The First Canals

Our previous papers looking at early canals and navigations, focused on developments in Britain and Ireland[1]. While these papers acknowledge earlier developments in Europe and elsewhere, they did not go into any detail. The objective of this paper is to fill in some of those gaps, and looks at the first few thousand years of canal development in Europe, Asia and elsewhere.

Canal construction is an interesting branch of both engineering and project management. From the engineering perspective, planning a route that works (water flows in the right direction at the right speed), retaining the water within the canal and overcoming natural obstacles indicates a degree of sophistication. From a management perspective organising the 100s, or 1000s of people needed for the work and ensuring the work is done correctly is a significant exercise in organisation, logistics and control. As with most early projects, there's scant information on how this was accomplished, but the results are self-evident[2].

Canals have been excavated and used for drainage and irrigation for thousands of years. But for most of this time, the use of canals was restricted to relatively flat areas with good water supply. It was the advances in technology in the Middle Ages that allowed canals and navigations to overcome the problem of hills, resulting in canals becoming a major form of transport. This evolution of the technology that facilitated this is discussed in ***Early Canals, The Evolution of the Technology***[3]***,*** this paper focuses on where and when the canals were built.

Inland waterways have always tended to serve multiple purposes (drainage, irrigation, trade, defence, etc.), and from earliest times many drainage and irrigation canals were also used for trade (boats were far more efficient than wagons for moving goods) and a few of the canals were built specifically for commerce. This continued through to the fall of the Roman Empire, when canal building In Europe appears to have lapsed.

The building of canals and improvements in river navigations was revived by the commercial and economic expansion of Europe in the 12th century. River navigation was considerably improved, and artificial waterways were developed with the construction of stanches, or flash locks, in the weirs (dams) of water mills and at intervals along the waterways. Then, because shipping was handicapped where barges had to be towed over the weirs with windlasses or manually, the lock and lock basin were evolved to raise boats from one level to another.

Finally, the development of the mitre lock, a double-leaf gate the closure of which formed an angle pointing upstream, heralded a period of extensive canal construction during the 16th and 17th centuries.

Ancient Canals

Most of the improvement of rivers and construction of artificial waterways in antiquity was for irrigation purposes. The oldest-known irrigation canals were built for in Mesopotamia, most likely by the early

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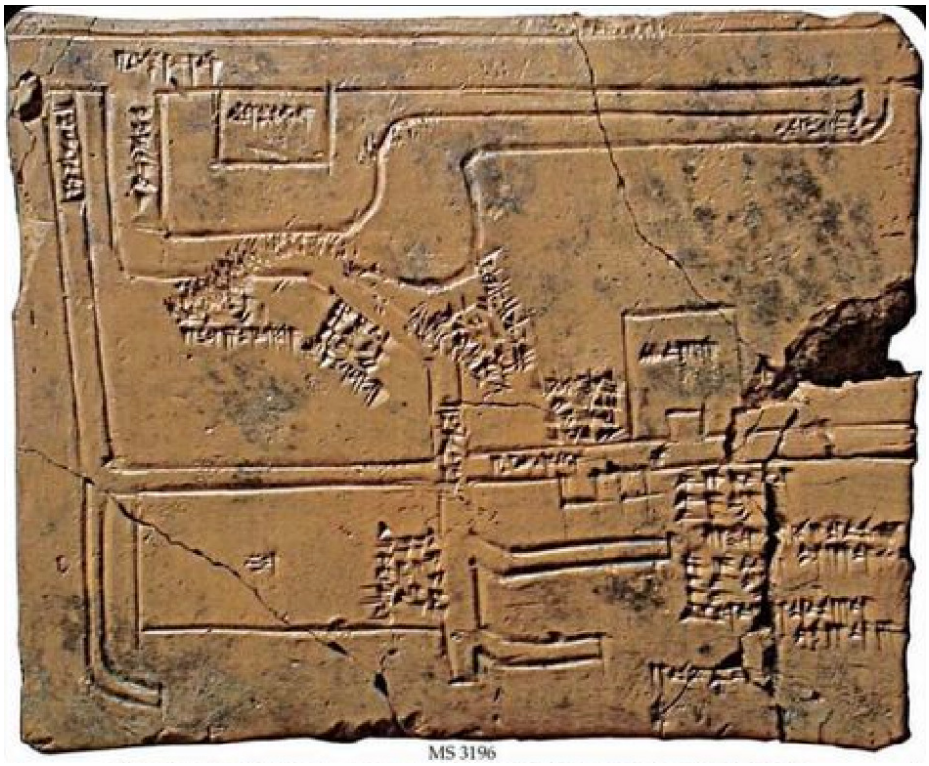
1 These papers can be downloaded from ***The evolution of construction management - Transport projects***: https://mosaicprojects.com.au/PMKI-ZSY-005.php#Process2

2 For more on ***The evolution of management and project management*** see: https://mosaicprojects.com.au/PMKI-ZSY-005.php#Overview

3 See ***Early Canals, The Evolution of the Technology***: https://mosaicprojects.com.au/Mag_Articles/AA035_Early_Canals_The_Technology.pdf

Samarra Culture from circa 5,500 to 4,800 BCE. This period partially overlaps with Hassuna and early Ubaid cultures, which were the precursor to the Mesopotamian culture of the Ubaid period[4], all of which built canals. The Phoenicians, Assyrians, and Egyptians also constructed elaborate canal systems.

Using canals was an essential part of the civilizations of the 'fertile crescent', controlling the water of the Euphrates, the Tigris, or the Nile to reduce flooding and irrigate crops. In Mesopotamia, several canals link the Euphrates and the Tigris, and small boats used these waterways for trade. This practice continued for millennia and many elaborate canals are known to have been built in Babylonian period.



Map of canals and irrigation systems west of Euphrates, Babylonia. 1684 – 1647 BCE

Canals also acted as aqueducts, in the 7th century BCE the Assyrian king Sennacherib built a stone-lined canal 80 km (50 miles) long and 20 metres (66 feet) wide to bring fresh water from Bavian to Nineveh in modern day Iraq. The work, which included a stone aqueduct 300 metres (330 yards) long, was constructed in one year and three months, according to a plaque that survives on the site. Surprisingly advanced techniques were used, including a dam with sluice gates allowing regulation of the flow of the water stored.

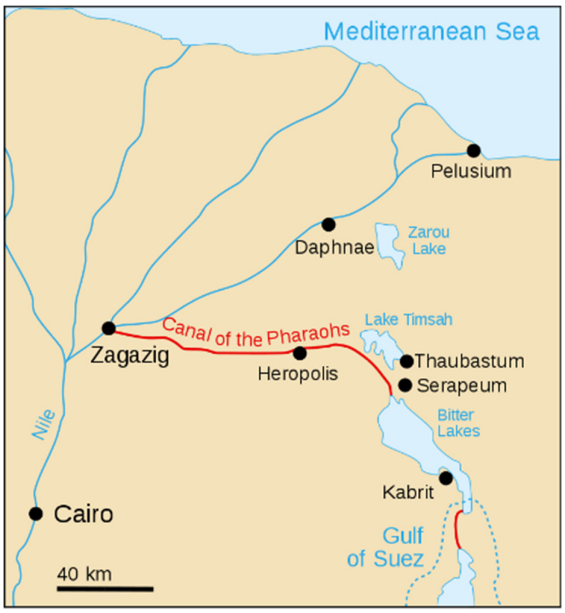
Canals continued to be built in the area, The most spectacular canal from the 6th century CE was probably Nahrawān, 122 metres (400 feet wide) and 322 km (200 miles) long, built to provide a year-round fresh water to the Abbasid capital of Baghdad, as well as a navigation channel from near Sāmarrāʾ to Al-Kūt, this canal fell into disuse in the 10th century CE.

[4] Similar developments occurred in the Indus Valley Civilization in Pakistan and North India from circa 2600 BCE.

The great canal of Darius I: 6th century BC

In Egypt the Nile floods were controlled by an extensive system of basin irrigation where flood waters were held in a basin until the soil was thoroughly irrigated, then released and crops planted. The earliest reference to irrigation in Egyptian archaeology has been found on the mace head of the Scorpion King, which has been roughly dated to about 3100 BC.

More relevant to this paper, the world's first canal created purely for water transport was constructed in the 6th century BCE when the Persian emperor, Darius I, built a canal linking the Nile and the Red Sea. The canal was probably first cut or at least begun by Necho II (r. 610–595 BC), in the late 7th century BC, and it was either re-dug or possibly completed by Darius the Great (r. 550–486 BC). Classical sources disagree as to when it was finally completed. The canal was closed in 767 CE, and a direct sea route between the Mediterranean and the Red Sea was not reestablished until the opening of the Suez Canal in 1869.



The Romans

The Romans were responsible for very extensive systems of river regulation and canals in France, Italy, the Netherlands, and Great Britain primarily for military logistics. The legions in Gaul canalized one of the mouths of the Rhône River to protect their overseas supply route. In the 1st century BCE the Roman consul Marcus Livius Drusus dug a canal between the Rhine and IJssel rivers to relieve the Rhine of surplus water, and the Roman general Corbulo linked the Rhine and Meuse with a canal 37 km (23 miles) long to avoid the stormy North Sea passage along the coast from Germany. Attempting to reclaim the Fens in England, the Romans connected the River Cam with the Ouse by a 13-km (8-mile) canal, the Nene with the Witham by one 40 km (25 miles) long, and the Witham with the Trent by the Fosse Dyke (ditch), which is still in use.

Chinese Developments

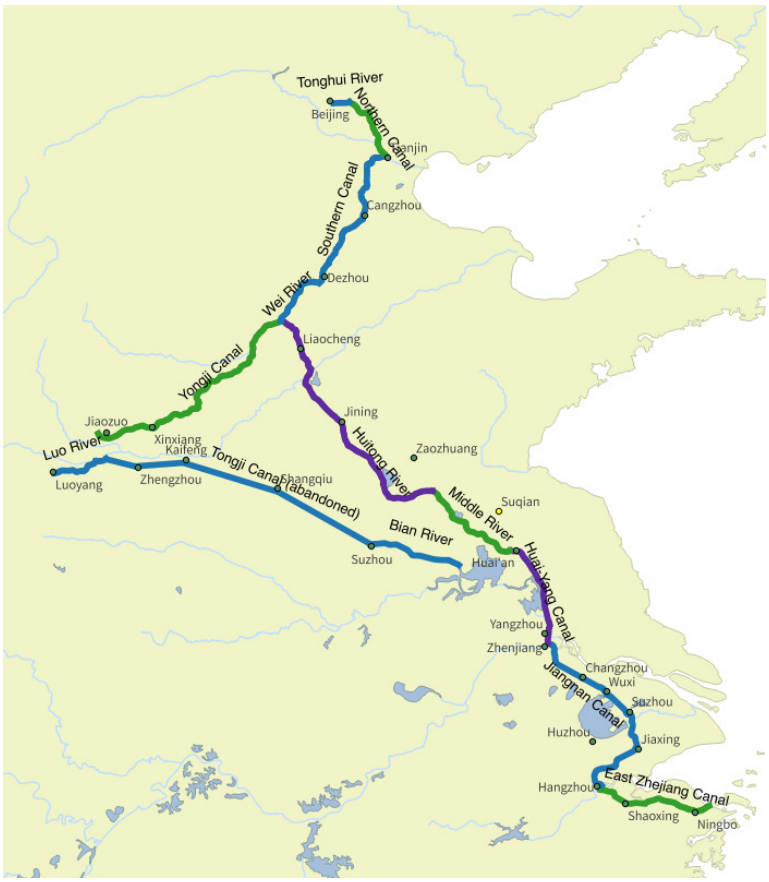
The largest canal from antiquity is the Grand Canal in China. This started as a series of connected canals, rivers, and lakes. The two oldest sections are the Han or Hangou Canal, and the Hong Canal.

Work began on the Han Canal in 486 BCE, from south of Yangzhou to north of Huai'an in Jiangsu. Within three years the Han Canal had connected the Yangtze with the Huai River.

Work on the Hong Canal most likely preceded it, modern scholars consider its construction to be in the 6th century BCE. It links the Yellow River near Kaifeng to the Si and Bian rivers and became the model for the shape of the Grand Canal in the north.

Other early Chinese canals include the Ling Canal in Guangxi, southeastern China, constructed to connect the headwaters of the Xiang River, flowing north into Hunan province, with the Li River, and the Bian Canal in Henan.

Developments and enhancements have been continuous. The construction of the 'grand canal' began in 605 CE. This waterway is 1794 kilometers (1115 miles) long and was built to carry the Emperor Yang Guang between Beijing and Hangzhou as well as facilitating trade, taxation and internal control of the country. The first 966-km (600-mile) section was opened to navigation in 610 CE. This waterway enabled grain to be transported from the lower Yangtze River (Chang Jiang) and Huai River valleys to Kaifeng and Luoyang.



These canals had easy gradients (changes in water levels). At about 5-km (3-mile) intervals there were single gates of stone or timber abutments with vertical grooves up or down along which the log closure was manually hauled by ropes to hold or release the water, thus controlling the water level. A few more elaborate gates had to be raised by windlasses. Where water level changes were too great for such simple devices, double slipways were built and vessels were hauled up the inclines[5].

Between 1280 and 1293 the 1,126.5-km (700-mile) northern branch of the Grand Canal was built from Huai'an to Beijing. One section, crossing the Shandong foothills, was in effect the first summit-level canal that rises to the top of a hill, and then falls down the other side. This change in levels was facilitated by the use of locks, invented in China in 984 CE. As part of this development, the Huang He (Yellow River) was linked with a group of lakes about 161 km (100 miles) south, where the land rose 15 metres (50 feet) higher, and, to overcome water lost through operation of the lock gates, two small rivers were partially diverted to flow into the summit level.

Early Italian Developments

Canals and river navigations have been built in Italy since Roman times but developments largely stopped following the fall of the Roman Empire in the 5th century. One city to restart the canal building in 15th century was Milan (some 300 years before the canal boom in the UK[6]), some of the early canals built at this time include:

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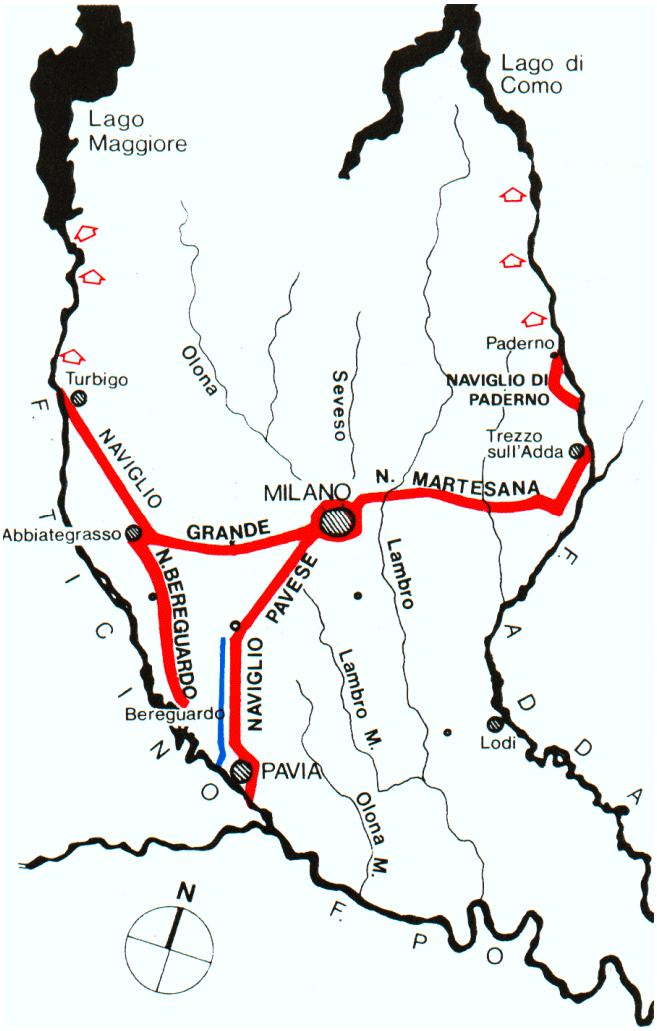
[5] See ***Early Canals, The Evolution of the Technology***: https://mosaicprojects.com.au/Mag_Articles/AA035_Early_Canals_The_Technology.pdf

[6] Canal construction in the UK started in the middle of the 18th century, see ***Cost Overruns on Early Canal & Railway Projects***: https://mosaicprojects.com.au/PDF_Papers/P207_Canal+Wagonway_Cost_Overruns.pdf



Naviglio Grande

The Naviglio Grande was the most important of the Milanese "navigli". Probably originating as a ditch dug in 1157 between Abbiategrasso and Landriano as a defense against Frederick Barbarossa, it was one of the largest medieval engineering projects. Initially built as a water-supply canal, it was also used for carrying stone needed for building the cathedral of Milan from the quarries and over time allowed development of commerce, transport, and agriculture.

Construction began near Tornavento in 1177, but problems stopped work almost immediately. Then in 1179, a dam was constructed and water from the Ticino was directed towards Turbigo and work continued. In 1258, the Naviglio Grande reached Milan. New taxes were levied to continue the digging, and although the work stopped again following opposition from the citizens and clergy, the whole canal was navigable from 1272, when the deepening and widening of the canal bed was completed by Giacomo Arribotti and the canal reached the bridge of Sant'Eustorgio (now Porta Ticinese). From the intake on the Ticino River, there is a fall of 33.5 metres (110 feet) in 50 km (31 miles) to Abbiategrasso and Milan, the water level being controlled by sluices.

A single lock (also known as a staunch lock) with vertically lifting gates was built in 1438. When Leonardo da Vinci became ducal engineer in 1482, he reconstructed the Naviglio Grande, building six locks to manage the changes in level. In 1487, the canal was linked with the old moat surrounding the city at San Marco. The pound lock at the junction had vertically hinged mitre gates, the first use of this important development[7].

Naviglio di Bereguardo,

This was the first canal in Europe to use a series of pound locks (locks with gates at both ends) to overcome a large change in elevation. When Bertola da Novate became ducal engineer to Milan in 1451, he was asked to construct a canal link with Pavia. His canal, from Abbiategrasso on the existing Naviglio Grande to Bereguardo, terminated just short of the Ticino River when he stopped in 1458. This meant goods had to be ported a short distance to complete a journey from Milan to Pavia. The Bereguardo Canal was 19 km (12 miles) long and had a fall of 24 metres (80 feet), a difference in elevation overcome by 18 locks.

[7] For more on the miter lock gate see ***Early Canals, The Evolution of the Technology***: https://mosaicprojects.com.au/Mag_Articles/AA035_Early_Canals_The_Technology.pdf

Naviglio Martesana

Bertola also built the Martesana Canal to the Adda River east of Milan. The history of this canal begins on June 3, 1443, the date of a document by Filippo Maria Visconti, Duke of Milan, approving the ambitious project. However, because of the political situation of the time, nothing happened until 1457, when design work started. The project was seen as being of great public benefit, so the project was modified to put it into a wider context giving the city of Milan a water connection to the Rivers Adda and Ticino. It was constructed by the engineer Bertola de Nova (1410–75) and inaugurated in 1465 by Bianca Maria Sforza. When fully opened in 1470, it had two locks and the earliest known canal aqueduct.

Naviglio Pavese

The Naviglio Pavese is 33 km (21 miles) long and connected the city of Milan to Pavia, and through a flight of six locks to the River Ticino. Construction started in 1564, but was interrupted 20 years later just outside Milan due to technical problems: the lock there is still called Conca Fallata, which in Italian means 'Failed Lock'. Building resumed at the beginning of the 19th century and was completed in 1819.

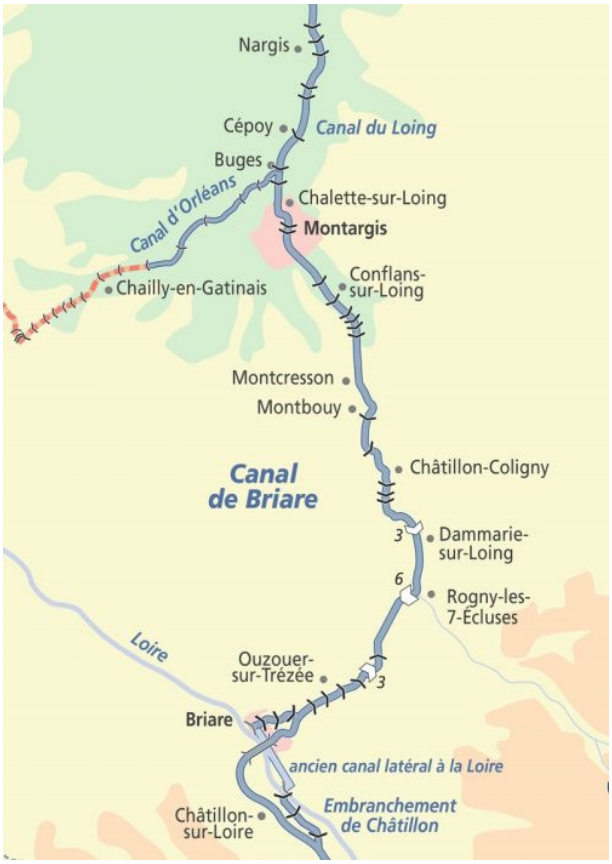
Early French Developments

Briare Canal

The Briare Canal is one of the oldest canals in France, connecting the Rhone-Saône and Seine valleys. Its construction started in 1604 and was completed in 1642. Between 6,000 and 12,000 labourers worked on this canal.

The Briare Canal was the first summit level canal in Europe that was built using pound locks. It is 57 kilometres (35 miles) long and is now part of the Bourbonnais route from Saint-Mammès on the Seine to Chalon-sur-Saône on the Saône. From Briare to Buges, the canal rises some 41 m (135 ft) through the first 12 locks, and then falls 85 m (279 ft) through the remaining 24 locks.

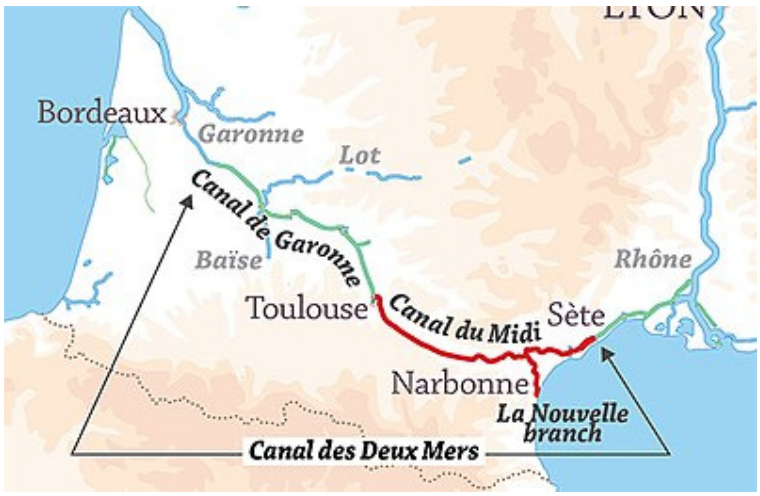
The canal was initiated by Maximilien de Béthune, duc de Sully, with support from Henry IV in order to develop the grain trade, and to reduce food shortages. Hugues Cosnier obtained the contract to build the canal. After Henri IV's assassination, Cosnier had to give up work in 1611. In 1638, Guillaume Boutheroue and Jacques Guyon applied to resume work, and received letters patent from Louis XIII for this purpose. They created with other nobles the Compagnie des seigneurs du canal de Loyre en Seine and work was completed by 1642.



Reservoirs were dug to supply the approximately 2000 cubic meters of water displaced at each lock. They include the reservoirs of Turfs, Chesnoy, Grand-rû, Tilery, Du Chateau, Cahauderie, Beaurois, the Bourdon

reservoir, and the Moutiers reservoir on the Loing. The original source of water was the Étang de la Gazonne. This canal is still in operation.

Canal du Midi



The Canal du Midi is a 240 km (150 mile) long canal in Southern France, and is considered one of the greatest construction works of the 17th century. The canal connects the Garonne River at Toulouse, with Les Onglous, Marseillan, on the Mediterranean, where the canal opens into the étang de Thau (between Agde and Sète).

The Canal du Midi forms part of the larger Deux-Mers canal project joining the Mediterranean and the Atlantic. Initially, the Canal du Midi joined the Garonne River which was more-or-less navigable between Toulouse and Bordeaux. Later the Garonne Lateral Canal was built to improve navigation to Bordeaux, before joining the Garonne estuary, and the Atlantic.

The canal was built during the reign of Louis XIV with the aim of developing the wheat trade. Jean-Baptiste Colbert authorized the start of work in October, 1666, and construction lasted from 1666 to 1681 under the supervision of Pierre-Paul Riquet. One of the key challenges was to supply water to the summit levels. This was accomplished by a feeder canal from the Montagne Noire (Black Mountains) to the Seuil de Naurouze, the highest point of the canal.

The canal rises 57.18 metres (187.6 ft), over a distance of 52 kilometres (32 miles), from Toulouse to the summit level at an altitude of 189.43 metres (621.5 ft), where the feeder canal enters. It then falls to sea level over the remaining distance of 188 kilometres (117 miles) from Naurouze to Les Onglous on the Étang de Thau.

Joining the Canals

France's integrated canal network is largely the result of a plan proposed by Francois Becquey, he originally conceived his plan in 1820-22 which resulted in the government paying a steep price to a handful of financial consortia to take over the existing canals and assume all the risks and costs of building and operating the canal system.

Under this plan, France took the lead in integrating its national waterway system by forging the missing links[8]. In the north the Saint-Quentin Canal, with a 5.6-km (3.5-mile) tunnel, opened in 1810, linking the North Sea and the Schelde and Lys systems with the English Channel via the Somme and with Paris and Le Havre via the Oise and Seine. In the interior the Canal du Centre connected the Loire at Digoin with the Sâone at Chalon and completed the first inland route from the English Channel to the Mediterranean; the

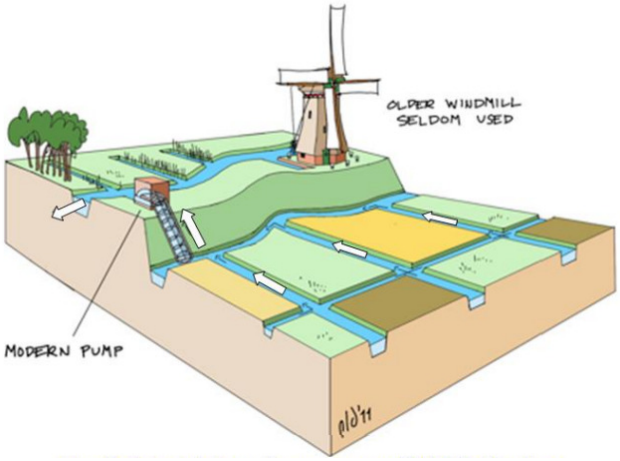
[8] The UK used a different approach, the legislation approving each canal required interconnectivity and allowed any boat owner to navigate on any canal for a set fee. Canal companies were prohibited from owning canal boats.

Sâone and Seine were linked farther north to give a more direct route from Paris to Lyon; the Rhine-Rhône Canal, opened in 1834, provided a direct north-to-south route; while the Sambre-Oise Canal linked the French canal system with the Belgian network via the Meuse. Toward the end of the 19th century, France embarked on the standardization of its canal system to facilitate through communication without the need for transshipment. The ultimate result was a doubling of traffic between the opening of the century and World War II.

The French canal building started some 150 years before the start of the UK canal boom[9] and transport of cargos by water remains an important part of the French transportation systems.

Early Low Countries Developments

Unlike the other canals in this brief overview, the Dutch and their ancestors have been working to hold back and reclaim land from the North Sea for over 2000 years. The Frisians who first settled the Netherlands pre-Roman times began to build dykes to hold back the waters of the North Sea and control the major rivers crossing the country. Once dikes were built, canals and pumps drained the land and to keep it dry, and from the 1200s, windmills were used to power those pumps.



As part of this process, the commercially advanced Low Countries developed a system of canals for the drainage of the marshland at the mouths of the Scheldt, Meuse, and Rhine rivers, leading to about 85 percent of medieval transport in the region going by inland waterway.

[9] The Newry Canal, located in Northern Ireland appears to be the first true canal built in the UK, opening in 1742, followed by the Sankey Canal in 1757. See ***Cost Overruns on Early Canal & Railway Projects***: https://mosaicprojects.com.au/PDF_Papers/P207_Canal+Wagonway_Cost_Overruns.pdf

These early canals evolved into the Trekvaart, a system of canals built in the 17th century, used exclusively by boats carrying passengers and parcels. The canals connected the main towns and cities of the area, their construction and operation being organized by local authorities.

Newly built sections usually followed a straight line between towns, and other sections were reconstructions of older waterways. A towpath was provided in order for trekschuiten (passenger boats) to be pulled by horse at an average of 7 km (4.5 miles) per hour. The boats, about 15 metres (50 feet) in length and 2.5 metres (8 feet) in breadth, could carry some 30 people. The trekvaart were a cheap form of transport, being used by a wide cross section of the population, and they were important in allowing the movement of population and in stimulating economic expansion.

Permission to build the first trekvaart, between Amsterdam and Haarlem, was granted in 1631; the last was built in 1665. They operated to a timetable and were noted for their punctuality. On some routes, such as Amsterdam to Haarlem, there were boats every hour from 5 AM to 8 PM, while those serving less-populated areas operated only once a day. They continued to be used throughout the 18th century, the last one being withdrawn in 1839 as railways took over the passenger and parcel services.

Responsibility for managing the water was fragmented and divided among central government, the provinces, water boards, and local authorities, until 1798 when the Dutch set up a national organisation known as the *Bureau voor den Waterstaat*. Its principal tasks were to construct, manage and maintain rivers, canals, flood defences and polders[10]. Its name was changed to *Rijkswaterstaat* in 1848, and the organisation's responsibilities continue to the current time. At the beginning of the 19th century, on the initiative of King William I of the Netherlands (1815-1840) the, Rijkswaterstaat dug almost 500 kilometres of new canals to support industry.

The Dutch continued to extended their canals to serve the continental European industrial north. The Maastricht-Liège Canal was opened in 1850, enabling raw materials and steel to be transported from the Meuse and Sambre industrial areas by waterway throughout the Netherlands. In 1824 a long ship canal was built to bypass silting that obstructed navigation on the IJsselmeer (Zuiderzee) and to enter the North Sea in the Texel Roads. Later an even shorter ship canal was built to IJmuiden.

[10] Polders are drained areas of land below sea level, and protected by dykes.

Flanders

The early canal system in Flanders included:

- A 30-km (18.5-mile) canal with four locks between Brussels and Willebroeck on the Rupel constructed between 1550 and 15059 to shorten navigation by half.
- A 71 km (44 miles) canal constructed from Brugge to Passchendaele, Nieuport, and Dunkirk and was later extended to Ostend, while Dunkirk was linked with the Aa River, at the mouth of which a large tide lock was constructed at Gravelines. Construction started in 1618, it was finished in 1623.

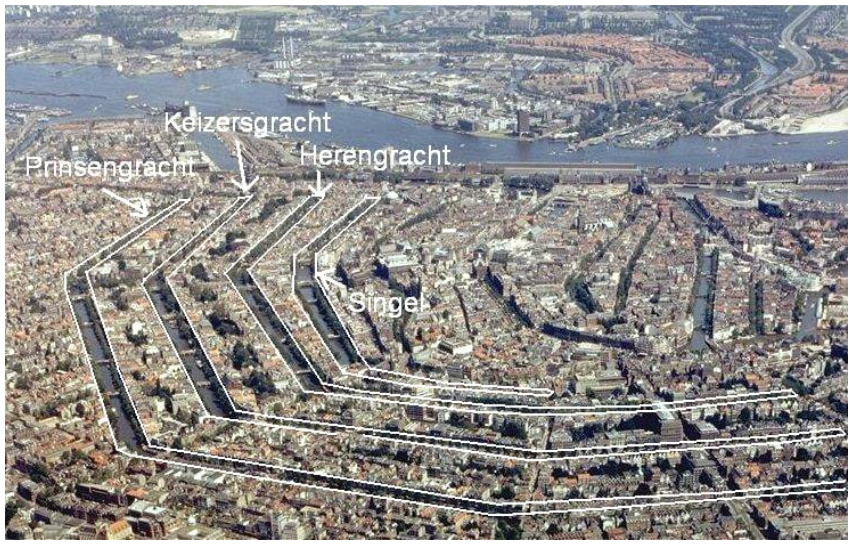
An outstanding achievement was a very deep lock at Boesinghe on the canal from Ypres to Boesinghe beside the Yser River. The fall of 6 metres (20 feet) on this 6-km (4-mile) stretch was contained by a single large lock. Side ponds with ground sluices were provided for the first time to reduce the loss of water during the lock's operation. The ponds took one-third of the water when the lock was emptied and returned it for the filling.

Similar to the Netherlands, industrial development in the early 19th century prompted Belgium to extend its inland waterways, especially to carry coal from Mons and Charleroi to Paris and northern France. Among the new canals and extensions built were the Mons-Condé and the Pommeroeul-Antoing canals, which connected the Haine and the Schelde; the Sambre was canalized; the Willebroek Canal was extended southward with the building of the Charleroi-Brussels Canal in 1827; and somewhat later the Campine routes were opened to serve Antwerp and connect the Meuse and Schelde. When the growth of the textile trade in Ghent created a need for better water transport, the Ghent Ship Canal, cut through to Terneuzen, was opened in 1827, giving a shorter route to the sea.

Amsterdam

Much of the Amsterdam canal system is the successful outcome of city planning. Its oldest canal is the Singel which dates back to the 15th century. The canal was originally a moat that surrounded the entire city before Amsterdam began to expand, it is very small at only 1 mile (1.6 km) long.

In the early part of the 17th century, with immigration rising, a comprehensive plan was put together, calling for four main, concentric half-circles of canals with their ends resting on the IJ Bay. Known as the "grachtengordel", three of the canals were mostly for residential development, and a fourth, outer canal, for purposes of defence and water management. The plan also envisaged interconnecting canals along radii; a set of parallel canals in the Jordaan quarter (primarily for the transportation of goods, for example, beer); the conversion of the existing, inner perimeter canal (Singel) from a defensive purpose to residential and commercial development; and more than one hundred bridges. The defensive purpose of the



Nassau/Stadhouderskade was served by moat and earthen dikes, with gates at transit points but otherwise no masonry superstructures.

Construction proceeded from west to east, across the breadth of the layout, like a gigantic windshield wiper. Construction of the north-western sector was started in 1613 and was finished around 1625. After 1664, building in the southern sector was started, but the eastern part of the concentric canal plan, covering the area between the Amstel river and the IJ Bay, was not implemented for a long time.

Canals in Germany

The earliest canals were in North East Germany extending into modern Poland (Prussia). The Stecknitz Canal, built in Germany (1391–98), ran 34 km (21 miles) from Lake Möllner down to Lübeck, with a fall of 12 metres (40 feet) controlled with four stanches; the canal was later extended south to Lauenburg on the Elbe to establish a link between the Baltic and the North Sea.

in the late 17th and early 18th centuries; the 24-km (15-mile) Friedrich Wilhelm Summit Canal, completed in 1669, rose from Neuhaus on the Spree for 10 feet in two locks and from west of the summit fell 20 metres (65 feet) to Brieskow on the Oder. The Plauer Canal opened in 1746, running from the Elbe to the Havel. The 40-km (25-mile) Finow Canal along the Havel to the Liepe, a tributary of the Oder, had been built earlier but fell into decay and was not rebuilt until 1751. These linked the three great rivers, the Elbe, Oder, and Weser.

The political climate was less favourable for canal building in central Europe, but the Ludwig Canal, forming part of the Rhine-Main-Danube route,

was opened in 1840. The Kiel Canal and the full length of the Rhine-Main-Danube Canal were built much later.

Canals in the Americas

In the United States, canal building began slowly. Only 161 km (100 miles) of canals had been built at the beginning of the 19th century, but before the end of the century more than 6,437 km (4,000 miles) were open to navigation. The early canals included the South Hadley Canal, opened in 1795. The Turners Falls Canal opened in 1798. These were followed by the Dismal Swamp Canal in Virginia, the Santee Canal in South Carolina, the Bellows Falls Canal in Bellows Falls, Vermont, and the Middlesex Canal in Massachusetts, all completed before 1812.

The Erie Canal, 584 km (363 miles) long with 82 locks from Albany on the Hudson to Buffalo on Lake Erie, was built by the state of New York between 1817 to 1825. Highly successful from the start, this canal gave New York predominance in trade with the Mid-West over other Atlantic Seaboard ports.

The Champlain Canal was opened in 1823, but it was not until 1843, with the completion of the Chambly Canal, that access to the St. Lawrence was made possible via the Richelieu River.

Meanwhile, Canada had constructed the Welland Canal linking Lakes Ontario and Erie. Opened in 1829, it overcame the 100-metre (327-foot) difference in elevation with 40 locks, making navigation possible to Lake Michigan and Chicago. Later the St. Mary's Falls Canal connected Lake Huron and Lake Superior.

The Louisiana Purchase of 1803 had given the United States control of the Mississippi River, and it became the main waterway for the movement of Midwestern produce via New Orleans and the Gulf of Mexico. Developments included the Illinois-Michigan Canal, connecting the two great water systems of the continent, the Great Lakes, and the Mississippi. Entering Lake Michigan at Chicago, the canal triggered the city's explosive growth. Several canals were constructed subsequently to link up with the Erie and Welland canals and the St. Lawrence, and a comprehensive network of inland waterways was established.

Work on the Panama Canal started in 1881 but stalled due to the difficult working conditions and disease, the United States took over the project in 1904, and the canal opened in 1914.

Other European Canals

The construction of canals in the UK are discussed in two papers:
- Early Canal Projects in the UK[11]
- Cost Overruns on Early Canal & Railway Projects[12].

In Scandinavia new canals were built to facilitate transport of timber and mineral products. In 1832 the new Göta Canal was opened, crossing the country from the Baltic to the Skagerrak and incorporating 63 locks.

At the same time, steps were taken in Europe to improve river navigation generally, to provide speedier transport, and to enable a greater volume of freight to be carried. The Danube was regulated for 232 km (144 miles) from Ennsmundung to Theuben, and the Franz Canal was dug in Hungary to join the Danube and Tisza. A nationwide Russian canal system connecting the Baltic and Caspian seas via the Neva and Volga rivers became navigable in 1718. A more direct route was established in 1804 with a canal between the Beresina and Dvina rivers. In the 19th century Russia made connections between the heads of navigation of its great rivers, the Volga, Dnepr, Don, Dvina, and Ob.

An outstanding engineering achievement in Greece was the cutting of a deep ship canal at sea level through the Isthmus of Corinth to connect the Aegean and Ionian seas. The canal is about 6 km (4 miles) long. It was dug in 1881–93, and is bounded by almost vertical rock cliffs that rise to more than 79 metres (259 feet) above water level in the canal's midsection[13].

Conclusions

The transport of cargo by inland waterways may be on navigable rivers, or those made navigable by canalization (dredging and bank protection – often called 'navigations'), or on artificial waterways called canals. However, until the start of the industrial revolution in the 17th century, most canals and navigations were limited in scope and restricted to flat lowlands were the canals also served as drainage and irrigation systems.

The needs of industry for both raw materials and to ship finished goods to market changed this dynamic. Before the advent of railways, water transport was by far the most efficient way of moving all types of cargo. Driving a boom in the construction of both navigations and canals, but topography and changes in water levels require many rivers and canals to be regulated to make them fully navigable. Since the 15th century, the chief regulating method has been the lock, the development of which contributed significantly to the Industrial Revolution and the development of modern industrial society.

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[11] ***Early Canal Projects in the UK***: https://mosaicprojects.com.au/PDF_Papers/P207_The_first_canal_projects.pdf

[12] ***Cost Overruns on Early Canal & Railway Projects***: https://mosaicprojects.com.au/PDF_Papers/P207_Canal+Wagonway_Cost_Overruns.pdf

[13] This canal replicated the function of the ***Diolkos***, which was built at beginning of the 6th century BCE, and operated for some 650 years: https://mosaicprojects.wordpress.com/2023/04/17/the-diolkos-the-first-truly-commercial-project/

Railways ended the canal boom, but for many types of commodities, particularly bulk commodities such as grains, coal, and ore, inland waterway transport is still more economical than any other kind of transport. This is particularly evident on the major river systems of Europe, Asia, and America.

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