CHAPTER SIX

A PROPOSED GROUNDWATER MONITORING NETWORK FOR THE HOLLAND AND BLACK RIVER BASINS

By

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6.1 LOCATION

The Holland and Black River drainage basins are located in southern Ontario between latitudes 43^0 56' and $44^0$21' N and longitudes 79^0 48' and $79^0$12' W. The basins, which cover about 1,046 km^2 , are bounded on the north by Lake Simcoe, on the east by the Pefferlaw Brook watershed, on the south by the Oak Ridges Moraine, and on the west by the Nottawasaga River basin.

The main tributary basins are the Holland River basin (596 km^2), the Black River basin (334 km^2), the Moskinonge River basin (54 km^2), and a number of small catchments draining directly into Lake Simcoe (62 km^2). Large swamp areas occur in the north toward Lake Simcoe in both the Black River and Holland River basins. The most famous of these areas is the Holland Marsh which is a topographic depression extending from the Lake Simcoe to the Oak Ridges Moraine. The Holland and Black River basins include parts of the Regional Municipalities of Simcoe, York, and Durham.

NOTE: A Key Map was included as part of the figures for this chapter. Those who wish to make a hard copy of the chapter can also make a transparency of the Key Map and use it for orientation purposes with the other figures.

6.2 LAND USE

The Holland Marsh to the southeast of Bradford has been drained since 1935 and is considered one of the best producing vegetable areas in Ontario. The Marsh has been put into such crops as onions, lettuce, celery, spinach, carrots, potatoes, and other vegetables. The produce is shipped to Toronto markets and to other parts of Canada.

Good farming areas are also found near Bradford and Newmarket. The cropping pattern in these areas is made up of hay, pasture, grain corn, barley, mixed grain, winter wheat, silage corn, and oats. Dairying, beef cattle, and poultry are the mainstays of many farms.

Low swampy areas are found directly south of Cook’s Bay to the north of Holland Marsh.

Long and wide swampy areas that extend for several kilometers are also found along the valleys of the Black River and its tributaries, the Zephyr and Mount Albert Creeks.

About one third of the basin is barren land and another one fifth is in forests. The major urban centers within the Holland and Black River basins are Newmarket and Aurora. Other smaller centers include Bradford, Holland Landing, Keswick, Mount Albert, Sharon, Schomberg, and Sutton.

6.3 GROUNDWATER USE

The total number of wells within the Holland and Black River basins with predetermined geographic coordinates and topographic elevations and on file with the Ministry of the Environment is 9,034. Of these, 637 (7%) are bedrock wells, 8,145 (90%) are overburden wells, and the remaining 3% are of unknown type.

Ground water in the basins adequately supports water supplies for both private domestic and large municipal and industrial water systems. In addition, groundwater is an important source of water supply for market gardening, sod turf production, golf course irrigation, and recreation.

Most of the population within the basins is served by municipal water supply systems and the remaining population is serviced by private water wells. Large capacity wells serve municipal demands for the urban centers of Aurora, Bradford, Holland Landing, Keswick, Mount Albert, Newmarket, and Sharon.

To date, except for localized water-level interference incidents, there have been no apparent problems in supplying all large capacity water demands from groundwater sources. One area within the basins, which is heavily committed to high-capacity wells, is located in the vicinity of the towns of Aurora and Newmarket. These two communities make up the high growth area in the basins, where the future development of groundwater for municipal supplies is considered desirable. Also, the other smaller communities will continue to rely on groundwater.Therefore, the protection and proper utilization of groundwater cannot be overestimated in the context of the overall water management in the basins.

Nitrate concentrations were determined in 60 samples taken in a synoptic survey of general groundwater quality in 1977 and 1978. Subsequently, 62 additional samples were taken in 1978 and analyzed for nitrate and specific conductance in order to define areas of high nitrate levels. Nitrate levels in over 30% of the total of 122 samples exceeded the drinking water objective of 10 mg/L as N (Vallery et al.1982).

High concentrations of nitrates were found in the headwater areas of the Black River and along the height of land north and west of Bradford. High nitrate levels were common in both shallow and deep wells in the headwater areas of the Black River. In the Bradford area, on the other hand, high concentrations of nitrate were found almost exclusively in shallow wells. According to Vallery et al.(1982), the reasons for the high concentrations of nitrate are likely attributable to agricultural activity carried out in the two areas.

6.4 PHYSIOGRAPHY

The physiography of the Holland and Black River basins is a direct result of the deposition and erosion processes during glacial and post-glacial times. According to Chapman and Putnam (1984), parts of three major physiographic units are found within the basin. These regions are the Oak Ridges Moraine, the Schomberg Clay Plains, and the Simcoe Lowlands.

A distinctive topographic feature in the basins is the Oak Ridges Moraine, which forms the height of land at the southern boundary. By and large, the moraine is composed of sandy or gravely materials which are covered in places with till deposits. The surface is hilly with a knob-and-basin relief typical of end moraine with elevation in places is as much as 365 m (a.s.l.). The Moraine contains numerous small lakes and closed depressions or kettles, of which Musselman Lake, at an elevation of about 325 m (a.s.l.) is the largest.

The Schomberg Clay Plains are deep deposits of stratified clay and silt found in two large areas around Schomberg and Newmarket within the Holland and Black River Basins. The surface under the clay is that of a drumlinized till plain. Some of the larger drumlins are exposed through the clay. Since the rolling relief of the underlying till plain has not entirely been eliminated, these areas are not so flat as many lake plains. In the area along the Holland River between Newmarket and Holland Landing considerable dissection has taken place giving rise to rough topography. The Schomberg sediments are typically varved clays composed of about 50% clay and 40% silt behaving mostly as silt. The average depth of the clay deposit seems to be about 5 m, but deep deposits are known (Chapman and Putnam 1984).

Chapman and Putnam (1984) called the lowlands bordering Georgian Bay and Lake Simcoe as the Simcoe Lowlands physiographic region. Lake Simcoe and the lowlands surrounding it and lying between 218 and 260 m (a.s.l.) are part of this physiographic region. From the southern end of Lake Simcoe, known as Cook Bay, a broad valley extends southwestward for about 25 km between high morainic hills. Once a shallow extension of the lake, the floor of this valley is now a marsh of 20,000 acres through which the Holland River meanders sluggishly to Lake Simcoe. The rich organic soil of this area is used for market gardening. A low, swampy, sandy plain extends south of Lake Simcoe and is being drained by the Black River and the Pefferlaw Brook. Extending upstream along these two streams and their tributaries are long swampy valleys which may be considered as the southern extensions of this physiographic region.

6.5 BEDROCK ELEVATION AND GEOLOGY

The bedrock topography within the Holland and Black River basins displays a prominent depression which generally follows the trend of the Holland River Valley (Figure Ho-1). Bedrock surface elevations in the depression range from about 90 to 120 m (a.s.l.). The elevation of the bedrock increases towards the east and reaches about 215 m (a.s.l.) in the northeastern corner of the basins. Similarly, the bedrock elevation increases toward the west and reaches about 180 m (a.s.l.) in the southwestern corner of the basins. A prominent bedrock high south of Aurora at the southern basins boundary has a local relief of about 60 m above the adjoining valley.

The Palaeozoic bedrock in the basins consists primarily of limestone and shale of Middle and Upper Ordovician age. Young Quaternary deposits overlie most of the Palaeozoic rocks. Four formations have been identified within the basins, the Verulam, Lindsay, Blue Mountain, and Georgian Bay Formations (Figure Ho-2).

The Verulam Formation is the oldest formation in the basins and is limited to one area located just south of Cook's Bay and another area located north of Keswick along the eastern shores of Cook's Bay. The formation, which ranges in thickness from 32 to 65 m, is a member of the Simcoe Group and it is of Middle Ordovician age. It consists of fossiliferous limestone with inter-beds of calcareous shale (Thurston et al.1992).

Overlying the Verulam Formation is the Lindsay Formation which extends from the northeastern corner of the basins toward its southwestern corner and covers parts of the Townships of Georgina, East Gwillimbury, West Gwillimbury, and King. The formation, which consists mainly of limestone, is Middle Ordovician age and it is a member of the Simcoe Group (Thurston et al. 1992).

The Blue Mountain Formation (formerly the Whitby Formation) overlies the Lindsay Formation and has a sharp contact with it. The formation, which is Upper Ordovician in age, is present in the southeastern and southeastern corners of the basins. It consists of a blue-grey, poorly fossiliferous, non-calcareous shale up to 60 m thick (Thurston et al. 1992).

The Georgian Bay Formation of Upper Ordovician age is present in the southwestern end of the basins and has a gradational contact with the underlying Blue Mountain Formation. It consists of a blue-grey shale with minor siltstone and limestone inter-beds and ranges in thickness from 125 to 200 m (Thurston et al. 1992).

6.6 OVERBURDEN THICKNESS AND GEOLOGY

In general, the overburden thickness increases from the northwestern corner of the basins where it ranges between 10 and 30 m to the southern parts of the basins where it ranges between 100 and 200 m. Overburden deposits of more than 150 m thick are also found between Bradford and the basins topographic divide near Deerhurst (Figure Ho-3).

The overburden materials consist of glacial, glaciofluvial, and glaciolacustrine deposits of late Wisconsinan age and organic deposits of muck, peat and marl of recent age. Four different tills were identified within the basins, Newmarket Till, Kettleby Till, Halton Till, and undifferentiated Till Unit 19 (Figure Ho-4).

The Newmarket Till was deposited by the Simcoe Lobe during the later part of the Port Bruce Stade. The till is a calcareous silt to sandy silt til. It outcrops along the basins western topographic divide and forms most of the high rim surrounding the Holland Marsh. (Barnett 1992).

The Kettleby Till represents a southerly advance of the Simcoe Lobe to the Oak Ridges Moraine during Port Huron Stade. The till is highly calcareous silty clay to clay till. It occurs over the northern flank of the Oak Ridges Moraine in the south western part of the basins and also to the east of Aurora and Newmarket (Barnett 1992).

The Halton Till was deposited by the Erie-Ontario Lobe during the Port Huron advance. The till is primarily a sandy silt to silt till. It covers a small area over the northern flank of the Oak Ridges Moraine in the southeastern part of the basins (Barnett 1992).

Small areas along the northern and eastern parts of the basins are covered with sandy silt to silt till which was mapped as Unit 19 on Map 2556 of the Quaternary geology of Ontario. According to Barnett (1992), the till was deposited during the Two Creeks Interstade.

Large areas along the southern and southeastern boundaries of the basins are covered with stratified sand and gravel of glaciofluvial origin. Sediments of glaciolacustrine origin are also widespread throughout the basin. These sediments were deposited in glacial Lakes Schomberg and Algonquin.

Lake Schomberg was formed within a small area between the receding Lake Simcoe Lobe and the Oak Ridges Moraine. The lake left behind some small sand deposits between Happy Valley and kettleby and extensive stratified to varved silt and clay deposits to the west and east of Holland Marsh. Lake Algonquin followed Lake Schomberg and occupied the Lake Simcoe basin as well as parts of Lake Huron and Lake Michigan basins. Lake Algonquin left behind extensive sand deposits within the valleys of the Holland and black Rivers.

Fluvial silt, sand and gravel deposits are found at the surface along the northwestern and eastern topographic divides. Peat and muck deposits are found to the south of Cook's Bay, and within the flood plains of the Holland and Black Rivers and their tributaries.

6.7 GROUNDWATER OCCURRENCE IN THE BEDROCK

Most of the bedrock wells are located in areas where the overburden is relatively thin or does not include water bearing sand or gravel deposits. This is particularly true in the northern and central parts of the basins where the overburden is underlain by the Lindsay and Verulam Formations. Some 580 wells penetrate the Lindsay Formation, 32 wells penetrate the Verulam Formation, 20 wells penetrate the Blue Mountain Formation, and 5 wells penetrate the Georgian Bay Formation.

Singer et al.(1997) identified 28,172 water wells within all the formations of the Simcoe Group which were treated together as one hydrogeologic unit in southern Ontario. Of these wells, a sample of 6,414 wells was selected to determine the transmissivity distribution for the hydrogeologic unit. The minimum and maximum transmissivity values were determined to range from 0.05 to 3,062 m^2/day, respectively, and the geometric mean was estimated to be 5.7 m^2/day. The water-yielding capability of the Simcoe Group was described as being fair.

Singer et al.(1997) treated the Blue Mountain and Georgian Bay Formations as one hydrogeologic unit. The authors identified 2,130 wells within the unit in southern Ontario. Of these, a sample of 1,293 wells was selected to determine the transmissivity distribution for the unit. The minimum and maximum transmissivity values for the sample were determined to range from 0.06 to 1,194 m^2/day, respectively, and the geometric mean of the sample's transmissivity values was estimated to be 2.9 m^2/day. The water yielding-capability of the Blue Mountain-Georgian Bay unit was described as being poor.

Specific capacity data are available for 382 bedrock wells within the basin. Of these, 191 wells (50%) have specific capacities less than 5 l/min/m (Figure Ho-5), 139 wells (36%) have specific capacities between 5 and 25 l/min/l (Figure Ho-6), 21 wells (5 %) have specific capacities between 25 and 50 l/min/m (Figure Ho-7), and 31 wells (8%) have specific capacities higher than 50 l/min/m (Figure Ho-8). Based on the distribution of wells on Figure Ho-8, it is possible to conclude that the limestones of the Lindsay Formation are the best bedrock water-yielding formation within the Holland and Black River basins.

The relatively low specific capacity values for wells within the four bedrock formations in basin are consistent with the findings of Singer et al.(1997) for southern Ontario. Compared to the overburden, the bedrock within the Holland and Black River basins is not an important source of groundwater.

6.8 GROUNDWATER OCCURRENCE IN THE OVERBURDEN

Most wells in the basins are drilled or bored in overburden and usually satisfy domestic water-supply demands. Vallery et al. (1982) noted that groundwater is obtained from a number of discrete water-bearing overburden sediments that are not in most cases continuous over large areas, but rather occur as individual lenses that have limited extent. For this reason, the term "aquifer complex" was used to describe water-bearing sediments that have similar elevations and piezometric levels. Seven such aquifer complexes were identified within the basins, including the Alliston, Algonquin, Holt , Kame Outwash, Mount Albert, Oak Ridges, and Schomberg Aquifer Complexes (Vallery et al. 1982).

The Oak Ridges and Kame Outwash Aquifer Complexes in the southern part of the basins, and the Algonquin Aquifer Complex in the northeastern part of the basins are the major water-bearing sediments occurring at elevations above 215 m (a.s.l.). Water yields from wells in the three complexes are adequate to support domestic water requirements, and high yields are common in the Oak Ridges Aquifer Complex.

The Oak Ridges Aquifer Complex consists of permeable sands and gravels which outcrop at the surface or occur at depth between layers of less permeable clay, silt, and till deposits. The Kame Outwash Complex consists mainly of sand and minor amounts of gravel at elevations above 240 m (a.s.l.). The Algonquin Aquifer Complex consists of shallow lenses of sand and gravel in tills. The permeable lenses are often thin and isolated, and their water yields are limited.

The Schomberg Aquifer Complex in the west and the Holt Aquifer Complex in the east consist of buried sands and gravels at elevations between 205 and 245 m (a.s.l.). Individual well yields in these two complexes are variable, and are generally adequate to support domestic water supplies. Several wells within the Holt Aquifer Complex have estimated yields of up to 30 l/sec and one municipal well in the Schomberg Aquifer Complex serves the community of Schomberg and yields up to 38 l/sec.

International Water Consultants Ltd. (1991) described an aquifer zone of sand and gravel deposits within the East Holland River subwatershed which occur at an elevation range of 180 to 260 m (a.s.l.). This aquifer zone, which was called the Intermediate Aquifers, overlaps the range of the Holt Aquifer Complex identified by Vallery et al. (1982).

Hunter et al. (1996) described an aquifer complex, which they named the Lowland Aquifer Complex, that occurs in the general elevation range from 200 to about 260 m (a.s.l.). The elevation range of this aquifer complex overlaps the elevation ranges of the Holt Aquifer Complex identified by Vallery et al. (1982) and the Intermediate Aquifers zone identified by International Water Consultants Ltd. (1991). According to Hunter et al. (1996), the Lowland Aquifer Complex includes sandy meltwater channel deposits which extend up gradient into the tunnel channels that cut into and through the Newmarket Till. It also extends under the moraine as deep channel deposits fanning out into the regional lowlands as discrete aquifer units between elevations from about 220 to 240 m (a.s.l.).

Hunter et al. (1996) noted that many rural settlements on the lower slopes adjacent to the Oak Ridges Moraine depend on this aquifer for potable water supply. In addition, a number of golf course irrigation wells and a number of municipal production well fields are also located in the aquifer system.

Information related to the transmissivity of the Intermediate Aquifers has been reported in a number of hydrogeologic investigations. According to International Water Consultants Ltd. (1991), a number of municipal wells have been developed in the Intermediate Aquifers zone, including Newmarket Wells 9 and 14. The reported transmissivities for these wells are generally moderate and in the order of 100 to 400 m^2/day.

The Alliston and Mount Albert Aquifer complexes are found at elevations between 110 and 220 m (a.s.l.). The Alliston Aquifer Complex consists of a series of primarily fine to coarse-grained sand lenses which yield up to 90 l/sec in a number of municipal wells in the vicinity of Aurora and Newmarket. The Mount Albert Aquifer Complex consists primarily of deep sands and gravels averaging about 3 m in thickness. Well yields are generally good with one municipal well serving the community of Mount Albert and rated at 45 l/sec (Vallery et al. 1982).

It appears that the Alliston Aquifer Complex which was identified by Vallery et al. (1982) and described by Turner (1977) is the same as the Yonge Street Aquifer that generally follows Yonge Street from Aurora to Holland Landing and then swings to the northeast. The name for the aquifer is widely used locally and reflects the fact that the aquifer extends for a distance along Yonge Street which is a famous landmark in southern Ontario. The aquifer is found at elevations between110 and 200 m (a.s.l.) and consists of a series of primarily fine to coarse-grained sands and gravels. The sands and gravels are thicker and coarse-grained in the aquifer core and become thinner and finer towards the flank areas to the east and west.

International Water Consultants Ltd. (1991) described a lower aquifer along the Yonge Street core which ranges in elevation from 150 to 200 m (a.s.l.), and they also described another aquifer in the Bradford and Holland Marsh area which appears to range in elevation from 110 to 180 m (a.s.l.). Where the two aquifers overlap, the Bradford aquifer occurs below the Yonge Street Aquifer which indicates that the two aquifers are separate. According to International Water Consultants Ltd. (1991), the Yonge Street Aquifer is a channel deposit which trends generally in a north-south direction and appears to be loosely associated with bedrock valleys.

Hunter et al. (1996) indicated that bounded, channel aquifers occur at elevations below 180 m (a.s.l.) at many locations within the Oak Ridges Moraine and up to150 m (a.s.l.) or deeper south of the moraine. These aquifers, which they named the “Bounded Channel

Aquifer Complex" include the deep well fields at Aurora and Newmarket. Further, the authors suggested that the Yonge Street Aquifer is a member of the Bounded Channel Aquifer Complex. Pumping tests of wells that tap water from the aquifer indicate that it is about one kilometer wide in Aurora area and it exhibits strong proximal boundaries.

Information related to the transmissivity of the Yonge Street Aquifer has been reported in a number of hydrogeologic investigations. According to International Water Consultants Ltd. (1991), testing of York Region municipal wells indicated local that transmissivities within the Yonge Street Aquifer core that range from about 1,000 m^2/day in the Newmarket area up to about 4,000 m^2/day in the Holland Landing and Sharon/ Queensville areas.

Data related to short-term pumping tests are available for 4,466 overburden wells. The data indicate that 2,185 wells (49%) have specific capacities ranging from 1 to 5 l/min/m (Figure Ho-9), 1,765 wells (39.5%) have specific capacities between 5 and 25 l/min/m (Figure Ho-10), 264 wells (5.9%) have specific capacities between 25 and 50 l/min/m (Figure Ho-11), and the remaining 252 wells (5.6%) have specific capacities larger than 50 l/min/m (Figure Ho-12).

Figure Ho-12 indicates that high-capacity water wells occur mainly within four areas in the basins. One area is located within Georgina Township and extends from Beverly Hills on Cook's Bay to the eastern topographic boundary of the basins east of the Zephyr Creek. A large number of high capacity wells in this area are located along Cook's Bay between Beverly Hills and Keswick.

A second area is located mainly within the headwaters of the Black River, and the Mount Albert and Vivian Creeks extending from the basins divide in the east to a point between Newmarket and Holland Landing in the west. A large number of the high-capacity wells in this area are located to the east and south of Mount Albert.

A third area extends along the headwaters of the Holland River drainage basin from Musselman Lake in the east through Aurora, Happy Valley, and Lloydtown in the west. The area includes parts of the Oak Ridges Moraine and the Schomberg Clay Plains. Most of the high capacity wells in this area are located between Musselman Lake and Wesley Corners. A forth small area is located in the western parts of the basin around Coulson's Hills.

6.9 SUGGESTED BEDROCK MONITORING AREAS

Figure Ho-13 shows the locations of bedrock wells with specific capacities of over 25 l/min/m and the boundaries of suggested areas for monitoring of groundwater within the bedrock. The susceptibility of groundwater to contamination in these areas was determined based on information related to the thickness and type of overburden materials above the bedrock (Figure Ho-14).

Areas where groundwater in the bedrock is highly susceptible to contamination are defined as those where the bedrock is either near or at the surface or is covered by highly permeable sand and/or gravel deposits. Areas where the bedrock is moderately susceptible to contamination are defined as those where the overburden above the bedrock contains clay or clay till deposits that are less than 3 m in thickness. Areas where the bedrock has low susceptibility to contamination are defined as those where the overburden contains clay or clay till deposits that are more than 3 m in thickness. The term variable susceptibility to contamination is used for areas where the susceptibility of groundwater to contamination ranges from low to high.

Based on this definition, four areas (A, B, C, and D) are suggested for groundwater monitoring in the bedrock. The susceptibility of groundwater to contamination within area (A) ranges from moderate to variable; whereas it is low within areas (B), (C), and (D) due to the presence of over 15 m of clay material protecting the bedrock (Figure Ho-13).

Area (A) is located in the northern part of the basins in the vicinity of Jackson's Point on Lake Simcoe. It is underlain by the Lindsay Formation and many well logs reveal the presence of sands and/or gravels with clay deposits of less than 3 meters in thickness over the bedrock. Areas (B) and (C) are also underlain by the Lindsay Formation. Area (B) covers parts of the Black and Maskinonge Rivers watersheds, while Area (C) is centered in the Holland Marsh. Monitoring within areas (B and C) would provide information about ambient groundwater conditions within the Lindsay Formation and reveal the impacts, if any, of past agricultural chemical use.

To monitor the ambient groundwater conditions within the Verulam Formation, a monitoring well is recommended for Area (D). Although the susceptibility of groundwater to contamination in Area (D) is low, a growing population and an increasing number of septic tanks may affect the groundwater quality.

No groundwater monitoring is recommended for the Georgian Bay or the Blue Mountain Formations because of the following three reasons. First, these two formations have a small percentage of the total wells used in the area. Secondly, the formations produce minimal quantities of water. Third, groundwater in the formations has extremely low susceptibility to contamination due to the extensive thickness of the overburden above the bedrock.

6.10 SUGGESTED OVERBURDEN MONITORING AREAS

Figure Ho-15 shows the location of overburden wells with specific capacities of more than 50 l/min/m, and the boundaries of areas where groundwater within the overburden has a high, low or variable susceptibility to contamination. Data related to well yields and the geology of overburden were used to determine the susceptibility of groundwater to contamination in these areas (Figure Ho-16).

Areas where the shallow overburden aquifers are highly susceptible to contamination are defined as those where sand and/or gravel deposits are either near or at the surface. Areas where shallow overburden aquifers are moderately susceptible to contamination are defined as those where the sand and/or gravel deposits are covered by clay or clay till deposits that are less than 3 m in thickness. Areas where the overburden aquifers have low susceptibility to contamination are defined as those where the overburden contains clay or clay till deposits that are more than 3 m in thickness. The term variable susceptibility to contamination is used for areas where the susceptibility of groundwater to contamination ranges from low to high.

Based on the above definitions, four areas (E, F, G, and H) are proposed for groundwater monitoring in the overburden. The susceptibility of groundwater to contamination within Area (H) is variable and within areas (E, F, and G) are mainly low. However, parts of the later three areas have either high or variable susceptibility to contamination. Although monitoring of groundwater is recommended within areas (E, F, and G), it is highly recommended within the portions of these areas that are highly susceptible to contaminations.

Area (E) extends between the southern topographic divide and a line extending roughly from part of the basin from Musselman Lake through Newmarket and Lloydtown in the west. Area (F) extends from the eastern topographic divide through the middle parts of the black River watershed and further to the northern part of Holland Marsh. Area (G) extends between the northeastern boundaries of the basins and a line extending from Keswick to Cedarbrae. Area (H) is located to northwest of Holland Marsh in the vicinity of Coulson's Hill.

6.11 HISTORICAL MONITORING WELLS

One bedrock well and 11 overburden wells were used in the past for monitoring groundwater in the Holland and Black Rivers drainage basin. The types and locations of these wells are as follows:

Well No. 147	An overburden well, 2.75 m deep, and located in York County, Concession 6, Lot 26.
Well No. 340	An Overburden well, 8.84 m deep, and located in York County, Concession 5, Lot 34.
Well No. 341	An Overburden well, 17.07 m deep, and located in York County, Concession 3, Lot 29.

Well No. 342	An overburden well, 92.96 m deep, and located in York County, Concession 2, Lot 19.
Well No. 343	An overburden well, 3.66 m deep, and located in York County, Concession 3, Lot 9.
Well No. 344.	An overburden well, 3.35 m deep, and located in York County, Concession 1, Lot 121.
Well No. 527	An overburden well, 3.96 m deep, and located in York County, Concession 7, Lot 17.
Well No. 528	An overburden well, 4.27 m deep, and located in York County, Concession 5, Lot 26.
Well No. 568	An overburden well, 99.06 m deep, and located in York County, Town of Aurora.
Well No. 569	An overburden well, 99.06 m deep, and located in York County, Town of Aurora, Concession 1, Lot 86.
Well No. 570	An overburden well, 117.35 m deep, and located in York County, Town of Newmarket, Concession 1, Lot 96.
Well No. 571	A bedrock well, 137.16 m deep, and located in York County, Town of Newmarket.

Figure Ho-17 shows the locations of the historical monitoring wells and Appendix I gives the geographic coordinates of these wells.

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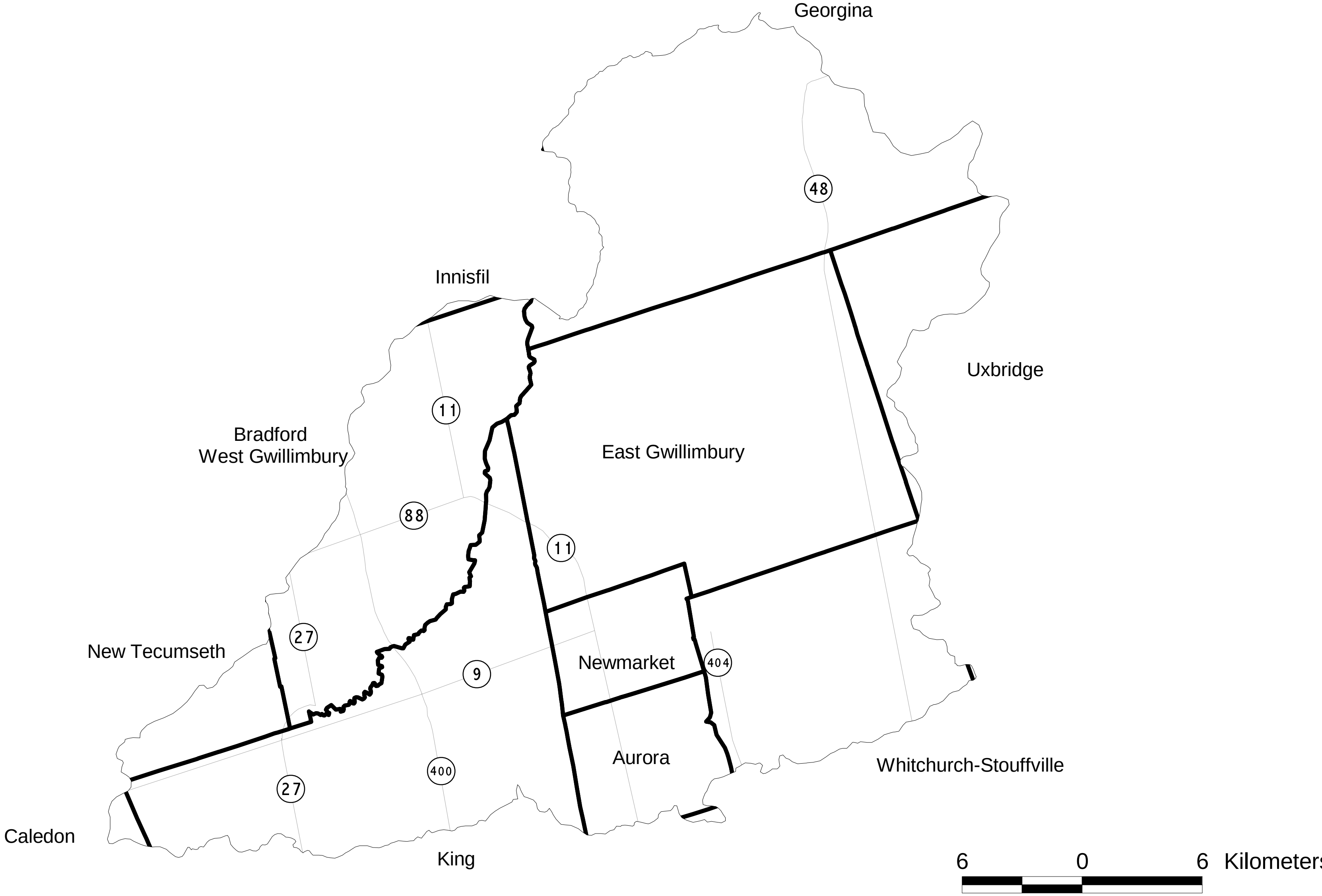
FIGURES



Key Map - Ho A transparency to be used with other figures for orientation purposes.

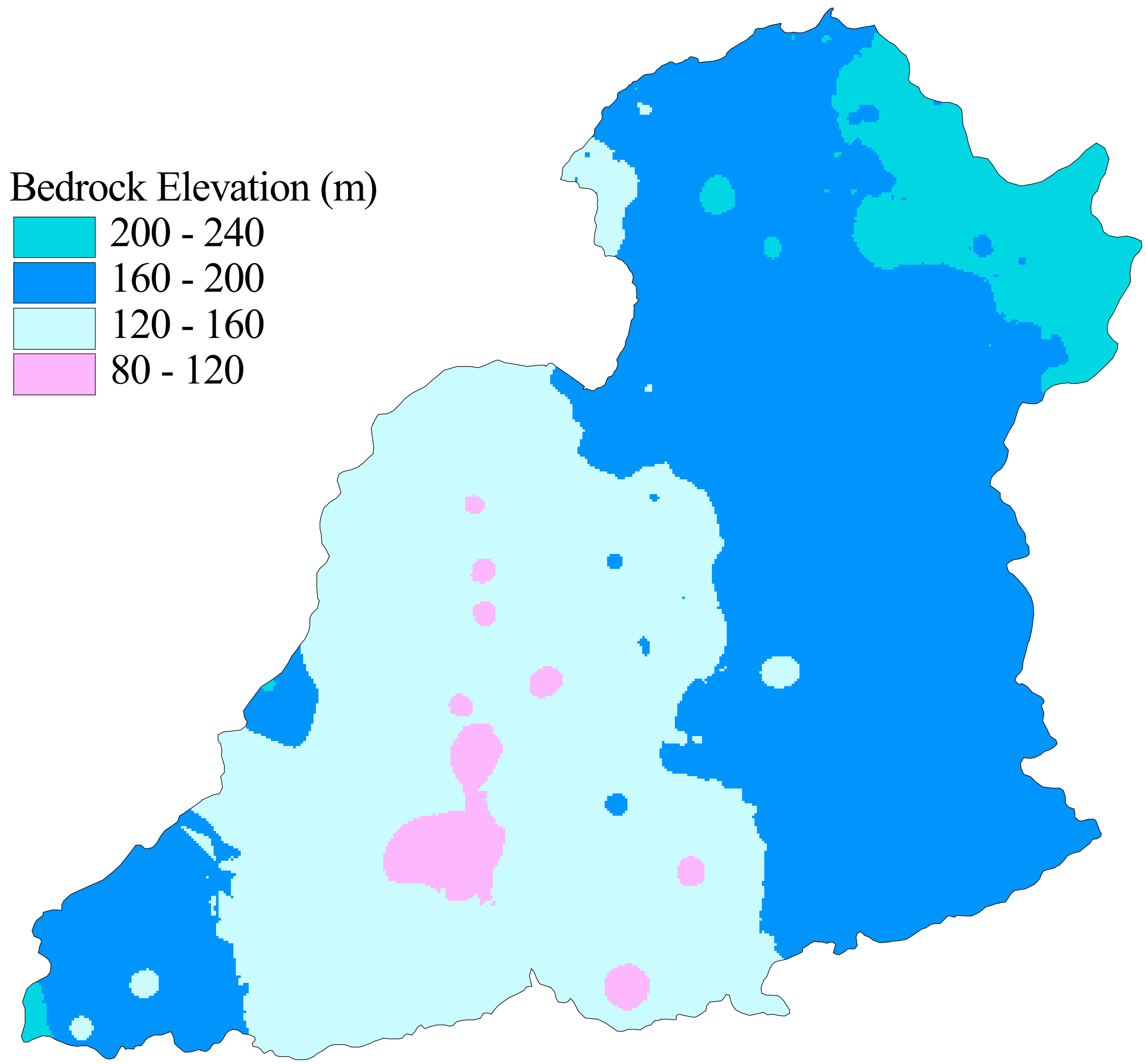


Figure Ho-1 Bedrock topography in the Holland and Black River drainage basins.

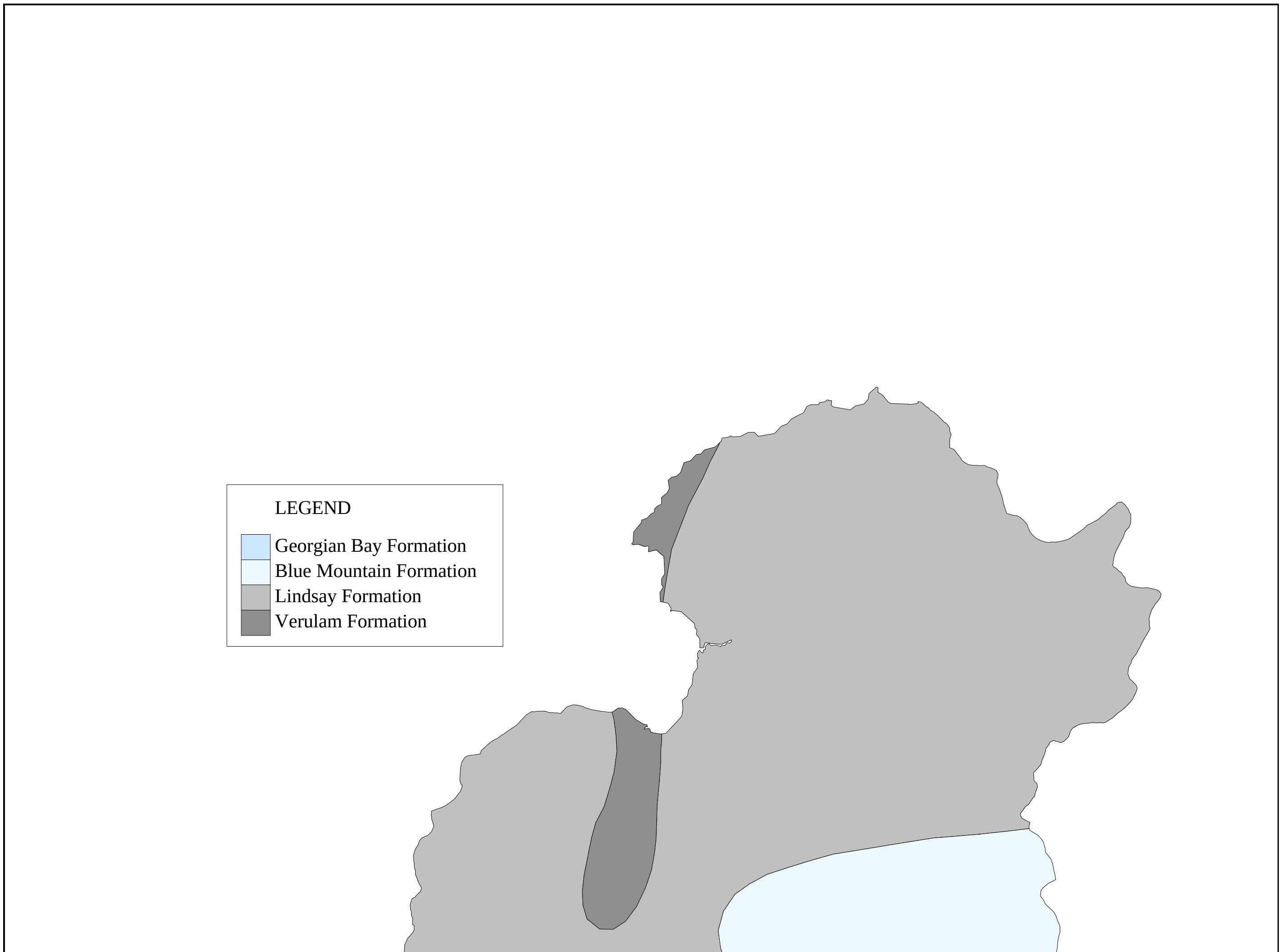


Figure Ho-2. Bedrock geology in the Holland and Black River drainage basins.

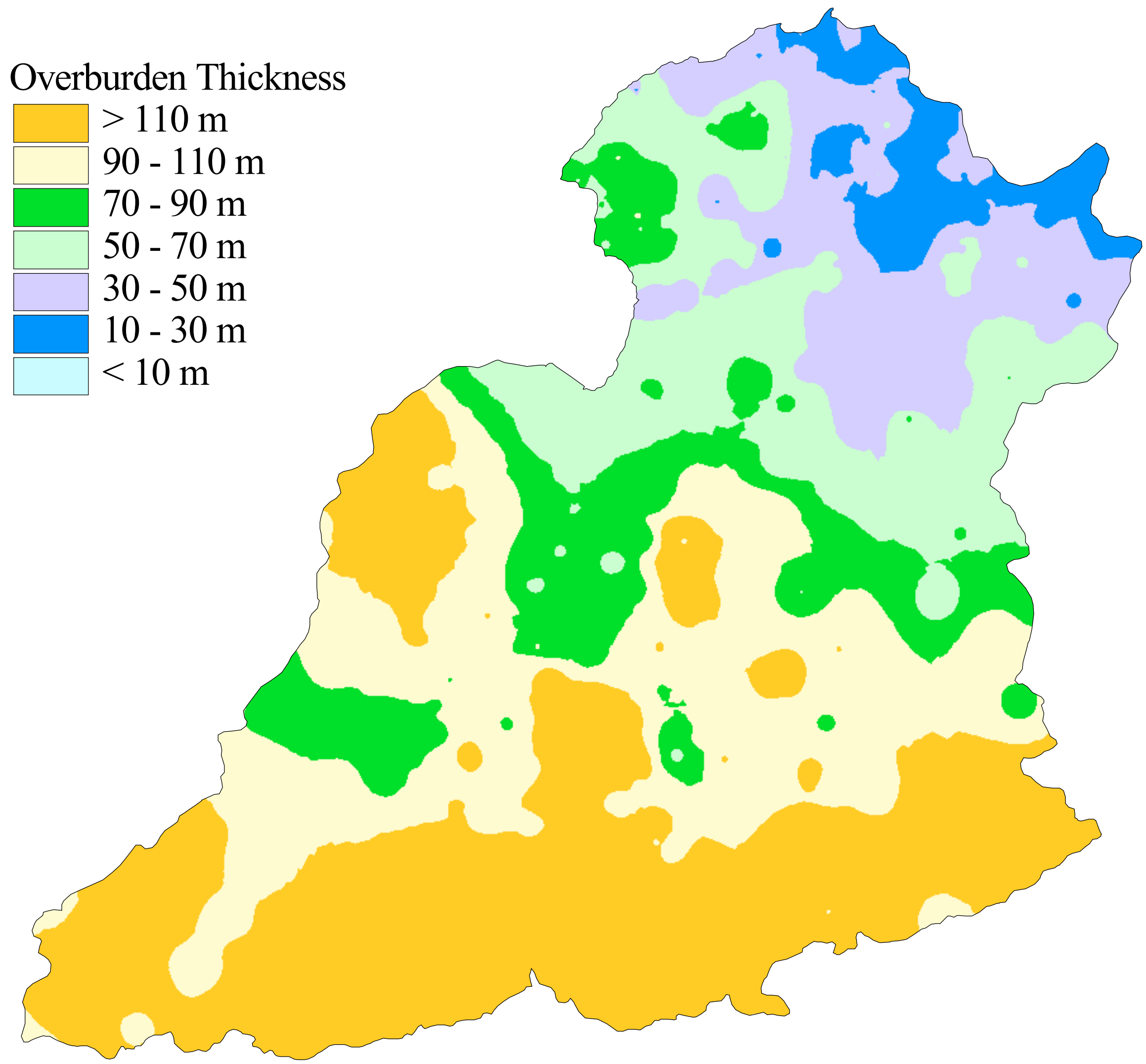


Figure Ho-3 Overburden thickness in the Holland and Black River drainage basins.

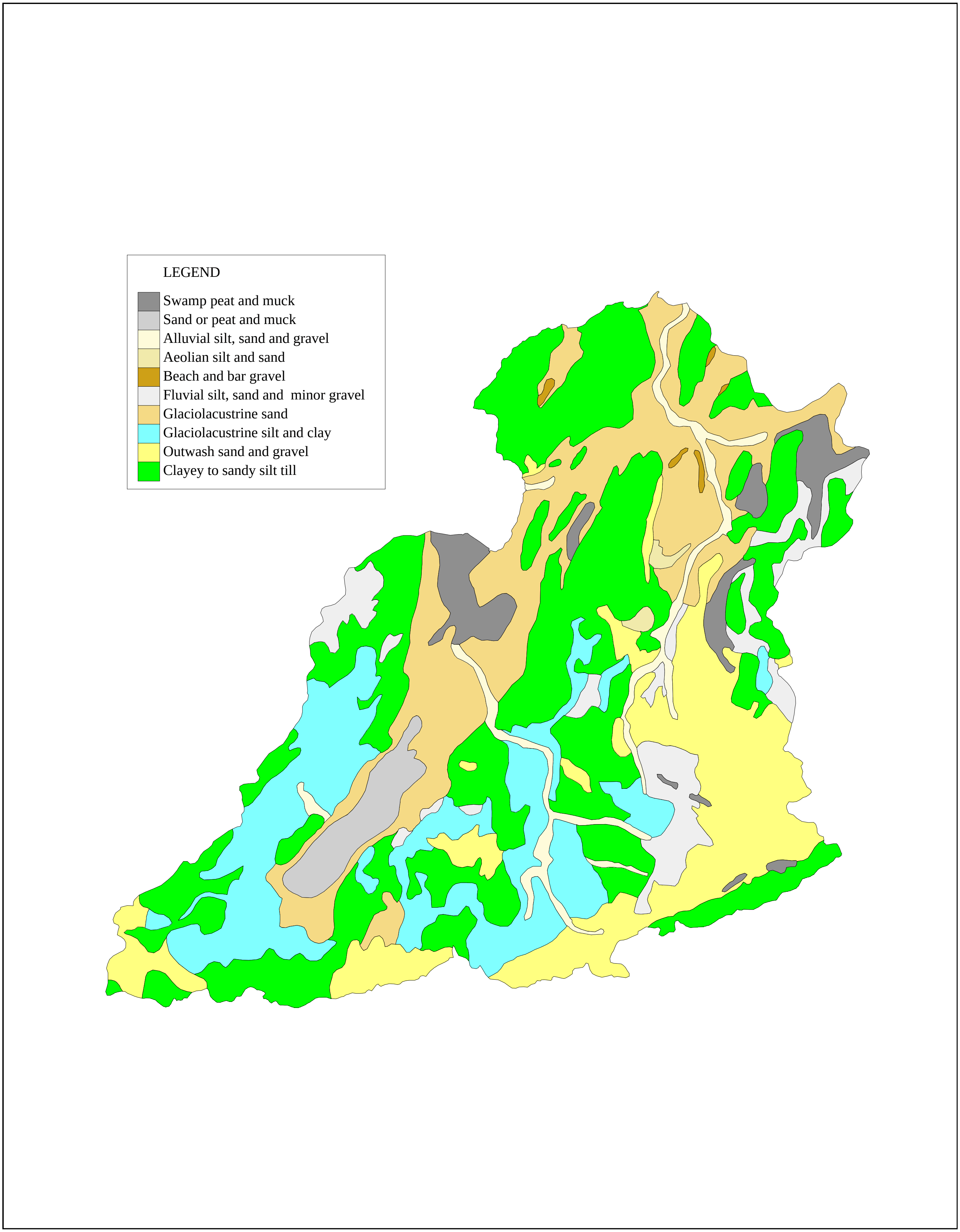


Figure Ho-4. Overburden geology in the Holland and Black River drainage basins.

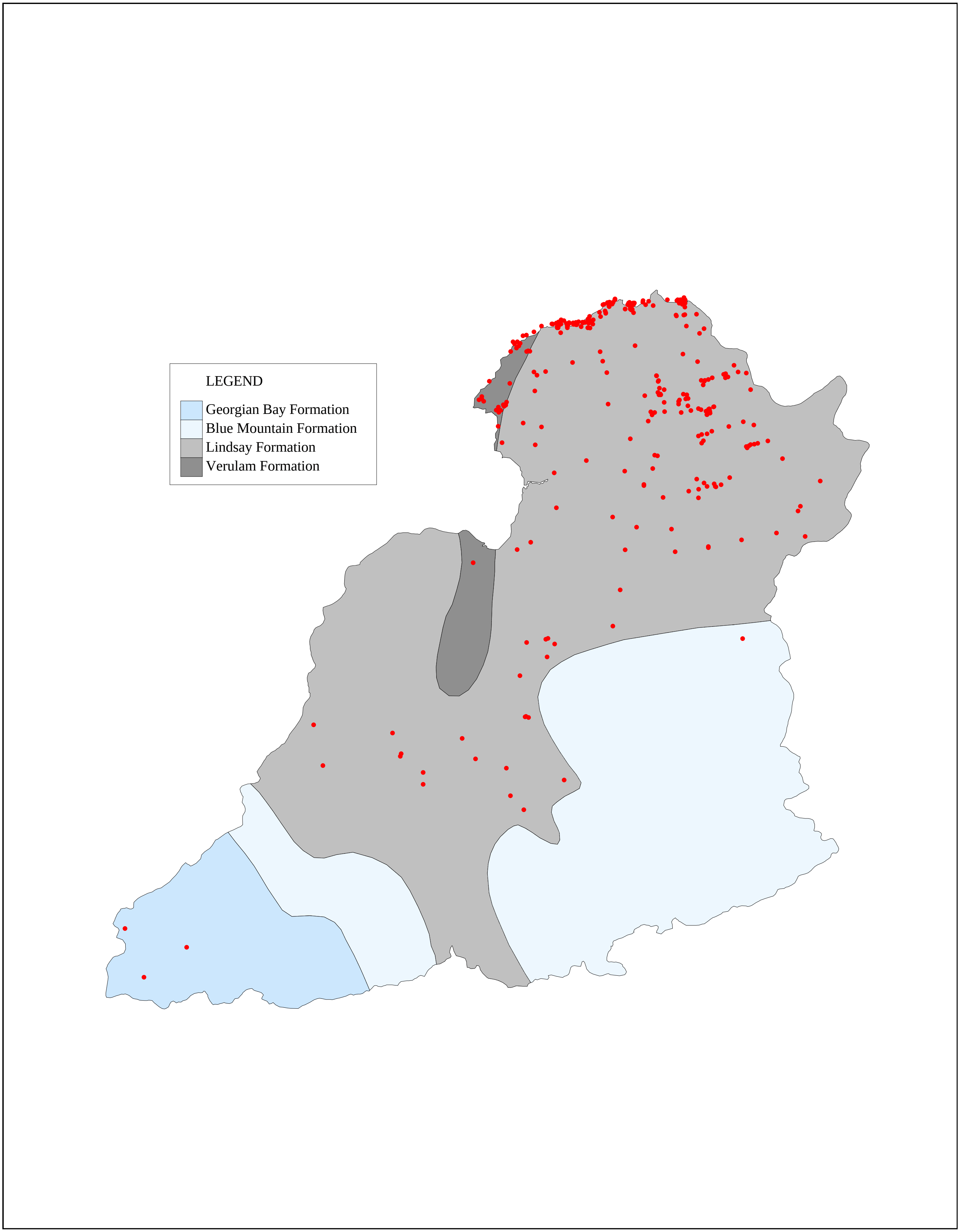


Figure Ho-5. Bedrock wells with specific capacities equal to or less than 5 l/min/m.

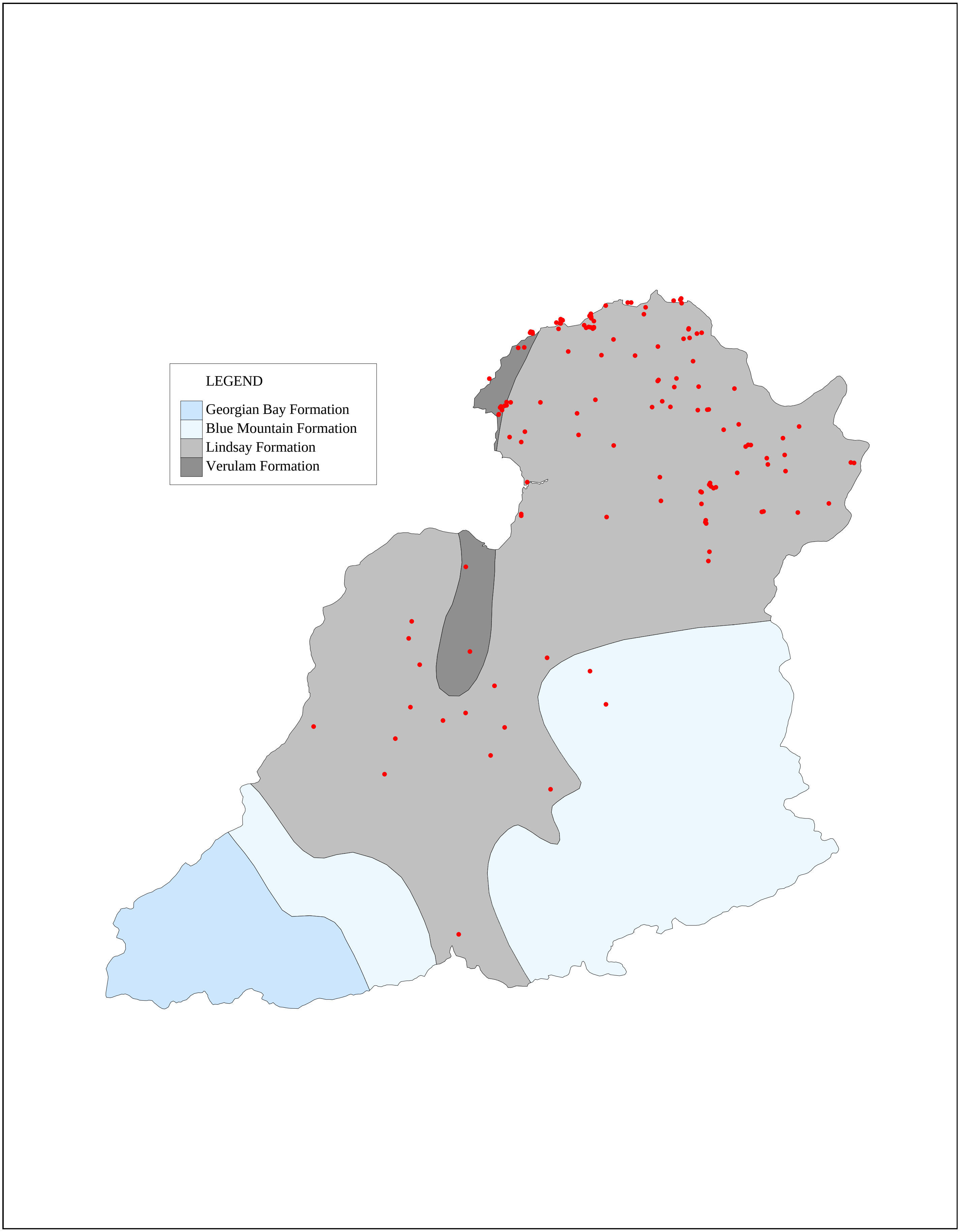


Figure Ho-6. Bedrock wells with specific capacities between 5 and 25 l/min/m.

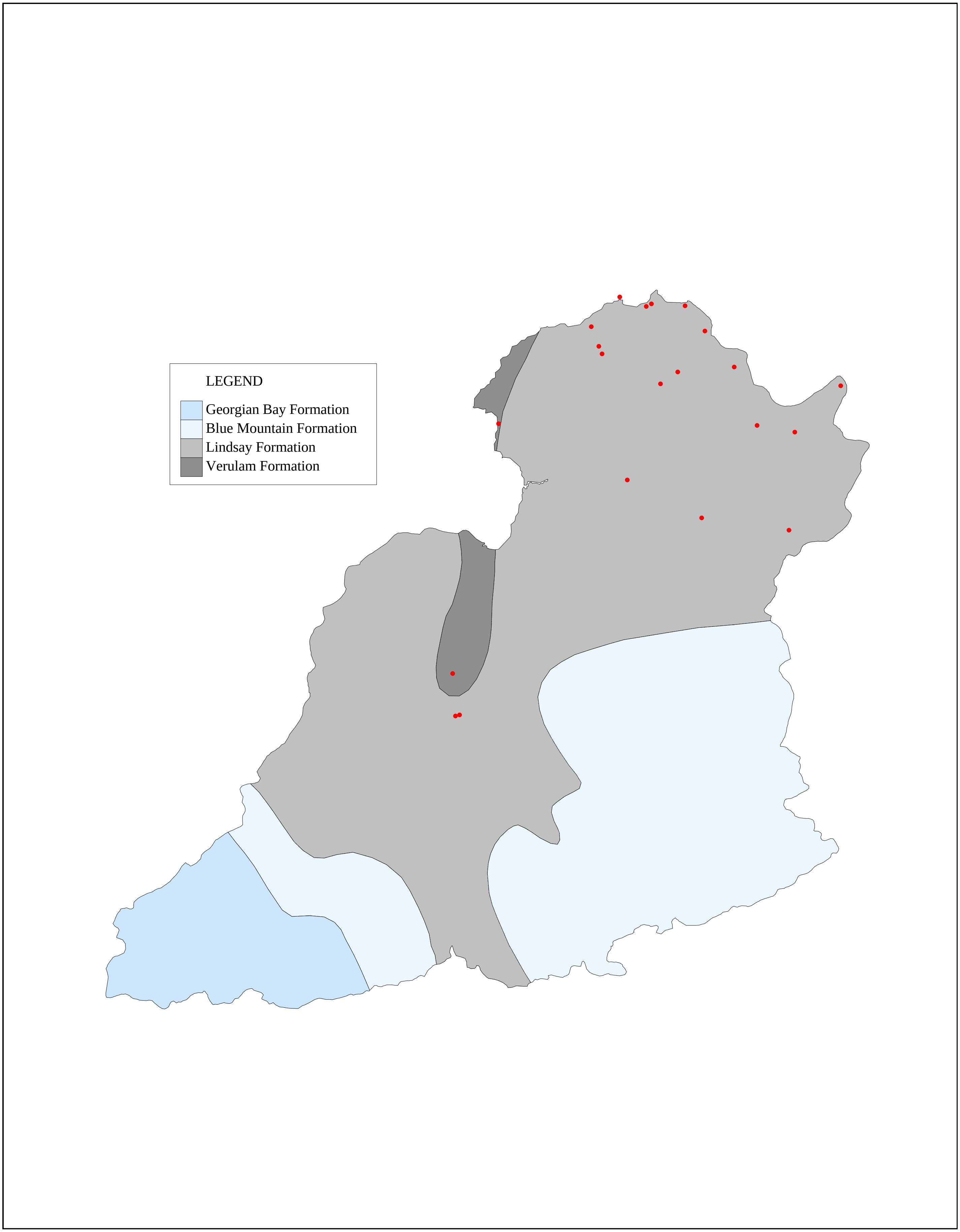


Figure Ho-7. Bedrock wells with specific capacities between 25 and 50 l/min/m.

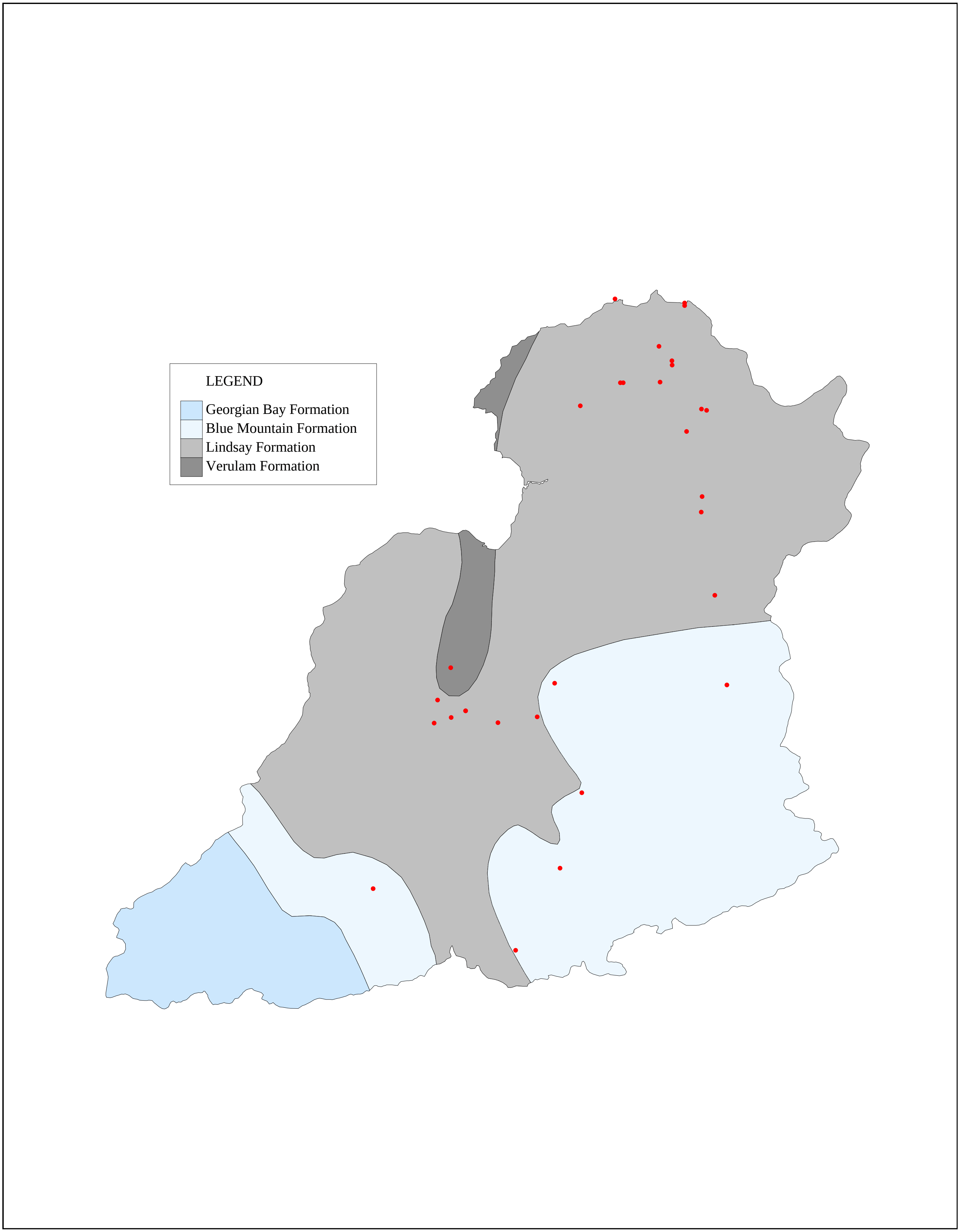


Figure Ho-8. Bedrock wells with specific capacities higher than 50 l/min/m.

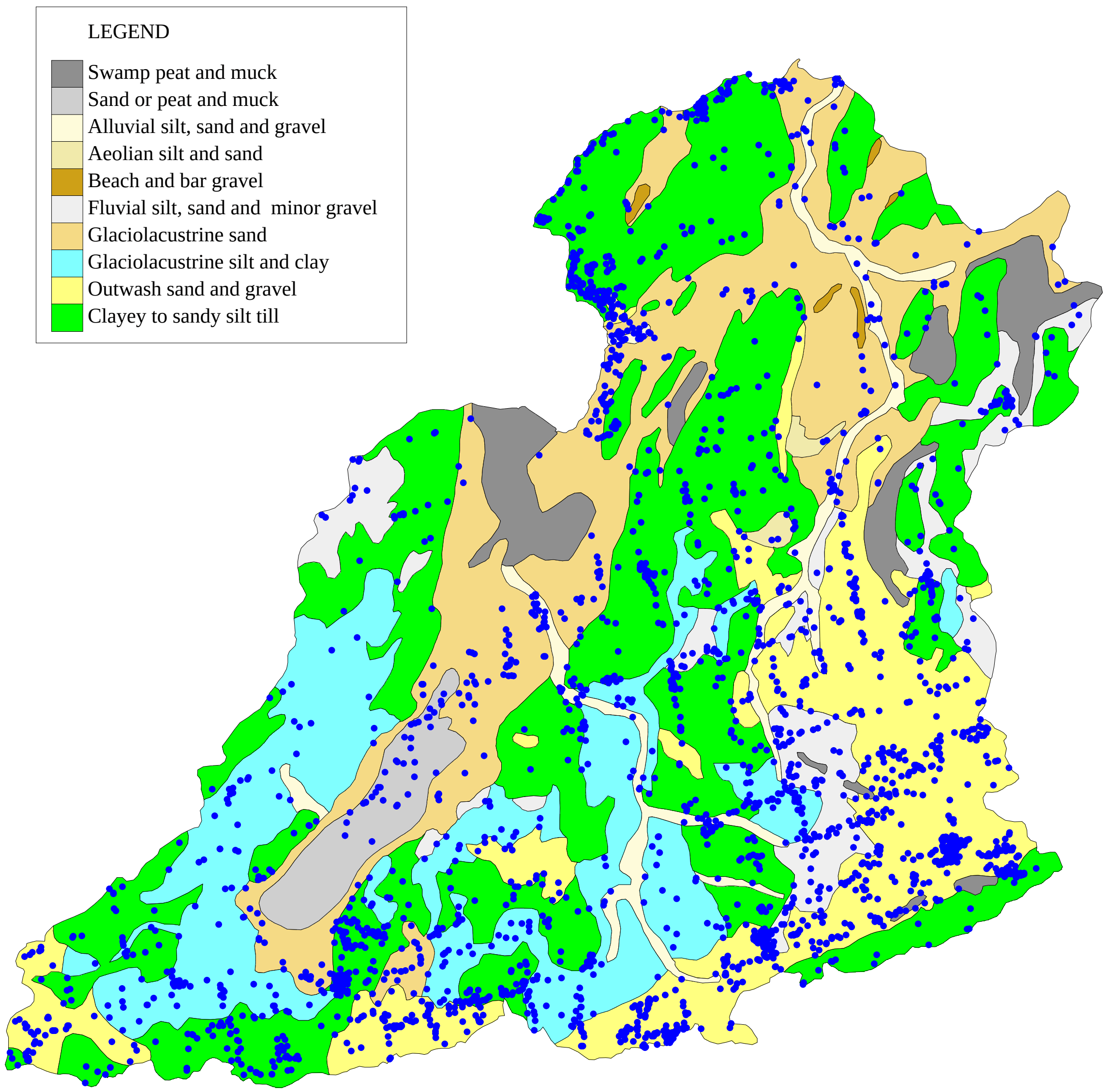


Figure Ho-9. Overburden wells with specific capacities equal to or less than 5 l/min/m.

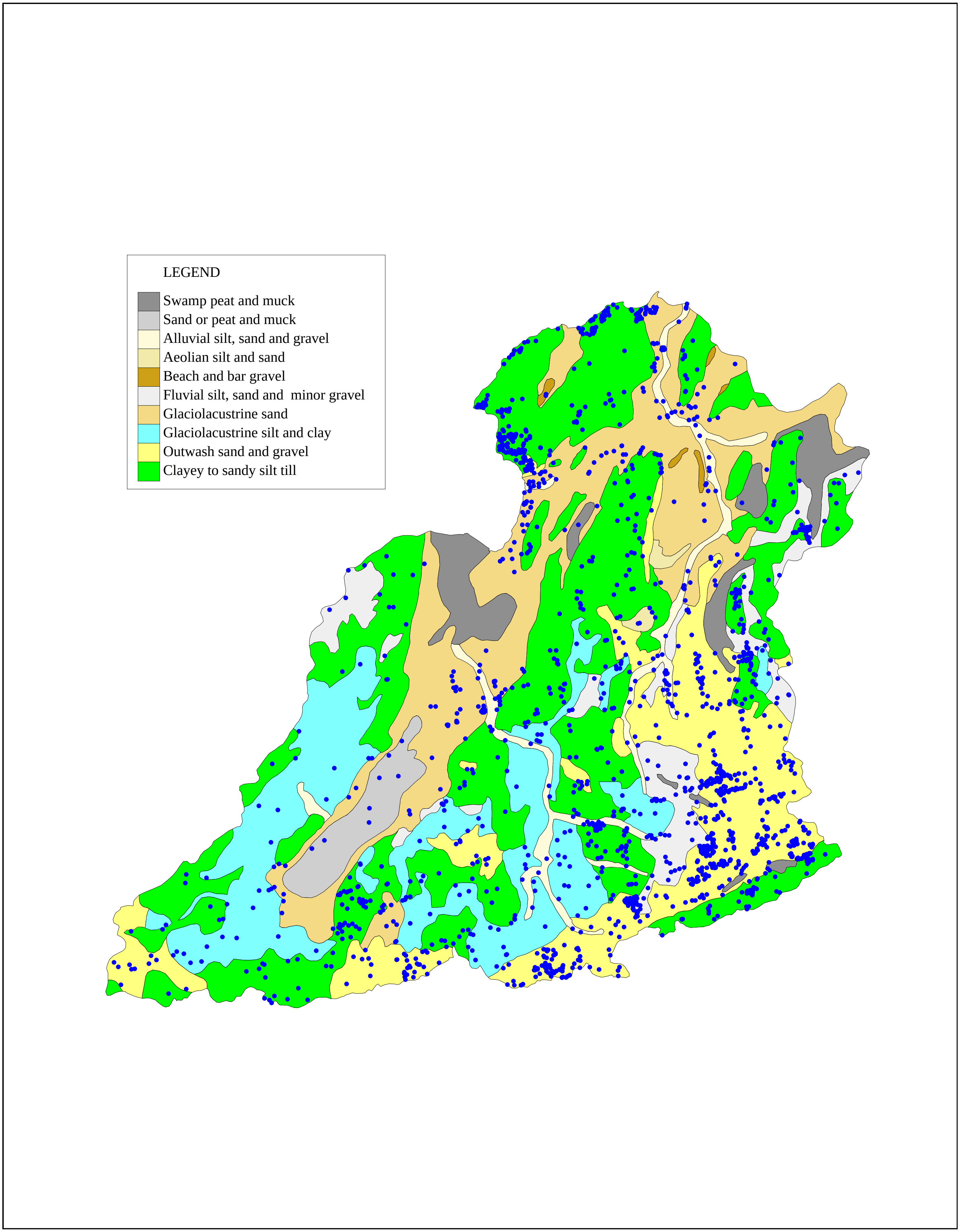


Figure Ho-10. Overburden wells with specific capacities between 5 and 25 l/min/m.

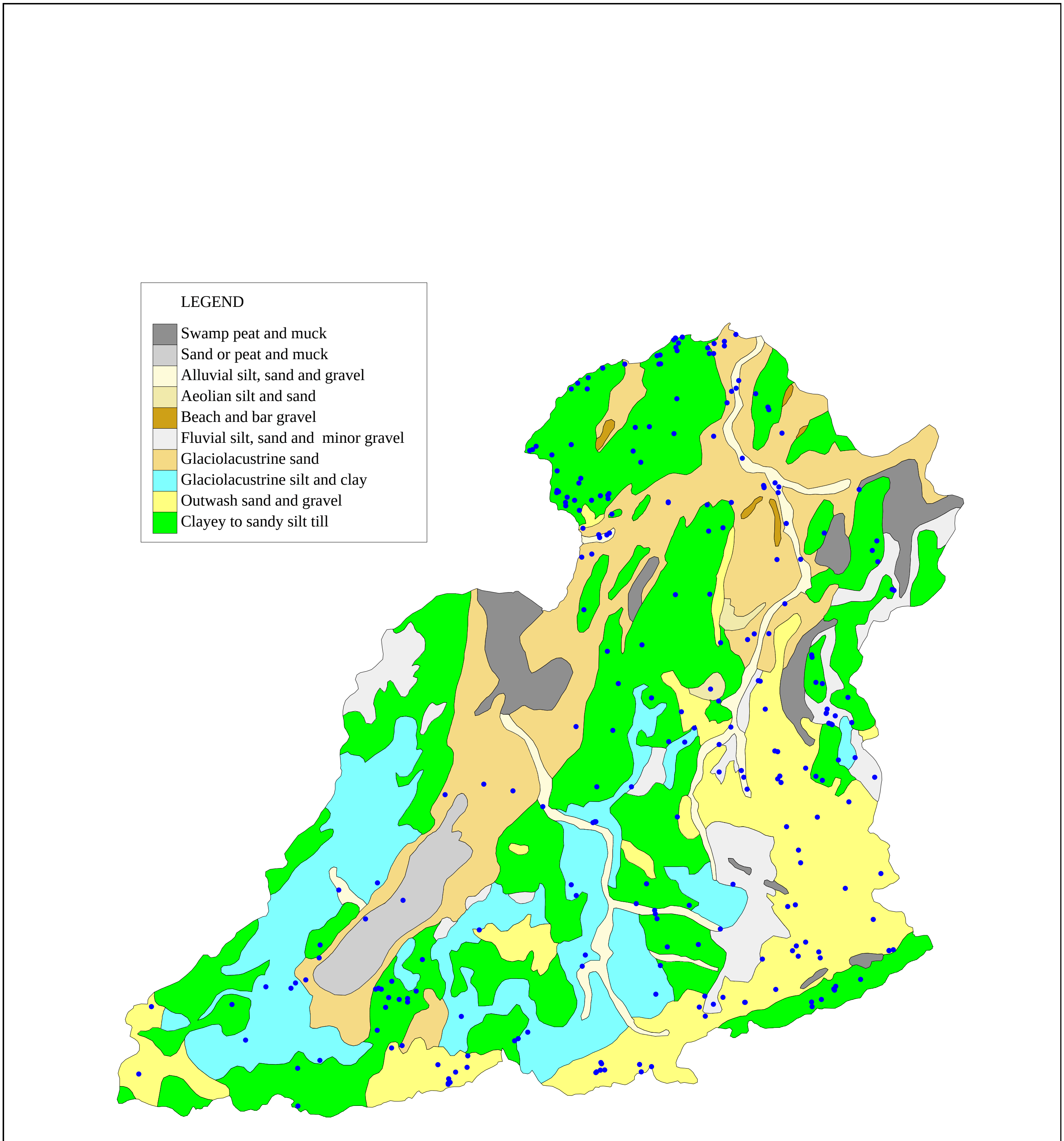


Figure Ho-11. Overburden wells with specific capacities between 25 and 50 l/min/m.

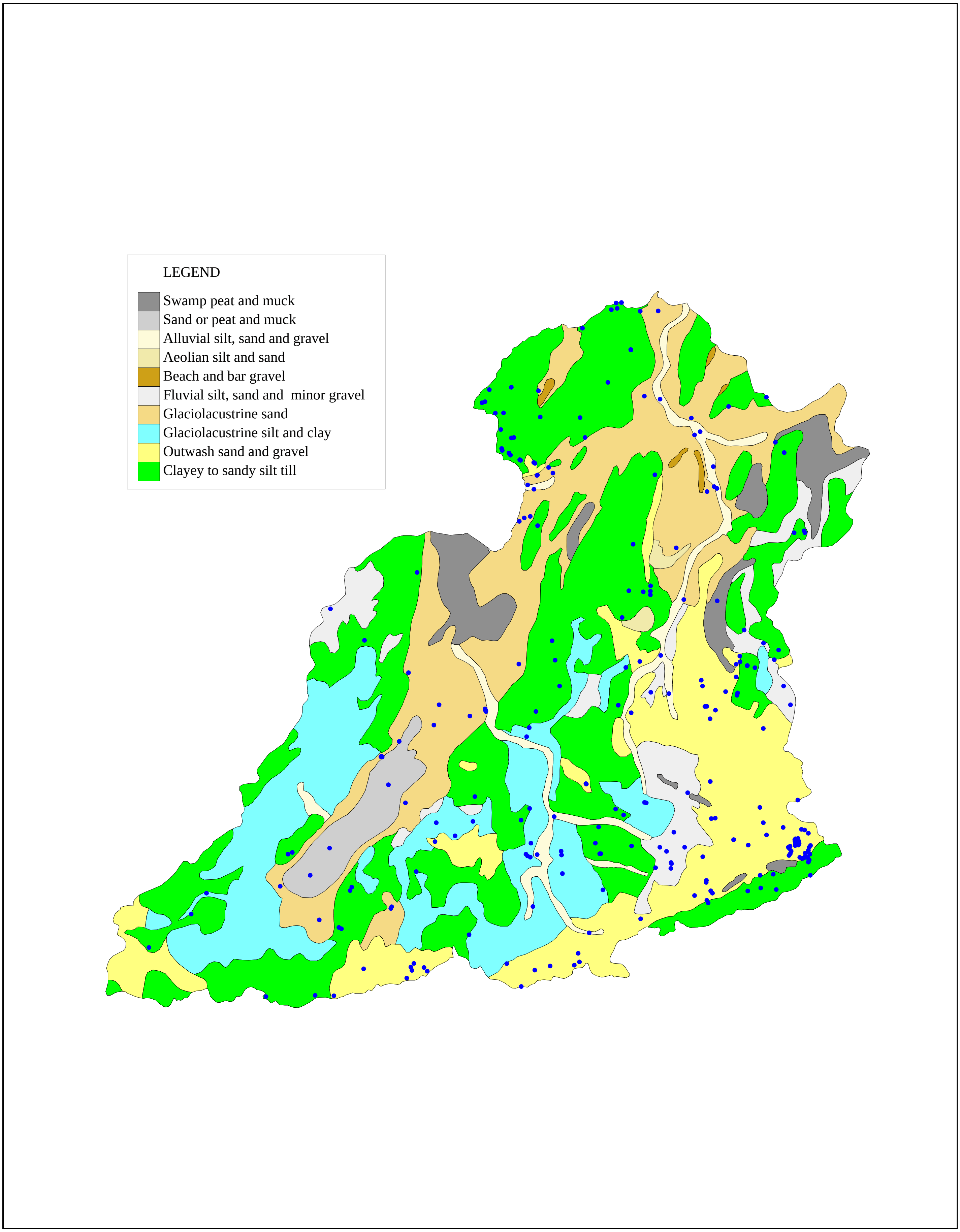


Figure Ho-12. Overburden wells with specific capacities higher than 50 l/min/m.

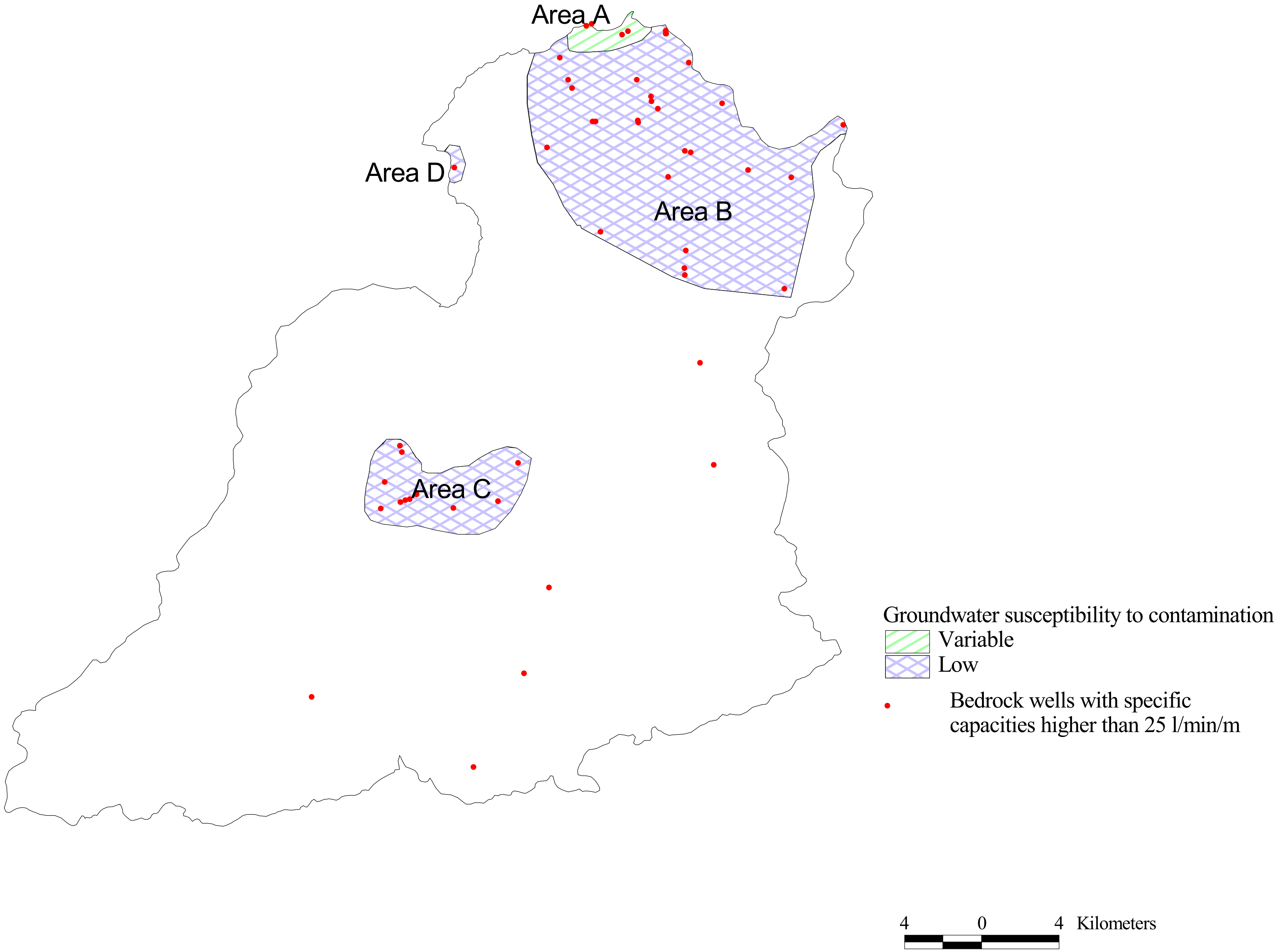


Figure Ho-13. Suggested areas for monitoring groundwater in the bedrock.

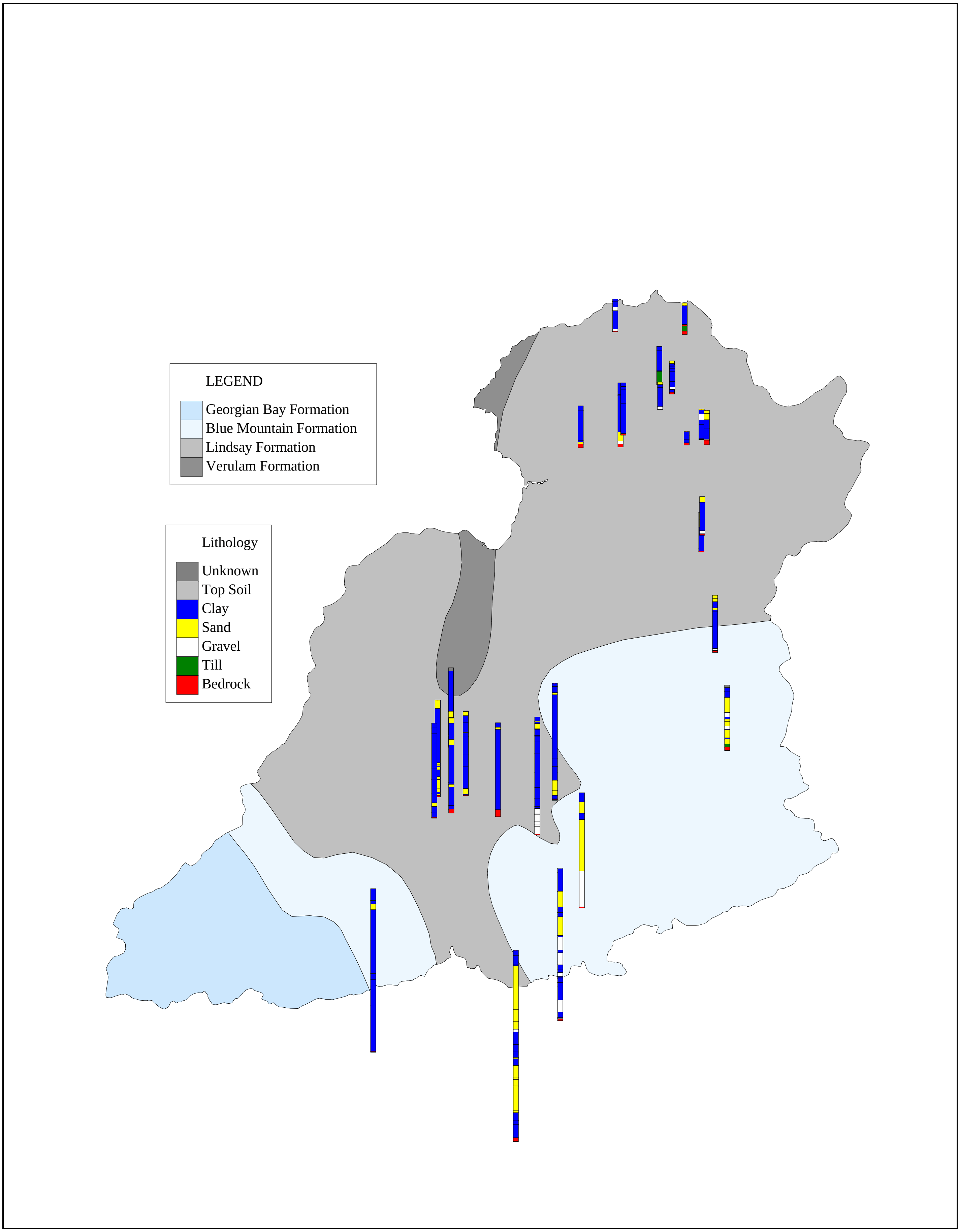


Figure Ho-14. Panel diagram showing the geologic logs of bedrock wells with specific capacities higher than 50 l/min/m.

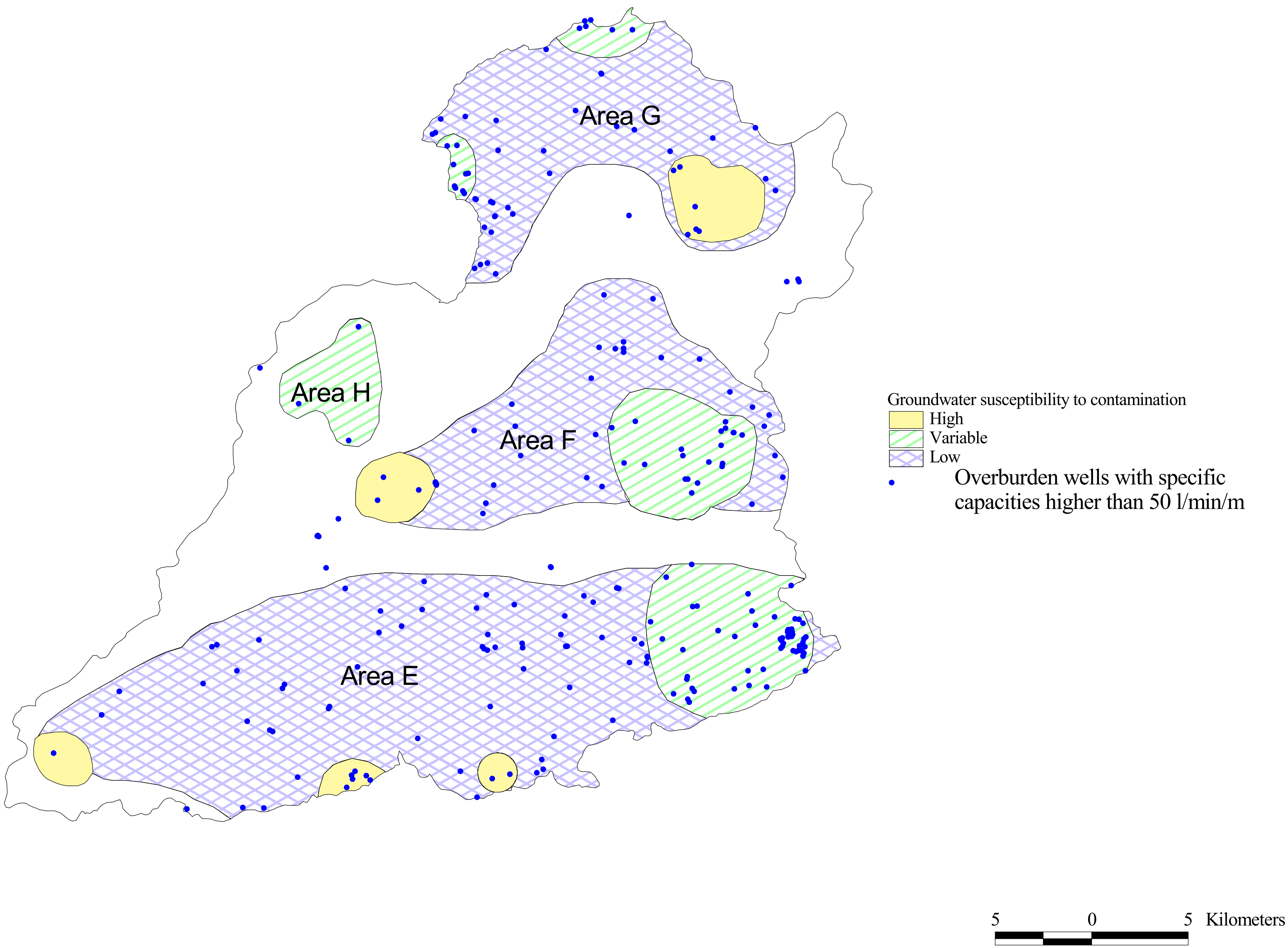


Figure Ho-15. Suggested areas for monitoring groundwater in the overburden.

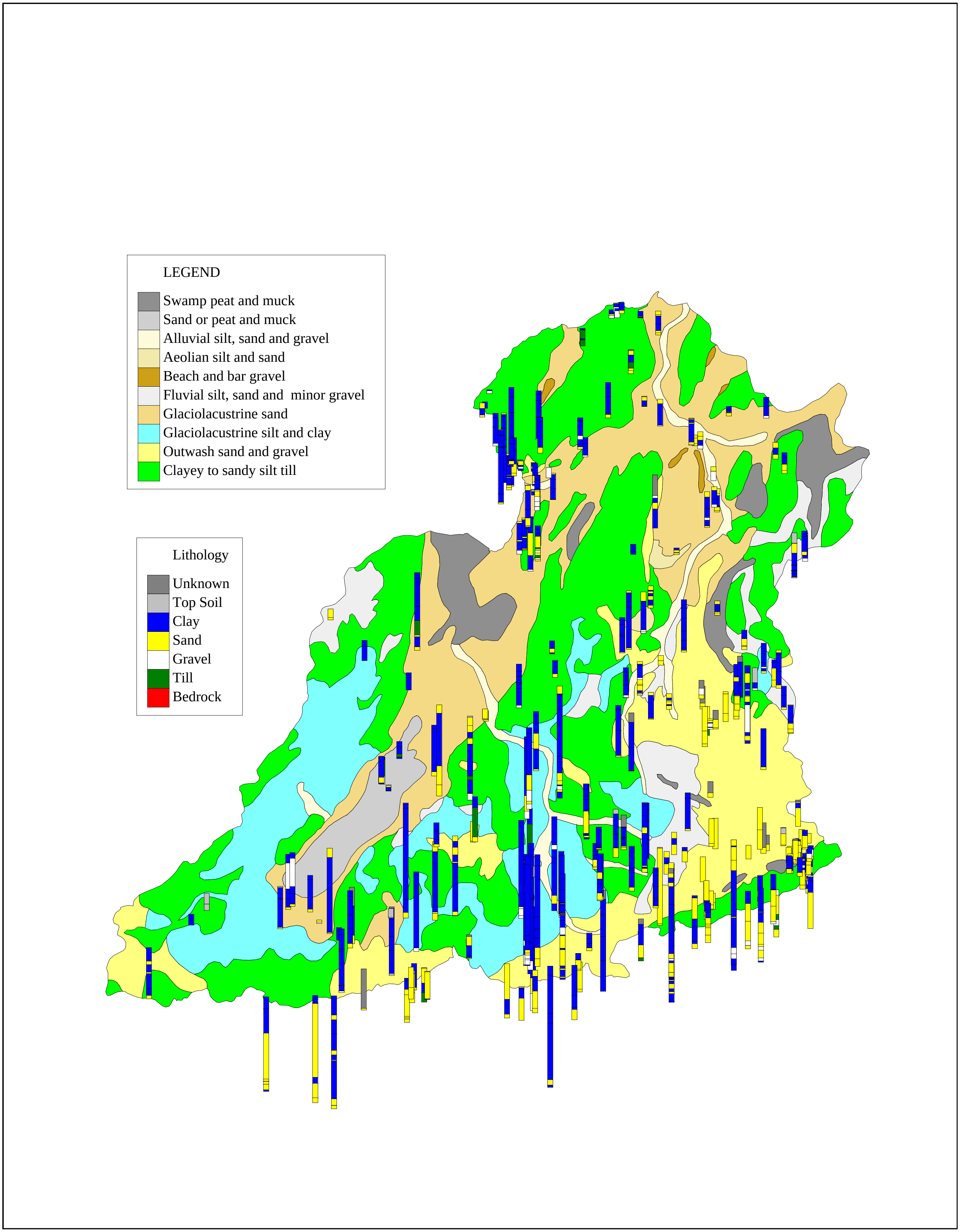


Figure Ho-16. Panel diagram showing the geologic logs of overburden wells with specific capacities higher than 50 l/min/m.

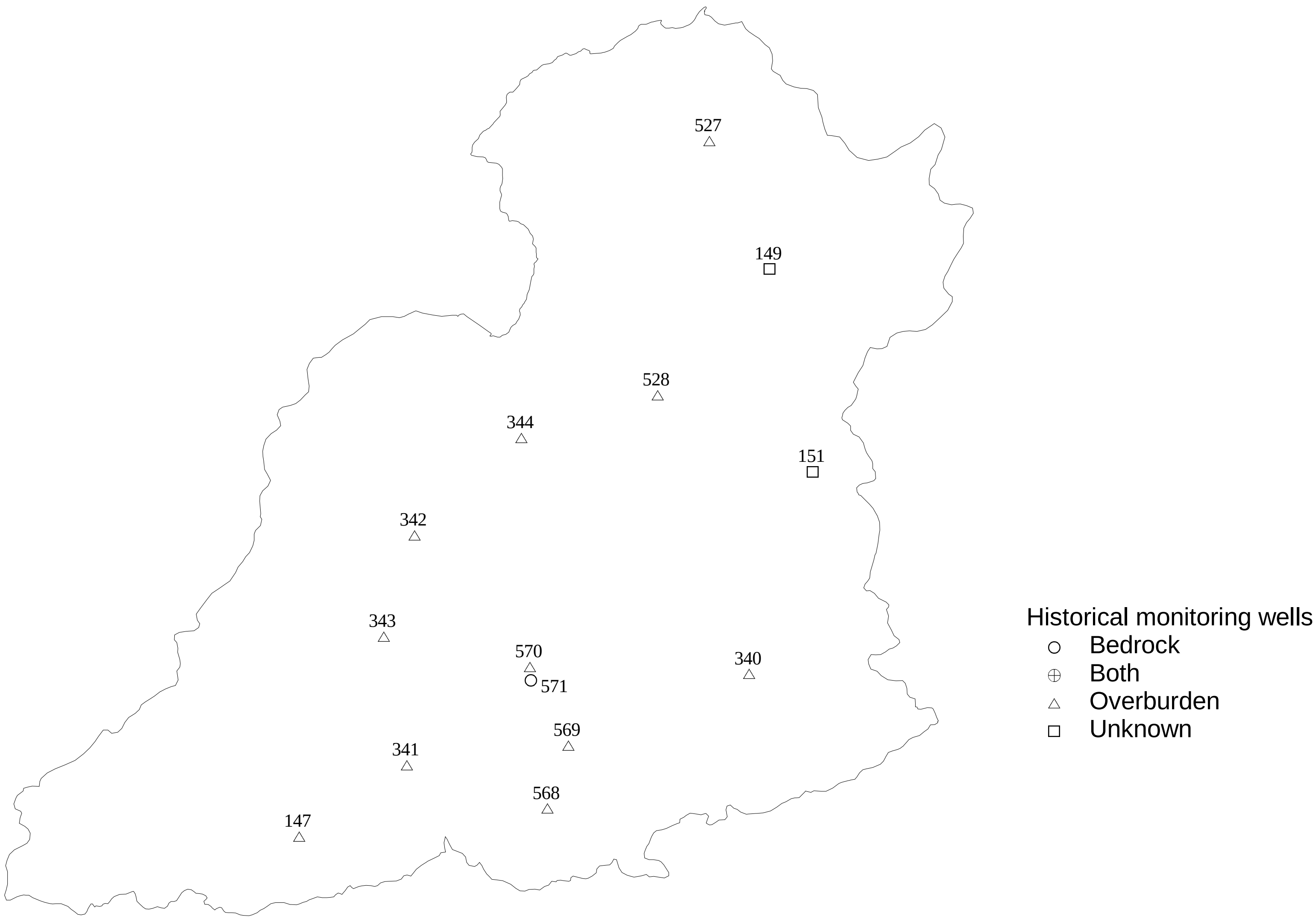


Figure Ho-17. Locations of historical monitoring wells in the Holland and Black River drainage basins.