CHAPTER 9

A PROPOSED GROUNDWATER MONITORING NETWORK FOR THE SOUTH NATION RIVER DRAINAGE BASIN

By

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9.1 LOCATION

The South Nation River drainage basin is located to the east-southeast of Ottawa between longitudes 74^0 41' and 75 ^{0} 44' W and latitudes 44 ^{0} 38' and 45 ^{0} 34' N. The basin covers an area of about 3915 km^2, which includes a small area of about 215 km ^{2} drained by a number of small tributaries to the Ottawa River. From its source, a few kilometers north of Brockville, to its confluence with the Ottawa River, the South Nation River traces a course of 177 km and descends about 84 m. Major sub-basins are the Castor River (733 km^2), the Bear Brook (487 km^2), and the Scotch River (272 km^2).

The South Nation River drains an almost flat plain. Surface elevations range between 45 m above mean sea level in the north and 122 m in the south. Land drainage in many parts of the basin is poor and many ditches have been constructed to improve drainage. Numerous swamps and bogs occur in topographically low areas, the largest ones being Alfred, Mer Bleue, Winchester and Moose Creek bogs.

Large sections of the South Nation River are characterized by small channel capacities and low gradients which are responsible for flooding. Spring floods which are virtually an annual occurrence and occasional summer floods occur mainly above Chesterville and above Plantagenet.

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.

9.2 LAND USE

Approximately 60% of the land base within the South Nation River basin is devoted to agriculture. The main agricultural products are corn, grain, and hay. Specialty agriculture includes market gardens, nurseries, orchards, and sod farms. Woodlands cover about 23% of the basin, idle lands about 9%, and urban areas, forest plantations, and wetlands cover the remaining 8%.The main urban centres in the basin are Casselman, Chesterville, Plantagenet, and Winchester.

9.3 GROUNDWATER USE

There are 10,562 records on file with the Ministry of the Environment for water wells constructed in the South Nation River basin. Of these, 8,811 (83.42%) are bedrock wells, 1,138 (10.77%) are overburden wells, and the remaining 613 (5.81%) are of unknown type.

Although groundwater in the basin is available in adequate quantities for private domestic supplies and municipal supply for many small communities, it is not readily available to meet the needs of large municipalities or industries. Of the aquifers identified in the basin, only the Rideau Front Aquifer along the western boundary of the basin appears to have the potential for large-capacity municipal and industrial wells.

Because groundwater is used by thousands of home owners and by many small communities in the basin, it represents an important asset. As communities grow, surface waters will have to play an increasingly important role in augmenting the available groundwater supplies.

The most common groundwater concerns in the basin relate to inadequate supply and poor quality. Wells with inadequate supplies are located predominantly in the clay plain areas in the central and northern parts of the basin where there are no dependable overburden aquifers and where groundwater in bedrock is highly mineralized. Groundwater quality problems consist of salty, highly mineralized, and sulphurous waters. Salty and highly mineralized waters are derived predominantly from bedrock wells in the northern part of the basin, notably in the Bear Brook Valley and the South Nation Valley. Sulphurous waters occur mainly in bedrock wells in the central parts of the basin.

9.4 PHYSIOGRAPHY

According to Chapman and Putnam (1984), parts of five physiographic regions are found within the South Nation River basin. These are the Edwardsburg Sand Plain, the Glengarry Till Plain, the Winchester Clay Plain, the Russell and Prescott Sand Plains, and the Ottawa Valley Clay Plains.

The Edwardsburg Sand Plain physiographic region lies almost completely within the southwestern parts of the basin. The topography of the sand plain is mostly level or gently undulating, although hummocks and ridges appear in places. According to Chapman and Putnam (1984), the sand was deposited by the melting glacier in the form of kames and subsequently spread about by the waves of the Champlain Sea. The main urban centres within this region are Maynard, Domville, and Spencerville.

The Glengarry Till Plain physiographic region is located in the southeastern portion of the basin and it is a part of a larger region of low relief forming the drainage divide between the international section of the St. Lawrence and the Ottawa basin. The surface of the plain is undulating to rolling, consisting of long morainic ridges and a few well-formed drumlins together with intervening clay flats and swamps (Chapman and Putnam 1984). A number of tributaries to the South Nation River arise within this physiographic region, including the South Branch, the Black Creek, Payne River, and Scotch River. The main urban centres are Avonmore, Finch, Newington, and Williamsburg.

The Winchester Clay Plain lies between the Glengarry Till Plain and the sand plains of United Counties of Prescott and Russell. It is an area of low relief, lying almost entirely within the drainage basin of the South Nation River. In many places within the clay plain, the underlying till protrudes and there are a few low drumlins. The soils are imperfectly drained and municipal ditches have been cut to provide drainage throughout the clay plain, and very little uncleared land remains. The main urban centres include Winchester, Chesterville, Casselman, and Maxville (Chapman and Putnam 1984).

The Russell and Prescott Sand Plains physiographic region is located in the United Counties of Prescott and Russell, and the Regional Municipality of Carleton-Ottawa. The region consists of a belt of large sand plains separated by the clays of the lower Ottawa valley. Most of the plains are within the drainage basin of the South Nation River, but smaller parts drain to the Rideau and Ottawa Rivers. The South Nation River cuts a canyon 22 m deep across the plains from Casselman to Lemieux.

The Russell and Prescott Sand Plains have a level surface whose elevation is approximately 75 m above sea-level, while the bottoms of the intervening clay-floored valleys lie below 60 m. According to Chapman and Putnam (1984), the plains, excepting the higher sands south of Ottawa, were at first a continuous delta built by the Ottawa River into the Champlain Sea. The delta was cut to pieces later by the Ottawa River when it rose above sea level.

The Ottawa Valley Clay Plains physiographic region extends between Pembroke and Hawkesbury and occurs within the basin in Plantagenet, Clarence, and Cumberland Townships where the valley is occupied by the South Nation River and its tributary the Bear Brook. The region consists of clay plains interrupted by ridges of rock or sand. Drainage is generally poor and the Nation River above Plantagenet periodically overflows its banks, flooding the adjacent flats and depositing a little alluvium in the process.

9.5 BEDROCK TOPOGRAPHY AND GEOLOGY

The bedrock elevation within the South Nation River basin ranges from 40 and 120 m , but most of the basin is between 40 and 80 m (Figure So-1). Areas with higher bedrock elevations are located along the eastern, southern, and western boundaries. The largest bedrock valley extends northeastward from the Russell-Embrun area and coincides roughly with the present valley of the South Nation River. The channel of the valley is about 10 km wide and 15 m deep. The valley is joined by smaller bedrock valleys that coincide with valleys of Castor, the Bear Brook and Scotch Rivers. Faulting is extensive throughout the bedrock. In many cases the faults serve as geologic boundaries.

A very small area near the northwestern boundaries of the basin in Gloucester Township has been identified as part of the Nepean Formation of Upper Cambrian age. The formation consists of sandstones with conglomerate interbeds, and has thickness of up to 300 m (Thurston et al.1992) . Due to its limited areal extent, the Nepean Formation is of no hydrogeologic significance in the basin.

Much of the southwestern parts of the basin is underlain by rocks of the March and Oxford Formations of Lower Ordovician age. The March Formation consists of sandstones, dolomitic sandstones, sandy dolostones and dolostones. It ranges in thickness from 6 to 64 m. The Oxford Formation consists of dolostones with a maximum thickness of 200 m.

The Rockcliffe Formation of Middle Ordovician age occurs in a number of small areas in the central and northern parts of the basin. It consists mainly of sandstones and shales and has a thickness up to 125 m (Thurston et al.1992).

Rocks of the Gull River, Bobcaygeon, Verulam and Lindsay Formations occur over large areas in the eastern and northern parts of the basin. Along with the Shadow Lake Formation, these units comprise the Ottawa Group in eastern Ontario.

The Gull River Formation, with a thickness range of 7.5 to 136 m, is divided into a lower member and an upper member. The lower member consists of limestones and silty dolostones, whereas the upper member consists of limestones. The Bobcaygeon Formation consists of 7 to 87 m of limestones with some shales. The Verulam Formation consists of limestones with interbeds of shales and has a thickness range of 32 to 65 m. The youngest unit in the sequence is the Lindsay Formation. It has a thickness of up to 67 m and consists of limestones and calcareous shales (Thurston et al. 1992).

The Upper Ordovician strata within the upper part of the basin is represented by the Billings, Carlsbad and Queenston Formations. The Billings Formation consists of shales and has a thickness of up to 62 m. The Carlsbad Formation, with a maximum thickness of 186 m, is comprised of interbedded shales, siltstones and limestones. The youngest unit in the Upper Ordovician sequence is the Queenston Formation which consists of shales with interbeds of limestones and calcareous siltstones (Thurston et al. 1992).

Figure So-2 is a simplified bedrock map geologic of the basin. The rocks of Nepean, March and Oxford Formations are shown as one unit. Similarly the rocks of the Billings, Carlsbad and Queenston Formations are shown as a single unit. Further, the Gull River, Bobcaygeon, and Lindsay Formations are combined under the Ottawa Group. Such grouping of formations, which is based largely on lithology, is extremely useful from a hydrogeologic point of view.

9.6 OVERBURDEN THICKNESS AND GEOLOGY

The overburden deposits within the South Nation River basin consist of glacial, glaciomarine, marine, and fluvial deposits of Pleistocene age with minor amounts of alluvial and swamp deposits of Recent age. The bedrock outcrops at the surface at several locations within the basin, namely, in the southernmost parts of the basin, along the western topographic divide near South Gloucester and Metcalfe, and in the northwestern parts of the basin. Elsewhere, the overburden thickness ranges from less than10 m over most of the southern areas to more than 50 m in the northeastern and central areas (Figure So-3). Within most of the Prescott and Russell Sand Plains, the thickness of the overburden is generally greater than 30 m, however, the thickness of sand deposits themselves are usually less than 6 m.

Glacial deposits occur as undrumlinized and drumlinized till plains. The undrumlinized till plain occurs mostly along the eastern boundaries of the basin, whereas the drumlinized plain occurs mainly within Edwardsburg Sand Plain and the Winchester Clay Plain physiographic regions where the till protrudes as low drumlins. The Champlain Sea, which inundated the area following the last glaciation, has removed or modified the till within the Winchester Clay Plain physiographic region through erosion. Barnett et al.(1991) mapped the undifferentiated till within the South Nation River basin as Map Unit 19 on Map 2556 of the Quaternary Geology of Ontario. According to Barnett (1992), the till of Map Unit 19 was deposited during the Two Creeks Interstade as a result of minor oscillations of the ice margin. It is predominantly a stoney, sandy silt to silt till with a loamy texture.

Fine-grained marine sediments of silt and clay cover most of the Winchester Clay Plain and the Ottawa Valley Clay Plains. These sediments were deposited in deep water. Coarse-grained marine and deltaic sediments form the Edwardsburg Sand Plain and Russell and Prescott Sand Plains. By and large, these sediments were deposited under shallow water conditions. In addition, a small esker-like, ice-contact deposits extend to the north and south of Sarsfield.

Marine beach and bar deposits are found to the south of Maxwell along the eastern topographic divide and to the south of Greely along the western topographic divide. Extensive swamp deposits consisting of peat and muck are found in topographically low areas mainly within Alfred, Mer Bleue, Winchester, and Moose Creek bogs (Figure So-4).

9.7 GROUNDWATER OCCURRENCE IN THE BEDROCK

As indicated earlier, most of the wells in the South Nation River basin are bedrock wells.

Chin et al.(1990) indicated that the groundwater supplies from bedrock aquifers in the basin provide adequate quantities of water for domestic uses but are generally inadequate for uses requiring higher yields. Based on lithologic composition, Chin et al.(1980) identified three major bedrock aquifers in the basin, a limestone/shale aquifer, a limestone/dolomite aquifer, and a sandstone aquifer. Together, the limestone/shale and limestone/dolomite aquifers cover about four-fifth the basin.

From a geologic point of view, the sandstone aquifer, identified by Chin et al.(1980), is most likely the March formation, the limestone /dolomite aquifer is the Oxford Formation, and the limestone/shale aquifer consists of formations which are members of the Ottawa Group. According to Chin et al.(1980), the sandstone aquifer, which has a limited extent, is the most productive bedrock aquifer in the basin. The limestone/dolomite aquifer has the potential for higher yields and it usually contains fresh water. The limestone/shale aquifer, on the other hand, often contains saline and highly mineralized waters.

Based on lithologic considerations, Singer et al.(1997) treated Nepean, March, and Oxford Formations in eastern Ontario as one hydrogeologic unit. For the same reasons, they treated all the formations within the Ottawa Group as well as the Billings, Carlsbad and Queenston Formations as single hydrogeologic units.

Singer et al.(1997) calculated the transmissivity values for a sample of 7,418 wells constructed within the Nepean-March-Oxford hydrogeologic unit in eastern Ontario. The geometric mean of the sample’s transmissivity values was estimated to be about 20 m^2/day and the water-yielding capability of the hydrogeologic unit was assessed as being good.

The transmissivity values for a sample of 1,771 wells constructed in the Rockcliffe Formation in eastern Ontario were also calculated by Singer et al.(1997). The minimum and maximum transmissivity values for the sample were estimated to range between 0.10 and 2,906 m^2/day, respectively, the geometric mean of the sample's transmissivity values was estimated to be 15.52 m^2/day, and the water-yielding capability of the Rockcliffe Formation was described as being good.

Singer et al.(1997) calculated the transmissivity values for a sample of 7,251 wells constructed within the Ottawa Group in eastern Ontario. The minimum and maximum transmissivity values for the sample were estimated to range between 0.05 and 8,080 m^2/day, respectively. The geometric mean of the sample's transmissivity values was estimated to be about 12 m^2/day, and the water-yielding capability of the Ottawa Group was assessed as being good.

A sample of 969 wells, constructed in the Billings-Carlsbad-Queenston hydrogeologic unit in eastern Ontario, was selected by Singer et al. (1997) to evaluate the transmissivity distribution for the unit. The minimum and maximum transmissivity values for the sample were estimated to range between 0.06 and 1,803 m^2/day. The geometric mean of the sample's transmissivity values was estimated to be about 6 m^2/day and the water-yielding capability of the unit was assessed as being fair.

Short-term pumping tests are available for 8,117 bedrock wells within the basin. Of these, 2,445 wells (30.12 %) have specific capacities less than 5 l/min/m (Figure So-5), 3,590 wells (44.22 %) have specific capacities between 5 and 25 l/min/l (Figure So-6), 910 wells (11.22 %) have specific capacities between 25 and 50 l/min/m (Figure So-7), and 1,172 wells (14.44 %) have specific capacities higher than 50 l/min/m (Figure So-8).

Based on the spatial distribution of high capacity bedrock wells on Figure So-8, it is possible to conclude that the majority of these wells are located within the March, Oxford, and Rockcliffe Formations and the Ottawa Group. Fewer high capacity wells are found within the Billings, Carlsbad, and Queenston Formations. The spatial distribution of the high capacity wells on Figure So-8 is consistent with the findings of Singer et al.(1997). It is also consistent with the general description of groundwater occurrence in the bedrock by Chin et al.(1980).

9.8 GROUNDWATER OCCURRENCE IN THE OVERBURDEN

Compared to the bedrock, the overburden is not a significant source of groundwater within the South Nation River basin. Overburden aquifers are generally the main sources of ground water in the north. In the southern parts of the basin, the overburden deposits are generally thin (less than 15 m) and are predominantly clays, silts, and tills. Permeable sands occur as surficial deposits over large areas in the north. Also, highly permeable surficial sand and gravel deposits occur along the western boundary of the basin. The latter are generally over 15 m thick. Elsewhere, sands and gravels occur as thin lenticular and discontinuous layers in buried deposits and are generally less than 3 m thick.

Chin et al.(1980) identified a number of overburden aquifers in the basin. The largest overburden aquifer, the Champlain Aquifer, is composed of surficial sands. The aquifer covers an area of nearly 570 km^2. The boundaries of this aquifer as outlined by Chin et al.(1980) correspond to the boundaries of the Prescott and Russell sand Plains.

The most important overburden aquifer is the Rideau Front Aquifer, which is composed of surficial sands and gravels. Compared to the Champlain Aquifer, this aquifer is of smaller extent (105 km^2) but is significant because of its potential for high well yields.

Chin et al.(1980) also identified nine smaller aquifers composed of buried sand and gravel. These aquifers are the Rockland, Plantagenet, Sarsfield, Notre Dame, Clarence, Bourget, St. Rose de Prescott, Maple Ridge, and Berwick aquifers. These aquifers occupy a total area of about 60 km^2.

Data related to short-term pumping tests are available for 1,102 overburden wells. The data indicate that 213 wells (49%) have specific capacities ranging from 1 to 5 l/min/m

(Figure So-9), 557 wells (39.5%) have specific capacities between 5 and 25 l/min/m (Figure So-10), 131 wells (5.9%) have specific capacities between 25 and 50 l/min/m (Figure So-11), and the remaining 201 wells (5.6%) have specific capacities larger than 50 l/min/m (Figure So-12).

Figure So-12 indicates that there are no high-capacity wells within the Champlain Aquifer. Most of the high-capacity wells are found along a belt extending to the south of the Champlain Aquifer from St. Isidore de Prescott in the east to the western boundaries of the basin. This belt includes the St. Isidore de Prescott and the Rideau Front Aquifers, which were identified by Chin et al.(1980). High-capacity wells are also found in the northwestern part of the basin near Sarsfield, Rockland, and Clarence which correspond to the Sarsfield, Rockland, and Clarence Aquifers identified by Chen et al.(1980).

9.9 SUGGESTED BEDROCK MONITORING AREAS

Figure So-13 shows the locations of bedrock wells with specific capacities of over 50 l/min/m and the boundaries of suggested areas for monitoring of groundwater in 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 So-14, Panel Diagram).

Areas where groundwater in the bedrock is highly susceptible to contamination are defined as those areas 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 those areas 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 those where the overburden contains clay or clay till deposits that are much more than 3 m in thickness.

Based on the above definitions, eight areas (A, B, C, D, E, F, G and H) are proposed for groundwater monitoring within the bedrock. Areas (A, B, and C) are underlain by the March and Oxford Formations, Area (D) is underlain by the Rockcliffe Formation, areas (E, F, and G) are underlain by the rocks of the Ottawa Group, and Area (H) is underlain by the Billings, Carlsbad and Queenston Formations.

Groundwater susceptibility to contamination within areas (A and B) is high. Area (A) is located at the lower end of the basin and the bedrock in this area is at or close to the surface. Area (B), on the other hand, extends along the basin's western boundary from Kempark to Mountain and includes the headwaters of the North, Middle, and South Rivers and the Allen, Silver, and Wylie Creeks. The bedrock within Area (B) is either at the surface or it is covered by permeable deposits of sand and gravel.

Groundwater susceptibility to contamination within Areas (C, D, E, and H) is moderate.

Area (C) covers parts of Edwardsburgh, Oxford, and South Gower Townships; Area (D) is located between Winchester in the northeast, Winchester Bog in the northwest, and Inkermar in the south; Area (E) is located within Osnabruck and Finch Townships extending from the southeastern basin's boundaries to Crysler; and Area (H) is located within the headwaters of Bear Brook extending from Vars in the southeast to Navah in the northwest.

Groundwater susceptibility to contamination within areas (F and G) is low. Area (F) is located within South Plantagenet and Kenyon Townships in the headwater areas of the East Branch Scotch River and the west Branch Scotch River, and Area (G) is located within Clarence Township between Bourget in the south, St. Pascnal in the east, and the Clarence Creek in the northwest.

9.10 SUGGESTED OVERBURDEN MONITORING AREAS

Figure So-15 shows the location of overburden wells with specific capacities of over 50 l/min/m, and the boundaries of suggested areas for groundwater monitoring. Groundwater within the suggested areas has a high, variable, or low susceptibility to contamination. The susceptibility of groundwater to contamination in these areas was determined based on information related to the thickness and type of overburden materials (Figure So-16, Panel Diagram).

Areas where groundwater in the overburden is highly susceptible to contamination are defined as those areas where the overburden aquifer is at the surface and consists of sand and gravel materials. Areas where the susceptibility of the groundwater is variable are those areas where the overburden aquifer of sand and gravel is at the surface or is covered by thin clay or clay till deposits. Areas where the susceptibility of groundwater to contamination is low are those where the overburden aquifer is protected by thick clay till or clay deposits.

Based on the above definitions, six areas (A, B, C, D, E, and F) are proposed for groundwater monitoring in the overburden. Area (A) is located along the basin's western topographic divide within the headwaters of the North, Middle , and South Castor Rivers.

The susceptibility of groundwater to contamination within areas (B and C) varies from high to low. Area (B) is located within Winchester and Russell Townships to the northwest of Morewood; and Area (C) is located within Cumberland Township arround Sarsfield.

The susceptibility of groundwater to contamination in areas (D, E, and F) is low. Area (D) is occupies parts of Finch, Cambridge, and Russell Townships extending from Crysler in the south to Embrun in the west. Area (E) is located within Plantagenet and Cambridge Townships extending from St.Isidore de Prescott in the east to Casselman in the west. Finally, area (F) is located in the vicinity of Cumberland in Cumberland Township.

9.11 HISTORICAL MONITORING WELLS

Six bedrock wells, two overburden wells, and three wells of unknown type were used in the past for monitoring groundwater in the South Nation River basin. The types and locations of these wells are as follows:

Well No. 152	A bedrock well, 15.54 m deep, and located in Dundas County, Chesterville Village.
Well No. 257	An overburden well,10.67 m deep, and located in Prescott County, Plantagenet Village.
Well No. 517	A bedrock well, 50.29 m deep, and located in Dundas County, Matilda Township, Concession 4, Lot 13.
Well No. 518	A bedrock well, 38.10 m deep, and located in Grenville county, Augusta Township, Concession 4, Lot 14.
Well No. 519	A bedrock well, 31.39 m deep, and located in Glengarry County, Kenyon Township, Concession 21, Lot 6.
Well No. 520	A well of unknown type, 1.83 m deep, and located in Stormont County, Finch Township, concession 6, Lot 23.
Well No. 522	A well of unknown type, 4.88 m deep, and located in Dundas County, Chesterville Village.
Well No. 523	A well of unknown type, 9.45 m deep, and located in Grenville County, Edwardsburgh Township, Concession 7, Lot 32.
Well No. 525	An overburden well, 14.33 m deep, and located in Russell County, Russell Township, Concession 9, Lot 3.
Well No. 546	A bedrock well, 44.81 m deep, and located in Russell County, Clarence Township, Concession 6, Lot 18.
Well No. 547	A bedrock well, 42.98 m deep, and located in Dundas County, Winchester Township, Concession 6, Lot 1.
Well No. 555	A bedrock well, 21.33 m deep, and located in Ottawa-Carlton County, Gloucester Township, Concession 5, Lot 28.

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

REFERENCES

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FIGURES

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

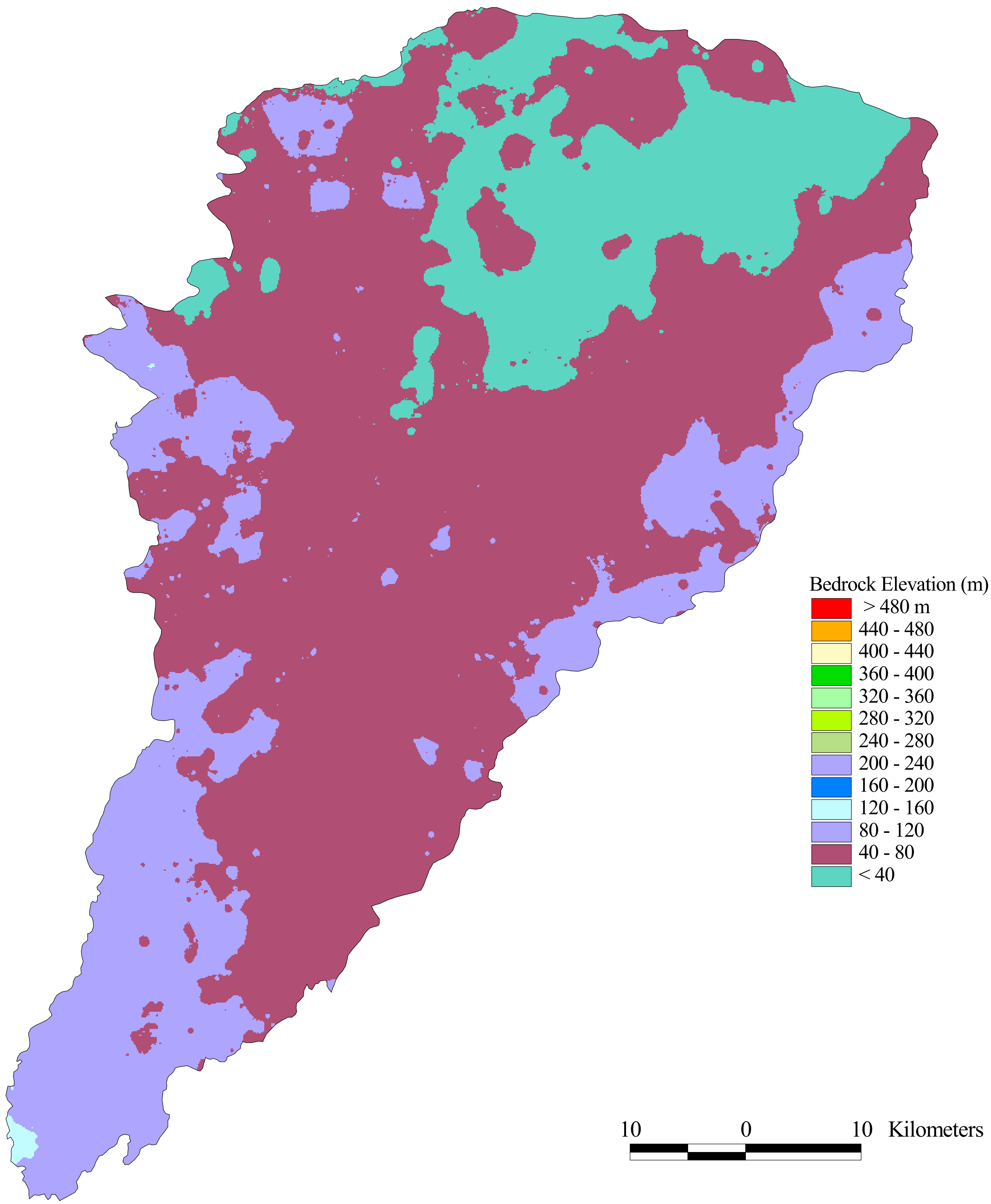

Figure So-1. Bedrock topography in the South Nation River drainage basin.

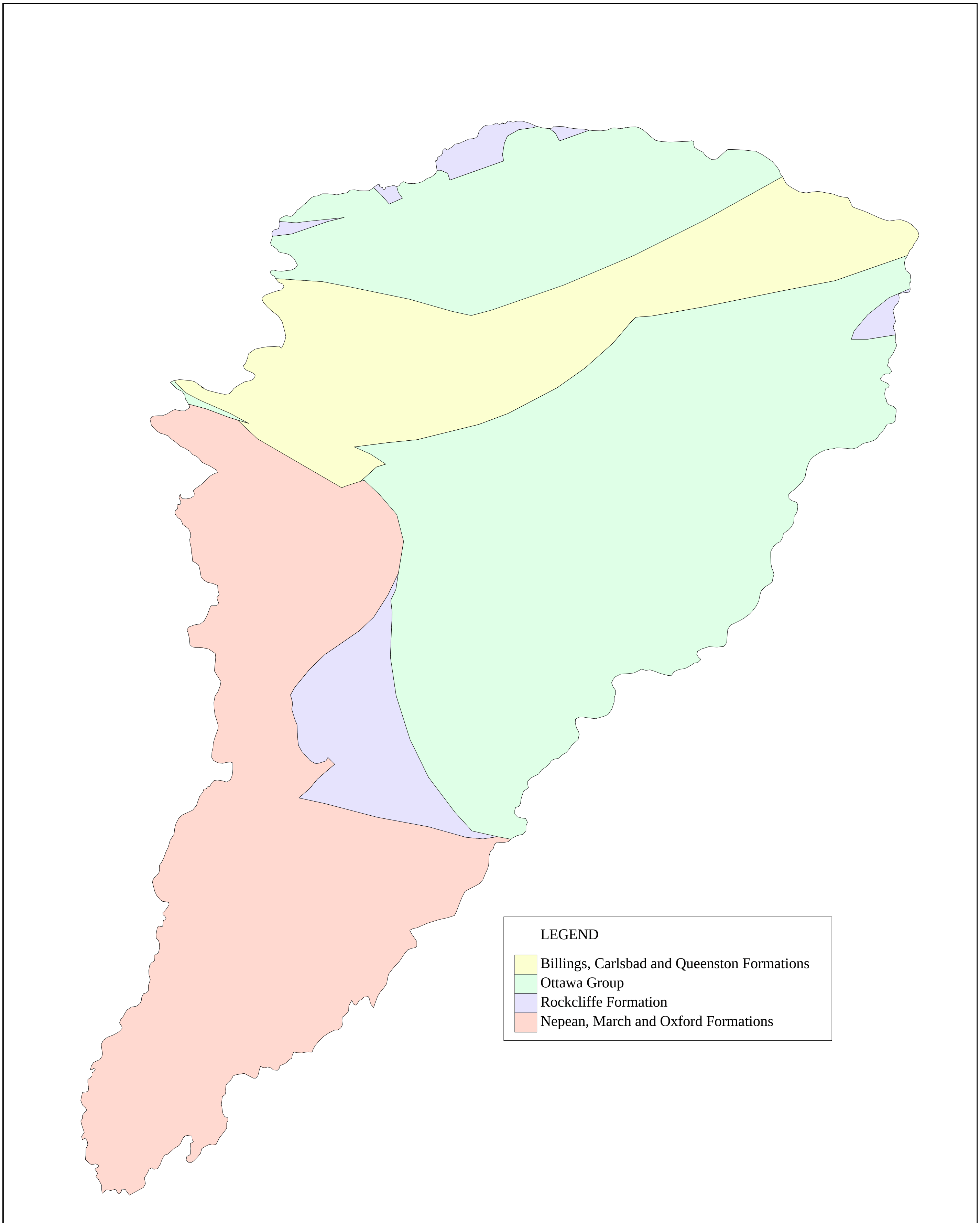

Figure So-2. Bedrock geology in the South Nation River drainage basin.

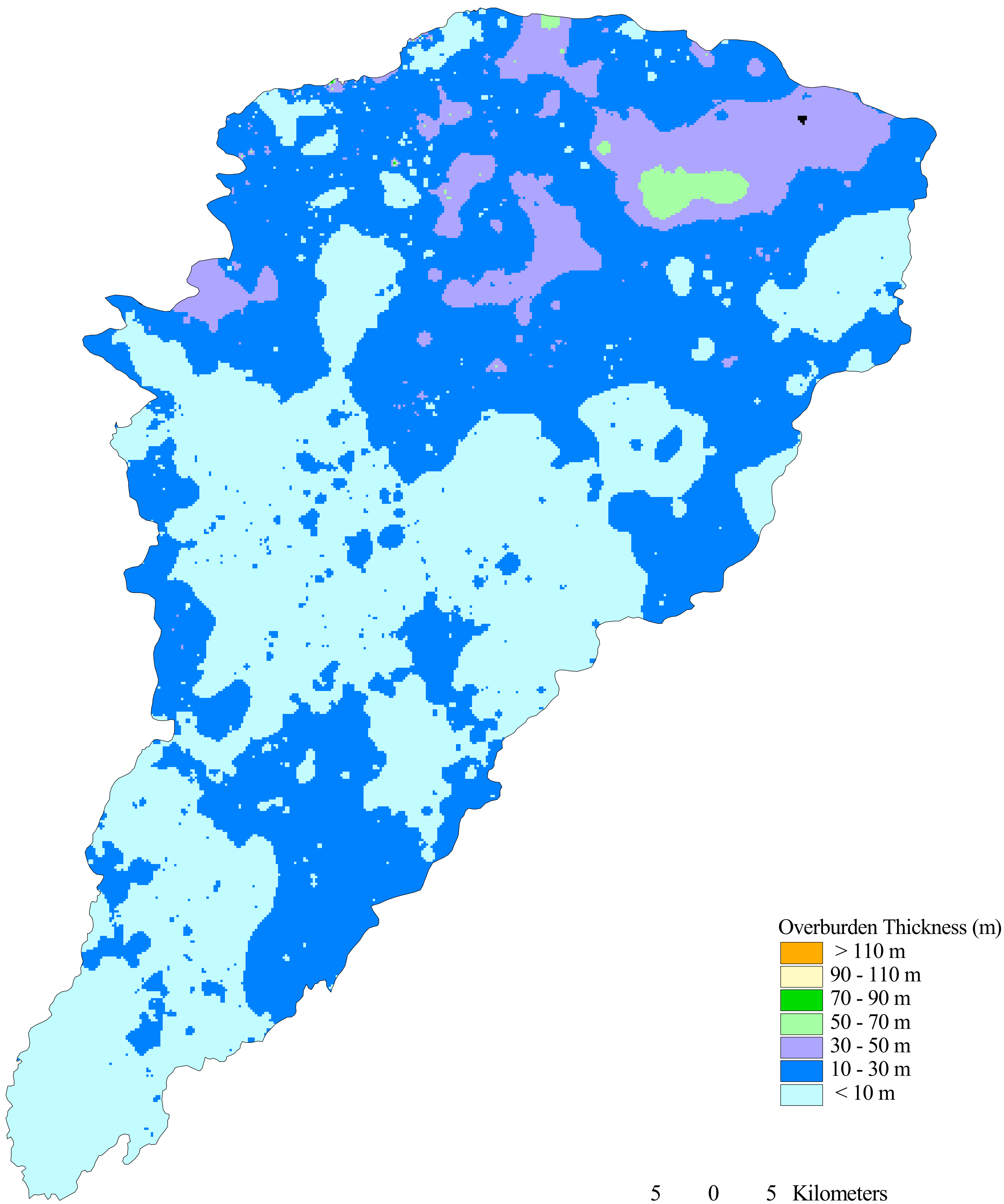

Figure So-3. Overburden thickness in the South Nation River drainage basin.

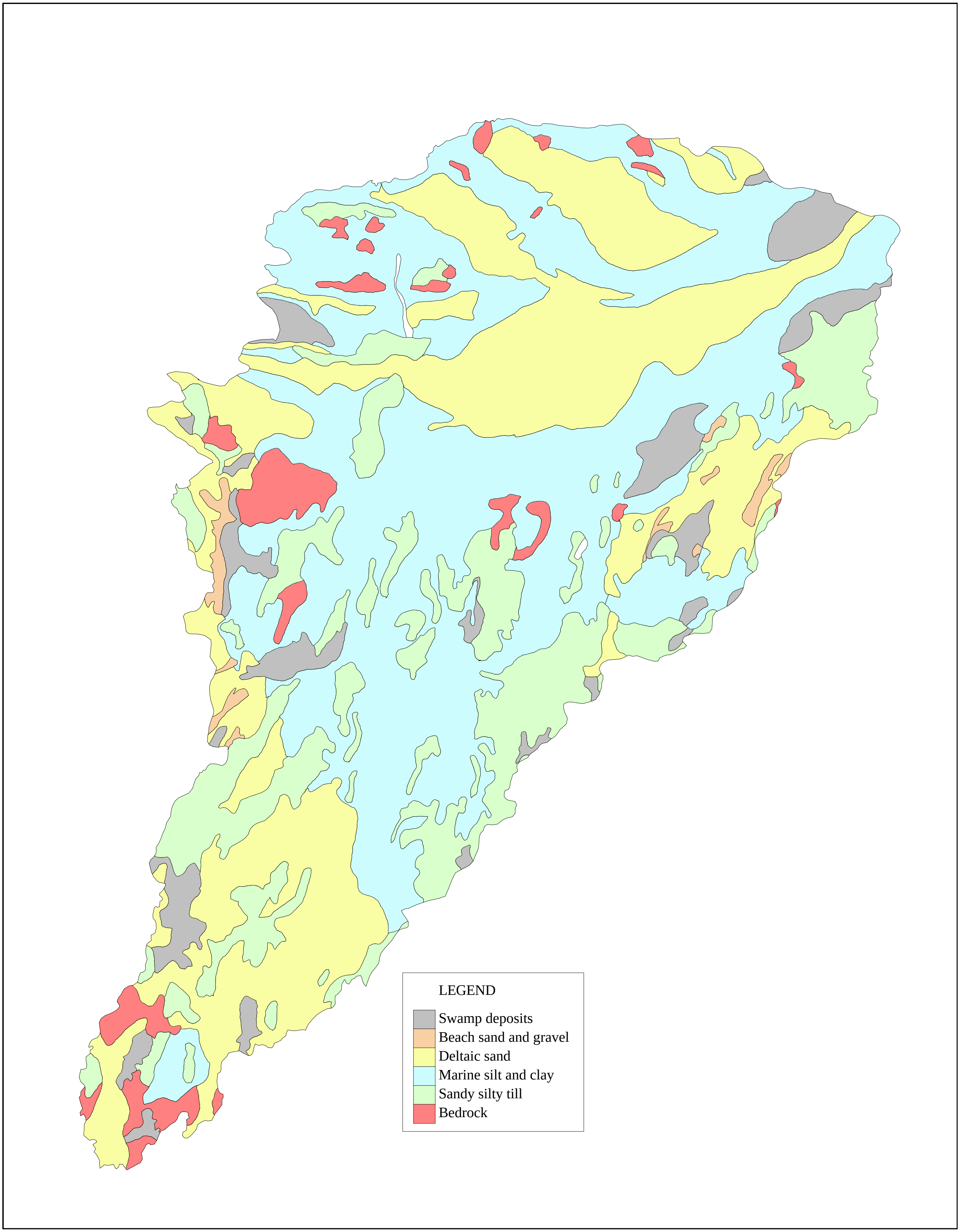

Figure So-4. Overburden geology in the South Nation River drainage basin.

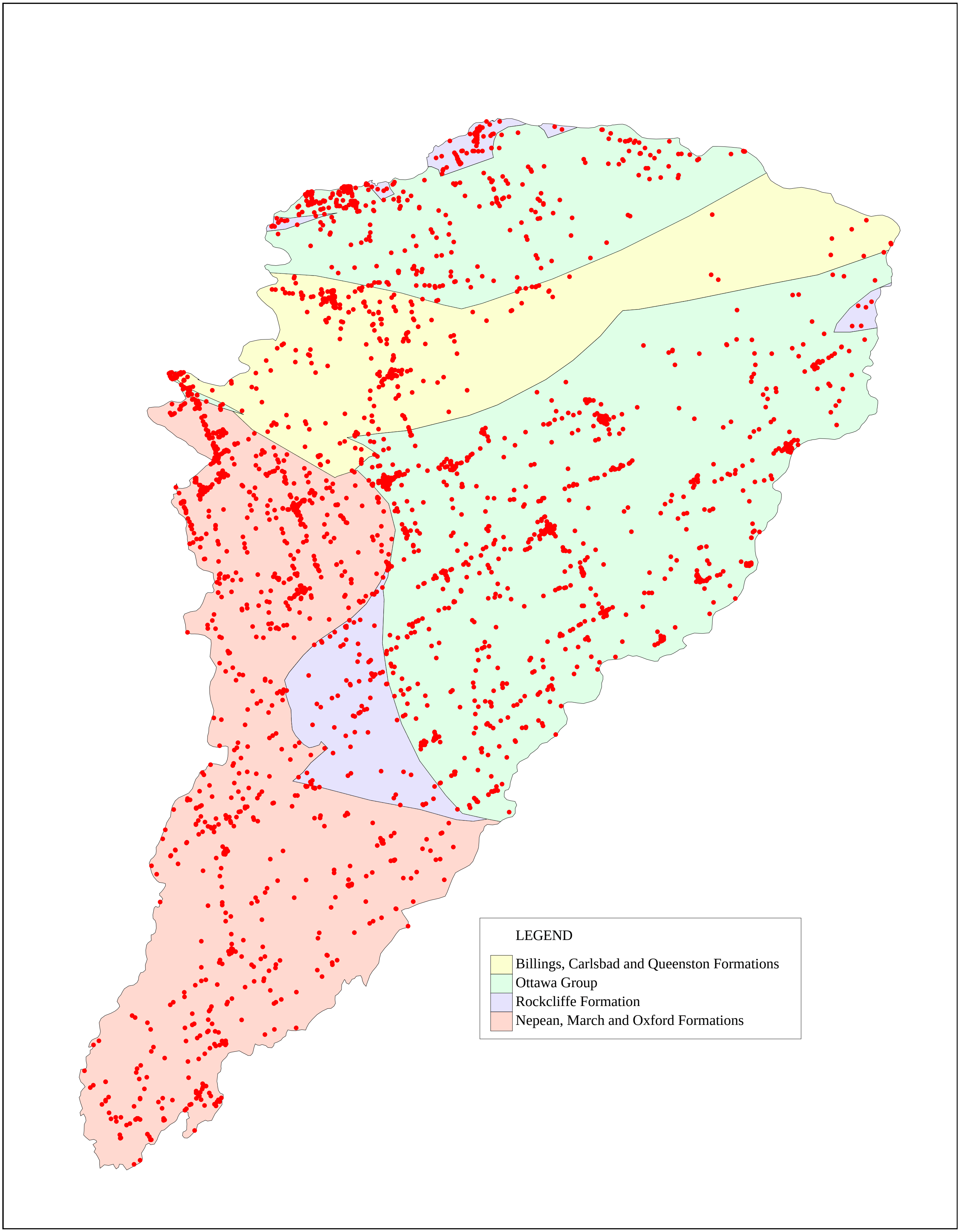

Figure So-5. Bedrock wells with specific capacities equal to or less than 5 l/min/m.

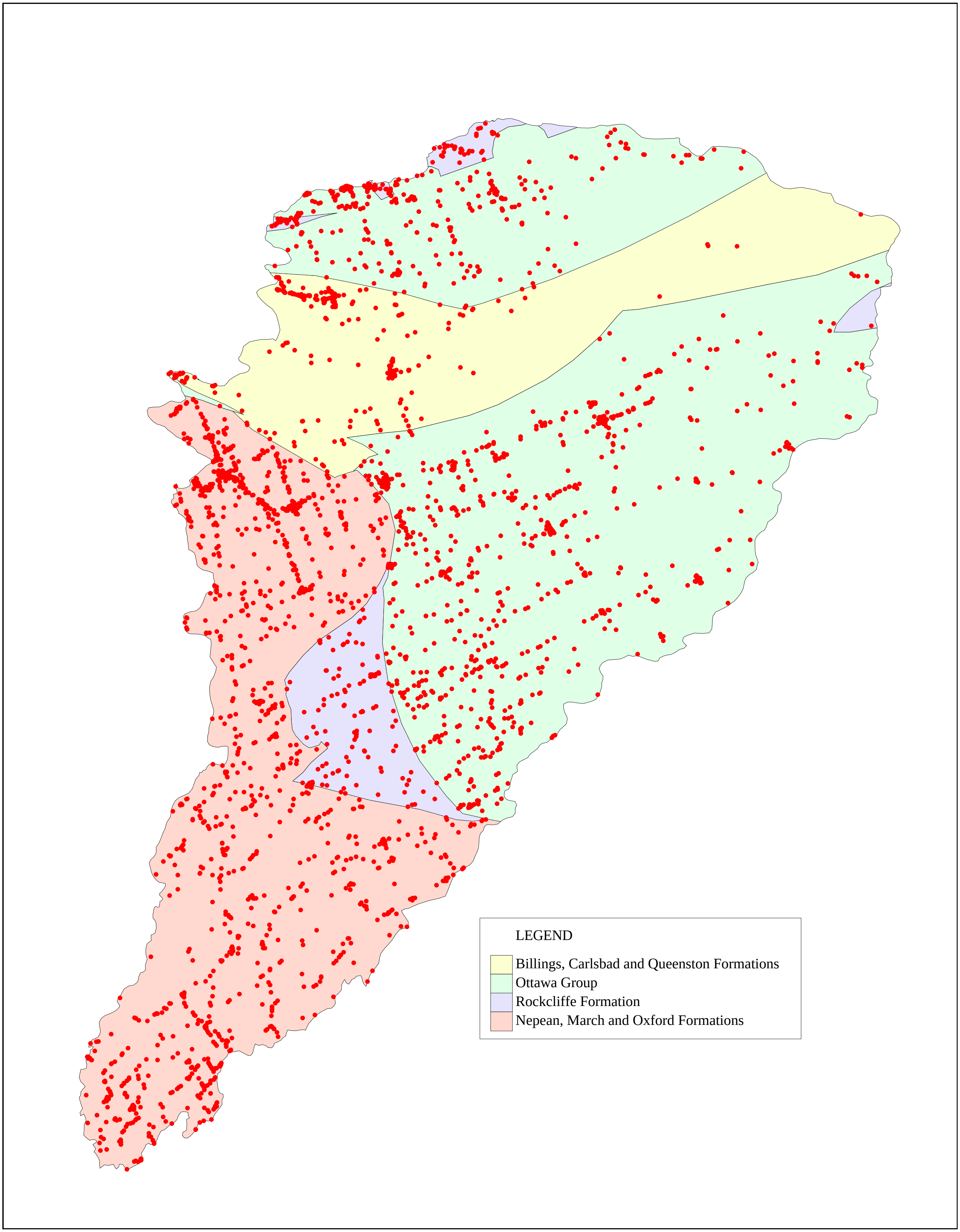

Figure So-6. Bedrock wells with specific capacities between 5 and 25 l/min/m.

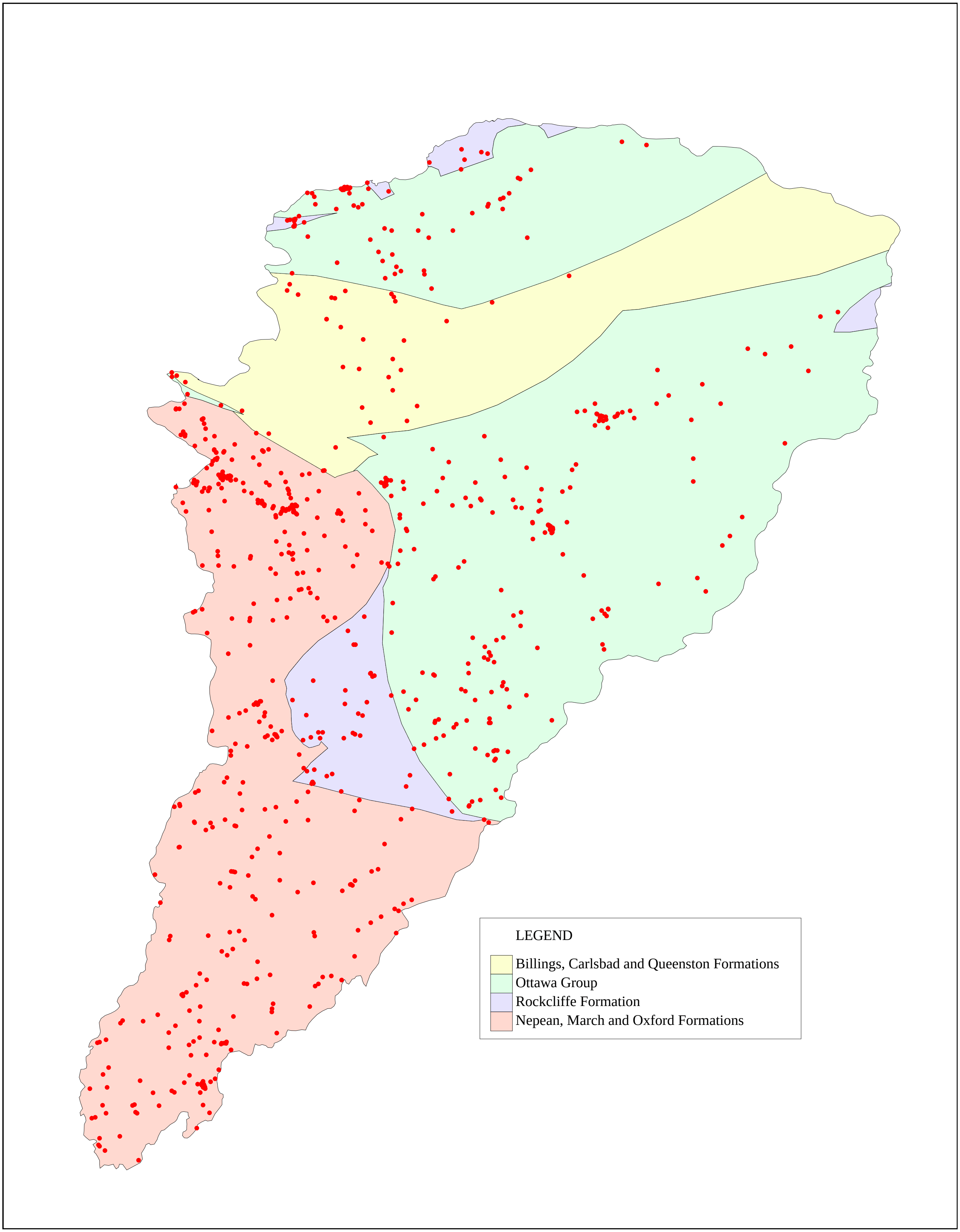

Figure So-7. Bedrock wells with specific capacities between 25 and 50 l/min/m.

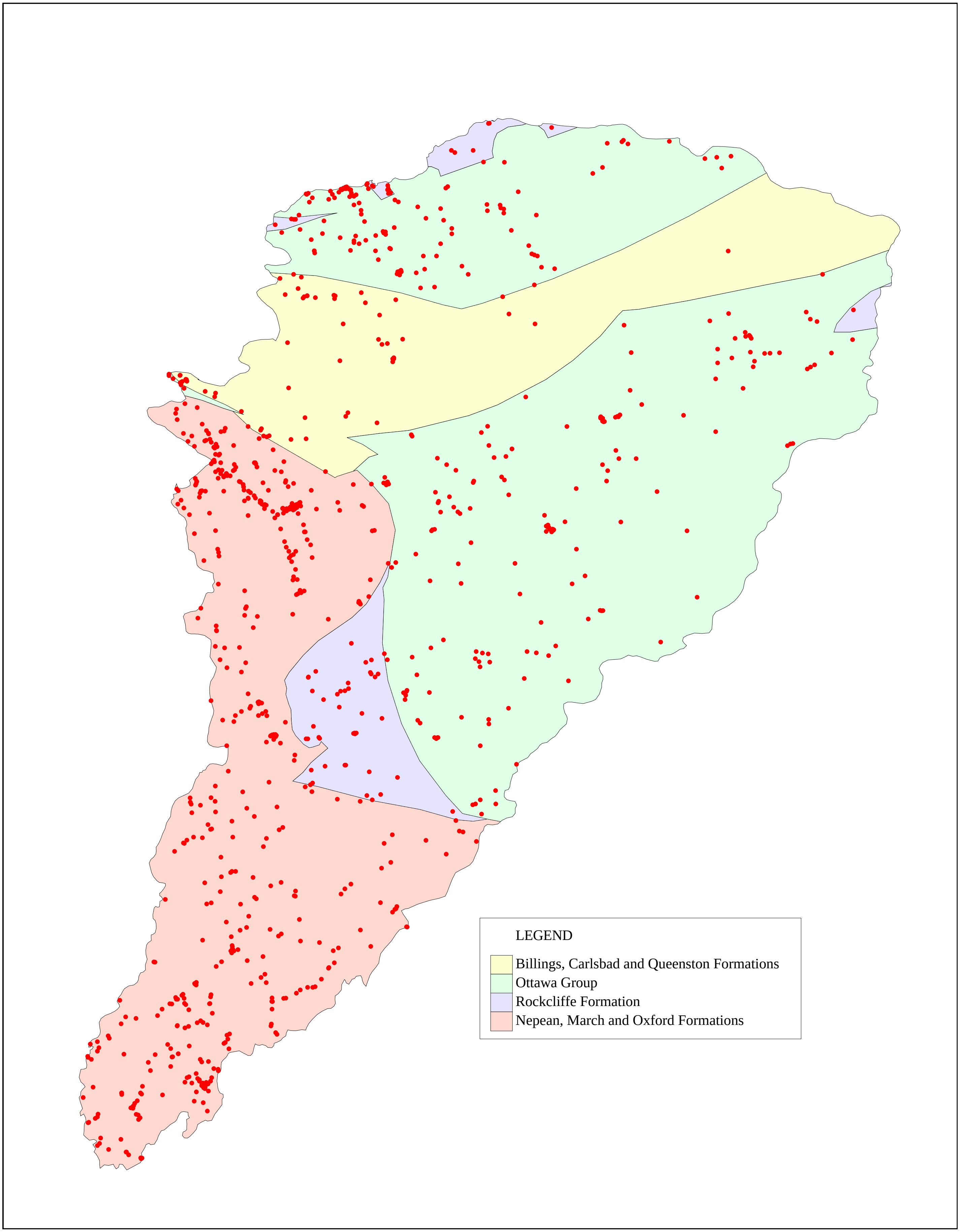

Figure So-8. Bedrock wells with specific capacities higher than 50 l/min/m.

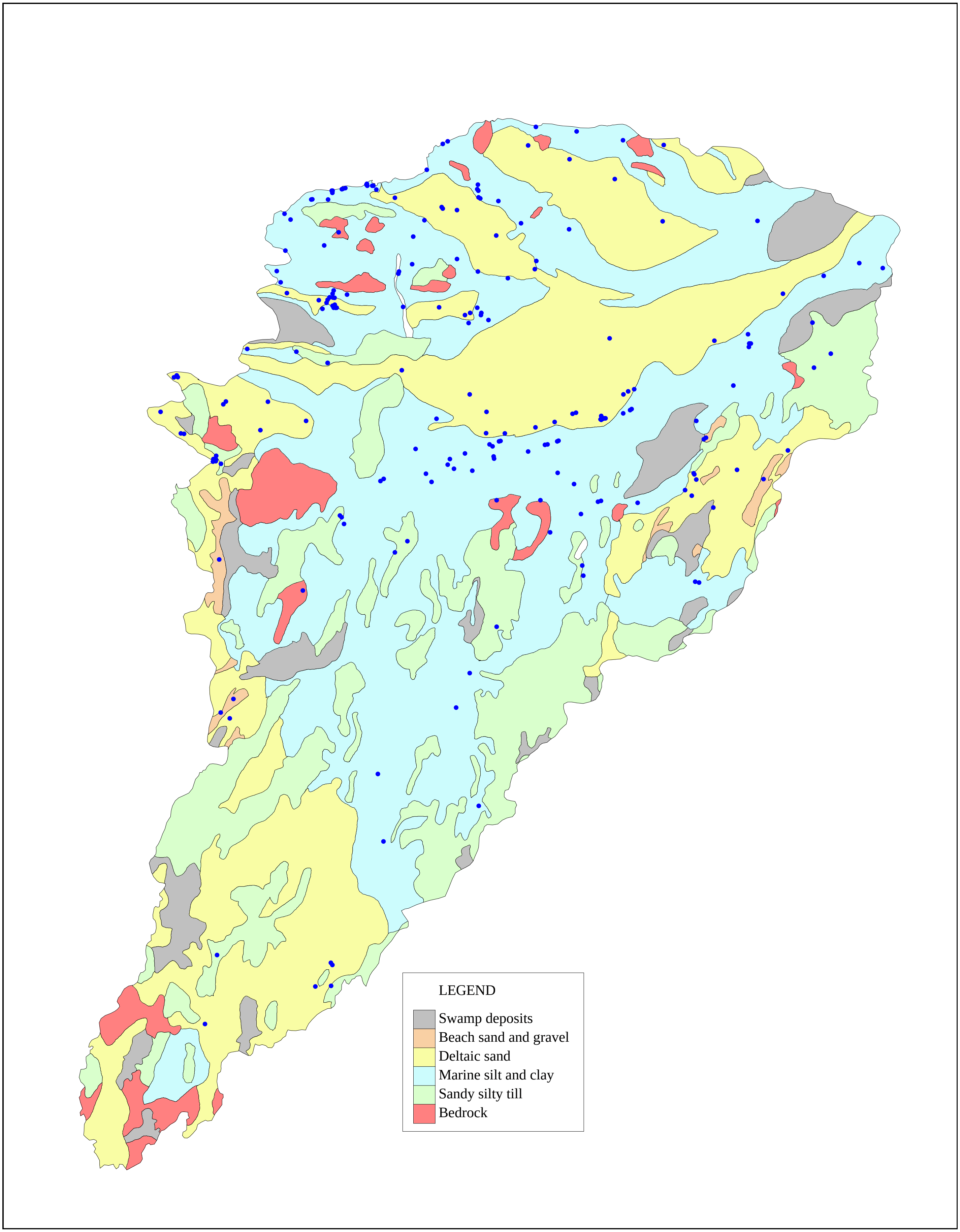

Figure So-9. Overburden wells with specific capacities equal to or less than 5 l/min/m.

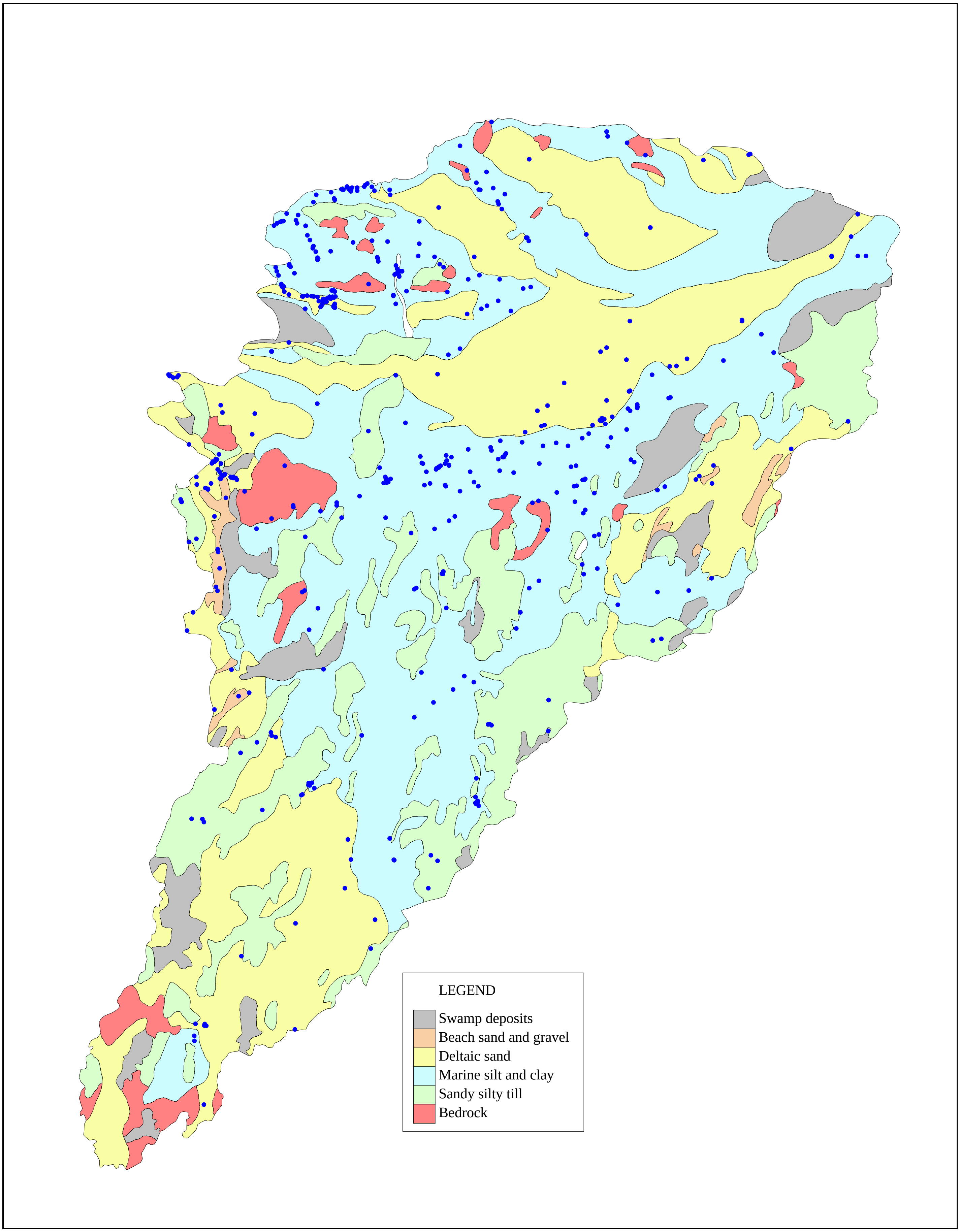

Figure So-10. Overburden wells with specific capacities between 5 and 25 l/min/m.

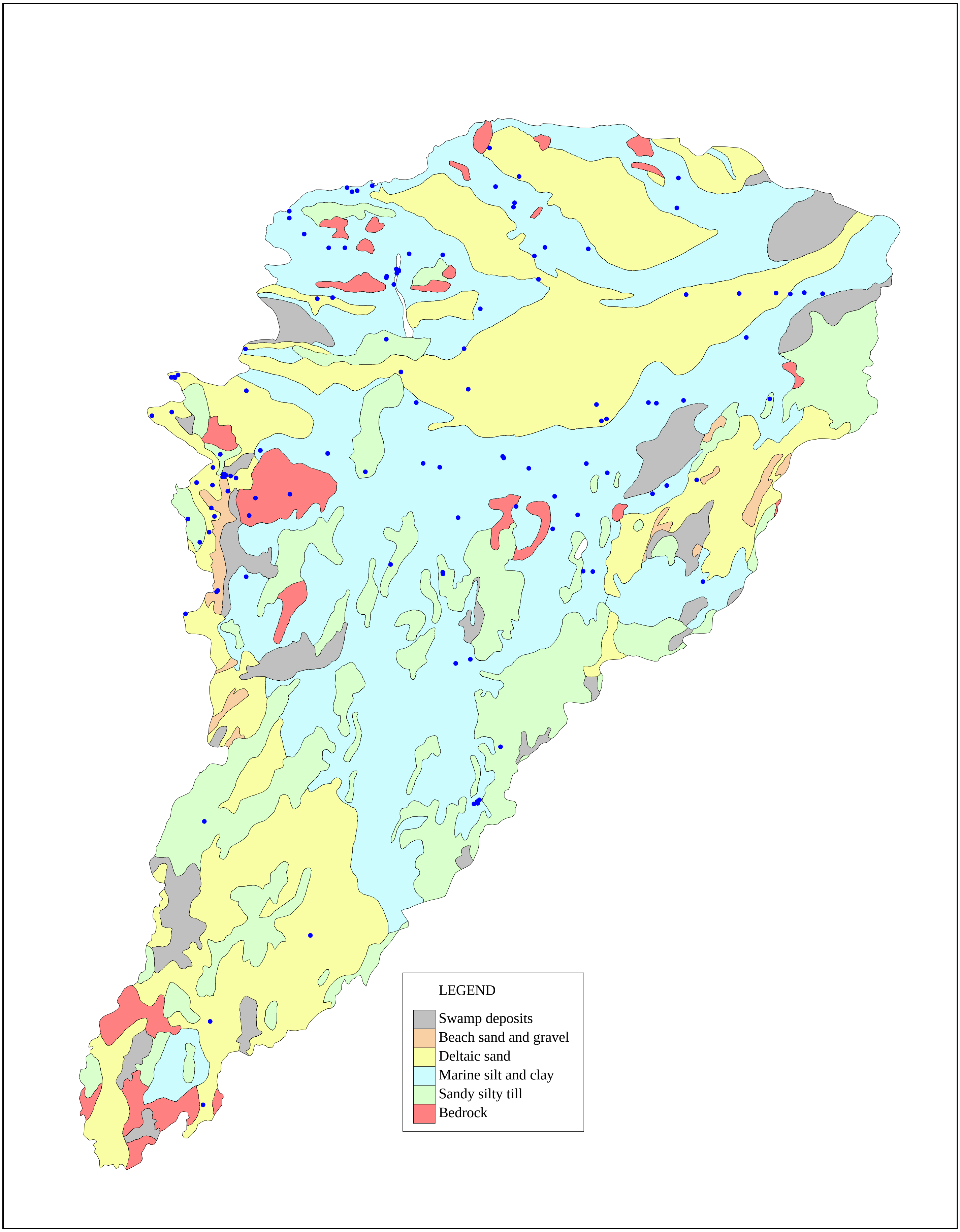

Figure So-11. Overburden wells with specific capacities between 25 and 50 l/min/m.

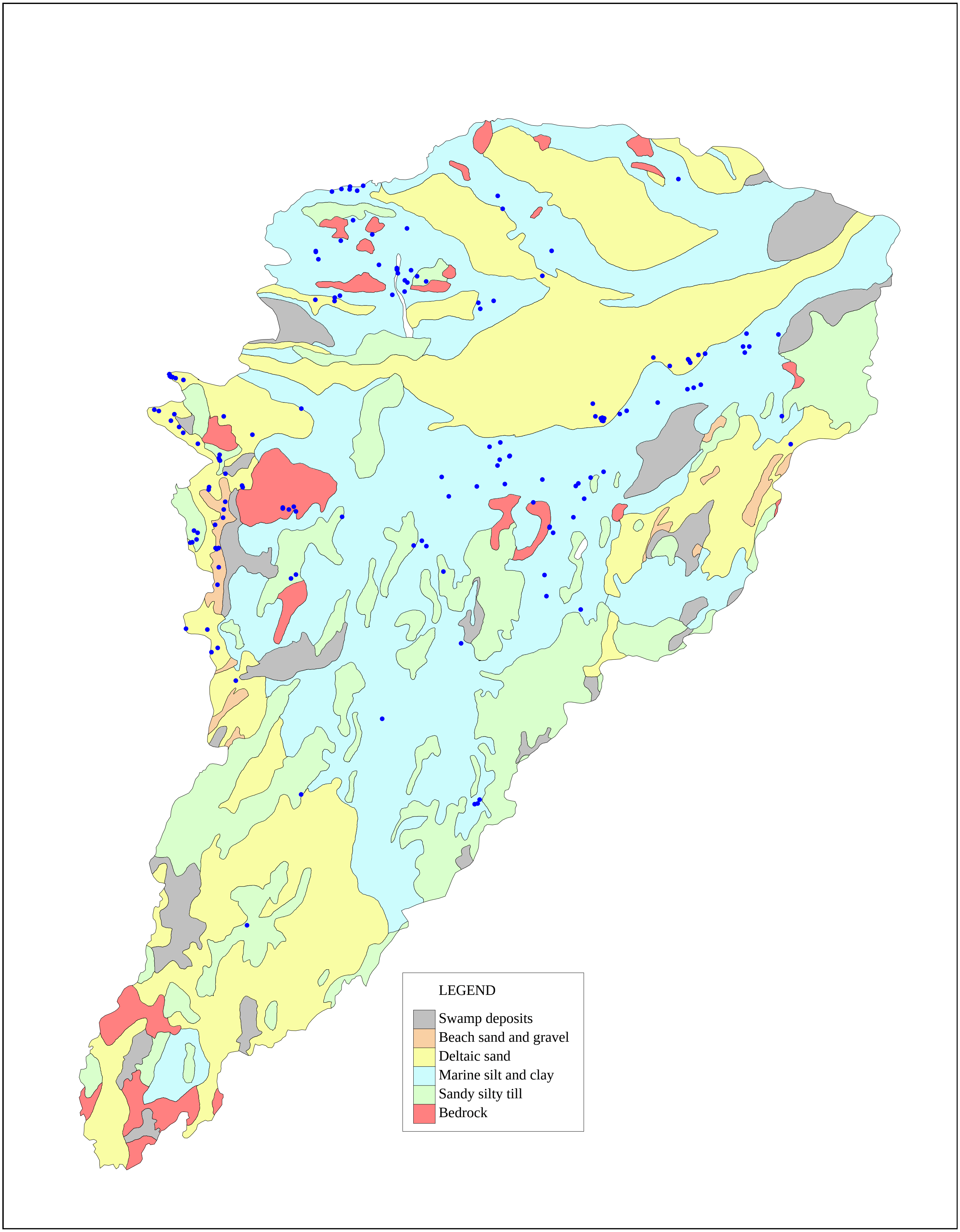

Figure So-12. Overburden wells with specific capacities higher than 50 l/min/m.

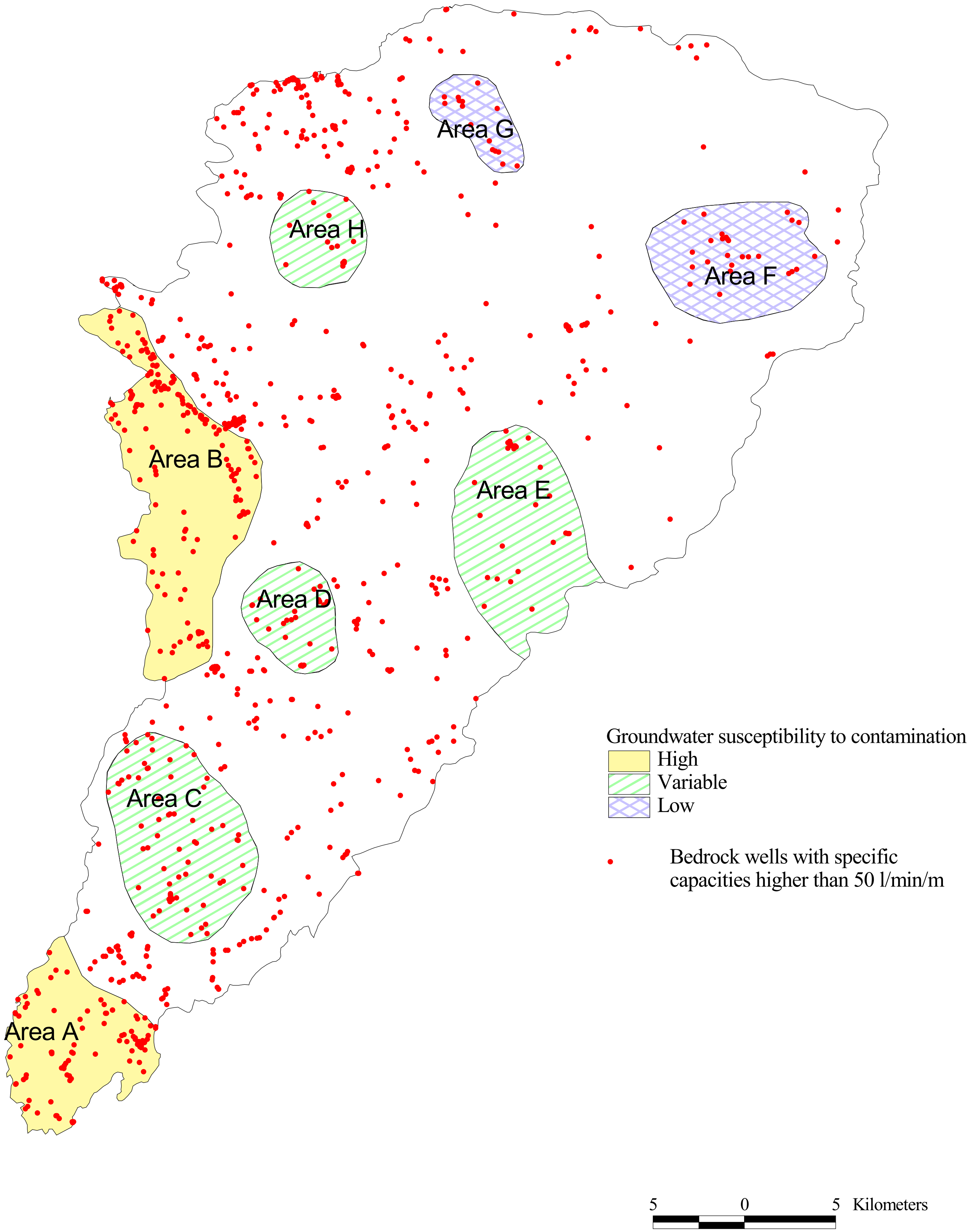

Figure So-13. Suggested areas for monitoring groundwater in the bedrock.

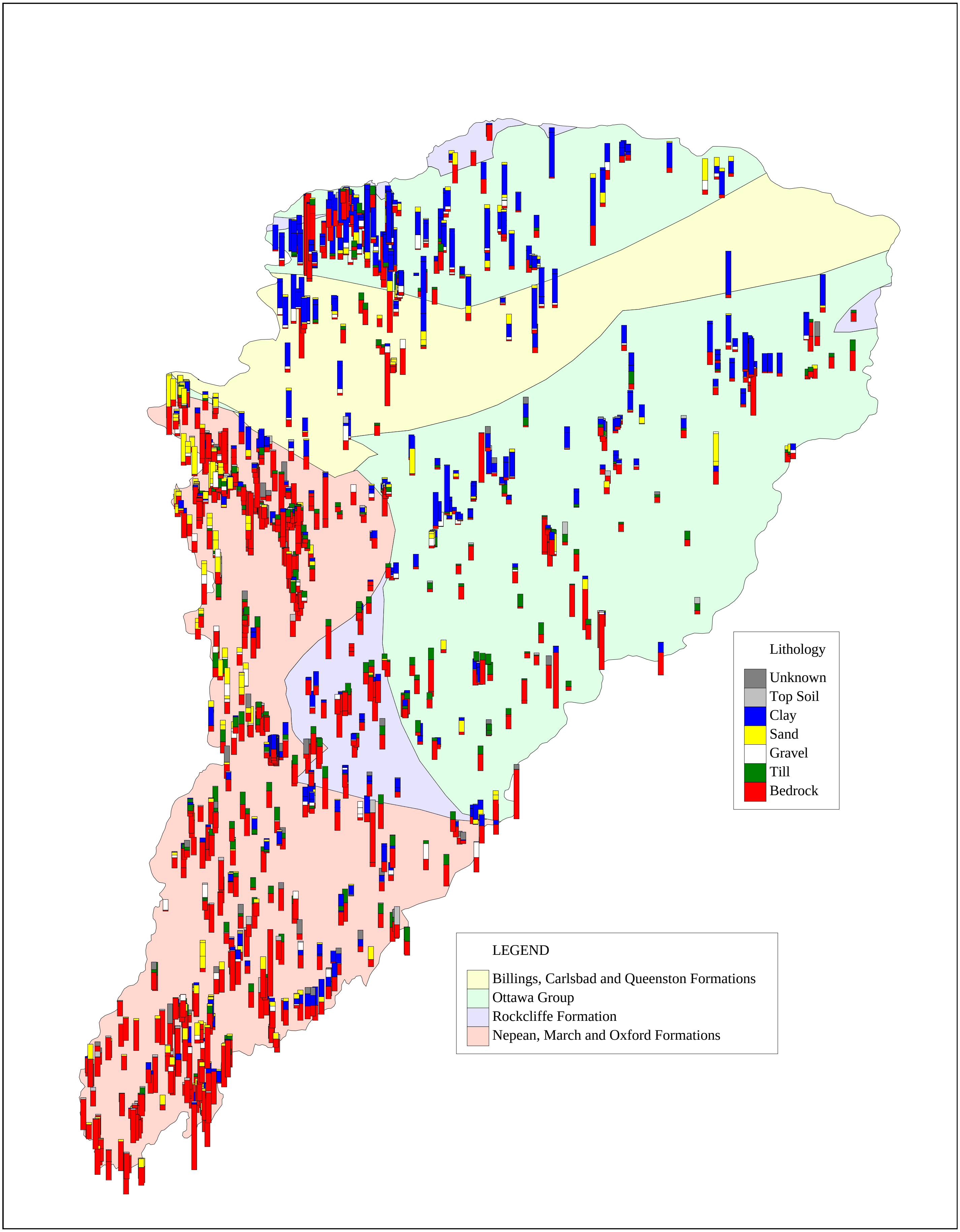

Figure So-14. Panel diagram showing the geologic logs of bedrock wells with specific capacities higher than 50 l/min/m.

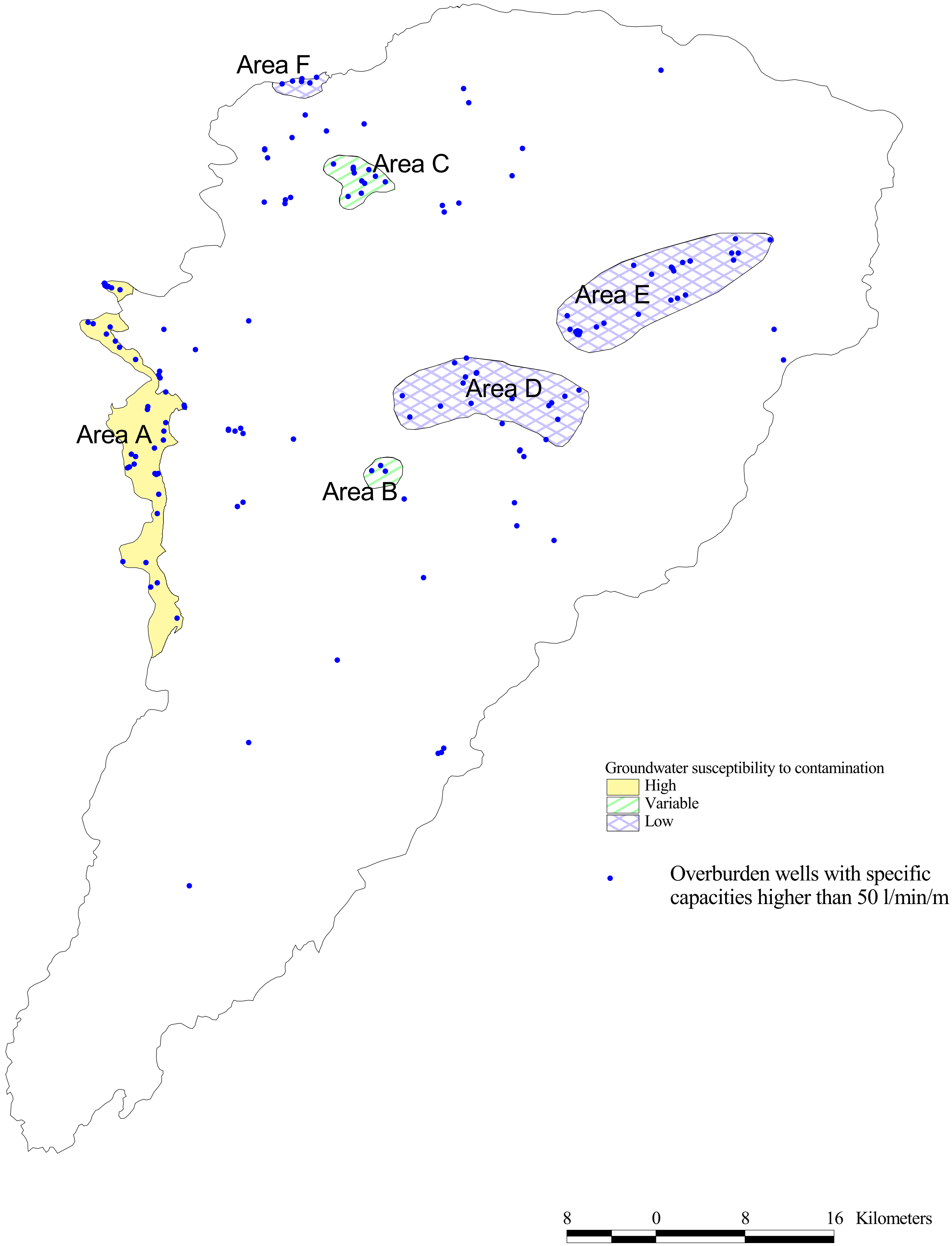

Figure So-15. Suggested areas for monitoring groundwater in the overburden.

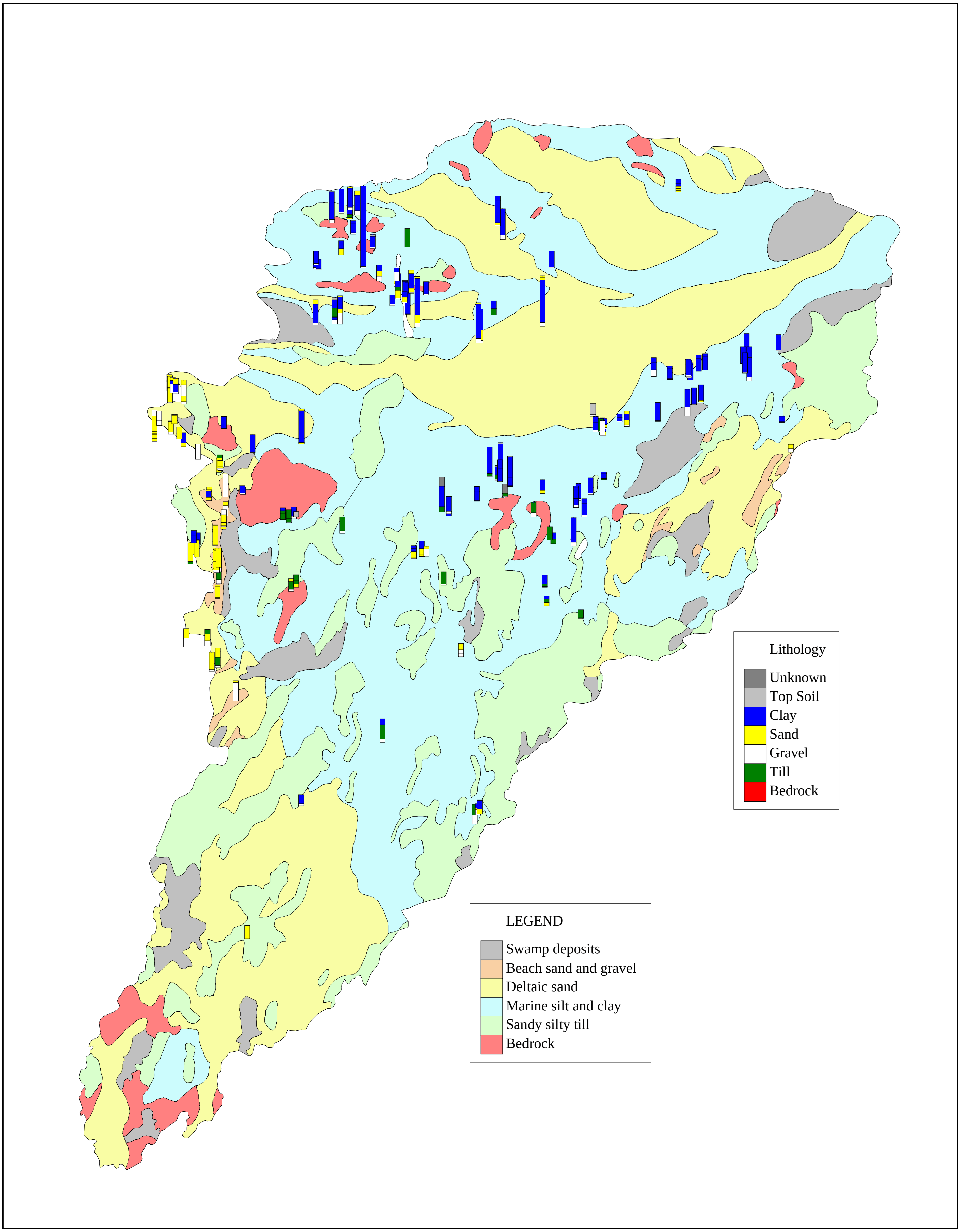

Figure So-16. Panel diagram showing the geologic logs of overburden wells with specific capacities higher than 50 l/min/m.

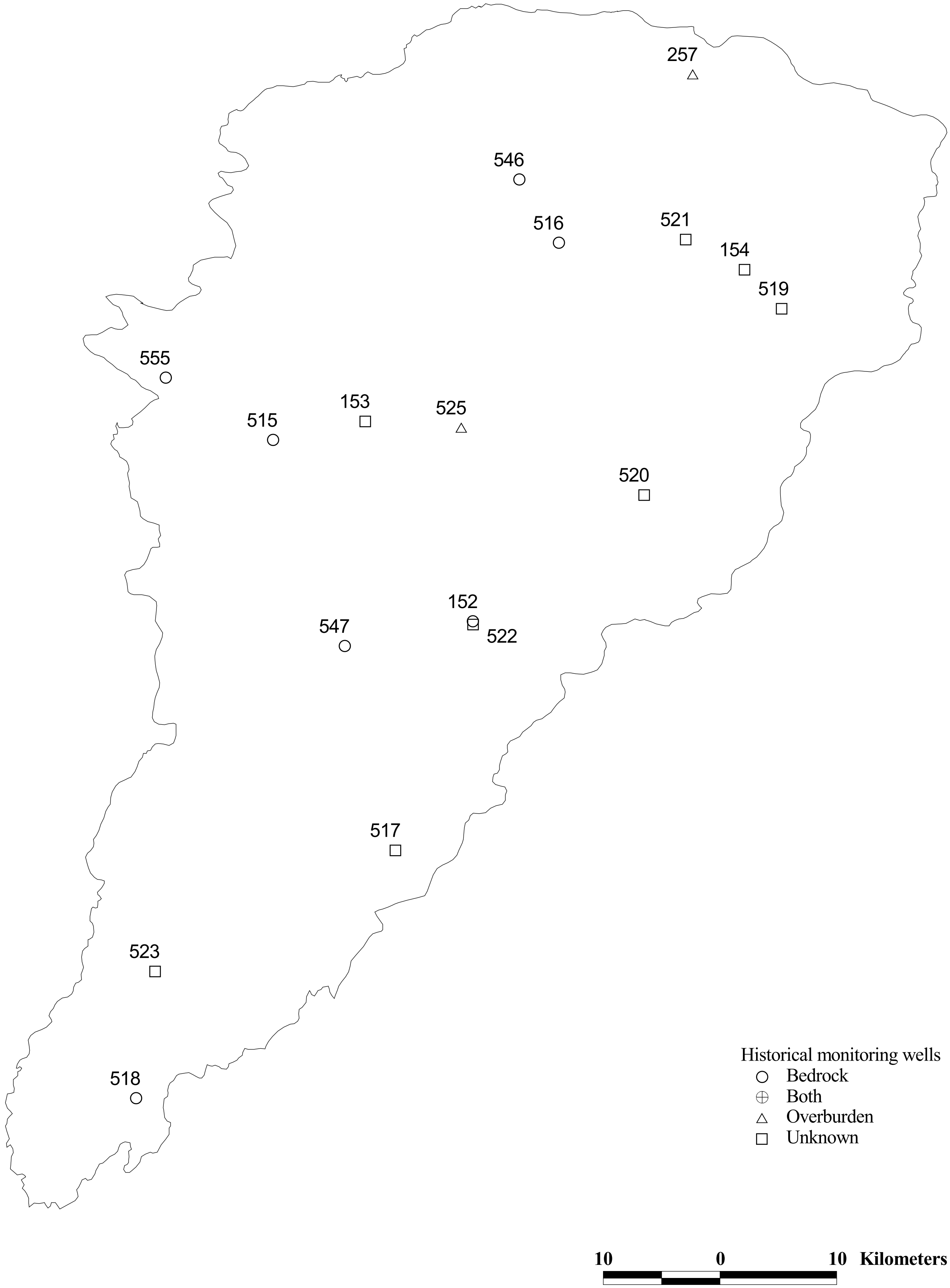

Figure Sn-17. Locations of historical monitoring wells in the South Nation River drainage basin.