, Replacement Wells in close proximity to the existing Production Wells are viewed as an option that may result in nominal increases, unless significantly greater well efficiencies can be realized. The restriction of groundwater flow through fine-grained deposits surrounding the current wells in this aquifer is likely the more significant impediment to increasing groundwater withdrawals.

2.2.3 Option #3: Installing a New Well or Wells to Connect to the Existing Wellfield

The installation of a new Production Well in an area beyond the boundaries of the existing Wellfield may be the most feasible alternative for increasing groundwater withdrawals. A new Production Well at some distance from the existing wells will allow for increased leakage through the restrictive fine-grained material by increasing the total area through which Lake water can infiltrate into the Aquifer. Based on the distribution of well borings on the peninsula, the best location for a new Production Well is likely in the southwest corner of NLSWSP Easement around the existing Production Wells on the west side of the peninsula (**Figure 4**). Test well installations in that area followed by groundwater level monitoring while the other Production Wells continue pumping would be recommended to test the benefits of this option.

2.2.4 Option #4: Utilization of Horizontal Well or Wells

Horizontal Production Wells offer a potential solution to capturing more groundwater recharge. As discussed earlier, the Production Wells are limited in their ability to steepen the groundwater flow gradient over a wide area because they are relatively shallow. Rather than creating point sources of drawdown, horizontal wells installed with long well screens would create a line of drawdown, thereby allowing steeper groundwater flow gradients to be established over a wider area. Once installed, horizontal wells also offer the benefit of being largely hidden from view and may take up a smaller footprint on the peninsula. However, there are several serious limitations to this option, including:

- Although the final wells are hidden beneath the site, the installation of horizontal wells require large footprints on the ground surface at both ends. Those footprints may well extend beyond the easement boundaries.
- The discontinuous nature of the productive sand & gravel deposits may force the horizontal well to penetrate both fine-grained material and Aquifer deposits, making screen locations difficult to establish.
- The discontinuous nature of the productive sand and gravel deposits may also require that two horizontal wells be installed on either side of the peninsula. Earlier test borings penetrated fine-grained material in the middle of the peninsula in some areas, and therefore a single line source may not be capable of drawing groundwater from both sides of the peninsula.

- Horizontal drilling design and construction could be prohibitively expensive.

A study to assess the potential to use horizontal wells to enhance well yields would need to be conducted independently of this investigation.

2.2.5 Option #5: Application of Artificial Recharge

Artificial recharge (AR) can be used to enhance natural groundwater recharge to aquifers in some circumstances. There are two primary mechanisms by which water can be artificially recharged: 1) gravity-driven infiltration using surface water pumped into infiltration basins, or 2) injection of water directly into underlying aquifers through the use of wells. Due to the nature of the fine-grained deposits that overlie the aquifer that restrict flow from Little Lake Sunapee into the Aquifer, infiltration basins would need to be deep enough to intercept aquifer materials. Such basins would have a large footprint on the peninsula and would need to be far enough from the existing Production Wells to provide adequate natural filtration and treatment of the surface water.

Alternatively, one or more injection wells could be installed on the peninsula to pump surface water from the Lake directly into the productive sand & gravel beneath the peninsula. This could be effective if the infiltration wells are far enough away to provide effective treatment of the surface water. The use of injection wells is not common in New Hampshire and their use would likely undergo significant scrutiny/review from NHDES, so there could be a significant regulatory process for the approval of injection wells. A study to assess the potential to use artificial recharge to enhance well yields should be conducted independently of this investigation.

2.2.6 Option #6: Deep Bedrock Well(s)

It is also possible that deep bedrock wells could be installed within the footprint of the existing Well Easement on the peninsula. If that is of interest, EGGI would recommend conducting geophysical surveys on the peninsula to investigate the underlying bedrock. Water-bearing fractures often have an anomalous geophysical signature compared to the competent rock around it and if they were identified, test well drilling targets could be considered in the same vicinity as the six existing Production Wells. If deep water-bearing fractures were intercepted, it would likely receive recharge from a distant source than the shallow Production Wells, so interference between the Wells might be insignificant.

3.0 EXPLORATION FOR ADDITIONAL GROUNDWATER SOURCES FROM SAND & GRAVEL AND FRACTURED BEDROCK AQUIFERS

Significant groundwater resources can be developed in both sand and gravel or fractured bedrock aquifers and the groundwater exploration program included investigating both types of aquifers. The primary focus area for the study was the NLSWSP Precinct Boundary, but some areas of interest outside the Precinct were also identified and are noted in the discussion.

3.1 GEOLOGIC FIELD MAPPING OF SAND & GRAVEL DEPOSITS

Surficial maps published by the New Hampshire Geological Survey show the distribution and genesis of unconsolidated deposits and one such map is available for the New London, New Hampshire 7.5-minute Quadrangle (Barker and Olson, 2017). However, that map only covers the eastern half of the Precinct. No published surficial map is available for the western half of the Precinct, which lies on the Sunapee Lake North, 7.5-

minute quadrangle. Therefore, in those specific areas, reconnaissance level geologic mapping was conducted by EGGI, supplemented by information regarding the depth to bedrock in the area, local soil maps, and the use of remote imagery.

3.1.1 Application of Remote Sensing for Mapping of Unconsolidated Deposits

Preparations for the field mapping of unconsolidated (surficial) deposits were greatly assisted by utilizing remote sensing platforms to characterize the surface morphology of different depositional landforms. The application of Light Detection and Ranging (LiDAR) data was of particular value. This relatively new high-resolution imaging provides unprecedented detail of the morphology of surficial materials (**Figure 5**). This allows in-office filtering of large areas of Town to help focus field activities in those areas that are most likely to be favorable for groundwater development and to help extrapolate the mapping of surficial geologic deposits into inaccessible areas.

The LiDAR images of the Precinct clearly show the widespread area of streamlined glacial till formed when the advancing glacial ice scraped off most of the overburden material, depositing a thin veneer of poorly-sorted glacial till (hard pan) that is generally unsuitable for water supply development. The relatively small amount overburden material that was carried by glacial meltwater was deposited in just a few limited areas along stream valleys.

3.1.2 Estimation of Aquifer Thickness Using Available Well Data

Another means of assessing the presence of sand & gravel aquifers is to search for areas with thick overburden deposits. This was done by using depth to bedrock data from the New Hampshire Water Well Inventory. This database contains data for depth to bedrock at locations of domestic wells, existing production wells, and other wells installed for various purposes. The distribution of depth to bedrock values generally confirms that overburden across most of the Precinct is shallow and that no extensive areas of thick overburden are available for exploration.

3.1.3 Field Observations of Surficial Geologic Deposits

Field mapping of surficial deposits consisted of reconnaissance level observations along roadsides and areas open to the public to evaluate the distribution of favorable sand and gravel deposits. Observations were made of the type and lateral extent of sand and gravel deposits and the presence of potential barriers to groundwater flow (i.e., proximity of glacial till, bedrock, etc.).

The unconsolidated geologic deposits that do exist are remnants of glacial processes related to the growth (advancement) and melting (recession) of the continental ice sheet that receded about 13,000 years ago. As the glacier advanced throughout the area from approximately northwest to southeast, it scoured the underlying ground, removing essentially all previously existing sediments and material derived from weathered bedrock. These scoured materials, ranging in size from clay particles to boulders, were deposited as a compact, thin veneer of till over the scoured bedrock (**Figure 5)**). The wide grain size distribution, high clay content, and compaction of the till deposits resulted in a relatively low permeability material that is generally unsuitable as an aquifer.

In just a few areas, sand & gravel deposits were sorted by glacial meltwater or later stream flow and the finer materials were removed, leaving behind "cleaner" sediments that are more capable of storing and transmitting groundwater. Some of those areas, such as the area of the Water Precinct Office, have been utilized for other land uses and are no longer available for the development of public supply wells.

3.1.4 Potential Groundwater Development Zones in Areas of Sand & Gravel

Exploration for sand & gravel deposits capable of supporting a public water supply well has resulted in the identification of four potential Groundwater Development Zones (GDZ), three of which are significantly beyond the boundaries of the Precinct (**Figure 5**). A description of each of the four potential GDZ's (designated with an "SG" suffix) is as follows:

3.1.4.1 Groundwater Development Zone SG-1 – Twin Lake Village Golf Course

This potential groundwater development lies within the Twin Lakes Village Golf Course and has only a limited area available where required NHDES sanitary setbacks can be met (**Figure 5**). The area consists of sand & gravel deposits that were carried by water down the valley of Kidder Brook and deposited as an alluvial fan which prograded out into Little Lake Sunapee. Therefore, the geologic setting is considered potentially favorable for the deposition of productive sand & gravel and would be in good hydraulic connection with the Lake. However, the thickness of the deposit is unknown and may be limited based on the proximity of exposures of glacial till. If the Golf Course is amenable to exploration on its property, then EGGI recommends that geophysical surveys be conducted to estimate the thickness of overburden. The most favorable potential location for a Production Well would be near the Lake.

GDZ-SG1 is located directly along the route of the existing water main, so connection costs would be minimal. If the NLSWSP installed a Production Well on the Golf Course property, the Precinct would need to acquire the Sanitary Protective Area (up to a 400-foot radius for a well exceeding 100 gallons per minute (gpm)) or have a perpetual lease granting them control of the property. The Golf Course would likely be able to continue operating, but the use of certain chemicals (fertilizers and pesticides) would be restricted.

3.1.4.2 Groundwater Development Zone SG-2 – North Shore of Pleasant Lake

GDZ-SG2 is located at the north end of Pleasant Lake near the mouth of Great Brook (**Figure 5**). This area is mapped as containing ice-contact deposits, which can be composed of productive sand and gravel, and alluvial deposits that formed at the north end of Pleasant Lake from erosion further up the Great Brook Valley. Many of the ice-contact deposits are mapped beneath the existing Slope & Shore Development, so exploration would be limited to those areas along the east side of the Great Brook Valley, where the thickness of the saturated deposits is unknown. NHDES sanitary setback requirements limit the area available for installing a Production Well, but if permission can be granted for geophysical surveys, it could be quickly determined if exploratory test well drilling is warranted.

The biggest limitation to developing a community water supply well in GDZ-SG2 is the great distance to the Precinct boundary (about 1.5 miles to the nearest boundary) and the great elevation difference between GDZ - SG2 and the Precinct (approximately 500 vertical feet).

3.1.4.3 Groundwater Development Zone SG-3 – Esther Currier Low Plain Natural Area

The area of the Low Plain Town Natural Area, south of Pleasant Lake and north of Pages Corner, has many ice-contact features (such as eskers), that suggest high-energy deposition in meltwater from the glaciers (**Figure 5**). Such areas are often favorable for groundwater development. It is suspected that overburden thickness may be very limited in this area, but it may be worth investigating using geophysical surveys. If thick packages of saturated material can be located, it would be worth further exploration via exploratory drilling. The fact that this area is largely held in protected Conservation Areas makes this locality very compatible with groundwater development and protection. The Town has designated wetlands in this area as Prime Wetlands, therefore any groundwater development in the area would need to consider the potential impact on the Prime Wetlands.

The Low Plain Area is a significant distance from the Precinct boundary and could require 1.5 to 2.0 miles of water main to connect to the existing distribution system depending upon where the favorable portion of the aquifer is discovered.

3.1.4.4 Groundwater Development Zone SG-4 – Wilmot, New Hampshire

The most favorable sand & gravel deposit in the area is in the neighboring Town of Wilmot, New Hampshire, along Pine Hill Road (the eastward extension of Mountain Road in New London) (**Figure 5**). This area contains extensive areas of ice-contact and outwash deposits and, if thick enough, could potentially provide for a very favorable aquifer.

The primary disadvantages of this area for groundwater development include the great distance to the Precinct (two to three miles, depending on the route), the great elevation difference (exceeding 500 feet), and the presence of the New London Landfill along Mountain Road at the Town boundary. The potential contamination represented by the Landfill would require careful consideration for any potential Production Well in this area to ensure they are adequately separated.

3.2 EVALUATION OF FRACTURED BEDROCK AQUIFERS

The water-bearing properties of bedrock within the Study Area are dependent upon the occurrence of fractures, faults, or other bedrock discontinuities that provide avenues for the storage and flow of groundwater. Therefore, a detailed investigation of these bedrock discontinuities was conducted as part of this study. To this end, the following three-fold approach was utilized by EGGI scientists:

1) Remote sensing analyses of the site were conducted using many scales and types of aerial photography and imagery;
2) Geologic field mapping was conducted to evaluate the different rock types within the Study Area, and;
3) Measurements of bedrock fracture characteristics were taken and recorded at numerous bedrock exposures in all different rock types.

3.2.1 Remote Sensing Analysis of Local Bedrock Aquifer

The underlying key to successfully evaluating the potential to develop groundwater supplies from fractured bedrock sources is the ability for geologists to consistently and accurately delineate zones of laterally extensive bedrock fracture systems and other structural discontinuities through which groundwater can flow. "Fracture trace" or lineament analyses, in conjunction with detailed structural mapping of brittle deformation features, are routinely applied by remote-sensing scientists as practical methods to delineate water-bearing bedrock systems.

Many subsurface features, such as fracture zones, bedrock discontinuities, faults, and geologic contacts, have ground surface expressions that can be detected through a remote sensing analysis of photographic and computer-enhanced images. These surface expressions typically appear on the ground surface as topographic depressions, vegetation changes, tonal anomalies (i.e., contrast changes), etc., and are known as 'lineaments.' A lineament can be loosely defined as a mappable linear feature, as seen on the terrain surface, whose parts are aligned in a rectilinear or curvilinear manner.

The approach used to collect and analyze lineaments is to first draw lineaments on different scales and types of images. The lineaments are then spatially and statistically evaluated using EGGI computer programs. Four image types were analyzed during this study using seven separate observational trials to develop a robust lineament data set for the Study Area. *Image types included, 'shaded relief' models of digital elevation data (DEM), and high-resolution color infrared photographs, Landsat satellite imagery, and topographic maps.*

EGGI's lineament analyses provided two main products (**Figure 6**). They included the following: 1) a rose diagram[1] of lineaments for comparison with fracture fabric data and 2) high confidence, reproducible lineaments (lineaments defined during multiple observational trials), called coincident lineaments. The rose diagram graphically presents the orientations of the most common lineament orientations (lineament families) and the relative dominance (is shown by the length of the rose petals of each orientation). All lineament data were used for comparison with other geologic data (i.e., bedrock fracture fabric analyses) to help identify favorable areas considered suitable for groundwater development.

3.2.2 Results of Remote Sensing Analysis

A cumulative rose diagram of lineaments was generated from 1,599 lineaments identified in this study. The rose diagram shows that the dominant orientations of the lineament families observed across the Study Area are 32°, 53°, 72°, 107°, and 132°, 150°, and 174° degrees east of north (**Figure 6**). The northwest-southeast (132°) and northeast-southwest (32°) trending lineament families are most dominant in the New London Study Area.

Coincident lineaments are defined where lineaments observed on different aerial platforms have similar trends and are located near each other (within ±2 mm at the scale of the source imagery). Coincident lineaments are shown superimposed across the Study Area on **Figure 6**. Those coincident lineaments that are sub-parallel with nearby bedrock fracture family orientations, bedding orientation, mapped fault zones, and/or lithologic contacts are highlighted in magenta on **Figure 6** as "fracture-supported" coincident lineaments. Intersections of coincident lineaments are generally considered to be more favorable for groundwater development than individual coincident lineaments for siting bedrock wells.
Emphasis was placed on the presence of coincident lineaments, their number, and orientation when selecting potential Groundwater Development Zones in bedrock aquifers because they are indicative of potentially more highly fractured bedrock in the subsurface.

3.2.3 Geologic Field Mapping & Bedrock Fracture Fabric Analysis

The hydrologic favorability of the rock units underlying the New London Study Area is dependent upon the presence of discontinuities, such as fractures and faults, to provide openings for groundwater storage and movement. The areas where such discontinuities are most prevalent are typically those with the greatest potential for developing groundwater resources within the bedrock.

The geology of the Study Area was investigated through a program of geologic field mapping conducted by EGGI geologists. As a part of this mapping exercise, EGGI compiled a geologic base map for the Study Area through the

[1] Rose diagrams are presented in a rose "petal" format (**Plate 3**). The trend of each rose petal is posted in degrees east of north. Petal width is a measure of data scatter and petal length is a measure of relative numbers of data in each lineament family.

identification and evaluation of numerous soil exposures and rock outcrops. The geologic map presented on **Figure 6** supplements the work previously conducted by others (**Lyons and others, 1997, Allen, Timothy, T., 2012**).

The pre-existing geologic maps, combined with EGGI's mapping efforts, indicate that the Study Area is underlain by two main rock types (**Figure 6**):

1. Igneous rocks of the Concord Granite, Kinsman Granodiorite, and Bethlehem Granodiorite
2. Meta-sedimentary rocks of the Littleton Formation;

The igneous rocks within the New London Study area are all part of the New Hampshire plutonic series (Billings, 1934). The Concord granite is a light gray, fine-to medium grained granite that underlies over 85% of the Study Area. The Kinsman Granodiorite occurs in the southern-central portion of the Study Area near Messer Pond. It is part of the Cardigan Pluton and contains characteristic white feldspar megacrysts in a coarse matrix of plagioclase, quartz, biotite, muscovite, and garnet. The Bethlehem Granodiorite is a medium grained, well foliated biotite gneiss that is part of the Mount Clough Pluton. It occurs in the northwest corner of the Study Area, north of Little Sunapee Lake. Metasedimentary rocks of the Littleton Formation are exposed in the southwestern portion of the Study Area and north of Little Lake Sunapee. The Littleton Formation contains metamorphosed rocks that were developed from mud and sand that was deposited in a deep ocean environment. It is dominantly a gray, medium-grained, massive to foliated alternating sequence of schist and micaceous quartzite.

Bedding and foliation within the metamorphosed sedimentary rocks generally strike (trend) to the northeast and dip[2] (are inclined) steeply to moderately to the northwest and southeast. However, the strike and dip of these rock fabrics vary locally, as shown by the structural symbols on **Figure 6**.

The Georges Mill Fault has not been recognized in outcrop but is marked by a large lineament that is defined by the arms at the north end of Lake Sunapee as well as the drainage patterns beyond the limit of the lake (Allen, T. T., 2012). Areas proximal to fault zones are often preferentially fractured and are therefore considered to be favorable targets for groundwater development.

Groundwater storage and flow within bedrock are controlled, in large part, by the secondary permeability associated with structural discontinuities such as fractures and faults. Therefore, EGGI's analysis of the groundwater potential within the Study Area also involved detailed characterization of the fracture fabric of the bedrock. These fracture fabric data have two primary uses in this study: 1) they enabled correlation of lineaments to ground features, thereby supporting extrapolation of fracture fabric features to areas where bedrock is not exposed; and 2) they provide a qualitative measure of the groundwater storage and secondary permeability characteristics within the bedrock. The ability to extrapolate the detailed fracture fabric data beyond specific bedrock outcrop locations where measurements are made is important because bedrock is exposed in less than approximately 5% of the Study Area.

[2] Dip refers to the angle at which a fracture, geologic bed, etc., is inclined from the horizontal plane (measured in degrees). Strike refers to the orientation of horizontal line in the plane of an inclined planar feature such as a fracture or a geologic bed. It is measured in degrees east of north.

3.2.4 Result/Key Observations About the Fracture Fabric

Detailed field measurements were made on over 75 bedrock fractures (and fracture systems) that were studied by EGGI geologists in the New London region. Due to the differential weathering characteristics of the rock units, many of the outcrops studied were of the Concord granite and Littleton Formation. Analysis focused on the characterization of structural features known to influence groundwater movement, such as fractures, brittle faults, and other structural discontinuities. In addition, specific characteristics, such as planarity, scale of fracture networks, interconnection of bedrock fractures, spacing of fractures, and associated mineralization were noted for each feature studied.

Bedrock fracture orientations for representative bedrock fractures measured in the Study Area are displayed using structure symbols on **Figure 6**. In addition, the synoptic rose diagram on **Figure 6** shows that the most common fracture family orientations observed within the entire Study Area are as follows (strike): 22°, 45°, 65°, 97°, and 112°. Note that other fracture orientations occur locally and are common within sub-areas of the Study Area, as shown on **Figure 6**.

Two of the seven lineament families can be correlated with bedrock fracture families as shown rose diagrams presented on Figure 6. The lineament families trending 22° and 45° matches the fracture family trending 32°. The 72° lineament family approximately matches the 65° fracture trend. The correlation of fracture and lineament family trends helps to validate the use of lineaments as indicators of fracture features in the bedrock underlying this study area.

3.2.5 Water Well Inventory

The NHDES Water Well Inventory is a statewide database containing well information for domestic wells and public water supply wells. Based upon 310 bedrock wells located within the Town of New London, reported airlift yields range from 0 to 100 gpm and the well depths range from 110 to 1,365 feet. The average yield of the wells is 12 gpm and their average depth is 460 feet. Fifty-one of the 310 wells reported yielding 25 gpm or more (or 16.7%) with only 17 wells exceeding 49 gpm (or only 5%).

Overall, these data show that yields of bedrock wells in the local area are highly variable but generally of moderate to low yield, which suggests that although possible to develop moderate- to high-yielding Production Wells in the study area, it will be certainly challenging. Detailed geophysical surveys will be required to specifically select the best drilling targets in the study area.

3.2.6 Selection of Potential Groundwater Development Zones in Fractured Bedrock Aquifers

Whereas the analyses of remote sensing data provided insights into potential bedrock discontinuities for 100% of the Study Area, data collected from EGGI's investigations of on-site bedrock exposures provide detailed "field" evidence for the orientation of faults, fracture systems, and other discontinuities at specific locations. The correlation of the mapped bedrock discontinuities with linear features, determined through remote sensing analysis (i.e., lineaments), provided the basis for using the lineaments to define sub-areas (or potential Groundwater Development Zones GDZ's) within the Study Area where the underlying bedrock is potentially preferentially fractured or faulted (**Wise, 1982**). These Groundwater Development Zones are considered favorable candidates for bedrock aquifer development.

The many criteria integrated to rank zones (sub-areas) according to their favorability for developing groundwater supplies cannot be quantified by a rigid mathematical equation. Rather, the results of the exploration program are dependent upon an experienced team of earth scientists integrating all of the hydrogeologic criteria and qualitatively assigning a "likelihood" of a particular zone to produce sustainable groundwater supplies of good quality. The technical criteria used to evaluate the selected zones included topography, bedrock geology, bedrock structural features, coincident lineaments, fracture fabric data, existing wells, and the location and type of potential contaminant threats. The results of this Phase I groundwater exploration program have served to delineate five potential Groundwater Development Zones which the groundwater investigation team has selected as being *"favorable"* for groundwater development. These groundwater development zones are distributed throughout the Study Area in a wide variety of hydrogeologic settings (**Figure 6**). The Groundwater Development Zones are divided into two categories: two *"Primary"* zones[3], and four *"Secondary"* zones.

3.2.6.1 Primary Groundwater Development Zone LON-1

The highest ranking GDZ in bedrock is in the southeastern portion of the Study Area, north of Interstate 89 in the area surrounding Clark Pond (**Figure 7**). This area is underlain by the Concord granite and lies along a major lineament which may be an extension of the Georges Mill Fault. A 100-gpm domestic well was drilled on the southeast side of Route 11, slightly east of potential Groundwater Development Zone which suggests it is possible to develop high yield bedrock wells in the area of Zone LON-1 and suggests groundwater investigations in this area are fully warranted.

Zone LON-1 incorporates a large Town-owned parcel (119-002) that is currently in Conservation and contains trails for public use. The biggest limitation to groundwater exploration in this area is the limited accessibility and the presence of wetlands.

3.2.6.2 Primary Groundwater Development Zone LON-2

The second highest ranking GDZ in bedrock is in the south-central portion of Town, northeast of Messer Pond (**Figure 8**) along County Road. This area is underlain by the Concord granite and the Kinsman Granodiorite. Zone LON-2 lies at the northern end of the linear feature that connects Messer Pond and Clark Pond. It is also located in an area of the Georges Mill Fault (**Figure 6**). Existing homes in the middle of the Zone will limit where geophysics can be conducted, and where wells may be drilled.

GDZ LON-2 is very well protected from commercial/industrial contaminant threats and contains one Town-owned conservation parcel (093-013) with a public trail.

3.2.6.3 Secondary Groundwater Development Zone LON-3

Bedrock Zone LON-3 is in the central portion of the Study Area and in underlain by Concord granite (**Figure 9**). Zone LON-3 contains a dominant linear feature trending from northwest to southeast along Lion Brook, co-parallel to the linear feature that the Georges Mill Fault follows. If a bedrock feature can be intercepted within this Zone, the available recharge to the bedrock aquifer in this area may limit groundwater withdrawals.

[3] Primary zones are considered more favorable than secondary zones and so forth. However, information obtained from Phase II investigations may serve to modify the relative priority ranking of these groundwater development areas.

GDZ LON-2 is also protected from commercial/industrial contaminant threats and contains three privately owned conservation parcels (083-008, 094-033, 083-009). The public works building is located on the southeast end of the Zone LON-3 which contains an underground storage tank; however, no spills have been reported.

3.2.6.4 Secondary Groundwater Development Zone LON-4

Zone LON-4 is considered a Secondary Zone and is located southeast Pleasant Street near the existing wastewater pump station (**Figure 10**). The underlying bedrock is Concord granite. This Zone is located along the linear features that is coincident with Lion Brook. The zone includes four large lots (096-035, 096-016,121-007), one of which is owned by the Town of New London (096-035). Similar to Zone 3, the available recharge to the bedrock aquifer may be somewhat limited in Zone LON-4.

3.2.6.5 Secondary Groundwater Development Zone LON-5

LON-5 is considered a Secondary Zone because it is likely to have limited recharge to sustain large groundwater withdrawals. However, the coalescent of several lineaments and contacts of multiple rock types (Concord granite, Bethlehem Gneiss, and Kinsman Granodiorite) increases the potential favorability of this Zone. LON-5 is in Springfield and contains a small reservoir and a water tower (**Figure 11**). Property in the Zone is mainly within the Gile State Forest. Careful consideration would have to be given to developing a public supply with the State Forest.

3.2.6.6 Secondary Groundwater Development Zone LON-6

Zone LON-6 is considered a Secondary GDZ and includes three private Conservation Lots (056-008, 056-007, 070-014) near the intersection of Burpee Hill Road and Newport Road (**Figure 12**). The Zone is on the north side of the Exeter River between Linden Street and Court Street. The Town transfer station is on the north side of the Zone.

4.0 TOWN-WIDE GROUNDWATER EXPLORATION CONSIDERATIONS

4.1 GROUNDWATER RECHARGE

Groundwater recharge is defined as the volume of precipitation that enters the deep groundwater system and is subsequently made available to pumping wells. When considering availability (recharge) of groundwater resources at any one site, the size and extent of the associated watershed, the type of soils overlying the aquifers, and the overall topographic setting are all considered. The volume of available recharge will ultimately determine the volume of water that can be derived from pumping wells on a long-term sustainable basis.

Given the widespread distribution of thin overburden and relatively steep slopes over much of the Precinct, groundwater recharge rates in New London are expected to be lower than in other parts of the region where more sandy soils exist and the slopes are moderate. Therefore, there is greater potential for groundwater recharge in New London if Production Wells are located near existing sources of water, such as Little Lake Sunapee, or the lowlands at the south end of the Precinct. Ideally, potential groundwater development zones will couple areas of favorable fractured bedrock aquifers with those areas with a greater propensity to store and transmit water in the overburden.

4.2 CONTAMINANT THREATS AND EXCLUSION ZONE ANALYSES

An important component of any groundwater development program is the assessment of the potential for groundwater contamination resulting from past, present, or projected future land uses (**Figure 13**). EGGI investigated potential threats to groundwater quality through a review of available State contaminant threat databases, existing reports, windshield surveys of current land uses, and in-office inspection of high-resolution aerial photographs.

As would be expected, potential contaminant threats within the Study Area are largely concentrated along the major traffic routes of New London (**Figure 13**). After a thorough review of the NHDES contaminant threats databases it has been determined, at the time of this report, there are three active remediation sites inside the Precinct boundary: two LUST (Leaking Underground Storage Tank) sites and a Hazardous Waste site. These sites, where some form of contaminant investigation, or remediation, has occurred are included in the Site Remediation and Groundwater Hazards Inventory (SRGHI). Aside from the aforementioned sites, most of the NHDES contaminant threats databases do not indicate actual contamination of groundwater, but rather the *potential* for contamination to occur. For example, the AST/UST databases only indicates the *presence* of a registered Aboveground Storage Tank or Underground Storage Tank, not that groundwater contamination from tank leakage has occurred.

In addition to contaminant threats, the exclusion zone includes roadways and a 400-foot buffer on either side of any roadway (**Figure 13**). This buffer provides the necessary setback to comply with the NHDES Sanitary Protective Area (SPA) requirement for Public Drinking Water Supply Wells.

Ideally, water resources should be developed only in areas where the potential for contamination is not present. However, because of the restricted availability of areas where additional water resources can be developed, some areas that are *hydrogeologically* favorable for groundwater development were still retained for further consideration, even though they are located proximal to *"potential"* contaminant threats. Detailed hydrologic and water quality studies will be required during the next phases of investigation to determine if groundwater quality is actually threatened at or near selected Groundwater Development Zones.

5.0 CONCLUSIONS

The NLSWSP currently withdraws all of its groundwater supplies from the Colby Point Wellfield, situated on a narrow peninsula in Little Lake Sunapee. Various alternatives for increasing the total production from the Colby Point Wellfield are evaluated in this report, but all have some limitations that will require further investigation to fully evaluate. In order to provide a redundant source of water and to reduce the vulnerability of the water system, EGGI strongly encourages the NLSWSP to consider identifying another groundwater source to supplement the Colby Point Wellfield. Within or near the Precinct boundaries, fractured bedrock aquifers offer the only realistic alternatives for a new wellfield. The sand & gravel aquifers that are most favorable for groundwater development are outside of the Study Area and will require significant infrastructure development to convey the groundwater to the existing system.

EGGI/GZA looks forward to meeting with the Precinct to discuss the various alternatives for developing additional groundwater resources and will be glad to prepare detailed scopes of service for any of the alternatives to assist the NLSWSP in selecting the most feasible and cost-effective options.

6.0 REFERENCES

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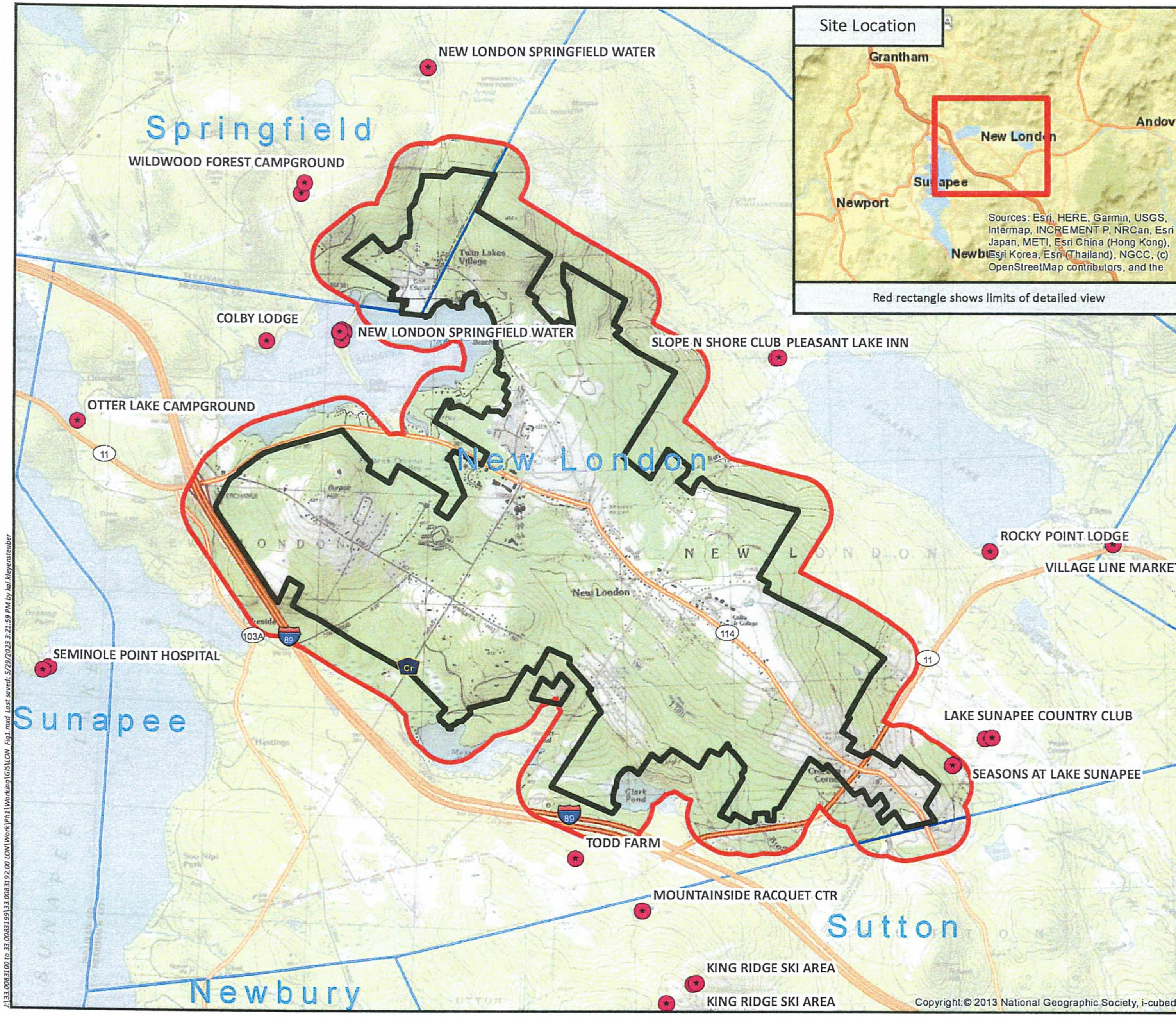

FIGURE 1

Topographic Setting
and Existing Water Sources

New London-Springfield Water Precinct
New London, New Hampshire

Legend

- Public Water Supply Wells
- Precinct Boundary
- Study Area

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N

Scale is 1:48,000
1 inch = 4,000 feet

0 500 1,000 2,000 Meters
0 2,000 4,000 8,000 Feet

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FIGURE 1

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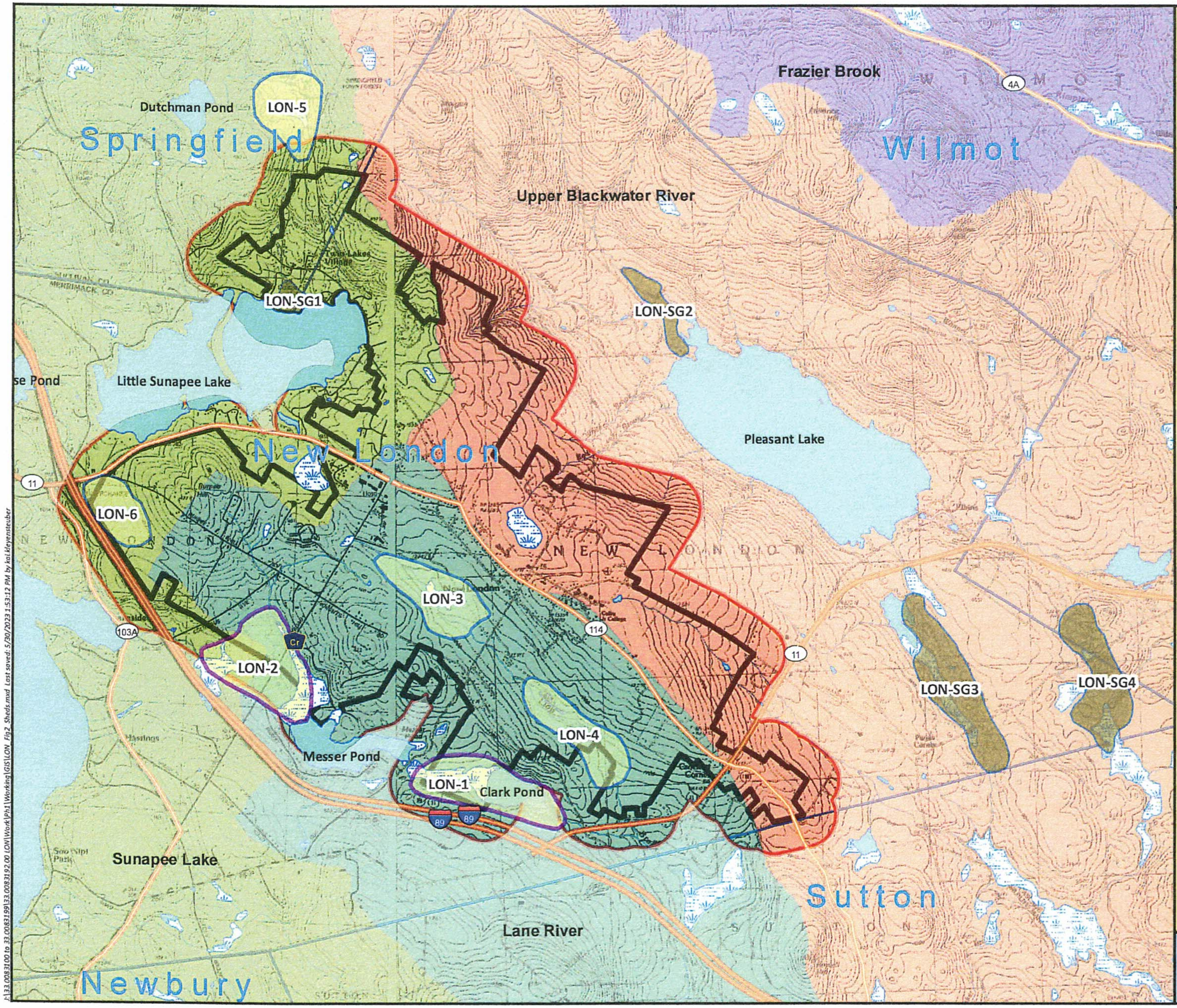

FIGURE 2

Regional Watersheds and
Potential Groundwater Development Zones

New London-Springfield Water Precinct
New London, New Hampshire

Legend

- Precinct Boundary
- Study Area

Regional Watersheds

- Frazier Brook
- Lane River
- Sunapee Lake
- Upper Blackwater River

Potential Groundwater Development Zones

- Primary
- Secondary
- Sand and Gravel Zone

N

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Scale is 1:48,000
1 inch = 4,000 feet

0 500 1,000 2,000 Meters
0 2,000 4,000 8,000 Feet

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FIGURE 2

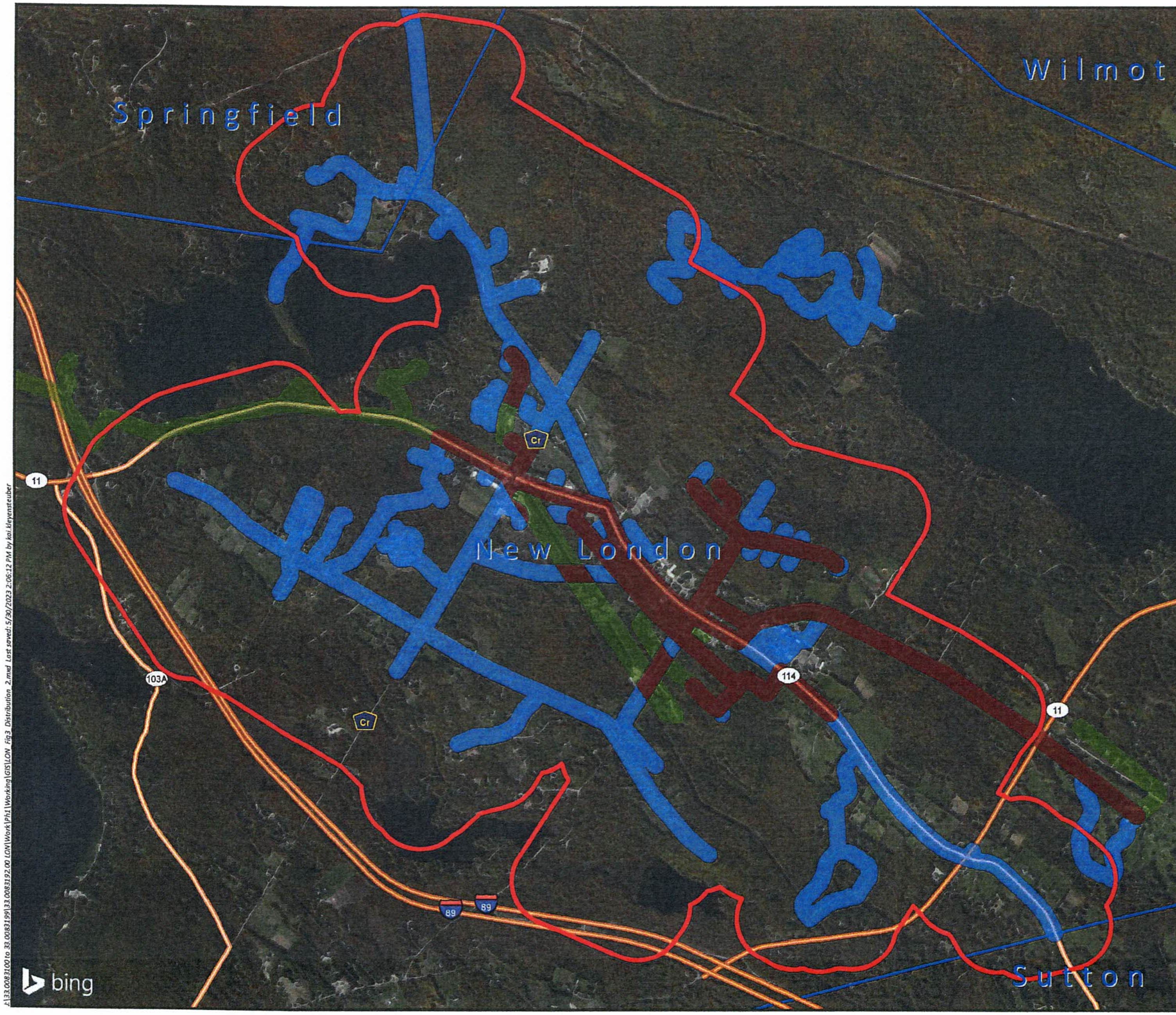

FIGURE 3

Existing Water and Sewer Lines on Aerial Photo Basemap

New London-Springfield Water Precinct
New London, New Hampshire

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FIGURE 3

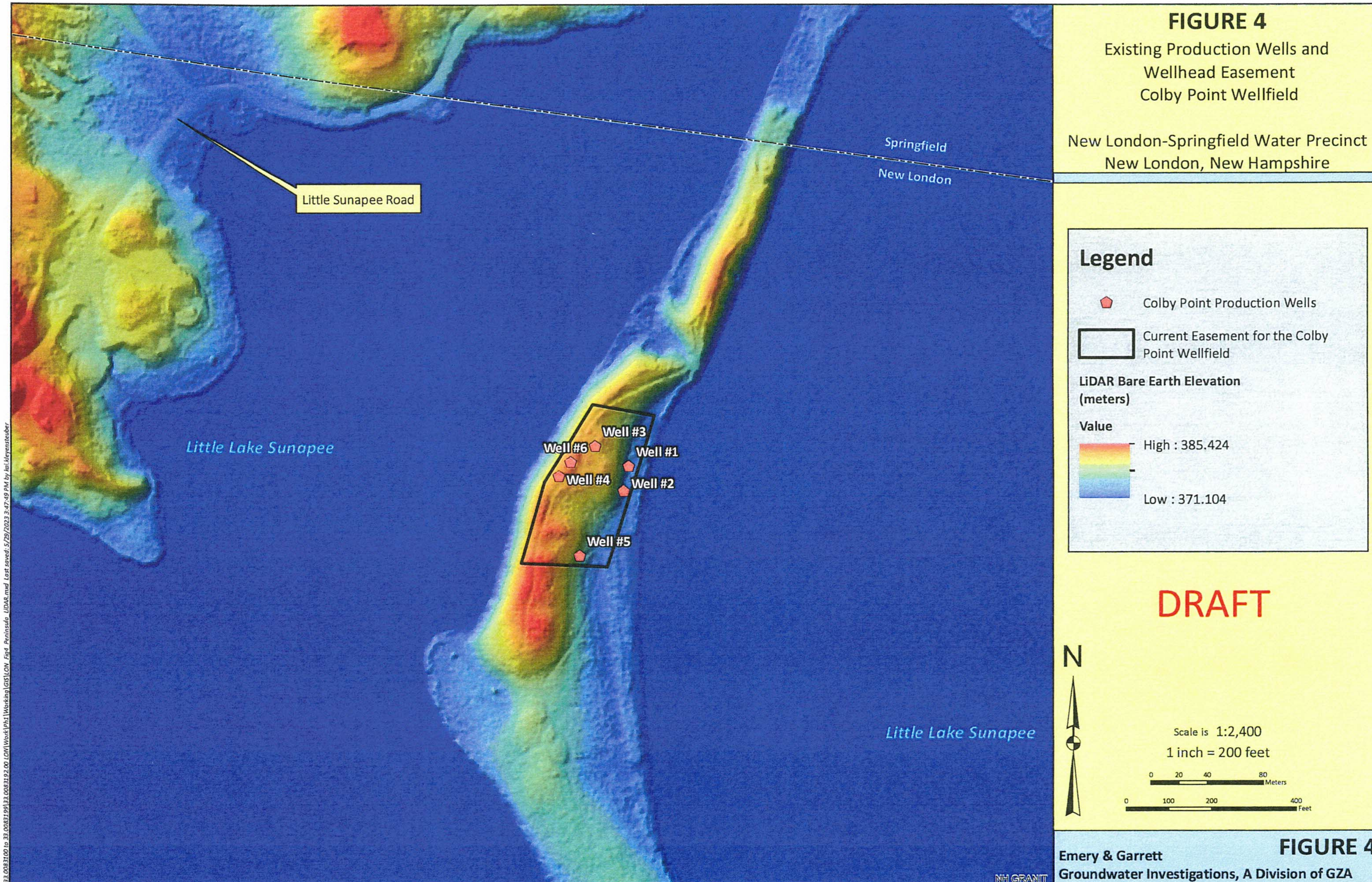

FIGURE 4
Existing Production Wells and
Wellhead Easement
Colby Point Wellfield
New London-Springfield Water Precinct
New London, New Hampshire
Legend
Colby Point Production Wells
Current Easement for the Colby Point Wellfield
LiDAR Bare Earth Elevation (meters)
Value
High : 385.424
Low : 371.104
DRAFT
N
Scale is 1:2,400
1 inch = 200 feet
0 20 40 80 Meters
0 100 200 400 Feet
Little Sunapee Road
Springfield
New London
Little Lake Sunapee
Little Lake Sunapee
Well #1
Well #2
Well #3
Well #4
Well #5
Well #6
NH GRANIT
Emery & Garrett
Groundwater Investigations, A Division of GZA
FIGURE 4

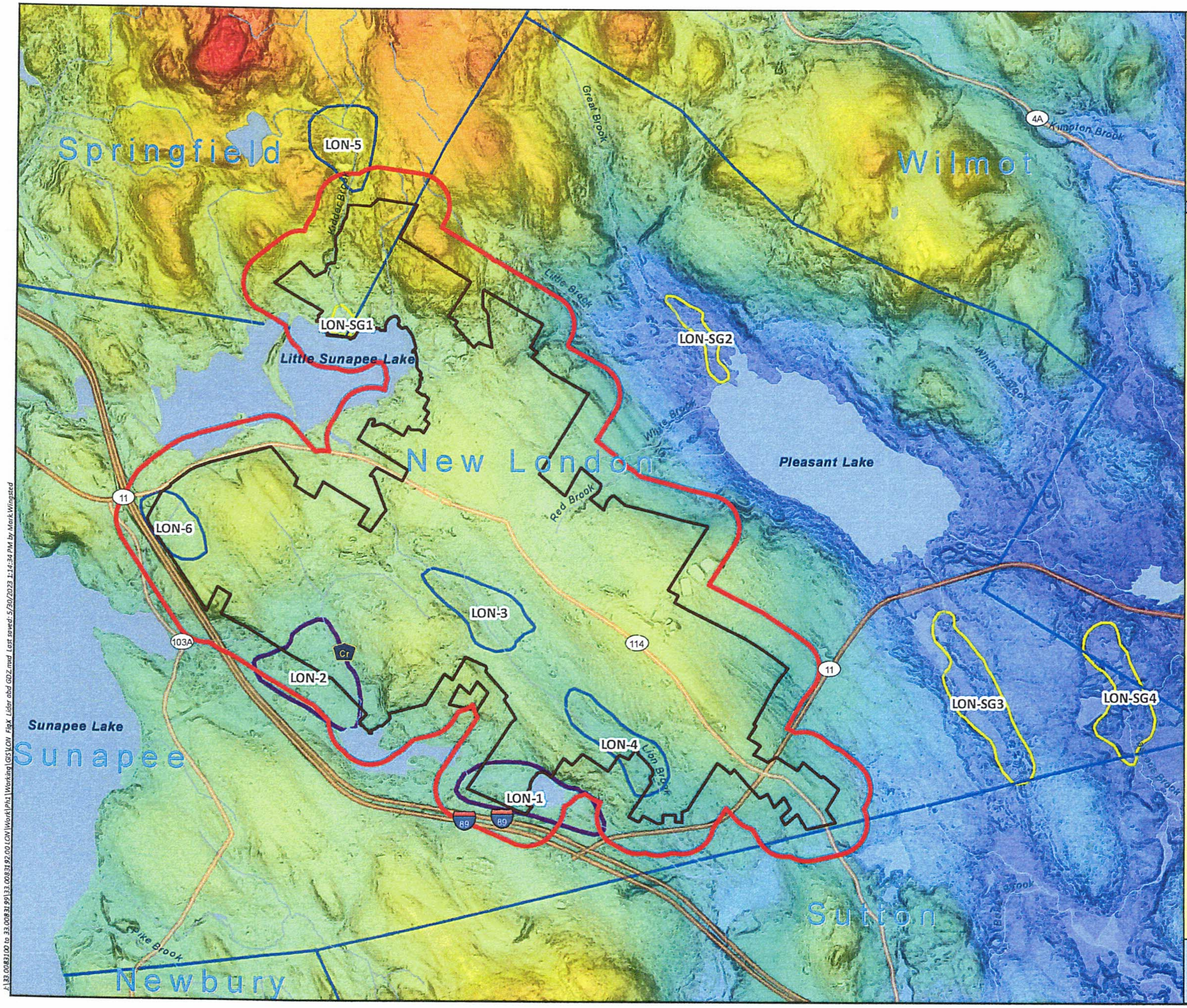

FIGURE 5

Proposed Groundwater Development Zones on a Digital Elevation Map

New London-Springfield Water Precinct
New London, New Hampshire

Legend

- Study Area
- Precinct_Boundary
- NH Political Boundaries

Potential Groundwater Development Zones

Status

- Primary Bedrock
- Secondary Bedrock
- Sand & Gravel

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N

Scale is 1:36,000
1 inch = 3,000 feet

0 315 630 1,260 Meters
0 1,500 3,000 6,000 Feet

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FIGURE 5

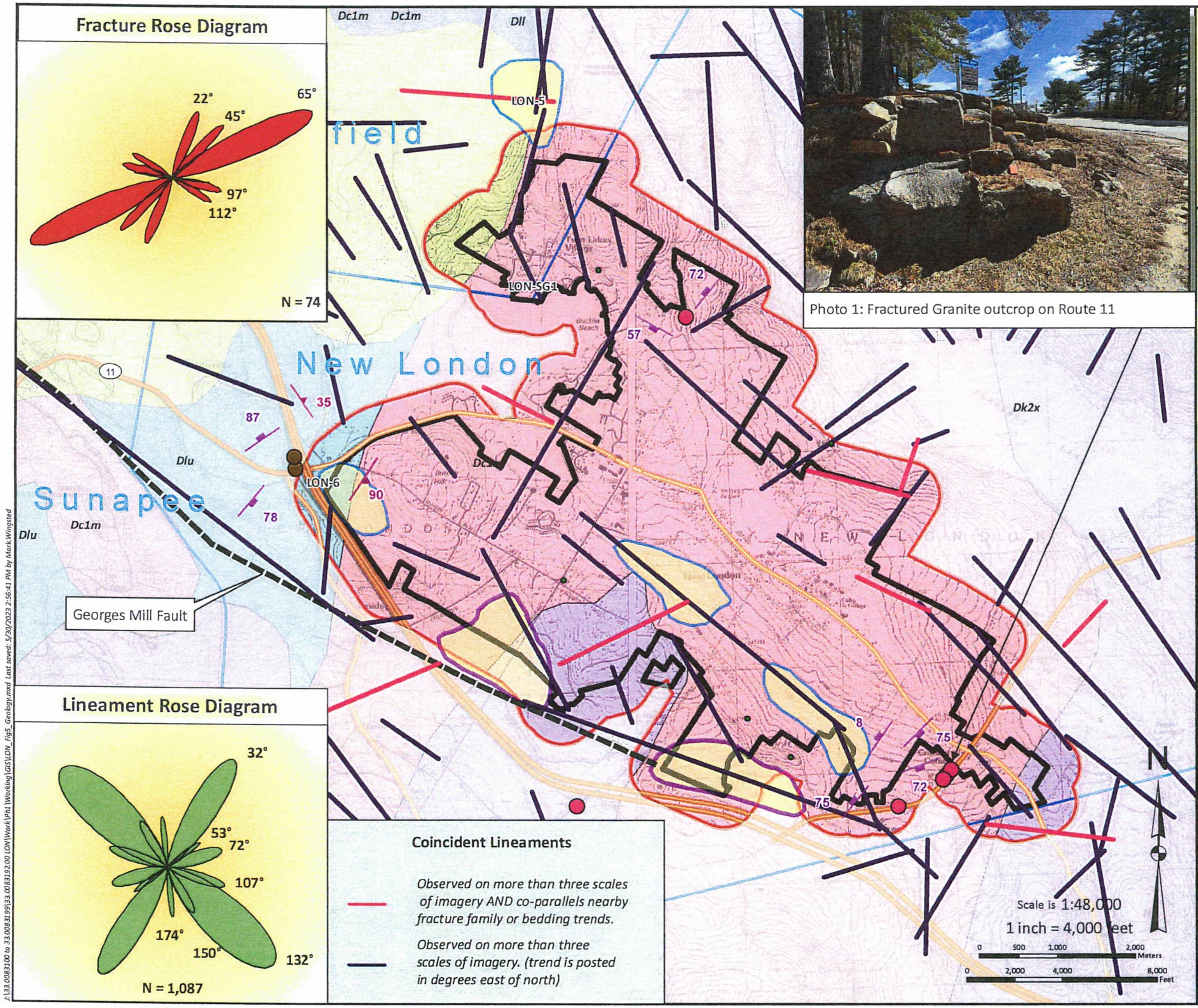

FIGURE 6

Bedrock Geology, Coincident Lineaments, and Potential Bedrock Groundwater Development Zones

New London-Springfield Water Precinct
New London,New Hampshire

Legend

Precinct Boundary
Study Area

Bedrock Geology

- Db2b - Bethlehem Granodiorite
- Dc1m - Concord Granite
- Dk2x - Kinsman Granodiorite
- Dll - Littleton Formation Lower member
- Dlu - Littleton Formation Upper member

Outcrop observed by EGGI

- biotite gneiss
- granite

Bedrock Structures

- EGGI Identified Bedrock Fracture Family *Strike and Dip of Fracture Family*
- Foliation *Strike and Dip of Foliation*

Potential Groundwater Development Zones

Status

- Primary
- Secondary

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FIGURE 6

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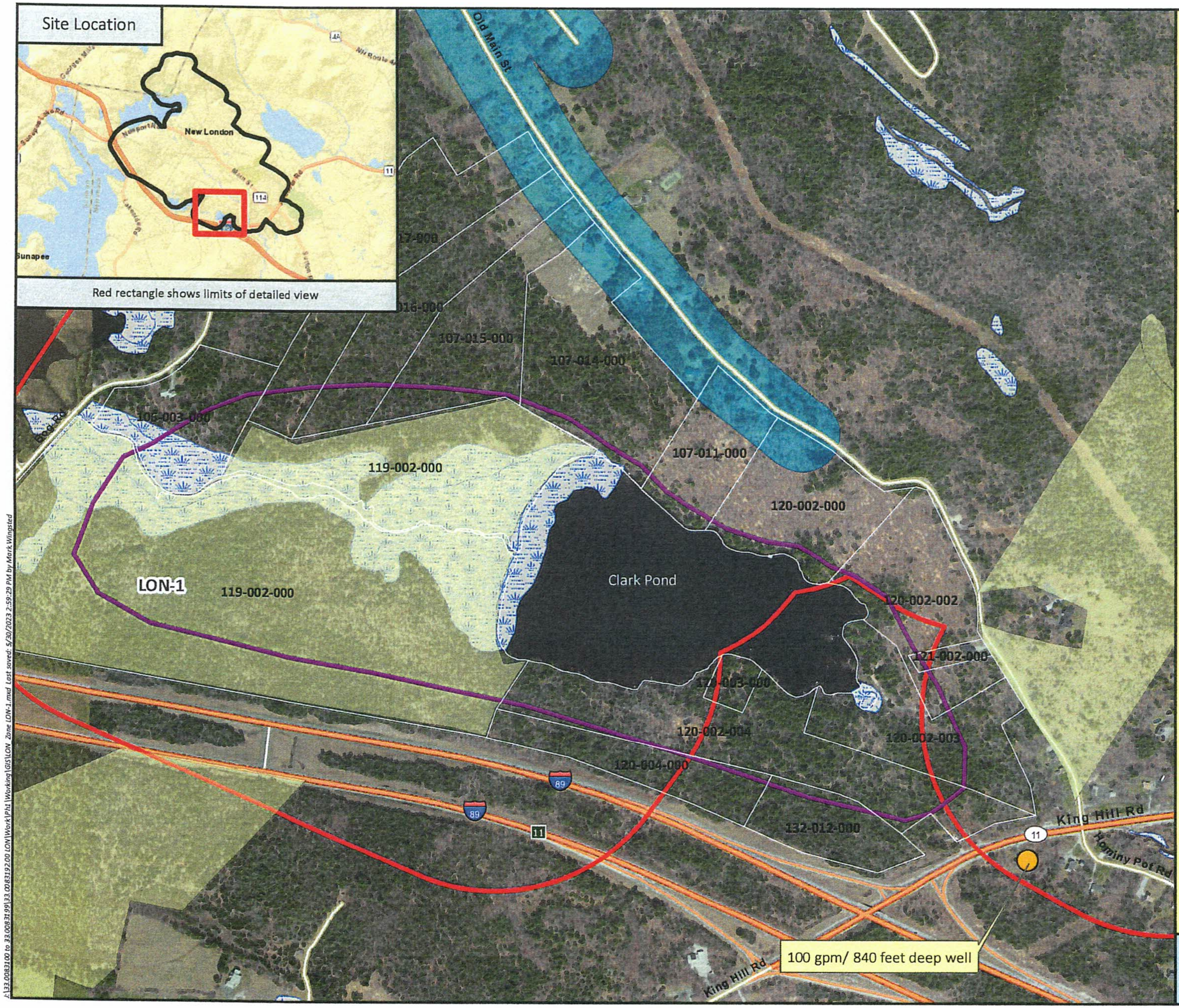

FIGURE 7

Potential Groundwater Development Zone
LON-1
New London-Springfield Water Precinct
New London, New Hampshire

Legend

- Study Area
- Parcels
- Conservation Land

Potential Groundwater Development Zones

Status

- Primary
- Secondary

Water_and_Sewer_Lines

- Water
- National Wetland Inventory (NWI)

DRAFT

N

Scale is 1:6,000
1 inch = 500 feet

0 62.5 125 250 Meters
0 250 500 1,000 Feet

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FIGURE 7

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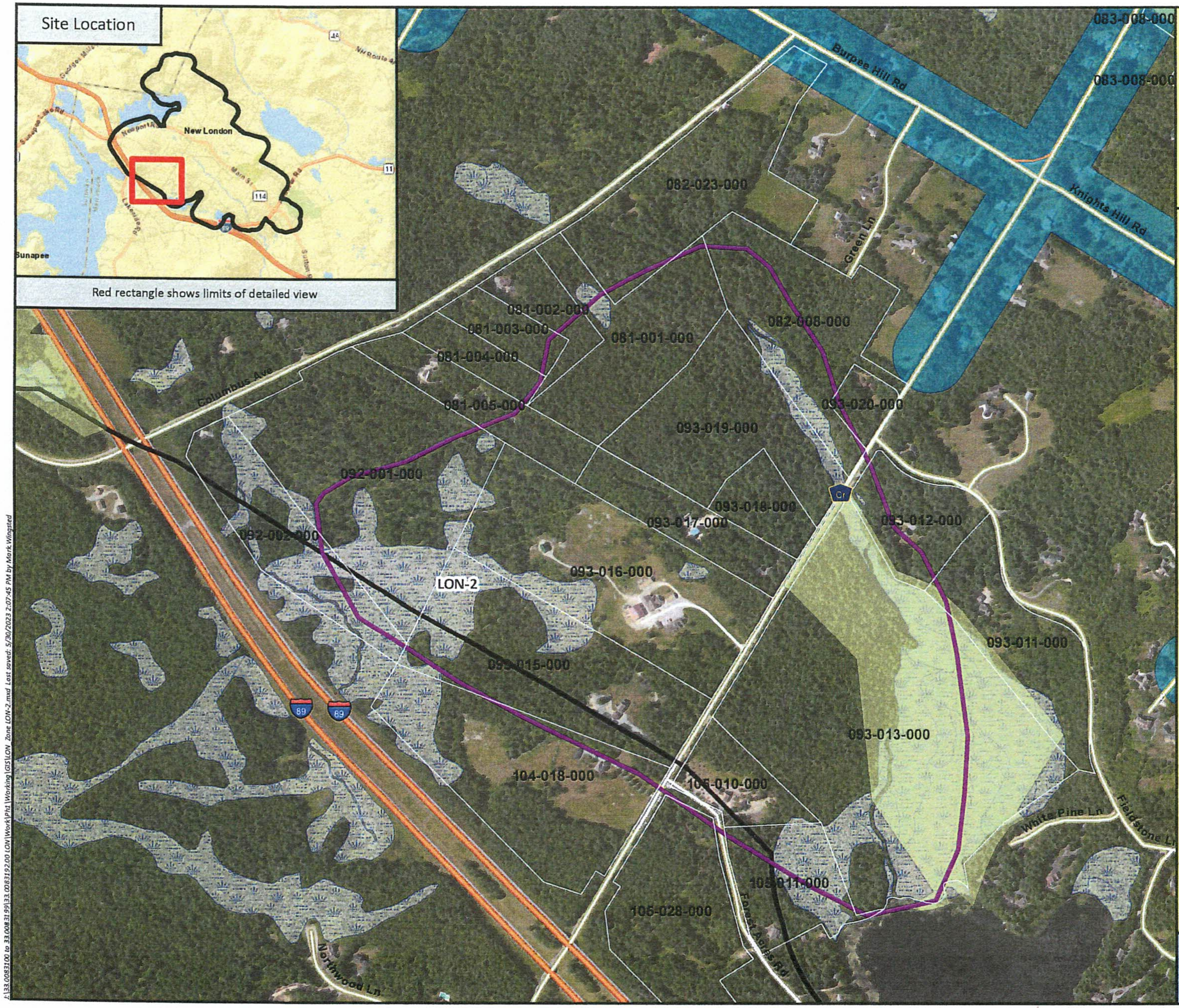

FIGURE 8

Potential Groundwater Development Zone
LON-2
New London-Springfield Water Precinct
New London, New Hampshire

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FIGURE 8

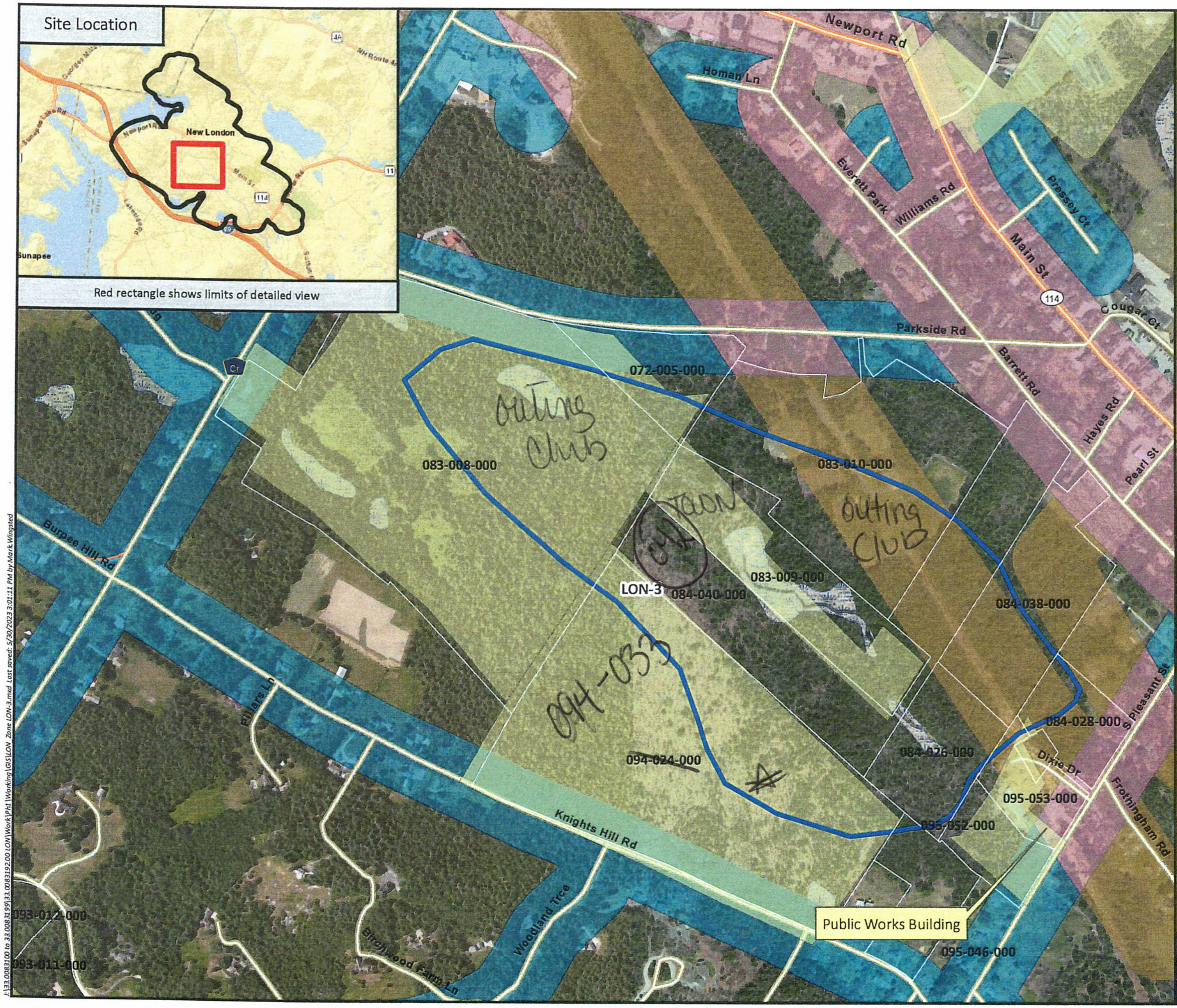

FIGURE 9

Potential Groundwater Development Zone
LON-3
New London-Springfield Water Precinct
New London, New Hampshire

Legend

- Study Area
- Parcels
- Conservation Land

Potential Groundwater Development Zones

Status

- Secondary

Water_and_Sewer_Lines

PIPE TYPE

- Both
- Sewer
- Water
- National Wetland Inventory (NWI)

DRAFT

N

Scale is 1:6,000
1 inch = 500 feet

0 62.5 125 250 Meters
0 250 500 1,000 Feet

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FIGURE 9

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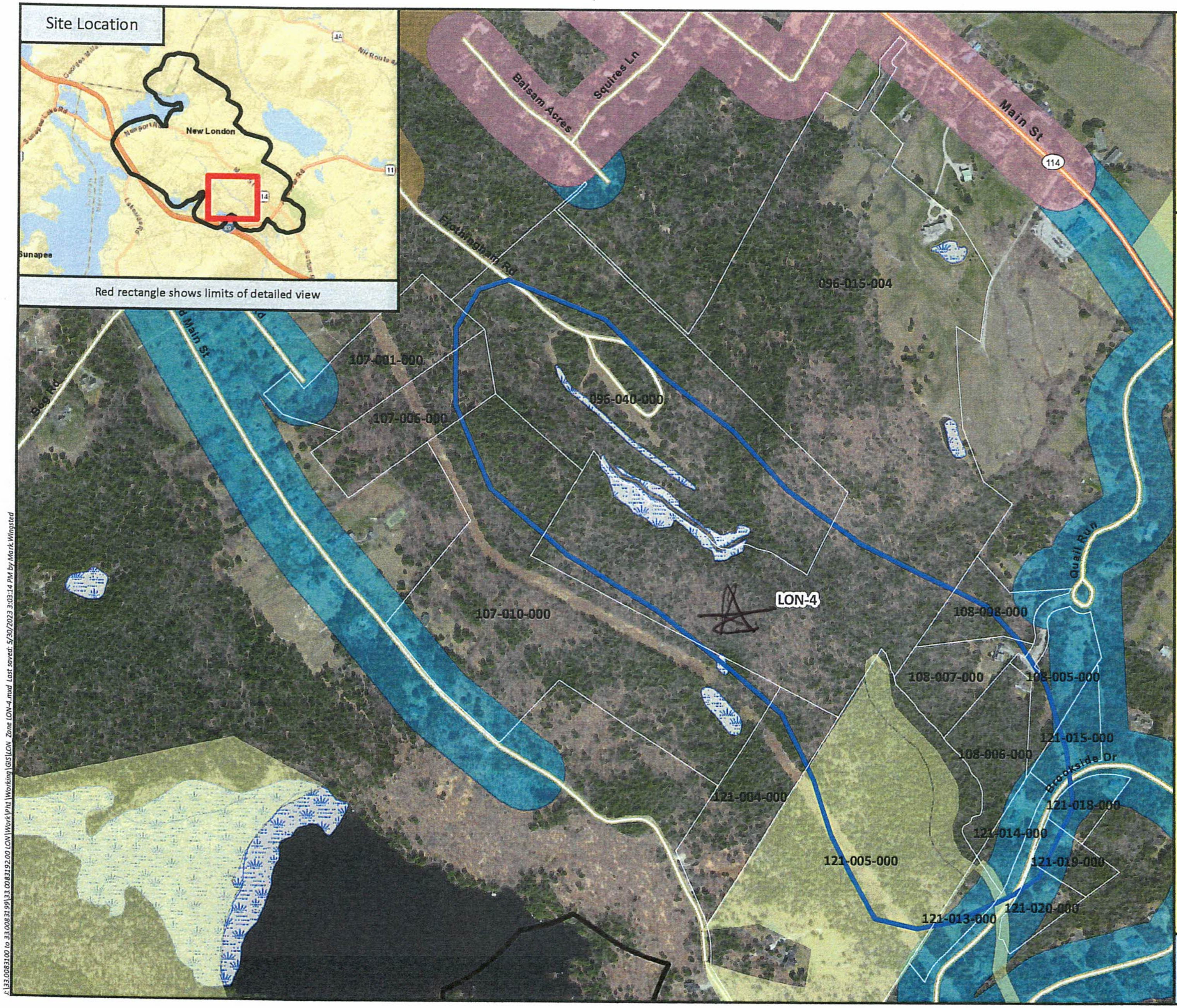

FIGURE 10

Potential Groundwater Development Zone
LON-4
New London-Springfield Water Precinct
New London, New Hampshire

Legend

- Study Area
- Parcels
- Conservation Land

Potential Groundwater Development Zones

Status

- Secondary

Water_and_Sewer_Lines

- Both
- Water
- National Wetland Inventory (NWI)

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N

Scale is 1:6,000
1 inch = 500 feet

0 62.5 125 250 Meters
0 250 500 1,000 Feet

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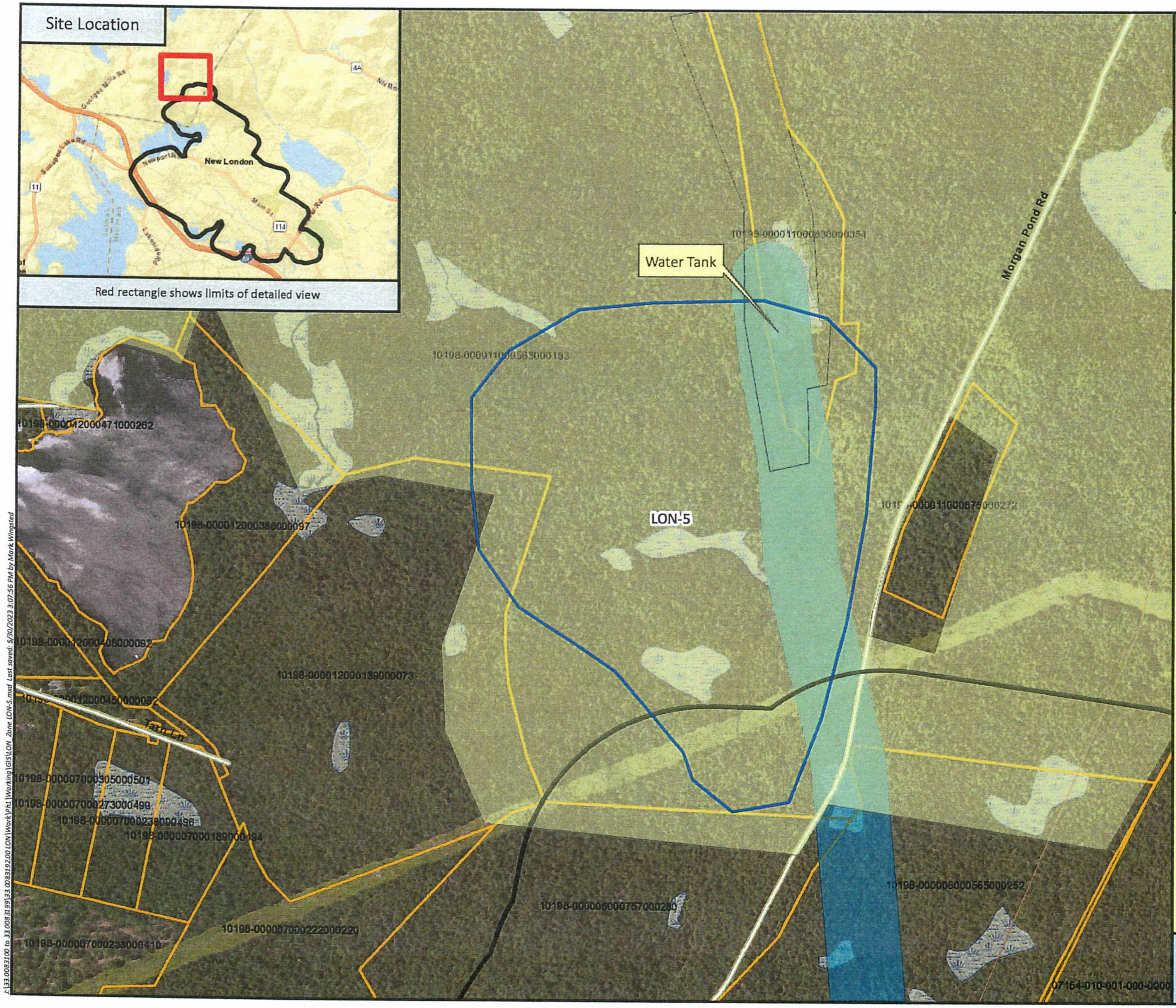
FIGURE 10

FIGURE 11

Potential Groundwater Development Zone
LON-5
New London-Springfield Water Precinct
New London, New Hampshire



Legend
- Study Area
- Parcels
- Conservation Land

Potential Groundwater Development Zones
- Secondary

Water_and_Sewer_Lines
- Water
- National Wetland Inventory (NWI)

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N

Scale is 1:6,000
1 inch = 500 feet
0 62.5 125 250 Meters
0 250 500 1,000 Feet

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FIGURE 11

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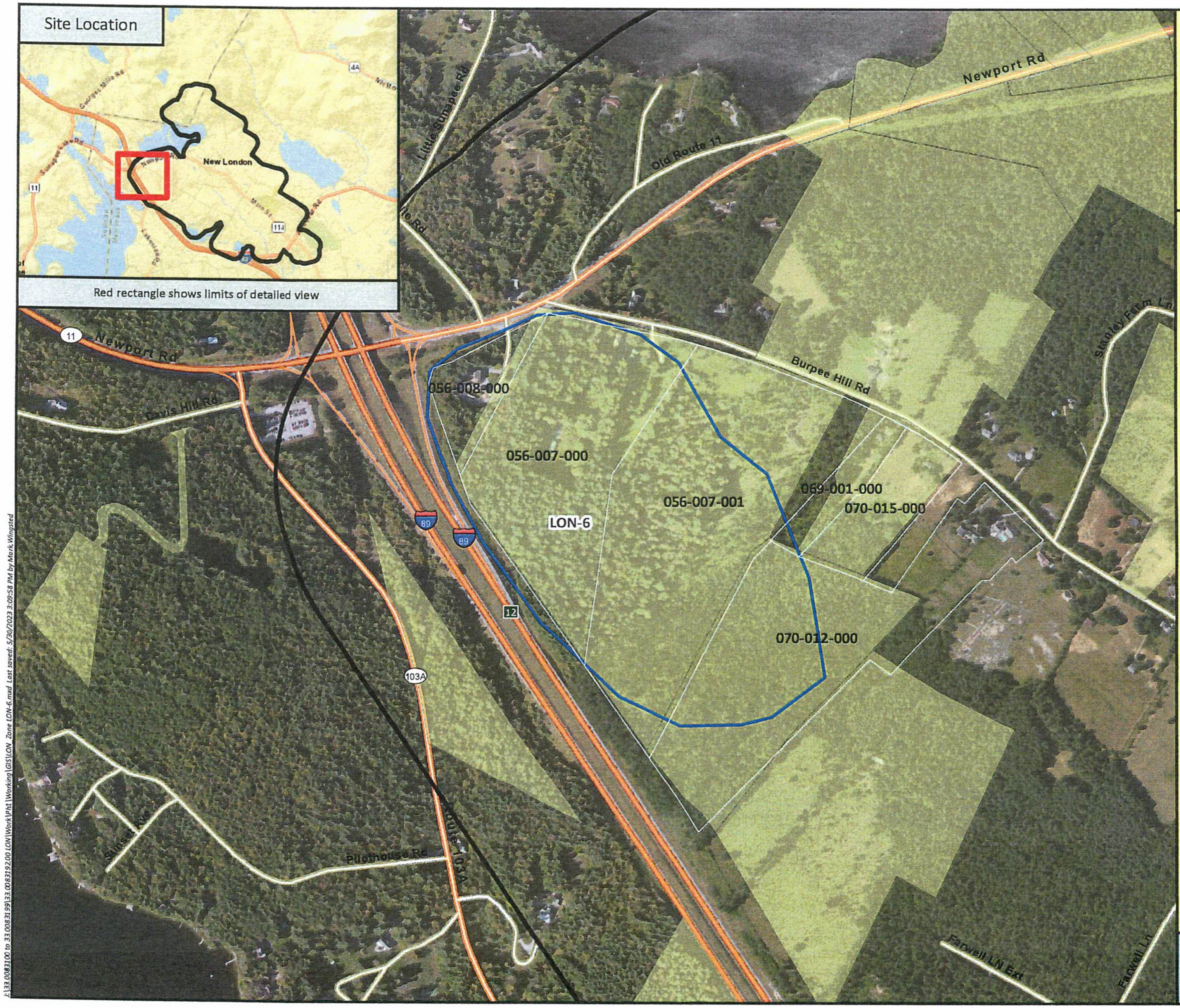

FIGURE 12

Potential Groundwater Development Zone
LON-6
New London-Springfield Water Precinct
New London, New Hampshire

Legend

Study Area

Parcels

Conservation Land

Potential Groundwater Development Zones

Status

Secondary

DRAFT

N

Scale is 1:6,000
1 inch = 500 feet
0 62.5 125 250 Meters
0 250 500 1,000 Feet

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FIGURE 12

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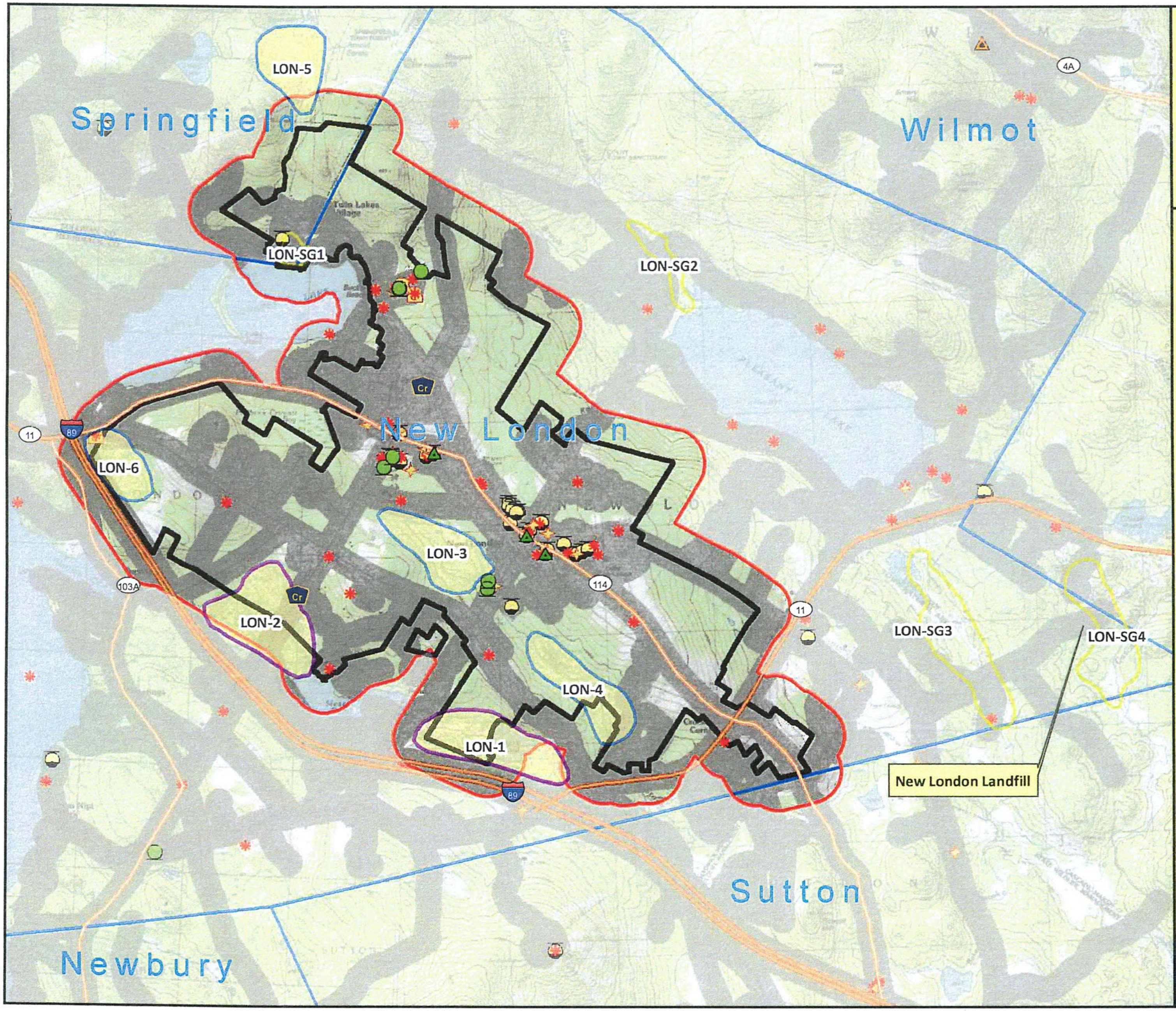

FIGURE 13

Potential Contaminant Threats
and Exclusion Zone Analyses

New London-Springfield Water Precinct
New London, New Hampshire

Legend

- Precinct_Boundary
- Study Area

Potential Groundwater Development Zones

Status

- Primary
- Secondary
- Sand and Gravel
- Active Remediation Sites
- Aboveground Storage Tank Sites
- Hazardous Waste Generators
- Local Potential Contamination Sources
- Remediation Sites
- Solid Waste
- Underground Storage Tank Sites
- Exclusion Buffer (400 Feet)

DRAFT

N

Scale is 1:48,000
1 inch = 4,000 feet

0 500 1,000 2,000 Meters
0 2,000 4,000 8,000 Feet

FIGURE 13

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