Historical development of subsurface drainage in Quebec from 1850 to 1970

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ABSTRACT

Despite its beginning in the 1850's and being first in Canada to purchase a tile drainage trencher, subsurface drainage of agricultural lands in Quebec is poorly documented, which the present paper will try to document from 1850 to 1970. In Quebec, Catholic priests and monks played an important role in educating rural communities by establishing French agricultural schools throughout the province. For the English rural communities, Macdonald College (Macdonald Campus of McGill University) played a major role especially in preparing plans, besides promoting the technology. The Quebec Ministry of Agriculture encouraged subsurface drainage early in 1912 but would prefer investing in land clearing and watercourse deepening to establish more farms, from the employment needs created by WWI, the great 1930 depression and WWII. This work mostly completed in the early 1960's, the Quebec Government would then initiate a major subsurface drainage program, allowing private enterprises to take over shortly after 1967. Although the Ministry changed names several times even after 1967, the term 'Ministry of Agriculture' will be used throughout this article. To compare trencher performance, a 15 m average spacing is presumed. This paper is limited to the main events and persons involved, without being able to cover them all.

KEYWORDS

History, subsurface drainage, Quebec

RÉSUMÉ

Peu documenté, le drainage souterrain fait partie de l'histoire du Québec depuis son tout début en 1850, et depuis son achat de la première draineuse mécanisée au Canada en 1902. Le but du présent article est donc de documenter cette historie de 1850 à 1967. L'église catholique a activement participé à l'éducation des communautés rurales francophones du Québec en fondant plusieurs écoles d'agriculture. Du côté anglophone, le Collège Macdonald (Campus Macdonald de l'Université McGill University) jouait un rôle important surtout pour la préparation de plans, en plus de sa vulgarisation. Le Ministère de l'Agriculture encourageait le drainage souterrain à compter de 1912 mais lui adressait peu d'importance pour défricher et excaver les cours d'eaux, afin de trouver des emplois à la suite des deux grandes guerres mondiales, et de la grande dépression de 1930. Une fois les travaux de creusage de cours d'eau pratiquement réalisés vers le début des années 1960, le Ministère lançait un important programme de drainage souterrain pour ensuite laisser la relève aux entrepreneurs privés peu après 1967. En dépit de ses nombreux changements de nom même après 1967, le présent article utilise simplement le nom de 'Ministère de l'Agriculture'. Pour comparer le taux d'installation de drainage souterrain, un écartement moyen de 15m sera présumé. Le présent article vise a souligner les éléments importants de l'histoire du drainage souterrain au Québec, ne pouvant mentionner tous ceux-ci ni toutes les personnes impliquées.

MOTS CLÉS

Histoire, drainage souterrain, Québec.

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MANUAL INSTALLATIONS AND INITIAL CLAY TILE MANUFACTURING

The manual installation of subsurface drains, made of stones trenches and clay tiles, was practiced in Quebec before 1850 and between 1870 and 1885, respectively. Remarks by R. Brodie of Westmount mention the use of stone trenches before 1850 to get rid of stones and provide subsurface drainage (Brodie 1913). Subsurface stone trenches are reported installed on the farm of the Dairy Transformation School of Saint-Denis de Kamouraska (120km East of Quebec City on the St-Lawrence South Shore). This school was founded in 1881 by Édouard-André Barnard, agronomist, who later created 'La Société d'industrie laitière du Québec', a society promoting high quality butter and cheese production (Proulx 1982).

Clay tile drainage was practiced in Saint-Augustin des Desmaures (3km West of the Quebec City airport), by Reverend François Pilote after his arrival in 1870 from the College of Sainte Anne College de La Pocatière. He is said to have, himself, purchased the clay tiles from Montreal (supplier not identified) (Proulx 1985), likely from Henderson & Lovelace of Montréal founded in 1868. Although Henderson & Lovelace were manufacturing clay smoking pipes from a deposit on the Island of Montreal, near Lafontaine and Ontario streets, they were also selling clay tiles (Katz 2019; Desrosiers et al. 2009). There was a pottery closer to Saint-Augustin, that of the farming family William & David Bell, founded in 1845. It was one of the first pottery in Quebec, located in La Petite Rivière (by the St-Charles River at the intersection of Blvd Hamel and Avenue St-Sacrement, now Quebec City), but it started to produce clay tiles at some later date (Desrosiers et al. 2009). Reverend Pilote then went on to encourage the opening of a clay tile manufacturer in St-Augustin (Proulx 1885). Two general potteries (for ceramics and vases) have operated in St-Augustin des Desmaures, from 1796 to 1816, namely Poterie Côté and Poterie Robitaille, but that of clay tiles promoted by Reverend Pilote probably did not operate for long as it is not documented (Desrosiers et al. 2009).

At the time, encouraging subsurface drainage among other practices, from Quebec City Eastward, aimed at improving the poor yields of the farms and preventing the population from immigrating to the United States. Many catholic priests would therefore put an effort in educating their rural parishioners and in establishing agricultural schools, many of them disappearing in the 1960's, while some are still renown as of today, such as La Pocatière (Lemieux 1972).

In perspective, the first extrusion machine to produce clay tiles (63.5 to 101.6 mm in diameter - 2.5 to 4 inches) was invented in England in 1843 and brought to Seneca County New York in 1847-1848 (Weaver 1964). Nevertheless, other clay tile producing mechanisms were used in New England at that time, such as the half circle, the pole type and the horseshoe.

In June 1940, Jean Ulric, a drainage technician for the Ministry of Agriculture, would write about intercepting some of these early subsurface drainage systems. Jean Ulric graduated from Ste-Anne-de-La-Pocatière in 1913 with a 'Brevet de capacité agricole' (Université Laval 1916). Just outside of Quebec City, he writes about a system built of 38 mm (1.5 inches) clay tiles running into box collectors built of 50 mm thick wooden boards which had disintegrated by then, while the clay drains were still working. Since no one then remembered such subsurface drainage installations, Jean Ulric suggests that the system was over 100 years old and that the 38 mm tiles were likely imported from Scotland. Nevertheless, in 1849, B.F. Whartenby of Waterloo, N.Y. was selling 38 mm clay tiles for $9.00 per 330 m (1000 ft) (Weaver 1964). Jean Ulric also reports intercepting subsurface clay tiles in the Saint-Augustin region, which he observed being 'of a different shape' compared to those closer to Quebec City and likely, according to him, of Canadian origin (Ulric 1940).

THE FIRST MECHANIZED TRENCHER

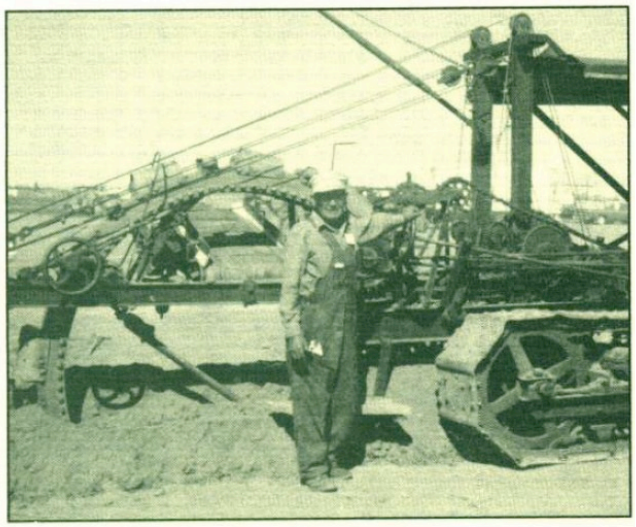
The first mechanized trencher to be purchased in Canada in 1902 was that of J.C. Jamieson of Bristol Quebec (Irwin 1989; Hamer 1911). It was a 1902 steam engine Buckeye, one of the first model sold by the Buckeye company of Ohio. J.C. Jamieson, likely a farmer, had heavily invested in this mechanical trencher because of labour shortages to install tile drains in the heavy clay soils South of Ottawa (Fig. 1). The trencher was not operated successfully until J.C. Jamieson hired a mechanically inclined operator, W.J. Tuck of Weirstead, Qc (some 10km North of Bristol, Qc).

The record installation rate of this machine in 1903 was 1120m (223 rods) with a trench depth of 0.9m (3 ft), but the average day would run between 380m and 755 m (75 to 150 rods). This translated to an average drainage rate of 0.85 ha/day at a trench spacing of 15 m. In 1910, this trencher survived driving itself to Lanark and then Perth Counties, Ontario, to do work in more stony soils, excavating stones of at least 13.6 kg (30 lbs). By 1911, there were some 700 buckeye trenchers operating in Ontario, while in Quebec, there was still the one doing work in Ontario (Hamer 1911).

THE WWI ERA OF 1909 TO 1918

In 1912, the Quebec Ministry of Agriculture purchased its very first 2 subsurface trenchers for $4667.25 (Fig. 2) and started to conduct subsurface drainage demonstrations following the preparation of plans, all this subsidized by an $8000 Federal grant (Agriculture Canada 1915; Quebec Government 1913). Under the same federal budget, Ontario received $5000, and Manitoba received $1 800. The Quebec trenchers were likely the 1908 Buckeye model with the first gasoline engine, a change from the earlier steam engine (American Society of Mechanical Engineers 1988). These 2 trenchers were delivered to St-Césaire, Qc (some 30 km South of Montréal) by Central Vermont Railways at a cost of $42.20 (Quebec Government 1913). From the expense reports produced by both the Federal and Quebec governments, Table 1 lists the farms which benefited from tile drainage in 1912-1914, and in 1915-1916. The Buckeye Company provided an expert, Mr. P. Perrin to help put the trenchers in operation (Quebec Government, 1913).

Fig. 1. The 1902 trencher of J.C. Jamieson, Bristol, QC. Photo courtesy of the O.A.C. Review. 1909. Vol 21 (No. 6) p325.



Feu Marc Poirier avec la première machine à roue qui date de 1908.

Fig. 2a. One of the 2 trenchers purchased by the Ministry of Agriculture in 1912, recovered by Marc and Marcel Poirier, drainage contractors, behind a barn in the region West of Montréal. The trencher was repaired and used for demonstrations by Marc Poirier. Photo courtesy of the Quebec Association of Agricultural Drainage Contractors (Association des entrepreneurs en drainage agricole du Québec inc. 1989).

Fig. 2b. A 2022 picture of a model 1908 Buckeye trencher likely one of the 2 trenchers purchased by the Ministry of Agriculture in 1912, recovered by Marc and Marcel Poirier, drainage contractors. This trencher is visible from highway 20 at Ste Madeleine, Qc. Photo courtesy of Normand Poirier, NMP Gold Inc.

Table 1. Farms subsurface drained by 2 Quebec Government trenchers (1912-1916).

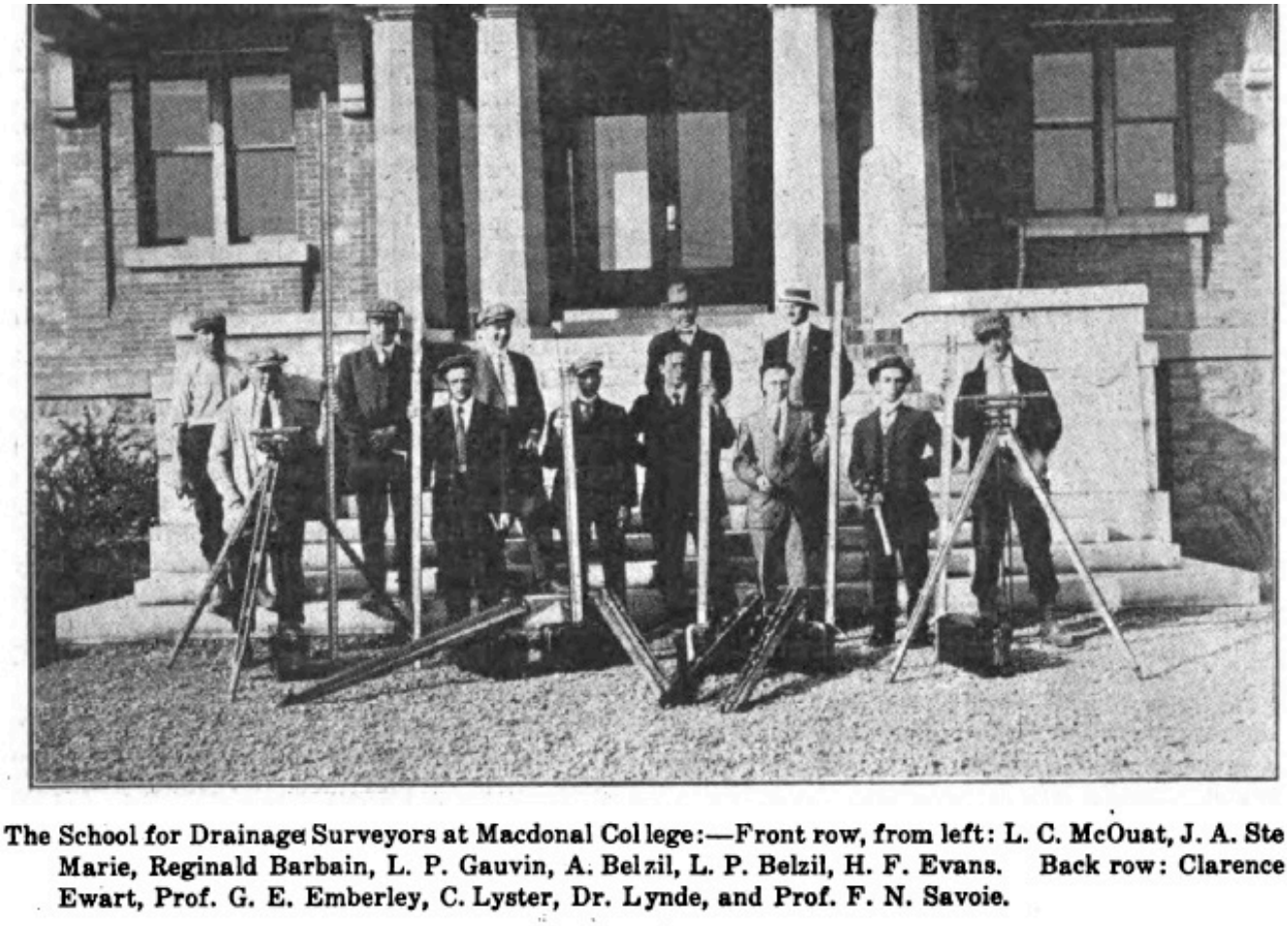
Eastern trencher		Western trencher	
1912-1914			
Region	Farms	Region	Farms
Plessisville	J.A. Savoie, Narcisse Savoie	Saint-Césaire, Champlain, Iberville and Henryville	Wilfred Giroux, Henri Cloutier, T. Phénix, Napoleon Ouimet, J.B. Saurette, Adelard Saltry, Dosyloe Leduc
Enfant-Jésus Saint-Augustin, L'Ancienne Lorette, Cap Rouge	Noel Roy Eleusippe Couture, Onesime Paquet, Pierre Beaumont Dominion experimental farm	Saint-Bruno Sainte-Anne-de-Bellevue	Farm of the Jesuit Brothers Macdonald College farm
Quebec, Charlesbourg, Montmorency	Quebec exhibition grounds H. Daigle, F.X. Gosselin, Étienne Paradis, Joseph Cloutier	Oka	Farm of the Oka Agricultural Institute, Alberto Guerri, T. Roy
Montmagny	F.X. Gosselin	Shawville	Jos. Bromby, Alex Smart, T. Smeeby, Andrew Sly, W.H. Barr, W. Hossefield, John Smaly
L'Islet	J.A. Talbot, J. E. St-Pierre, Amédée Gaudreault		
Sainte-Anne-de-la-Pocatière	Farm of the Agricultural school of Sainte-Anne-de-la-Pocatière		
1915-1916			
Sainte-Anne-de-la-Pocatière	Farm of the Agricultural school of Sainte-Anne-de-la-Pocatière	Shawville, Trout River, Beith	Name unavailable
Saint-Pascal	Saint-Pascal Domestic Science School	Huntingdon, Ormstown, Howick	H.S. Tannahill G. MacMillan John Tannahill Alex Anderson W. Rogers Geo Cottingham J.W. Logan

Ref: Agriculture Canada (1915); Quebec Government (1913); Quebec Ministry of Agriculture (1916, 1917).

The agreement with the federal government, was that these 2 trenchers would execute 2ha (5 acres) of subsurface drainage as demonstration on as many farms as possible. Along with the purchase of the trenchers, the Ministry of Agriculture had drainage plans prepared and technicians trained to carry out the drainage work. As early as 1911, Prof. C.J. Lynde of the Department of Physics of Macdonald College was responsible for the training and production of drainage plans for the Ministry of Agriculture (Fig. 3), which also included those of Sainte-Anne-de-La-Pocatière. At that time, the Drainage division of the Department of Physics of the Ontario Agricultural College in Guelph (Day 1912) was also preparing drainage plans for the Ontario Department of Agriculture since 1907. The surveyors were paid $50 monthly plus travelling expenses (Agriculture Canada 1915).

In the summer of 1912, the Ministry of Agriculture (Gigault 1912) was already advertising the services offered which consisted first, of a farm visit to provide advice: the honorariums were subsidized but the farmer had to provide room and board while at the farm. Applications for a drainage plan were made to the Department of Physics of Macdonald College. Once the plans were prepared, the farm would contact the Ministry of Agriculture which would dispatch a trencher along with a drainage technician. The farmer covered the cost of the fuel and the drainage pipe which represented 50% of the cost. With a provincial budget of $20000/year, a limited number of farms were drained annually.

In 1913, Narcisse Lavoie, professor of cereals, became responsible for drainage plans at the Agricultural School of Sainte-Anne-de-La-Pocatière and G.E. Emberley, professor of agricultural engineering, took over the job at Macdonald College. These two gentlemen supervised the work of 9 technicians who prepared subsurface drainage plans for 1 630ha (4082 acres) in 1913 (Quebec Government 1913). In 1918, the Macdonald College Department of Agricultural Engineering was founded (Snell 1963) and took over the preparation of drainage plans.



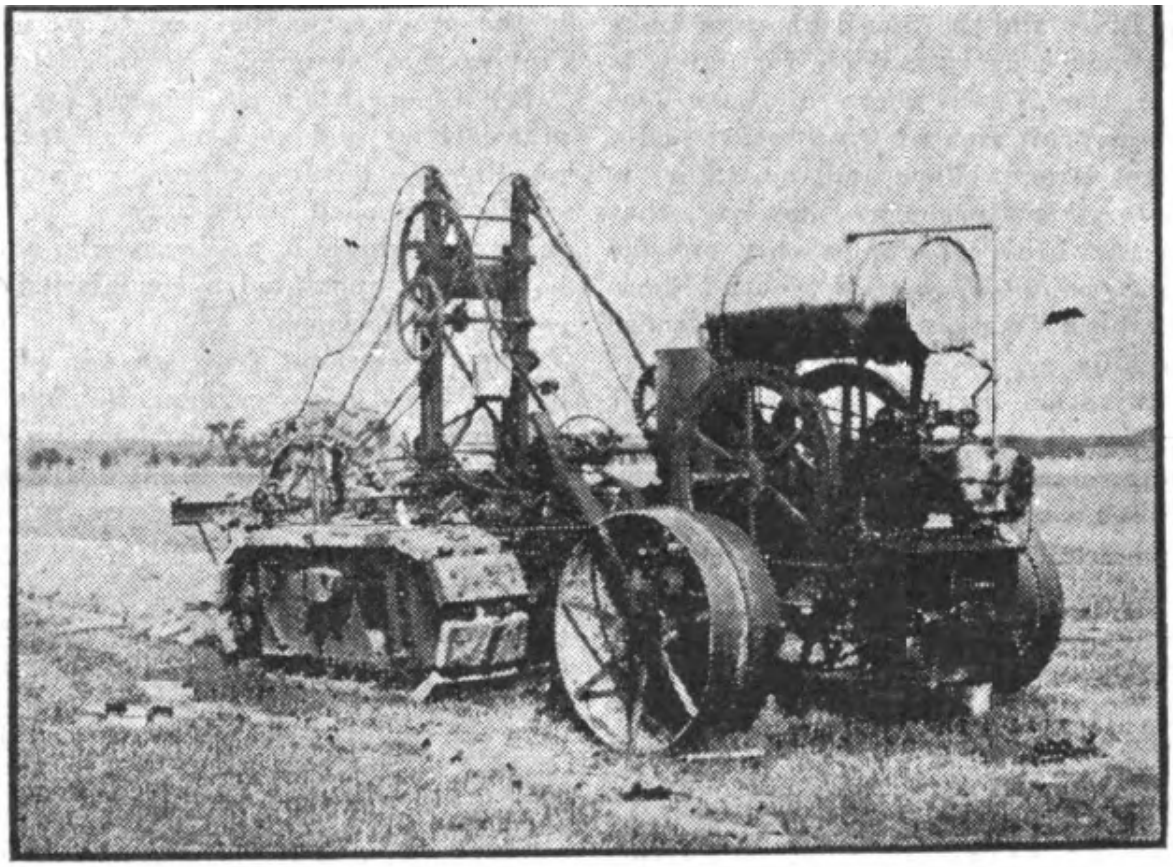
The School for Drainage Surveyors at Macdonal College:—Front row, from left: L. C. McOuat, J. A. Ste Marie, Reginald Barbain, L. P. Gauvin, A. Belzil, L. P. Belzil, H. F. Evans. Back row: Clarence Ewart, Prof. G. E. Emberley, C. Lyster, Dr. Lynde, and Prof. F. N. Savoie.

Fig. 3. Subsurface drainage training at Macdonald College (McGill University) in 1914. Photo courtesy of the Journal of Agriculture and Horticulture, June 1914, Vol 17 (No.2) page 232).

Also in 1913 to promote agriculture, including drainage, the Federal Ministry of Agriculture provided $10 000 to the Quebec Ministry to hire district agronomists: R.A. Rousseau graduate of Oka for Bagot-Drummondville; Henri Cloutier graduate of Oka for Rouville-Iberville-Sherville; J.C. Magna, graduate of Oka for Portneuf-Champlain; Abel Raymond graduate of Oka for Bellechasse-Dorchester; Alphone Roy graduate of Oka for Montmorency-Quebec (Lalonde, 1944); and J.M. Ladaire graduate of Macdonald College for l'Abitibi. Also, Macdonald College would provide representatives for the English-speaking districts (Agriculture Canada, 1915).

The two government trenchers would work all summer, usually from early May to the end of November, weather permitting. In 1915 and 1916, the Eastern trencher performed drainage works on the farms of the Saint-Pascal Domestic Science School and of the Agricultural School of Sainte-Anne-de-La-Pocatière. Founded in 1904-1905 by Reverend Alphonse Beaudet, the Saint-Pascal Domestic Science School was located 25 km East of La Pocatière and was designed to educate women because of 'the widespread ignorance of women concerning their marital and family obligations' (Hébert 2020; Lemieux 1972). The Eastern trencher was operated by John Drolet with L.P. Gauvin as instructor (Quebec Ministry of Agriculture 1916, 1917).

In 1915, the Western trencher worked in Shawville (Pontiac County), as well as Trout River and Beith (D.H. Brown – Huntingdon Gleaner 1917), Ormstown and Howick (Table 1) of the Chateauguay region West of Montreal. In 1915, both trenchers installed 15320m (50250 ft) of tile drain, while in 1916, the Eastern trencher installed 9615m (31530ft) from May 1st to October 18th, and the Western trencher installed 16130m (52900 ft) from May 1st to November 13th. The Western trencher was operated by driver Wilfrid Giroux with instructor Nolasque April. In 1916, the trenchers had lost 51.5 days in the season, because of a shortage of clay tiles. In all, both trenchers had drained 38.6 ha of land in 1916, for a drain spacing ranged between 12 and 16m and an installation depth of 0.9 m to 1.1 m (Quebec Minister of Agriculture 1916, 1917). During 1917, very little work was performed by both trencher because of poor weather, breakdowns of the trenchers with poor spare



The traction ditcher at work on the farm of Mr. W. T. Rodden, Vaudreuil. This machine digs, lays the tile and fills as it moves along.

Fig. 4. The trencher used on the farm of T.W. Rodden, Vaudreuil, in 1913. Photo courtesy of the Journal of Agriculture and Horticulture, Vol 17 (no. 9), March 1914, p. 172.

piece availability: whereas the Eastern trencher installed 2200 m of tile drain, the Western trencher installed some 3500 m. By comparison for 1909, the Buckeye trenchers were observed to dig at a rate of 450 m to 500 m (90 to 100 rods/day) in stoneless soil when no repairs were needed, or 0.75 ha/day at a spacing of 15m (Day, 1909). The selection of fields for subsurface drainage was generally limited by the presence of a watercourse deep enough to accommodate the outlet.

In 1921 and 1925 respectively, the Ministry of Agriculture received $6000 and $10000 in federal funds for drainage demonstrations. A mole drain plow was borrowed from England to test this type of drainage in the heavy clay soils along the St-Lawrence River such as in Huntingdon and Vaudreuil and some subsurface drainage work was performed using a plow and excavator (Quebec Minister of Agriculture, 1925).

As off the 1920's, the Ministry of Agriculture paid 50% of the cost of transporting clay tiles, a subsidy jumping to 100% in 1932. This budget was administered by the 'Service de la Grande Culture' (Editor 1932).

Some private contractors were also doing subsurface drainage. In 1913, Donat Raymond and William Thomas Rodden, two men of means, each purchased land in Vaudreuil to establish their own dairy farm. Whereas the cropped area of Raymondale Farm is not reported (occupied today by Cité des Jeunes and the school complex on Saint-Charles Road), it likely covered over 80 ha (200 acres), while the Rodden farm covered some 120 ha (300 acres) (Heimpel 1944; Editor 1913). Both farms had subsurface drains installed in 1913, that of W.T. Rodden at a spacing of 20 m (66 ft). The trencher used at the Rodden farm in 1913 was able to backfill after the trenching work (Editor 1913 – Fig. 4).

Drainage work slowed down after 1917 because of financial limitations imposed by WWI on both the government and the farms (Heimpel 1943b). Furthermore, subsurface drainage was facing major obstacles. The Ministry's trenchers would not drain large surfaces such as 40 ha at any one time unless the farmer paid for the trencher relocation besides the cost of $3500 for the drainage of 40 ha (Ponton 1919). In 1920, the Ministry of Agriculture produced 2 new Bills, No. 34, to allow municipalities to conduct drainage works on water courses and No. 35, to allow municipalities to borrow money for drainage works, including the lending of money to farmers for their own

surface and subsurface drainage works: the minimum and maximum amount of the 20-year loan were $100 and $1000 respectively, but could not exceed 75% of the cost (Editorial 1920). This program was seldom used as opposed to the same in Ontario (Heimpel 1943b). Finally, watercourses often lacked the depth required by subsurface drainage systems, despite excavation works conducted by the Ministry.

THE WATERCOURSE PRIORITY

From 1919 to the early 1960's, the Ministry of Agriculture continued to offer only 2 trenchers for subsurface drainage works, besides a few privately owned, at a farm cost of $75 per 1000m for the material and $30/1000m for the installation (Heimpel 1939). High immigration rates caused by WWI and WWII, and unemployment resulting from the 1930 depression, encouraged the Quebec Government to prioritized land clearing and watercourse excavation to expand its farmland and provide work (Société du patrimoine politique du Québec 2021). In 1932, the Quebec Government claimed to have established almost 50000 persons on farms over 18 months, with help of the Federal Government (Editorial 1932).

Besides contracting some work privately, watercourse priority is demonstrated by the equipment operated by the Ministry: 2 excavators in 1935, 12 by 1939 (Heimpel 1939), 20 by 1941, 29 by 1947, 37 by 1957, and 53 by 1967 (Quebec Government 1944 to 1967). Along with its excavator, the Ministry also operated up to 138 bulldozers, both on its watercourse projects and to clear and level farmland. In 1941, the 20 watercourse excavation teams were improving land at a rate of 30 ha/day. Excavation statistics are presented in Table 2.

According to Demers (1989), 5 private trenchers were in operation in 1925 besides the 2 owned by the Ministry (Fig. 5). At the end of 1928, 4400 ha (11 000 acres) benefited from subsurface drainage, for an average installation rate of 687.5 ha/yr over 16 years (Quebec Government 1929). In 1951, 2 private trenchers were in operation and most laterals were built of 100 mm clay tiles as opposed to 75 mm tiles before 1948 (Cossette 1951).

In 1929, Earl Fulford of Shawville purchased a trencher and installed some 80 km (125 ha) of drain by 1932 on 64 farms, and some 165 km (245 ha) by 1943, around Bristol and Clarendon (Gatineau region North of Ottawa). From 1929 to 1943, the Agricultural Engineering Department of Macdonald College produced some 75 drainage plans (Heimpel 1943a, 1943b). While the purchase of the trencher was partly subsidized by the Ministry of Agriculture, the full cost of the drainage plans was subsidized. Installation of tile drains was reported on the flat lands of Orval Smart of Southwest Shawville and Harold Cuthbertson on Front Road near Bristol. These drains were installed at an average depth of 0.9m (30 inches).

In 1944, Ross Clarkson of Knowlton purchased a used drainage trencher from Western Ontario, to solve drainage issues on his farm. Partly subsidized by the Ministry of Agriculture, this machine became widely used to drain the footing of hills where seepage would cause drainage problems (Heimpel 1944).

In 1941 to better control its watercourse work, the Ministry of Agriculture created 'l'Office du drainage'. Its job was to prepare plans, supervise the excavation of watercourses and help municipalities resolve disputes. David Clerk was the first President of this office besides heading the Agricultural Engineering Department of the Ministry of Agriculture (Department of Agriculture 1941).

In early 1960, work on watercourses slowed down, providing financial resources for subsurface drainage. The Ministry's 1960-1961 watercourse budget dropped to $4 million from $10.4 million for the previous year and some of the department's engineers were leaving because of a lack of work (Government of Quebec 1944 to 1967; Commission royale d'enquête sur l'agriculture au Québec 1967). Selling some of its watercourse excavators, the Ministry had to find work for its technicians.

Whereas one excavator and one bulldozer would employ two operators, a subsurface drainage team would require 12 persons, involving the plan preparation and the tile installation. Also, in early 1960's, the Agricultural Hydraulics Service decided to provide drainage at the watershed level, including not only the watercourses but also the tile drainage plans and their ditch depth requirement. This would lead to the publication of a series of reports on individual watershed during the early 1970s.

Table 2. Extent of drainage work subsidized by the Quebec Ministry of Agriculture.

Year	Watercourses			Subsurface drainage		
	Excavators**	Length installed km/yr	Spending $/yr	Trenchers**	Length installed* (km/yr)	Equivalent surface* (ha/yr)
1915			$45 000	2	15.4 km	23 ha
1928					46 km	69 ha
1935	2	490 km	$163 000	2	135 km	
1940	12	610 km	$505 000	2	180 km	270 ha
1950	29	750 km	$3.9 million	2	210 km	315 ha
1960		1570 km	$10.4 million			
1965	53		$0.4 million	6	915 km	1370 ha
1967				17	1525 km	2 300 ha

*Includes that installed by private trenchers. **Government owned. Ref: Quebec Government (1914 to 1947); Editor (1931); Fisk (1971); Le Canadien-Francais (1941); Cossette (1951).

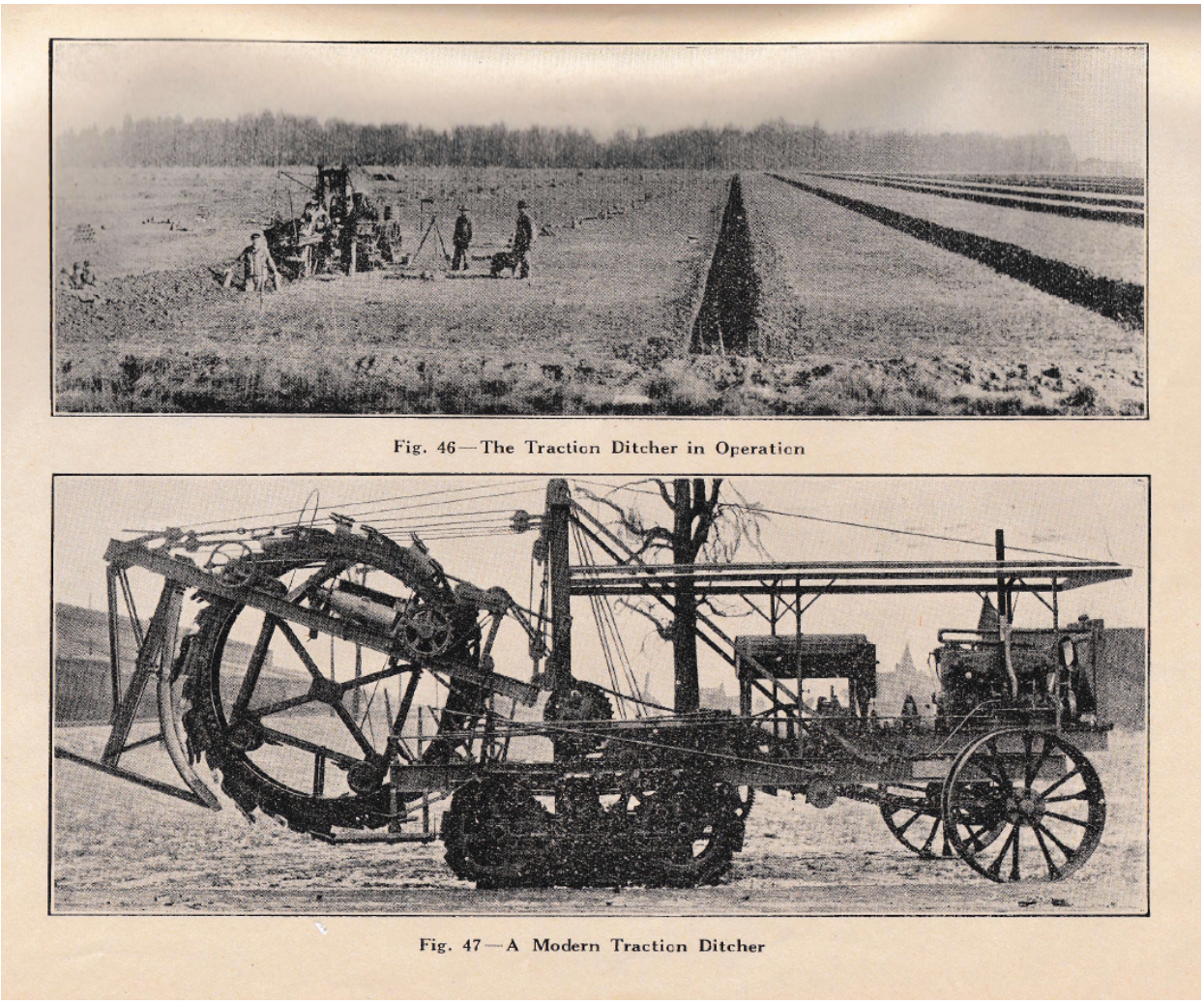


Fig. 46—The Traction Ditcher in Operation

Fig. 47—A Modern Traction Ditcher

Fig. 5. Subsurface drainage work in 1925. The excavation mechanism of the Buckeye trencher remained basically the same over the years: the only change was the size and capacity of the motor. Photo courtesy of Department of agriculture of the province of Quebec. Ref: Heimpel and North (1925).

In 1965, the Quebec Ministry of Agriculture had 6 tile drainage excavators, purchased 3 more in 1966 and 5 more in 1967, with 3 being retired in 1966, as 9 excavators remained in operation (Government of Quebec 1944 to 1967; Commission royale d'enquête sur l'agriculture au Québec 1967) (Fig. 6). In 1967, the Ministry had purchased even more trenchers to operate 17 (Fisk 1971). Whereas in 1966, 2 trenchers were operated privately, by 1970, the number had jumped to 18 (Fisk 1971).

In 1966, some 16 800ha (42 000 acres) benefited from subsurface drainage in Quebec (1.33% of land requiring subsurface drainage), the surface jumping to 43 000 ha by 1970 (Fisk 1971). The farm cost of a subsurface drainage system was still in the range of $250/ha, with the government subsidizing the other $250/ha.

Before the mid 1960's, all installation used clay tile which required much labour. In 1966, Robert Broughton of the Agricultural Engineering Department of McGill University imported plastic drains from the Netherlands for testing at the Macdonald Campus farm (Broughton 2011). The Quebec Ministry of Agriculture reported in 1967 that plastic drains were being tested at the experimental farms of Sainte-Anne-de-La-Pocatière, Saint-Hyacinthe, and Lac-Saint-Jean, besides some tile drainage research being conducted at the agricultural school of Sainte-Martine (35km West of the Island of Montreal) (Government of Quebec 1944 to 1967; Cossette 1965). Introducing the plastic drain allowed for the installation of 6km of subsurface drain in 8hr by one trencher, whereas with clay tiles, the installation rate was of the order of 1km/8hr (Broughton 2011). In 1970, two plastic drain manufacturers were in operation in Quebec.

Finally, a special report produced in 1967 (Commission royale d'enquête sur l'agriculture au Québec. 1967) justified the acceleration of subsurface drainage installations in Quebec, a rate which would peak by the early 1980's.

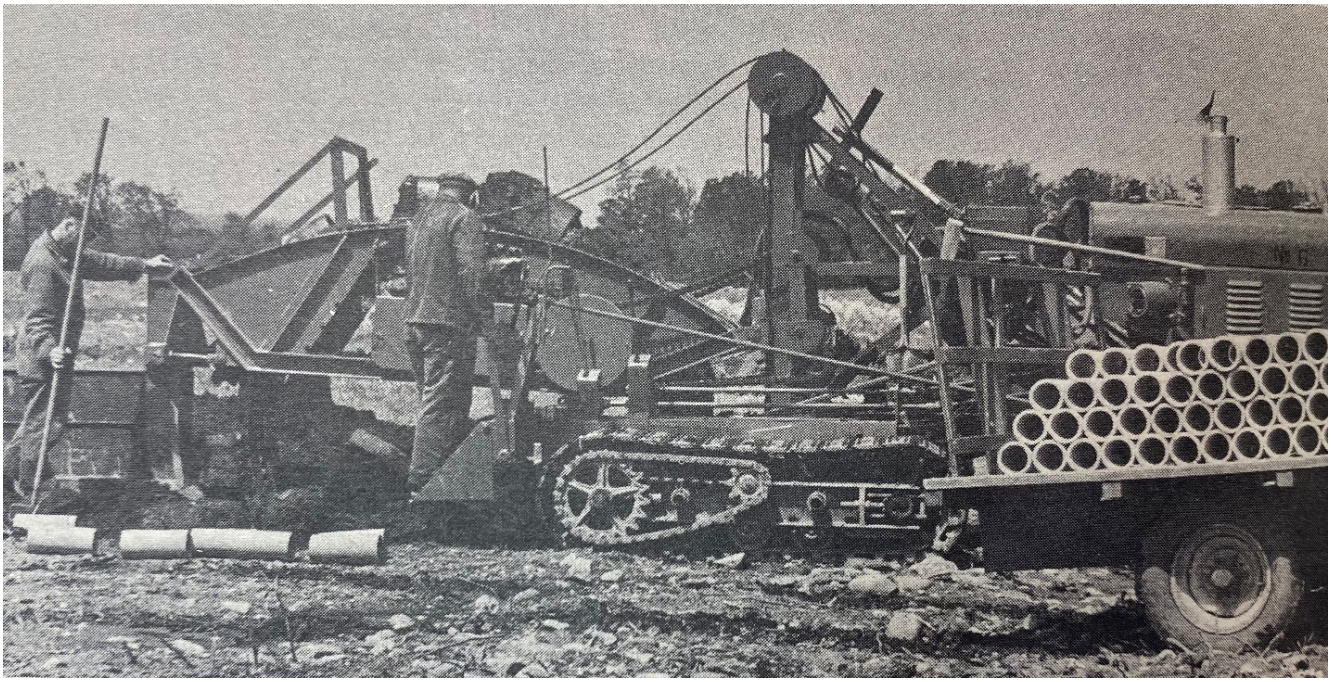


Fig. 6. Subsurface drainage work in 1961. Photo courtesy of Le Bulletin des agriculteurs. Ref: Cossette (1961).

CLAY TILE MANUFACTURING 1900'S

Clay tiles were being produced in Quebec at the time of purchase of the 2 Buckeye trencher in 1912. In Pointe Claire, the Terra Cotta Company operated from 1912 to 1962 (Pointe Claire 2020). Clay tiles produced by Briques Citadelles of Boischatel (near Montmorency Falls) were used for the subsurface installations on the farm of John Logan, Howick, in November 1916, tiles with an inside diameter of 95 mm (3.75 in): Briques Citadelles was in operation from 1913 to 1966. The W. & D. Bell enterprise of Quebec City was mentioned earlier. In 1921, the Quebec Ministry of Agriculture helped establish a clay tile manufacture in l'Islet, as major construction works after the war were creating clay tile shortages (Ponton 1921).

By 1926, the main clay tile drainage producers were: Terra Cotta of Pointe-Claire; National Brick of Laprairie; Citadel Brick of Boischatel; La Cie de tuyaux de drainage Ltée, l'Islet Station; Standard Clay Products Cie, St-Jean-sur-Richelieu; G.H. Farrar of Iberville, and; W. & D. Bell of Quebec City (Department of Colonization, Mines and Fisheries 1927).

During 1939, some 169km of clay tiles was sold for subsurface drainage projects, Citadelle of Quebec City providing 96km, Olivier Bégin de Petite Rivière providing 45 km, David-H. Hodgins of Shawville providing 16 km and Brique Lobtinière of Deschaillons providing 12 km. Per 1000 m, the 75 mm tiles were sold for $65 to $100, the 100 mm tiles sold $80 to $130, the 125 mm sold for $115 to $150 and the 150 mm sold for $150 to $200 (Ulric 1940). In 1951, the price of 100 mm clay tile had increased to $180/1000 m (Cossette 1951).

The maximum diameter of the clay tiles was limited to 150 mm because of its capacity to withstand soil pressures (Broughton 2022). The extrusion process required pressurizing a clay paste through a circular mold with the central part held in place by means of four wires. Accordingly, the clay paste had to fold back into place after these wires, which created a weak point in the tile. Because buried tiles are exposed to uneven soil pressure, high pressure or poor extrusion would 'quarter' the tile with time, in other words break the tile especially at the seam caused by these support wires. Accordingly, for collectors larger than 150 mm, cement tiles were used (Smith 1916).

THE DESIGN OF DRAINAGE SYSTEMS

Whereas the very first North American underdrainage guide was written by John H. Klippart of Ohio in 1861, the likely first Canadian Guide was written in 1913 by G. Michaud, of Lac-Saint-Jean (Michaud 1913), published by the Quebec Ministry of Agriculture. Michaud had recommended some land levelling be done before installation to eliminate minor depressions and high spots. Systematic subsurface drainage systems were recommended, if it was adapted to the general slope of the land. Tile spacing recommendations ranged from 20m to 33m for light soils, 15 m to 18 m for average soils and 7.6 m to 9.5 m for clay soils. For slopes under 4%, drain depth was less than 0.9 m (3 ft), otherwise, the depth would exceed 0.9 m. A minimum drain slope of 0.167% was recommended (2 inch per 100 ft) for 75 mm drains, and 0.04% for 150 mm drains (0.5 inch per 100ft). Nevertheless, maximum slopes of 4% and 1.3% were recommended for 75 mm and 150 mm drains respectively. Lateral built using 75 mm drains was accepted, but 100 mm drains were

preferable considering the wet climate of Quebec. This reference produced a table recommending drainage areas for 75 mm and 100 mm drains, as a function of slope, according to 'McConnell' which Michaud did not reference McConnel. Nevertheless, the likely reference was the Handbook produced by Primerose McConnel of the United Kingdom (McConnel 1910).

In 1910, McConnel recommended very close spacings for the UK, such as a spacing of 3.6 m and 5.0 m at a depth of 0.75m for soft clays and silty clays, respectively. Michaud's spacing recommendation of 7.6 m to 9.5 m was better adapted to the climate of Eastern Canada and an affordable cost of installation.

The other interesting fact is that G. Michaud was most likely an immigrant from Belgium who had settled in the Lac Saint Jean area. Some 7020 and 11687 Belgium immigrants had settled in Quebec from 1901 to 1910 and 1910 to 1920 respectively (Jaenen 1991). Michaud would always sign off as ingénieurs agronome, a title used by graduated of high-level universities in French Europe. At the end of the 19th century, in Western Europe, there were two main schools of farmland drainage: Lézardeau in the French Finistère (Northwestern France) and l'Institut Agricole de Gembloux (1860-1910) in Belgium, teaching hydraulics, drainage and irrigation under the option of agricultural engineering. Michaud wrote a few articles on farmland management for *Le Progrès du Sagnenay*, such as in 1913 on the spreading of manure (Michaud 1913), and in 1914 (Michaud 1914) on the economic analysis of subsurface drainage. In 1923, G. Michaud wrote an article for *Le Bulletin des agriculteurs* on a new form of credit in Switzerland, as the Secretary of the *Union centrale des producteurs suisses de lait* (Michaud, 1923).

In the early 1910's, the 100 mm diameter drain was preferred to that of 75 mm, likely based on observations reported in 1916 for Iowa flat lands. In this state, the 75 mm tile was no longer recommended around 1885, while the 100 mm was the size used in Illinois and Iowa, with the 125 mm preferred for large surfaces. The collectors were selected based on surface drained and tile slope. For a 0.167% slope, a 200 mm tile is said to drain 16ha, a 150 mm for 6.4 ha, a 125 mm for 4 ha and a 100 mm for 2.4 ha (Smith 1916). This same article stated that larger surfaces can be drained by 100 mm tiles but under rolling lands where surface drainage plays a greater role.

In 1925, a new document was prepared to support subsurface drainage spacing and depth for Quebec (Heimpel and North 1925), based on observations by the authors and by other at the Ontario College of Agriculture in Guelph. Lateral depth of 0.9m to 1.2 m was no longer recommended: in clay soils, 0.6 m was the minimum recommended, as opposed to 0.6 m to 0.75 m for lighter soils. In clay soils, drains at a depth of 0.6m to 0.75 m were observed to produce a water table rise was 0.3 m over a distance of 3.3 m to 7.6m: thus, the maximum spacing recommended for clay soils was 12 m to 18 m. For clay loams, with drains at a depth 0.7 m to 0.9 m, the maximum spacing was 21 m (70 ft). In light soils, with drains at a depth of 0.9 m to 1.05 m, the recommended spacing was 33 m (100ft). A drain collector was also preferred, although increasing the cost of the system, because it limited the number of drains running into the ditch for less risk of blockage: the outlet was built of material resistant to frost, such as of concrete, wood, or metal. Generally, systematic 100 mm laterals and 150 mm collectors were used in drainage plans.

In 1927, the experimental farm of Agriculture Canada in Ottawa was suggesting a tile spacing of 9m for heavy clay soils (Hopkins and Hooper 1927). Based on research conducted in the US, the Agricultural Institute of Oka was recommending the following (Fontaine, 1930). First, a ditch at least 1.2 m deep was required and maintained as emissary. Second, a 100 mm or 150 mm drain collector was used at a depth of 0.9 m (3 ft) to collect the water from lateral drains, and its diameter depended on the surface area drained and its slope; the collector's minimum slope was 1.25 m to 1.67 m per 1000 m and its outlet should be at least 150 mm above the ditch bottom. Third, the laterals were of 75 mm (3inches) clay tiles and installed slightly shallower than the collector, rather between 0.75 and 0.6 m (2.5 and 2.0 ft), with a minimum depth of 0.6m protecting the drain against frost. The recommended spacing for clay soil was 7.6 m to 10.7m (25 to 35 ft) whereas for lighter soils, the spacing can be increased but the maximum recommended was 22.9 m (75 ft). The maximum length of the laterals was 305 m (1000ft). The cost of subsurface drainage was of the order of $100/ha ($40/acre) but could reach $190/ha ($75/acre) in clay soils where the laterals were closer.

In the early 1950's, the US Bureau of Reclamation started to develop mathematical methods to calculate water table drawdown based on the properties of the soil profile (TeKrony et al. 2004). By 1966 in Quebec, two researchers became involved in the promotion and design of subsurface drainage systems: Pierre Jutras, one of the first agricultural engineer in Quebec (B. Sc. in Agriculture at McGill University and an M. Sc. at the University of Maine) was stationed at Laval University, and; Robert Broughton, chair of the Department of Agricultural Engineering at McGill University. Pierre Jutras was mostly involved with training and extension to promote subsurface drainage, being involved in conducting the 1967 enquiring for the Quebec Ministry of Agriculture (Temple de la renommé de l'agiculture du Québec 2002).

From his start at Macdonald College in 1962, Robert Broughton was more interested in researching the performance of subsurface drainage especially for the Saint-Lawrence lowlands (Broughton, 1972; Broughton 2011). With his graduate students, Robert Broughton conducted field testing to: establish the optimum use of surface and subsurface drainage techniques; test and develop plastic drains of larger diameter capable of withstanding soil pressures, and; improve the performance of subsurface installation equipment. With Laval University as off 1966, Gilbert Sylvestre was also performing similar research. The rest if present history and out of scope of the present paper.

CONCLUSIONS

The objective of the present paper was to trace the development of subsurface drainage since its very beginnings in the 1870's. Although Quebec had a very early start in Canada, in terms of subsurface drainage, by purchasing the very first trencher in 1902, it soon took a second stage behind Ontario, mainly to develop farmland in its territories of l'Abitibi, Timiskaming, and la Gaspésie. The reason for this, was to provide employment after WWI and WII for immigrants and returning soldiers, as well as during the 1930 depression. Although the private sector did provide some services along with the two trenchers of the Quebec Ministry of Agriculture, only 16 800ha had benefited from the technology by 1966. Nevertheless, a major program was initiated to broadly encourage subsurface drainage in 1967, following a major study by the Quebec Ministry of Agriculture, the scope of which ends the present historical development.

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