THE WATER-SUPPLY OF CITIES AND TOWNS.

CHAPTER I.

HISTORICAL SKETCH OF SOME OF THE MEANS THAT HAVE BEEN ADOPTED FOR THE SUPPLY OF WATER TO CITIES AND TOWNS.

Introduction—Ancient Wells—Egyptian Reservoirs—Pools of Jerusalem—Aqueduct of Carthage—Greece: Aqueduct near Patara—Rome: its Aqueducts; Knowledge of the Principles and Action of the Syphon; Distribution of the Water—Constantinople: its Reservoirs, Aqueducts, and Cisterns—Roman Aqueducts in Spain and France—Ruins of Aqueducts in Peru—Indian Reservoirs—Water Supply of Paris—Water Supply of London: Springs, Brooks, and Wells; Conduit Houses; Conveyance of Water from 'Tyborne'; Thames Water; Water brought in from Hampstead; London Bridge Waterworks; York Buildings Waterworks; Merchants' Waterworks; New River Company; Chelsea, Lambeth, Grand Junction, West Middlesex, East London, Southwark, Vauxhall, and Kent Waterworks Companies; Various Schemes proposed for the Supply of Water to London; Judgment of the Royal Commission—Conclusion.

A HISTORY of the modes of procuring Water for the wants of man would most certainly be incomplete did it not extend back as far as that of the human race itself. Only a brief reference, however, will be made to the simple practices of primeval times, as the more immediate subject of this chapter is the means which man in the course of time was compelled to invent and provide for collecting, storing, and distributing the necessary element, in consequence of the increase of population, and also for the purpose of supplying those localities which had been selected for habitation, but which were distant from sources adequate and suitable to the demand.

Ewbank, who, in his 'Hydraulics,'* has entered at great length into the early history of water-supply, treats this subject in a very interesting manner, drawing his conclusions from many sources, which to a great extent are only shadowed forth in the songs of Homer and other early writers. His inferences are no doubt perfectly fair and legitimate, but they are to a certain extent speculative, and have, moreover, a poetic colouring which will justify the brevity of our extracts from this versatile author.

'That man at the first imitated the lower animals,' says Ewbank, 'in quenching his thirst at the running stream, there can be no doubt. It was natural, and because it was so the descendants have always been found, when under similar circumstances, to follow his example. The inhabitants of New Holland and other savages quench their thirst in this manner (i.e. by lying down).

'The heathen deities, who in general were distinguished men and women, who were idolised after death, are represented as practising this and similar primeval customs. Thus Ovid describes Latona on a journey and languishing with thirst; she arrives at a brook,

> And kneeling on the brink,
> Stooped at the fresh repast, prepared to drink,
> But was hindered by the rabble race.
>
> METAM. vi. 500.

'When circumstances rendered it difficult to reach the liquid with the mouth, then the hollow of the hand was used to transfer it. Gideon's soldiers pursued both modes in allaying their thirst, and it was the practice of

* A Description and Historical Account of Hydraulic and other Machines, &c. By T. E. Ewbank. London, 1842.

the last which Diogenes witnessed in a boy at Athens which induced that philosopher to throw away his jug as an implement no longer necessary.

'At what period of man's history he first had recourse to wells, we have no account, nor of the circumstances which led him to penetrate the earth in search of water.

'Wells, we have no doubt, are of antediluvian origin, and the knowledge of them, like that of the primitive arts, has been preserved by an uninterrupted use from the period of their first discovery. At first they were probably nothing more than shallow cavities dug in moist places, and their depth accordingly increased in order to contain the surface-water that might drain into them within certain intervals of time, a mode of obtaining it still practised among barbarous people. . . . . These simple excavations would naturally be multiplied, and their dimensions enlarged, as far as the limited means of man in the early ages would permit, and his increasing wants require. But when the discovery of metals took place, the depth of wells would no longer be arrested by rocks, nor their construction limited to locations where these did not occur. From very ancient wells which still remain, it is certain that at a time long anterior to the commencement of history, the knowledge of procuring water by means of them was well understood, perhaps equally so as at present; on this supposition only can we reconcile the selections of location for them composed entirely of rock. Some of the oldest wells known are dug entirely through that material, and to a prodigious depth.'

One of the ancient proverbs of the Chinese is 'dig a well before you are thirsty,' and the numerous deep artesian wells found in their country give evidence of the proverb having been duly regarded. Wells were very numerous in ancient Greece: Vitruvius, Plutarch, Pliny, and Herodotus make mention of them. Previous to the time of Appius Claudius Cæsar, the city of Rome received its supply chiefly from wells. The disinterment of the cities of Herculaneum and Pompeii has proved the existence of many public wells in ancient Italy. At Pompeii, a very fine well, 116 feet in depth, was discovered near the gate of the Pantheon.

The storing of large volumes of water most probably had its origin among the Egyptians, who were also particularly distinguished for their ingenious contrivances for raising water from the river into elevated reservoirs. The water was conveyed to the tops of the hills into immense cisterns hewn in the rocks, whence it flowed to the desert wastes below, and transformed them into fertile fields.

In many ancient cities, and indeed in many comparatively modern cities of Eastern countries, the supply was and is principally, or at the least largely, from the rain-water caught on the roofs and stored in underground cisterns.

Ancient Jerusalem and its neighbourhood was famous for its reservoirs, or 'pools of water,' formed partly by excavation and partly by banks thrown across valleys : frequent reference is made to them in the sacred writings.

The reservoirs between Bethlehem and Hebron are attributed, without any reason for doubt, to the time of Solomon, though, singularly enough, they are not mentioned by Josephus; but excavations of a recent date (especially those of Mr. Meshullam, in the summer of 1861), discovering wells and conduits cut in the rock, in connection with other remains, establish the fact of there having been a system for supplying Jerusalem with water from this source. Other portions of this conduit are described as being built on foundations of stone, the water running in round earthen pipes about ten inches in diameter, which are cased with two stones hewn out so as to fit them, and covered over with rough stones well cemented together, the whole being so sunk into the hill-sides that in many places they are not visible.

Perhaps one of the earliest aqueducts ever constructed was that of which vast remains may be seen at this day, ranging for miles over the plains near the site of ancient Carthage. The conduit, of which the aqueduct formed a part,* extended for nearly sixty miles, and is supposed by some to have been constructed by the Romans. But Dr. Davis, who a few years ago conducted important explorations in the vicinity, argues strongly in favour of its Phœnician origin. Where it penetrates the mountains, ventilating shafts, six feet in diameter, occur about every twenty yards.† The aqueduct has two tiers of arches, and in some parts reaches to a height of 125 feet.

* In the following pages the term *conduit*, when not appearing in a direct quotation, with an obviously different signification, will be understood to mean the entire water-channel from the source to the point of distribution, *including* the tunnels and the *aqueducts* (sometimes in general works called *aqueduct-bridges*). The reader will of course be aware that many writers, both ancient and modern, employ the term aqueduct in the same sense as that here assigned to the word conduit. Used in a work treating entirely of water, the word conduit cannot fail to be understood as signifying a water-conduit; so that 'aqueduct' remains available to designate the entire structure at a part where a conduit passes over a valley, in the same way as viaduct is understood to mean, popularly, not any leading or passage of a way or road, but especially the entire structure upon which a road is carried over low ground or the like.

There is yet another sense in which the word conduit is sometimes understood, as will hereafter be seen when, in connection with the early history of the London water supply, quotations will be made from Stow and other old writers. 'Conduit' in former times was almost exclusively confined to the fountains or cisterns or small local stores of water from which the people immediately drew their supplies, and to which the water was by one means or another conveyed. The context, however, will always suffice to explain the sense in which the word is used.

† Carthage and her Remains. By Dr. N. Davis, F.R.G.S.

Some of the piers are formed entirely of masonry, but others are of mud, and seem to have been originally faced with large square slabs of stone. The water-channel is covered, and is high enough and broad enough for a man of ordinary size to walk in; it is, moreover, lined with cement throughout.* At the time Dr. Davis wrote (1860), works were in progress for supplying the city of Tunis with water from the spring which fed Carthage more than two thousand years before. More than three-fourths of the ancient aqueduct had only to be cleared of the accumulations of earth to be made serviceable. The intervals are not to be restored by arches, but by iron pipes.

Greece at a very early date possessed means of procuring water from a distance, as is shown by the vestiges of aqueducts now remaining in various parts of that country; and, indeed, the large populations of Athens and Corinth would render such works necessary. Homer, in his description of the gardens of Alcinous, says:†—

Two plenteous fountains the whole prospect crown'd;
This through the gardens leads its stream around,
Visits each plant, and waters all the ground,
While that in pipes, beneath the palace flows,
And thence its current on the town bestows;
To various use their various streams they bring:
The people one, and one supplies the king.

The earliest existing account of a conduit is that which Herodotus (iii. 60) gives of an ancient one constructed by Eupalinus, an architect of Megæra, for supplying water to the city of Samos. In the course of this conduit a tunnel nearly a mile in length, and a channel three feet wide, were made to convey the water.

The following is an account of a masonry aqueduct, of very primitive construction, discovered near Patara:—The ravine over which it passes is 200 feet across at the widest part, and 250 feet in depth. The aqueduct consisted of a line of square stone blocks laid upon the top of a rough stone wall or embankment, which crossed the valley from side to side, a passage for the stream below being reserved by means of a rude archway. The channel was not laid horizontally, but was depressed into a considerable curve, so that the greatest height of the embankment was much less than it would have been if raised to a straight line between its ends. The stone blocks just mentioned were each about 3 feet cube, with a bore through the centre about 13 inches in diameter. On one end of each block was an annular projection, which was received into a recess, 3 inches deep, in the face of the adjoining stone, forming a spigot and faucet. The joints were run with cement, and the blocks were additionally secured together by iron clamps run with lead. At a distance of about 20 feet apart, vents 7 inches in diameter were made for the escape of air.

The great attention paid by the ancient Romans to health and cleanliness led to the construction of very stupendous works for an abundant supply of water. Pliny says, 'If any person shall very attentively consider the abundance of water conveyed to the public for baths, fish-ponds, private houses, fountains, gardens, and villas, conducted over arches of considerable extent, through mountains perforated for the purpose, and even valleys filled up, he will be disposed to acknowledge that nothing was ever more wonderful in the world.'

The first time water was conveyed to Rome from a distance was in the year B.C. 322, when a conduit was constructed by Appius Claudius, the Censor, from whom it derived its name of Appia Claudia. Prior to this the inhabitants of Rome were supplied from the Tiber, or the wells or springs in the vicinity. The Appia Claudia had its source in the district of Tusculum, whence, after making a circuitous course of 800 paces, it proceeded through a deep subterraneous channel more than ten miles in length, and entered the city by the Appian Way, delivering its water in the Campus Martius.

As the Romans found this mode of conveying water advantageous, they soon caused the number of conduits to be augmented. Pliny, in his 'Natural History,' mentions the Aqua Martia, the water of which he eulogises thus:—'Among the blessings conferred on the city by the bounty of the gods is the water of the Martia, the clearest of all the waters in the world and distinguished for coolness and salubrity.' Over the Marcian Aqueduct were conveyed the waters of the Marcia, Julia, and Sepula, in distinct channels one above the other, which together were supported by a single tier of arches. Occasionally there were two or more tiers of arches in one aqueduct, and this form of construction has given rise to much speculation as to its objects. Some have supposed that the two or more tiers were for separate conduits at different levels; others, again, have inferred the intention of the Roman architects was to provide roadways across the valleys, thus making the structure serve two purposes. From some of the remains, it is evident that at least occasionally the lower arches were introduced simply for the purpose of structural stability, as no means are provided either for a road or water-way at the level of the lower tier; moreover, there are several instances in which two and even three channels are carried on the same aqueduct with only one tier of arches, as in the case of Aqua Marcia. The Aqua Marcia conduit

* Shaw's Travels.

† Odyssey, book VII.

was built about 100 years after the Appia Claudia, and it originated with Quintus Martius. Its course commenced at a spring 33 miles from Rome, and, proceeding along the surface of the ground for three miles through a winding channel, it entered a tunnel 16 feet in diameter, whence it continued for 38 miles. At intervals along the line ot the conduit, cesses were formed for the interruption of solid matter carried along by the stream : there were also apertures in the upper part for the escape of air.

Agrippa, who held the office of curator of the public works in the reign of Augustus, constructed, among other works, the Aqua Virginia, a winding channel about 12 miles in length, in the course of which a tunnel of 800 paces was driven.

Pliny states that the conduits at this period were rendered eminently subservient to the embellishment of Rome, and that Agrippa in the course of one year actually formed 70 pools, 105 fountains, and 130 reservoirs, besides adorning all these works with marble statues and columns.* Sextus Frontinus, who was intrusted by the Emperor Nero with the superintendence of the conduits, has left behind some very valuable information on this subject in a treatise 'Concerning the Aqueducts of the City of Rome,' wherein he states that Rome was supplied by nine large conduits, constructed previous to his appointment as curator. They were of an aggregate length of 255 miles, and supplied 14,018 quinaria of water per day, which quantity is equivalent to 27,743,100 cubic feet ; but after the construction of others, the supply probably amounted to 50,000,000 cubic feet. As the population of Rome at that time consisted of about 1,000,000 souls, this gives an average of 50 cubic feet for each inhabitant per day. So abundant indeed was the supply, that Strabo says, 'Whole rivers flowed through the streets of Rome.'

In addition to the ancient conduits just noticed, were the Old and New Anio, constructed in the reign of the Emperor Nero, and deriving their names from being the means of conveying the water of the Anio to Rome. The former was nearly 43 miles in length; the latter was constructed on a higher level, with its course along the surface for 7,543 paces, when it entered a tunnel of the length of 54,267 paces. Along the line of the conduit were more than 600 arches, some of which exceeded 100 feet in height.

The Aqua Claudia, another magnificent conduit, was begun in the reign of Caligula, and finished during the reign of Cladius. It was built with hewn stone, and commenced at a distance of 38 miles from Rome, at an elevation which enabled it to supply the highest hills of the city. It had a subterranean channel for 36¼ miles, thence it ran along the surface of the ground for 10¾ miles, passed through a vaulted tunnel of about 3 miles, and continued for 7 miles on arcades, some of them very lofty. Professor Leslie observes that 'Trajan showed particular solicitude in improving the aqueducts. These works were executed in the boldest manner. Nothing could resist the skill and enterprise of the Romans; they drained whole lakes, droves mines through mountains, and raised up the level of valleys by accumulated arcades. The water was kept cool by covering it with vaults, which were often so spacious that, according to Procopius, who wrote in the time of Belisarius, a man on horseback could ride through them.'

Referring to the scientific knowledge and mechanical skill of the ancient Romans, Professor Leslie says: 'It is a prevailing opinion that the Romans, amidst all their magnificence, were ignorant of the simplest elements of hydrostatics, and therefore totally unacquainted with the method of conducting and raising water by a train of pipes. Nothing could be worse founded than this notion. Pliny, the natural historian, lays down the main principle that water will invariably rise to the height of its source—*Subit altitudinem exortus sui.* He subjoins that leaden pipes must be employed to carry water up to an eminence.† Palladius, in his treatise "De Re Rustica," speaking of how to find springs, directs that the water be conducted to the farm or villa either by a channel constructed of masonry, or by means of pipes of lead or wood or even of earthenware. He allows one foot in from sixty to a hundred, for a uniform descent; but if the ground should afterwards rise, he says, the conduits must be supported on piles or arches, or the water must be enclosed in leaden pipes, when it will mount just to the level of its head. But Palladius testifies his aversion to the use of lead as apt to become covered with ceruse, and thereby rendered unwholesome or even poisonous. This consideration had, no doubt, served to restrain the general adoption of leaden pipes among the Romans.' ‡

In connection with this subject, the following passage from Vitruvius (book VIII., chap. vii.) is of considerable interest:—'If a long valley should be interposed in the course of the conduit, the inclination of the descent being followed, and arriving at the bottom, you should build a low wall, in order that as long a level as possible should be obtained. This is what the Greeks call κοιλία, or ventre (belly). Where the pipes arrive at the opposite declivity, the current of the stream of water will be slightly swollen, and will thus force itself to the top of the height. If this belly is not made in the valley and there should occur an elbow, the force of the water will burst and disunite the joints of the pipe. In the belly you must make air-holes, so that the violence of the wind may escape.'

* Pliny, Nat. Hist. lib. XXXVI. cap. XV.

† Pliny, Ibid. XXXVI. vii.

‡ Leslie's Elements of Natural Philosophy.

Vitruvius, in referring to the different modes of conveying water, directs, as a preliminary operation, that a level (*libramentum*) should be traced on the ground. This *libration* was performed by the *dioptron*, the *water-level*, or the *chorabates.* The dioptron seems to have been a sort of quadrant, fitted with sights; the water-level consisted of a tube, probably of copper, five feet long and an inch wide, turned up an inch and a half at both ends, and was adjusted until the water rose equally in them. The chorabates, or perambulator, which he considered as the most accurate instrument, was composed of a rod 20 feet long, having a square and plummet attached at each extremity.

'After the water had reached the walls of the city, it was admitted in a reservoir or *castellum*, divided into three distinct and equal compartments, one to feed the pools and fountains, another to supply the public baths, and a third for the accommodation of palaces and private houses. The distribution of the water was commonly effected by leaden pipes.' *

Glorious in constructive achievement as in arms, the Romans, not content with affording to their great city the most liberal supply of water of which a city ever boasted, executed works of considerable magnitude in other countries of their dominion. Constantinople, with its many advantages of site, and the picturesque scenery of its neighbourhood, is withal naturally deficient in its supply of water. Barbyses and Cydares are the only streams in its vicinity flowing towards the city, and these are not unusually dry during the summer seasons. The first plan adopted was the construction of cisterns below the houses to preserve the rain whenever it fell, but the quantity obtained was not sufficient for the wants of the people. Recourse was then had to the formation of a series of storage reservoirs on the hills near the Black Sea, and about 15 miles distant from Constantinople. The dams were faced with white marble, finely sculptured in the oriental style. From these reservoirs the water was led in different channels to the four principal conduits which ran into the city. In the course of the latter several aqueducts were constructed; one of them is 440 feet long and 107 feet high, and has a double tier of arches; another, situated in the interior of the city, and attributed to Valens, is formed with alternate courses of stones and Roman tiles. It is recorded that Valens, having met with opposition from the inhabitants of Chalcedone, demolished the walls of their city, and had the materials conveyed to Constantinople for the construction of the aqueduct.† Every care was taken to preserve the reservoirs and conduits, and the water they contained, from injury or depredation; so much so that a law, promulgated in the year 404, imposed the fine of a pound of gold for every ounce of water surreptitiously taken away.

In conveying the water across some of the valleys a 'souterezi,' or sort of hydraulic column, or obelisk, was employed. It was constructed of masonry, and on one side a narrow channel rose and discharged into a basin at the top, whence a similar channel descended on the other side. The only practical advantages resulting from the souterezi were the facility they afforded for the escape of air from the pipes, and the deposition in the tanks of solid matters, which might otherwise have accumulated in the lower part of the inverted syphon tube.

In addition to the conduits, immense cisterns were constructed to collect and preserve the water in case of sieges. One of these, situated in the Basilica, and described by Procopius as a spacious building of great length and breadth, encompassed with pillars in a quadrangular manner, was built by Justinian on rocky ground, and carried to a great height. Petrus Gyllius, a Frenchman, who resided at Constantinople during the early part of the sixteenth century, describes this cistern as being 336 feet long and 182 feet broad. The roof, arches, and sides are all brickwork, covered with terrass, and are not in the least impaired by time. The roof is supported by 336 marble pillars. The space of intercolumnation is 12 feet, and each pillar is above 40 feet 9 inches high: they stand lengthwise in 12 ranges, and 28 in the breadth. Another great cistern described by Gyllius was called Philoxenon, the roof of which is supported by 424 marble pillars, 212 supporting the same number above them. The Turks have named this structure the 'Thousand and one Columns.' 'There is another cistern, the arches of which are supported by 32 Corinthian pillars, standing in four ranges, each consisting of eight pillars, with shafts nine feet in compass.' Gyllius mentions others, amongst which 'the cistern of St. Benedict, now despoiled of its roof and 300 pillars which supported it, showing it to be a very antique and expensive work, though now turned into a cistern for watering the priests' garden.'

The Romans in other countries also have left memorable traces of their skill and genius. Not only in Italy and Sicily, but in Greece, Spain, and France, we find the remains of their gigantic conduits; and although many centuries have elapsed since they were constructed, several of them still afford those advantages for which they were originally intended.

The Roman conduits of Segovia and Seville, in Spain, still supply those towns with water. The noble structure at Segovia is described as being about 2,400 feet in length, and about 100 feet in height. It is formed by two tiers of arches, composed of large square stones placed together without cement. The number

* Leslie's Elements of Natural Philosophy.

† Ammianus Marcellinus, lib. XXXI. cap. i.

of arches in the lower range is 42; they are of 15 feet span, and have a height of 65 feet; in the upper tier are 119 arches, with a height of 27 feet.*

Several magnificent aqueducts were constructed by the Romans in France; one, the Pont du Gard, formed part of a conduit which supplied the town of Nismes with water from the sources of the Airan, which rose near St.-Quentin, and the Ure, near Uzès. This noble structure is, perhaps, one of the grandest monuments which the Romans have left in France or any other country. 'It consists of three tiers of arches, the lowest, of six arches, supporting 11 of equal span in the centre tier, surmounted by 35 of smaller size; the whole is in a simple style of architecture, destitute of ornament. It is by its magnitude, and the skilful fittings of its enormous blocks, that it makes an impression on the mind. It is the more striking from the utter solitude in which it stands—a rocky valley partly covered with brushwood and greensward, with scarcely a human habitation in sight. After the lapse of sixteen centuries, this colossal monument still spans the valley, joining hill to hill in a nearly perfect state, only the upper part, at the north extremity, being broken away. The highest range of arches carries a covered canal about five feet high and two feet wide, shaped in section like the letter U. It is covered with stone slabs, along which it is possible to walk from one end to the other, and to overlook the valley of the Gardon. The arches of the middle tier are formed of three distinct ribs or bands, apparently unconnected. The height of the Pont du Gard is 180 feet, and the length of the highest arcade 873 feet. Its date and builder are alike lost in oblivion, but it is attributed to M. Agrippa, son-in-law of Augustus, B.C. 19.' M. Genieys, formerly engineer-in-chief to the municipality of Paris, estimated that the quantity of water conveyed by this conduit amounted to nearly 14 million gallons per day.

At Lyons traces still exist of a conduit constructed, it is said, by the soldiers of Marc Antony, when his legion was quartered there. It was remarkable for the beauty and boldness of its design. It may still be traced for miles, crossing the valleys on arches, of which the most considerable remains are at Bionnat (six arches), Chappourest, Chardonniers, and Oullins.

In Metz are the very interesting remains of a Roman conduit, which conveyed the waters of a streamlet from Gorze, a distance of 15 miles. Superb and lofty arches were erected to convey the water over the Moselle, the breadth of which is here considerable. Out of 118 arches, five are still standing on the left bank of the river, and 17 in the village Lony, on the right; that under which the road passes is 60 feet high.

In France are to be found the remains of other conduits, amongst which are the imposing ruins of one crossing the valley of Eure, near Maintenon. This was constructed at the mandate of Louis XIV., to convey the waters of the Pont-Gonin to Versailles; but it was afterwards abandoned for a machine at Marly. Earl Russell says of this undertaking: 'As Louis had committed the blunder of building in a place without water, he proposed to remedy his mistake by conveying the river eight leagues by a new channel to adorn his park. To accomplish this, it was necessary to join two mountains at Maintenon, and form an aqueduct. Forty thousand troops were employed in this great work, and a camp was formed expressly for that purpose. It was partly pulled down, after a lapse of 65 years, to build the villa of Crécy for Madame de Pompadour. The remains consist of 47 arches, 42 feet span and 83 feet high. The total length of the canal, of which this was to form a part, would, if completed, have exceeded 33 miles.'

Although the conduits constructed by the Romans are unequalled either in their grandeur or extent, yet similar works have been executed by other nations for the purpose of conveying water to their principal cities. In Mexico and Peru are found remains of artificial water-channels of vast extent. 'These aqueducts,' says a French writer, 'were often of great magnitude, executed with much skill, patience, and ingenuity, and were boldly carried along the most precipitous mountains, frequently to distances of 15 or 20 leagues. The seventh Inca of Peru, Verachocha, constructed one aqueduct 120 leagues in length, and 12 feet in depth, and in the province of Cuntisuyu there are to be seen the remains of another aqueduct running above 150 leagues.' †

Reference has already been made to the reservoirs of Egypt, constructed for the purpose of storage. It is probable, however, that the antiquity of the numerous tanks or cisterns found in India is even more remote. Mr. Vignoles, F.R.S., in his presidential address delivered before the Institution of Civil Engineers (1870), states that 'in the presidency of Madras there are upwards of 53,000 tanks or reservoirs for irrigation purposes alone, exclusive of small tanks near the villages, all executed by the natives prior to the occupation of the Deccan by the British. The aggregate length of the embankments of these reservoirs is fully 30,000 miles—that is, more than double the length of all the railways in the United Kingdom; and the bridges, culverts, and sluices are more than 300,000 in number. The stored-up waters sent forth at the proper season still bring to the exchequer of the Madras Presidency a yearly income of a million and a half sterling (one-sixth of the whole revenue), although many of the finest of these reservoirs are in ruins, or useless from want of being properly kept up. One of them, the Poniary reservoir, in the district of Trichinopoly, has a superficial area of about 80 square miles, say 50,000

* Matthews's Hydraulia.

† *Vide* Rawlinson's Report on the Liverpool Water-Supply, 1866.

acres; the banks are 30 miles in extent. Another, the Veranum reservoir, has nearly 35 square miles of area, or upwards of 20,000 acres, and 10 miles of banks.'

Having thus briefly referred to the efforts of ancient times, and brought before the mind of the reader in rapid review the vast and superb structures which conveyed water to some of the great cities of old, a transition is now made to the two most renowned cities of modern times, Paris and London.

The earliest efforts for supplying the city of Paris with water appear to have been made chiefly under the patronage of religious bodies, it being stated that 'the aqueduct of Près-Saint-Gervais, the most ancient in this vicinity, originally belonged to the abbey of St.-Laurent, situate at the foot of Montmartre: the precise period of its formation is unknown. The hills of Romanville, Bruyères, and Menilmontant, supplied it with water, which, being collected in a reservoir situated at the village of Près-St.-Gervais, was thence conveyed to Paris by leaden pipes.'*

It is recorded that an aqueduct, bearing the same name as the modern aqueduct of Arcueil, was totally destroyed by the Normans in the ninth century. A comparison, however, of the ruins of this aqueduct with the remains of that at Près-St.-Gervais, leads to the supposition that the latter is of much earlier origin. It appears from the channels that have been discovered, that the water for the ancient aqueduct was obtained from sources in the vicinity of the village of Rungis.

In 1550 the inhabitants of Paris received a supply of only one quart per day, and nine-tenths of the people were compelled to obtain their supply direct from the Seine. The attention of Henry IV. having been drawn to these matters, he immediately and very generously reduced the supply of the palace to aid the inhabitants. This monarch, it is related, entertained the idea, in 1609, of restoring the ancient conduit of Arcueil, to augment the supply, which had for a long time depended mainly on the water conveyed by the conduits of Près-St.-Gervais and Belleville. Various difficulties in tracing the old conduits were met with, and eventually a new conduit was determined upon, which was constructed in 1613, under the regency of Marie de Medici, and completed in 1624.

About this period a Fleming named John Sintlear constructed a pump, to which motion was given by the current of the Seine, and which raised the water from the river above Pont-Neuf, whence it was conveyed to the Louvre and Tuileries. It was erected by order of Henry IV., and was known by the appellation of 'Pompe de la Samaritaine,' from the gilt-leaden figures that decorated its front. The success of this experiment suggested others of a similar kind upon Pont-Notre-Dame, one of which was completed in 1670 and another in 1671. At the end of the seventeenth century, Paris is said to have received only 1,800 cubic metres a day, or about five pints per head.

Many were the schemes subsequently proposed for the supply of Paris during the eighteenth century. One, in 1735, was for raising water from the Seine by means of steam-engines, and distributing it by pipes; but this met with no success, as the details of the plan were not sufficiently understood to be appreciated.

In 1778 MM. Perrier endeavoured to form a company for supplying Paris from the Seine, but various difficulties were thrown in their way; yet they succeeded in erecting two steam-engines as part of the works, which subsequently became the property of the City of Paris.

In 1762 a conduit was projected to bring water from the river Yvette, that source being considered preferable to others, as it enabled the water to flow into a reservoir six feet higher than that of Arcueil. This plan, which was designed by M. de Parcieux, member of the Academy of Sciences, received but little favour, although in 1775 MM. Peronett and Chezy expressed a high opinion of it, and clearly pointed out its advantages by plans and estimates. In 1782 MM. de Fer de la Noverre proposed a modification of the plan, and offered to construct the works without having recourse to pecuniary aid from the City of Paris. After some interval, authorisation for making the canal was granted, and the preliminary steps taken for vigorously carrying out the works. But the Revolution unfortunately impeded their progress, and they were finally abandoned.

Among the numerous useful works executed at the commencement of the present century, that of the Canal de l'Ourcq is the principal. It was projected in 1797, and the plan is attributed to M. Girard, who subsequently carried out and completed the undertaking. According to the original estimate, the additional quantity of water furnished from this source would amount to more than 670,000 hogsheads daily.† The canal commences at the river Ourcq, about 60 miles from Paris, receiving in its course the waters of the Grisette, May Theronaime, and the Benveonne, terminating in a reservoir at the north-eastern extremity of the Barrière de la Villette. The work was commenced in 1801, and completed in 1822.

The quality of the water obtained from the Canal de l'Ourcq and the Seine was, however, found to be very objectionable: that of the former on account of the impurities contracted during the flow, or during the time the water remained exposed in the Bassin de la Villette, and that of the latter because it was for the most part

* Recherches sur les Eaux publiques de Paris. Par M. Girard.

† Rapport sur le Canal de l'Ourcq

obtained from below Paris, and therefore was exposed to contamination by sewage, there being, according to the report of M. Dumas, one litre of sewer water to every forty-four litres pumped up. The water supplied by the conduit of Arcueil, though tolerably limpid, was, like that furnished by the springs rising on the north side of Paris and in the Près-St.-Gervais, excessively and permanently hard.

The bad quality and insufficient quantity of the water supplied to the city of Paris were crying evils, and the authorities at last determined to investigate the subject, and institute a better state of things. More than three hundred schemes were submitted and examined. Eventually, a careful survey of the hydrographical basin, comprised under the general name of the Basin of the Seine, was determined upon, and M. Belgrand was instructed by the Prefect of the Seine to carry it out. M. Belgrand found the city of Paris only received the following quantity of water from the sources mentioned:—

	Cubic Feet.
The water of the Canal de l'Ourcq	3,671,200
" Seine from the pumps of Challiot	1,412,000
" " at Quai d'Austerlitz	28,240
" Aqueduct of Arcueil	56,480
" Well of Grenelle	31,770
" Springs on the north side of Paris and of the Près-St.-Gervais .	17,650
	5,217,340

or 32,503,028 gallons per day. This quantity had to meet the wants of a population then estimated at more than 1,600,000. The amount per head would therefore have been more than 20 gallons, if the whole had been for the use of the citizens. After a careful examination of all the sources that offered themselves, the choice fell upon two rivers of Champagne, the Dhuys, which rises between Château-Thierry and Châlons, and the Vanne, which has its source between Troyes and Sens. The water is conveyed to Paris from these sources, a distance of eighty-three miles. According to the 'Bulletin de Statistique Municipale,' the total supply to Paris varied in 1868 from 40,776,299 gallons per day (in October) to 58,229,778 gallons per day (in July); the average for the whole year being 46,561,472 gallons per day, or 24·6 gallons per head of the population. None of the water supplied to Paris is filtered, although it is chiefly derived from navigable streams. It now remains to trace from the earliest records downwards the history of the water-supply of our great metropolis.

Before the New River and London Bridge waterworks were constructed, the inhabitants of London obtained their principal supply from the river Thames, from various shallow wells, and from the various springs which were situate in the west and north of the city. In FitzStephen's description of London, in Henry II.'s reign, he says, that 'round the city again, and towards the north, arise certain excellent springs at a small distance, whose waters are sweet, salubrious, and clear—

Whose runnels murmur o'er the shining stones.

Among these, Holywell, Clerkenwell, and St. Clement's Well, may be esteemed the principal, as being much the best frequented both by scholars from the schools and youth from the city, when in a summer's evening they are disposed to take an airing.'

John Stow, the diligent antiquary, in his 'Survey of London,' published in the reign of Queen Elizabeth, records much in connection with this subject that is particularly interesting. He relates that before the Conqueror's time, and for two hundred years after, the southern part of the city of London was watered by the Thames; the westward part was supplied by the river Wels and also by the Oldbourne; the heart of the city was fed by the Walbrooke; and a fourth water, or bourne, ran within the city through Langbourne Ward, watering that part in the east. Stow also records in his 'Survey': 'There were three principal fountains or wells in the other suburbs: to wit, Holy Well, Clement's Well, and Clerk's Well. Neare unto this last fountain were divers other wells: to wit, Skinner's Well, Fag's Well, Tode Well, Soder's Well, and Rad Well. All which said wells, having the fall of their overflowing into the aforesaid river, much increased the streame, and in that place gave it the name of well. In West Smithfield there was a pool, in records called Horsepoole; and another, neare to the parish church of St. Giles's, Cripplegate. Besides which, they had in every gate and lane of the citie, divers faire wels, and fresh springs, and after this manner was this citie then served with sweet fresh waters; which being since decayed, other means have been sought to supply the want, as shall be showed.

'The first cisterne of lead castellated with stone in the citie of London was called the Great Conduit,* in Westcheap, which was begun to be builded in the yeare 1235, Henry Wales being then mason. The watercourse,

* See the note at foot of p. 2.

from Paddington to Jameshead, hath 510 rods; from Jameshead-on-the-Hill to Mewsgate, 102 rods; from the Mewsgate to the Crosse in Cheape, 484 rods.'

Nelson states, in his 'History of Islington': 'In digging for gravel at Islington, lead pipes of a large size have been discovered branching in various directions, supposed to have been connected with the springs that supplied the Priory in Smithfield from the place then called the Conduit Head of Saint Bartholomew. At the time of digging for the foundation of Highbury House, in 1781, a great collection of pipes, made of red earth baked, resembling those used for the conveyance of water about the time of Queen Elizabeth, were dug up; and similar discoveries of leaden pipes have been made at different times in the fields between Canonbury and Highbury.'

At about the time when the Great Conduit mentioned above was completed, operations were in progress for conveying water from 'Tyborne' to the City. This was an important undertaking, and originated in a grant from Gilbert de Sandford, enabling the 'Lord Mayor and Commonalty to lay down a leaden pipe, of six inches bore, from six fountains or wells' in that vicinity.

Some time elapsed, it would appear, before the pipes from Tyborne were continued into the heart of the City, for Stow states, in 1432, 'Tyborne water was laid into the Standard, Cheapside, at the expense of Sir John Wells, Lord Mayor; and likewise in 1438, by another Lord Mayor, Sir William Eastfield, from Tyborne to Fleet Street and Aldermanbury; and from Highbery to Cripplegate.'

Speaking of the Thames, Stow says that the citizens of former times supplied themselves with water from it for family uses, 'fetching it by many lanes that led to the water-side in divers wards in the city. But in time many of those lanes were stopt up, by those that dwelt thereabouts, for their own gain, who would suffer none to pass without paying a duty. This became a great grievance, insomuch that in 17 Edw. III. (1342) the maior, aldermen, and commonalty received great complaints of stopping up these lanes and passages to the Thames. Upon this an inquisition was made, and divers persons of the several wards sworn to make diligent enquiry into these grievances.'

In 1439 'the Abbot of Westminster granted to Robert Large, the Lord Mayor, and the citizens of London, and their successors, one head of water, containing 26 perches in length and one in breadth, together with all the springs in the manor of Paddington, in consideration of the City paying for ever to the said Abbot and his successors, on the feast of St. Peter, two peppercorns. But if the intended work should draw the water from the ancient wells in the manor of Hida, then the grant to cease, and become entirely void. This grant was confirmed by Henry VI.' *

Towards the close of the fifteenth century the supply of water was found to be very scanty, and additional conduits were constructed 'by Stocke's Market and at London Wall in 1500, at Bishopsgate in 1513, and at Coldgate, against Coleman Street, in 1528.'† In 1535 the Common Council granted a sum of money for the purpose of conveying water from Hackney to a conduit erected at Aldgate.‡

Notwithstanding these provisions, the Corporation deemed it advisable, in 1544, to apply to Parliament for an Act to enable them to convey water to London from Hampstead Heath, Marylebone, Hackney, and Muswell Hill. The Act was granted; but nearly fifty years elapsed before its object was realised. It was subsequently deemed eligible to convey the privilege of obtaining and supplying water from the Hampstead Works to several persons who were incorporated in 1692, by the denomination of the Hampstead Water Company.§

To supplement the supply from the conduits fed by springs, there was erected a 'conduit of Thames water, at Dowgate, 1568;' ‖ but no particulars seem to have been handed down concerning it. In all probability it was merely some structure or contrivance enabling the people to procure water with greater facility than at the several lanes and passages leading down to the river.

Nelson states that 'the means of obtaining water from the conduits consisted either in employing people who made a business of selling it, or sending servants to fetch it, and both plans had their inconveniences. For the purpose of carrying it, they used vessels that were made wider at the bottom than the top, having hoops like a pail, also an iron handle at the upper end, in form like that of a common pewter pot, and fitted with a cork or bung. Each contained about three gallons, so that their weight might easily be carried by a man or woman, either on the head or shoulders: they were called tankards, and resembled the vessels at present employed by the dealers in milk, when they convey it home in their carts.' ¶

Several conduits were erected from time to time as the wants of the population demanded, and as public or private funds could be raised to meet the expense. In this way most of the springs in the vicinity that were eligible were gradually appropriated, and it became necessary to look round for other sources to meet the

* Stow. † Ibid. ‡ Matthews's Hydraulia. § Ibid. ‖ Stow. ¶ Nelson's History of Islington.

increasing requirements. As already stated, most of the lanes and passages leading to the Thames had been stopped up, so that the river was not now generally accessible for dipping the water directly according to the former practice. Stow notices one of the plans that were proposed for increasing the water-supply, though unfortunately he does not give full particulars. He says: 'Before the New River was thus brought to the supply of the citie, the projecting for the conveniency of water from the north side of the citie was not out of the heads of the citizens, for about the year 1580 odd (as I conceive it) there was one Russel who propounded to bring it from Isleworth, viz. the river of Uxbridge, to the said north of London.'

An important era in the water-supply of London is marked by the erection of machines for raising Thames water into the houses of the city through pipes of lead. Stow says: 'Of later times Thames water was conveyed into men's houses by pipes of lead from a most artificial forcier standing neere to London Bridge, and made by Peter Maurice, a Dutchman, in the yeere 1582 for the service of the citie and the eastern part thereof,' on the condition of his paying annually ten shillings into the chamber of London.

It appears that the Lord Mayor and Commonalty of the City of London granted to this ingenious man a lease, dated May 30, 1581, for a term of 500 years, by which he was authorised to erect an engine within the first arch of London Bridge, for the purpose of supplying the city with water.* In 1583 conduits were erected by the Church of St. Mary Magdalene, and St. Nicholas, Cole Abbey, near to Fish Street Hill. Again, in 1610, another was built in Aldersgate, and these several conduits were, no doubt, fed by water pumped from the Thames.

Stow records that the conduits were annually inspected by the 'citie authorities with considerable shew and festivity ; but particularly on the 18th Sept. 1562, the Lord Maior (Harpen), Aldermen, and many worshipful persons, and divers of the Masters and Wardens of the twelve Companies, rid to the conduit head, for to see them after the old custom. And afore dinner they hunted the hare and killed her, and thence to dinner at the head of the conduit.'

The works erected by Peter Maurice in 1582 proved so successful, that in the following year another lease was granted for a term of 500 years, by which Maurice was privileged to erect another engine in the second arch of London Bridge. Speaking of the power of this machinery which served the upper parts of the city, and of the great pressure that was attained, Stow says: 'The Maior and Aldermen came down to observe the experiment, and they saw him throw the water over St. Magnus's steeple, before which time no such thing was known in England as this raising of water. It was done by a mill, and was the first waterwork that was made use of to supply the citie of London with Thames water, and this water-mill furnished the neighbouring parts of the citie as far as Gracechurch Street.'

These 'mills' consisted each of an undershot wheel, 20 feet in diameter, having 26 floats, 14 feet long by 18 inches broad. Each wheel gave motion, by means of toothed-wheels and levers, to sixteen pumps, in such a manner that for every revolution the plungers made $2\frac{1}{5}$ strokes, 2 feet 6 inches long. The plungers were 7 inches in diameter, and when the tide flowed quickly the water-wheels made about six revolutions per minute;† making no allowance for 'slip,' the two wheels would together be thus pumping at the rate of about two and a half million gallons in twenty-four hours.

In 1591 an Italian named Frederick Genebelli is stated by Stow to have 'propounded an invention to the Lord Burleigh for waterworks for London,' that should enable the ditches to be cleaned, and fires more readily extinguished.

In 1594 'a large horse-engine was erected, within a short distance of Blackfriars Bridge, at Broken Wharf, by Bevis Bulman. This machine gave motion to four pumps, and the conduit pipes immediately connected with them were made of very thick lead, with a large diameter.'‡ Eventually these works were discontinued, owing to the inability of the proprietors to supply water at the same moderate rate as other establishments. Their site is now occupied by the New River Company, of which mention will presently be made.

'In 1641 a Mr. Forde proposed a plan for bringing a navigable river from Rickmansworth, in Harfordshire, to St. Gyles in the fields.' This plan was opposed by 'a Sir Walter Roberts, who about the same time brought forward another plan of his own. A principal feature of this project consisted in the construction of a close conduit of brick or stone, to convey water from Hoddesdon, in Herfordshire, to Islington, where it was to be received into a *conserve* or reservoir, in order to supply the inhabitants with pure soft water.' § Neither of these schemes, however, were carried into effect, probably from the want of the necessary capital.

In the year 1691, works for supplying Piccadilly, Covent Garden, Whitehall, and the neighbourhood, were erected on the banks of the river, near the bottom of Villiers Street. The proprietors were incorporated by Act of Parliament as 'The Governor and Company of Undertakers for raising Thames water in York

* Matthews's Hydraulia. † Philosophical Transactions, 1731. ‡ Matthews's Hydraulia. § Ibid.

Buildings.' After more than a hundred years—that is, in 1818—the company resolved to dispose of the works, as for some time hardly any profits had been realised. The works were accordingly leased to the New River Company for a term of 2,000 years. In Maitland's 'History of London,' mention is made of another company, 'The Merchants' Waterworks,' which had 'three engines, viz. a windmill in Tottenham Court Field, and two others wrought by the common sewer at Tom's Coffee House in St. Martin's and Hartshorn Lanes, in the Strand, whence issue three mains of six and seven inches bore, whereby those neighbourhoods are supplied from six fountains or wells at Tyborne.'

Strype, who edited Stow's 'Survey' in 1663, in referring to the original agreement for establishing the London Bridge Waterworks, says that the 'lease and the business thereof continued in the family of the Morices till Michaelmas 1701, when the present owner, seeing how the New River undermined him and impaired his profits, agreed to sell all his right and title to Richard Soames, citizen and goldsmith of London, for the sum of £38,000.' Before the transfer was effected, Morice obtained from the Corporation of London the lease of another arch—the fourth (the third being occupied by a wharfinger)—for the purposes of the waterworks, and he then 'added his whole interest in this grant of the fourth arch to Soames's bargain.' Soames ultimately formed a company for the acquirement of the London Bridge Works, and in the year 1761 the proprietors obtained from the Corporation a lease of the third arch, and in 1767 one for the fifth, which latter was on the Southwark side of the bridge. Southwark had heretofore been dependent chiefly upon water that flowed from the Thames into a great pond at St. Mary Overies; but now the London Bridge Works began to supply a large portion of this district. From time to time additions and improvements were effected in these works (amongst which may be mentioned two large wheels of iron), until they were capable of affording a daily supply of nearly four million gallons.* Notwithstanding all this, however, the London Bridge Works were before long unable (chiefly from want of the necessary funds) to compete with the more powerful New River Company. The latter had laid down iron pipes through nearly the whole of the city, and, besides this, they were able to supply water to any desired elevation. The London Bridge Company ultimately transferred all their leases derived from the City to the New River Company for the sum of £3,750, payable annually for 260 years. The Southwark portion of the works was conveyed to the proprietor of the *Borough Works* for the annual consideration of £1,060. Old London Bridge, and the waterworks to which it lent its name, were demolished in conformity with an Act of Parliament obtained by the Corporation in 1822. We must now return to the early history of the New River.

'Next to the conduit-water,' says Stow, 'was that famous (and never to be forgotten) New River, brought from Chadwell and Amwell by the only care, cost, and liberal expenses of one worthy man—Master Hugh Myddelton, citizen and goldsmith of London—deserveth to be recorded in the everlasting remembrance.' Myddelton proposed to the Common Council to construct the works solely at his own expense, and an Act, dated March 28, 1609, authorised the conveyance to him of all the power necessary for his purpose. Such numerous difficulties, however, arose to impede the works, that Myddelton, finding his funds rapidly diminishing, applied to the Corporation for help, but was refused, as they could not foresee that any pecuniary or other advantage would be obtained sufficient to justify their support in the movement. However, he made an application to King James I. for the means of continuing and completing the works, and this, fortunately, was granted, but on the condition that a moiety of the whole concern should be conveyed to him as a security. After the required funds were obtained, Myddelton prosecuted his work with renewed vigour, until it was completed and the water brought to the reservoir, the New River Head, in the parish of Clerkenwell, on the 29th day of September, 1613, amidst great rejoicing.

This conduit, being the first of its kind constructed in England, excited much curiosity; in fact, the performance of the work was considered truly marvellous. The valleys were in most cases crossed by timber aqueducts, of which the water-way or trough was lined with lead. Constant repairs, however, were required, and there was, moreover, a considerable loss to the company through leakage. Ultimately these wooden aqueducts were replaced by embankments.

The *New River Company* was incorporated by a charter from James I. in the year 1619, Sir Hugh Myddelton being the first governor. Nelson, in his 'History of Islington,' states: 'On account of the unpromising aspect of the company's affairs, Charles I. regranted to Sir Hugh Myddelton, his heirs and assigns, the moiety of the undertaking, on condition that they should pay the Receiver-General or into the receipt of Exchequer £500 annually, which is still paid, almost entirely out of the King's shares; but those shares have no concern in the direction.'

The length of the New River was originally nearly 40 miles, but within the last few years it has been considerably straightened, and shortened to about 28 miles. The distance from London to the source, in a direct

* Matthews's Hydraulia.

line, is only about 20 miles. The fall of the original channel averaged about four inches in a mile; its width and depth average about 18 feet and 5 feet respectively.

The water which originally supplied the New River was, as already stated, obtained from the springs of Chadwell and Amwell, and it was fully anticipated that a sufficient quantity could at all times be obtained from these sources. Soon, however, the company deemed it advisable to increase the supply, and recourse was then had to the river Lea, which flowed near the New River. The terms for this accommodation were settled by an Act of Parliament in the year 1737.

In the early stages of the London water-supply the distributing mains were almost entirely of wood, small leaden pipes being used for the services, as in the present day. Trunks of elm trees were cut into the required lengths, and bored; but from the comparative inability of the material to resist excessive pressure from without or within, the internal diameter was limited in most cases to six or seven inches. Near the reservoirs, however, where the necessary precautions against failure could be taken, there were pipes of from ten to twelve inches bore. The joints were made by tapering, or forming into a conical shape, one end of the pipe, and hollowing out the other end similarly. The several lengths were then wedged the one into the other. Matthews states that, 'at one period, the New River Company alone had different trains of wooden pipes about 400 miles in extent; but every year, from one cause or other, it became necessary to take up such as were injured or defective, and lay down new ones, amounting to an average of twenty miles; so that in the course of twenty years the whole range was entirely renewed.' To compensate for the small capacity of these wooden mains, it was necessary in many cases to increase their number, and Matthews states that, 'in 1810, nine trains were laid side by side in one street.' The inconveniences attending such an arrangement as this may easily be imagined, and the increased difficulty of ascertaining the exact whereabouts of the frequent leakages must, in no small degree, have added to the cost of maintenance. The quantity of water lost by fractures &c. was estimated at about one-fourth of the whole that passed through the pipes. In the year 1820 the whole of the wooden pipes were replaced by others made of iron. The expense of this alteration amounted to nearly £300,000.

In addition to the river Lea and the springs at Chadwell, the company at present obtains a large quantity of water from wells on the line of the New River, and elsewhere. The New River Company's works and machinery for distribution now consist of steam-engines at Hornsey, Hornsey Lane, Highgate, Stoke Newington, and New River Head, of about 1,450-horse power in the aggregate; covered service reservoirs at Claremont Square, Maiden Lane, Highgate, and Hampstead, of a joint capacity of about 20,000,000 gallons; with main and service pipes of diameters varying from 3 inches to 36 inches, and a total length of about 630 miles. About 340 miles of roads and streets contain New River Company's pipes of different dimensions. The amount of water distributed in 1870 was 23,160,000 gallons per day; the estimated population was 830,000, and the number of houses 114,730. The whole pumping power of the company amounts to 1,700 horse. The company has 20 gathering and subsiding reservoirs, with a joint superficial area of about 100 acres, and capacity of 180,000,000 gallons. From their present available sources more than 35,000,000 gallons per day can be supplied. The amount of capital expended on these works has been more than £2,500,000. The dividend paid in 1821 was £2 10*s.* per cent., and this has steadily increased. In 1866, a dividend of £6 11*s.* 6¾*d.* per cent. was paid. Mr. James Muir is the present Engineer to the New River Company.

The establishment and success of the New River Company gave an impetus to the formation of others. In 1723 an Act of Parliament was obtained 'for better supplying the city and liberties of Westminster, and the parts adjacent.' The company was incorporated in 1724, under the name of the 'Governor and Company of *Chelsea Waterworks*.' These works were situated on the north of the Thames, from which the whole of the water was procured. The capital at first raised was £40,000; subsequently, however, the proprietors obtained letters patent to make an addition of £20,000. In 1829 a filter-bed was constructed—the first adopted by any of the London companies—and two reservoirs attached, the latter having an area of about one acre and a half. The cost of constructing them was nearly £12,000. In the year 1856, the works at Chelsea were abandoned, and a point was selected above the influence of the tide. The reservoirs and filter-beds now in use are on the banks of the Thames, at Seething Wells, whence the supply is at present derived; they comprise an area of nine acres. From Seething Wells the water is pumped to summit reservoirs on Putney Heath, through two cast-iron mains: one, of 30 inches diameter, carries filtered water for domestic consumption, and the other, of 15 inches diameter, is for unfiltered water, pumped by independent engines, for road watering and similar purposes. The mains are carried across the Thames on an iron aqueduct of nine spans. The engines are of about 1,000-horse power collectively. The daily supply of water is about 8½ million gallons, and the number of houses supplied about 27,000, with an estimated number of inhabitants of 200,000. The capital of the company is now £780,000, and the present Engineer is Mr. Arthur Simpson, son of the late Mr. James Simpson, the former Engineer.

The proprietors of the *Lambeth Waterworks* were incorporated as a company in the year 1785, by an Act of Parliament for 'supplying the parish of Lambeth and parts adjacent, in the county of Surrey, with water.'

The old works were situated in the Belvedere Road, at a short distance from Waterloo Bridge, and nearly opposite to Hungerford Market. They were abandoned in 1851. The supply of water is now obtained from the river Thames at Long Ditton, three miles one furlong above Teddington Lock. The reservoirs are contiguous to the river, and comprise an area of about 4½ acres. The water is pumped from Long Ditton through two 30-inch main pipes, each 10¼ miles in length, to reservoirs at Brixton, by engines situate at the former place and of a nominal horse-power of 970. At Brixton it is pumped by 5 engines of 330-horse power, which deliver the water into reservoirs at Streatham, Selhurst, and Rock Hill. The Kingston district is supplied by a separate main, delivering water into a reservoir at Combe.

The amount of capital at the present time is more than £900,000. The company supply 45,000 houses, whose estimated number of inhabitants is 290,000. The average daily supply of water is 10,500,000 gallons. Mr. John Taylor is the Engineer to the Lambeth Water Company.

In the year 1798 the *Grand Junction* (Canal) *Company* obtained an Act of Parliament to construct water-works for supplying Paddington and the adjacent parishes. Twelve years, however, elapsed before the project was carried out. The water was at first supplied from the Grand Junction Canal, which received it from the Colne and Brent, as well as from a large reservoir of nearly 100 acres, that was filled by the various streams of the vale of Rinship, in the north-western part of Middlesex.

In an elaborate document issued in November 1810, it was stated that 'the water, in its present state, has been analysed and found excellent for all culinary purposes; it is also lighter and contains less foreign matter than the Thames water.' Eventually, however, the waters of the Brent were discovered to be so foul that it was necessary to prevent them from entering the canal. The water from the Rinship reservoir also was found to be contaminated with land drainage, so that the supply from both these sources had to be abandoned, and the company determined to rely solely upon the Thames. Accordingly, four acres of land were purchased at Chelsea, on the bank of the river, and the necessary works were commenced. Two steam-engines were erected, each of 100-horse power. In 1834 a further change was made, and a point was selected higher up on the Surrey side of the Thames, 360 yards above Kew Bridge. Here the stream is separated from the Brentford or Middlesex side of the river by an ait, commencing about 150 yards above Kew Bridge, and extending in length nearly half a mile. The water, after passing through an iron pipe laid in the bed of the river, was received into a well 8 feet diameter and about 22 feet in depth, whence it was pumped into a depositing reservoir.

About the year 1852, the Grand Junction moved up the river to Hampton, in order to secure water of greater purity. At Hampton there are two subsiding reservoirs, with a joint area of about two acres, and two engines, each of 110-horse power; the latter are for pumping the water to Kew Bridge, a distance of 7¾ miles, through a 33-inch main. The company has at Kew three subsiding reservoirs, covering together about 9 acres, and constructed to hold about 28,000,000 gallons; there are also three filter-beds, with a joint area of 5¼ acres. The engines at Kew are of about 1,270-horse power in the aggregate, and pump through a 30-inch main into covered reservoirs at Campden Hill, Kensington. These reservoirs are about 120 feet above Trinity highwater-mark, and contain 18,000,000 gallons. There are also at this point three engines of 200-horse power, for the supply of the higher portion of the parish of Paddington, by an independent 30-inch main. The amount of capital in 1867 was £850,000; the number of houses supplied in 1870 was 32,000, with an estimated number of inhabitants of 288,000; the average daily supply of water, 10,500,000 gallons; the approximate area of district supplied, 24 square miles. The total length of the company's mains is upwards of 220 miles, and they extend along 140 miles of streets and roads. The Engineer to the company is Mr. Joseph Quick.

In 1806 an Act of Parliament was passed for constructing the *West Middlesex Waterworks*, authorising the company to raise a capital of £80,000, which, by a subsequent Act, obtained in 1810, was increased to £240,000. This sum having been found insufficient to carry out the object, another Act was obtained in 1813, and the amount of capital augmented to £340,566. The supply of water was originally taken from the Thames at Barnes, but is now obtained from the river at Hampton above the village. Here are two engines of 105-horse power each, which pump the water to the reservoirs at Barnes through two 36-inch mains, 8¾ miles in length. The subsiding reservoirs at Barnes have a collective area of 20½ acres, and adjoining them are five filter-beds, with an area of 8 acres. From these the water is conveyed in two 36-inch mains, laid under the bed of the river to the wells of the engines at Hammersmith, whence it is pumped into parts of the districts direct, and also into a covered reservoir at Campden Hill, Kensington, of 3,672,000 gallons, and into a covered reservoir of about 4¾ million gallons, situated on Barrow Hill, near Primrose Hill. From this point, other engines of 90-horse power pump into the Kidderpore reservoir, near Child's Hill, containing 2½ million gallons, for the supply of the higher districts. The gross nominal power of the company's engines is about 1,200 horse. The daily supply averages about 9,000,000 gallons. The capital of the company is nearly £850,000. The number of houses supplied is about 43,000, with about 321,000 inhabitants. Mr. William Boughton Hack is the Engineer.

The inhabitants of the eastern part of London were supplied, prior to the year 1679, by the New River, Shadwell, and West Ham Water Companies. The works at Shadwell originated on a small scale with Thomas Neale, Esq., who employed merely one 4-horse engine. In 1679 the works were reconstructed, and subsequently improved by additional machinery, in order to meet the demand of the increasing population of the neighbourhood. They then supplied a district extending from the Tower of London to Limehouse, and from Whitechapel to the river Thames. In 1807 the works were purchased by the London Dock Company. In 1745 the West Ham Waterworks were opened, and supplied Stepney, Bethnal Green, the lower part of Whitechapel, Bow, Stratford, and Bromley. These works were also purchased by the London Dock Company in 1807. The Shadwell and West Ham Works together formed the nucleus of what was subsequently designated the *East London Waterworks*; a company being incorporated in 1807, with authority to raise the sum of £100,000, which was afterwards increased to £280,000 by an Act in 1807.

The first undertaking of the new company was the construction of reservoirs and erection of pumping-engines at Bow. The former were by the side of the tidal portion of the river Lea, and the privilege which the company acquired was to take water from the river only during the tidal flow; but this having become objectionable, a movement was made to Lea Bridge, which is above the tidal influence. Under the Act of 1829, the company acquired the Lea Bridge Mills and Hackney Waterworks, and an open aqueduct was made from the river, near Lea Bridge, to the reservoirs at Old Ford, by which the latter were supplied up to 1852, when another change was brought about, and the company took their water from Tottenham Mill Tail and Copper Mill Tail, nearly two miles above Lea Bridge. Further alterations and purchases of mill-power have enabled the company to remove the intake to Higham Hill, and in the intervening space to construct on the Walthamstow side of the river a series of reservoirs or lakes, which have a water area of 250 acres.

These lakes have a capacity of 700 million gallons, of which 400 millions can be drawn off by simply opening the sluices ; the capacity of the reservoirs below the sluice level serving to purify the water by subsidence. These reservoirs render the company independent of the river for a month at a time.

From the settling reservoirs, the water passes by a straight open channel about 1¼ mile in length, to the filtering-beds at Lea Bridge. These are nineteen in number, and have a sand-area of 18 acres.

From the filtering-beds the water is conveyed by a covered brick channel, 6 feet by 3½ feet in section and 500 yards in length, to the engine wells of the northern or Lea Bridge pumping-station, and by an iron main, 4 feet in diameter and 4,240 yards in length, to the southern or Old Ford pumping-station.

At Old Ford the company has a covered basin or reservoir of about 1½ acre, into which the water is received, and from which it is pumped into the mains for a part—about one third—of the supply. This basin was constructed in 1810, and covered in 1855.

At Lea Bridge there are three engine-houses, with steam-engines of 630-horse power. At Old Ford there are five engine-houses, with steam-engines of 620-horse power. And here it will be interesting to note that, at Old Ford in 1838, the Cornish engine was, by Mr. Wicksteed, first applied to the pumping of water for the supply of towns. At Lea Bridge, water-power is usefully employed in addition to the steam above described ; and at Walthamstow there are auxiliary engines (steam and water) of 60-horse power. The horse-power given above is not the nominal, but the actual power ordinarily developed by the engines referred to. The average daily supply of water in 1871 was 20,437,000 gallons. The capital of this company is £1,825,000. The number of houses supplied is 102,624, with an estimated number of inhabitants of 750,000. The actual length of streets supplied is estimated at 350 miles. The East London Company will very shortly (1872) have completed a new and independent series of works for procuring water from the Thames at Sunbury Mills, above the intakes of the other London Companies. The works are proportioned to the further delivery of 10,000,000 gallons. The present Engineer to the East London Waterworks Company is Mr. Charles Greaves.

The *Southwark and Vauxhall Water Company* dates as such from the year 1845, for before that time the Vauxhall Company, incorporated in 1805, and the Southwark Company, authorised in 1835, were independent concerns.

Previous to 1857 the supply was drawn from the Thames at Battersea, but in that year the point of abstraction was shifted up to Hampton. At this place there are now depositing reservoirs, of about two acres in extent; and three engines, of 390-horse power collectively, which pump through a 36-inch main, 13 miles long, into the reservoirs at Battersea. These latter have together an area of about 12 acres, and capacity of 46 million gallons. Here there are also five filter-beds, with a joint area of 8¾ acres. The company has altogether six engines at work, of 1,200-horse power collectively. At Hampton there are also works for supplying filtered water, as follows :—a subsiding reservoir of 3½ acres ; three filter beds of 3 acres; and two engines of, together, 450-horse power. A 30-inch main, 10 miles long, conveys the water to London. About 660 miles of the company's mains and service-pipes, varying from 36 inches to 3 inches in diameter, extend along about 360 miles of streets and roads. The capital of the company is above £1,100,000; and 76,700 houses, with an estimated number of inhabitants of 480,000, are supplied by it. The daily supply of water is about 15 million gallons. Mr. Joseph Quick is the Engineer.

The *Kent Waterworks Company* was incorporated in 1809, and possession was taken of some ancient works on the river Ravensbourne, at Deptford, established as early as 1699. Down to 1857, the company relied solely upon the Ravensbourne water, but in that year it was found necessary to resort to wells sunk into the chalk, a source which proved so plentiful that in 1862 the river was entirely abandoned. In 1861 the Kent Company purchased the works and rights of the 'Plumstead, Woolwich, and Charlton Consumers' Pure Water Company,' which had been registered in 1852, under the Act 7 and 8 Vict. c. 110, and opened in 1854. The principal station of the Kent Waterworks Company is on the site of the old works at Deptford, where there are three wells, and a separate pumping-engine to each. The water is conveyed for distribution to other engines, which pump directly into the mains. There are also two wells at Charlton, one at Plumstead, one at Crayford, and two at Bromley; at each of these an engine is placed, which serves both for pumping and for distribution. In addition to the pumping power to the different wells, there are other engines near Shooters Hill, for supplying the more elevated districts. The company has altogether 18 engines, together working on an average up to about 1,200 horse power. The company has at Deptford a series of filter-beds and five depositing reservoirs; but since the river Ravensbourne was abandoned as a source of supply, these have not been required for the purpose for which they were originally constructed. One of the filter-beds, however, is at present used as a reservoir, to contain the excess of water when more is being pumped from the wells than is being forced through the mains, and to supply the deficiency when the contrary is the case. There are summit reservoirs in Greenwich Park, on Woolwich Common, and at Plumstead and Chiselhurst, of a joint capacity of about 4½ million gallons. The average daily supply is over 7,000,000 gallons; about 40,000 houses, with a population of nearly 300,000, being served. The capital of the company is about £500,000. Mr. W. R. Morris is the Engineer.

The whole of London is at present supplied under the 'intermittent' system (see Chap. XVI.).

In the year 1866 a Royal Commission was appointed 'for the purpose of ascertaining what supply of unpolluted and wholesome water can be obtained by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation for the supply of the large towns, and to report, firstly, which of such sources are best suited for the supply of the metropolis and its suburbs.' By a warrant dated April 1867, the Commissioners were further commanded to enquire into the present water-supply of the metropolis, and 'whether there are other districts in addition to the high districts of England and Wales from which a good supply of unpolluted and wholesome water can be obtained.' Connected with the mountainous districts of England and Wales, five engineering projects were laid before the Commissioners: four of them had for their object the supply of the metropolis, the fifth the supply of various towns in Lancashire and Yorkshire.

The first on the list was that of Mr. John F. Bateman, C.E., F.R.S., who proposed to collect water by reservoirs to be formed in the mountainous districts of North Wales, and to convey it by an artificial conduit to London, where it should be delivered at an elevation from which nearly the whole metropolis could be supplied without pumping. Mr. Bateman selected certain high drainage-grounds in North Wales lying to the south of Snowdon, and to the east of Plynlimmon and Cader Idris, and supplying the head-waters of the river Severn. He proposed to convey the water from the two districts, by separate conduits, converging to a point of junction at Morten Mere, near Montgomery; from this point, the joint volume of water would be conducted southwards by a common conduit, and discharged into large reservoirs, proposed to be constructed on the high land near Stanmore, about ten miles north-west of London. The total distance which the water would have to be brought is a little above 180 miles. The conduit is designed to be capable of conveying 230,000,000 gallons per day. The estimated outlay is £11,400,023.

The second plan was called the Cumberland Lake Scheme, and was brought forward by Messrs. Hemans and Hassard, who proposed to supply the metropolis with water from the lakes of Cumberland and Westmoreland. Speaking of the great distance of the source from London—240 miles—and the large expenditure that would be required, these gentlemen remark:—'We believe that, when the subject is fully investigated, it will appear that our project, although involving an apparently larger outlay in the first instance, will, from the absolute certainty of the rainfall, the extraordinary purity of the water, the facilities afforded by the existing lakes for the construction of the immense reservoirs, and from the revenue which may be fairly expected from the sale of water in the districts traversed by the aqueduct, be found the best and cheapest which has yet been proposed, and that ultimate economy will arise from its selection.' The cost of this project, complete for 250,000,000 gallons a day, is estimated at £13,500,000.

The third plan was proposed by Mr. Hamilton Fulton, and was for taking water from the upper sources of the river Wye, in Mid-Wales. The reasons adduced for the selection of this district are: 'That it is but thinly inhabited; that the water is scarcely used at all either for manufacturing, domestic, or navigation purposes; that the fisheries which exist could be protected from injury, and that there are no manufacturing towns in the water-shed, and only a few flour-mills.' The water would be conveyed from Rhyader to London—180 miles—by a conduit calculated to deliver 230,000,000 gallons per day. The estimated cost is given at £9,000,000.

A fourth plan, proposed by Mr. George Remington, was to bring water from the hills of Derbyshire, collecting it at a point above Mill Dale, on the river Dove, 586 feet above the sea, and bringing it by a conduit, 135 miles long, to a reservoir at Barnet Hill, 300 feet above Ordnance datum. Mr. Remington estimated that his scheme would cost £5,000,000.

The last plan proposed to the Commissioners for obtaining water from mountainous districts was that of Mr. Thomas Dale, Engineer to the Corporation Waterworks of Hull, who proposed to take water from the same sources as Messrs. Hemans and Hassard—namely, the Cumberland and Westmoreland lakes—and to convey it by pipes, to supply various towns in Lancashire and Yorkshire.

Of the other schemes proposed to the Commissioners, the following is a brief outline:—

Mr. McClean proposed to embank and canalise the Thames above Medmenham (between Henley and Great Marlow), so as to form in the present channel of the river a long series of impounding reservoirs, which would be advantageous not only for storing water, but for improving the navigation. A conduit 36 miles in length would suffice to bring the water to London, and the distribution would be effected partly by gravitation and partly by pumping. Mr. McClean's estimate is £1,500,000, excluding the pumping arrangements.

Mr. Bailey Denton proposed to obtain a supply of water from the upper streams of the Thames, the Wey, and the Mole, while the Colne and the Wandle could be included in the scheme when occasion demanded. Ample storage would be provided, and it was proposed to purchase the Thames and Severn and the North Wiltshire canals, and utilise them for the collection of the waters of the Thames. The main conduit would extend from Lechlade to London, a length of 127 miles. The cost is estimated at £5,320,000.

Mr. R. W. Mylne introduced a plan for increasing the supply of water from the basin of the river Lea, by collecting the streams and chalk springs into impounding reservoirs, to be formed at various places, but principally at Enfield Chase. This plan, it was stated, would enable 70,000,000 gallons to be brought daily into London, in substitution for the present supplies of the New River and East London Companies, thus adding about 28,000,000 gallons. This estimate is for the minimum of the driest years, and the cost, including compensation, is given by Mr. Mylne as £1,250,000.

The attention of the Commissioners was further directed to the chalk formation of the London Basin as the most eligible source of water for the metropolis. Mr. Clutterbuck recommended the collection of water from the chalk springs issuing at high levels in various places round London. Mr. Homersham proposed the sinking of wells down into the chalk; and Mr. Barlow suggested driving a tunnel parallel with the Thames for 20 miles, from Lewisham to Gravesend, so as to intercept the chalk springs that would otherwise drain into the river.

Of the miscellaneous schemes brought under the notice of the Commissioners, one was that of Mr. Hemel, who proposed to utilise springs from the chalk near Basingstoke, and from the Bagshot sands, between Farnborough and Woking. The Basingstoke Canal would bring the water to Weybridge, whence a conduit, eight miles long, could be made to the existing reservoirs at Thames Ditton, and the several water companies could then pump the water into their respective districts. £280,000 is set down as the estimated cost of the scheme.

The plan of Mr. Telford McNeil was to intercept 200,000,000 gallons of water daily from the Thames at Teddington, and to pump it into the Bagshot sands, through which it would be made to filter. Thence it could be conveyed in a closed conduit to London, and again pumped into reservoirs at Norwood and Hampstead. The estimate for this is above £6,000,000.

The judgment of the Royal Commission on the question of future supply is as follows:—'That the river Thames, supplemented if necessary by works for storing the flood waters, together with the river Lea and the water obtainable from the chalk from the south and south-east of London, as well, probably, from the lower greensand, will furnish a supply sufficient for any probable increase of the metropolitan population. . . . . That a probable increase of population to 4,500,000 or 5,000,000 may have to be provided for, though we believe that the time for such an extended provision will be very remote. That 200,000,000 gallons per day is the highest demand that need be reasonably looked forward to for the metropolitan supply, and that the various companies are prepared, with only moderate additions to their present engineering means, to supply a quantity little short of this amount.'

As succinctly as possible, without ignoring any important facts illustrative of a subject so interesting, the various measures adopted, more especially in ancient times, for procuring supplies of water for man's necessities, have been alluded to in the foregoing pages. And what a change in countries where great civilizations have flourished, from the time when the lone savage lay down by the river's brink to slake his thirst, to a long-after period, when some world-renowned city, full of all luxury and art, received its supply through magnificent artificial channels, constructed with transcendent skill, and of a monumental durability that could be overcome only by the earthquake or the ruthless violence of man!

And what has been the progress since the period of the great aqueducts? Structures more wonderful have been built it is true ; but for the supply of water to cities we are now enabled, from a thorough comprehension of the capabilities of iron, to meet the same ends by less costly means. The mighty energy of steam, the fertility of modern invention, and the general advance of science, have likewise in nothing more powerfully ministered to the wants of man than in bringing this great necessity of life within his immediate reach. With the vast structures of ancient Rome we need not be ashamed to contrast the mighty giants of iron, which, to quench the thirst of our great metropolis, labour from morn till night with the effort of ten thousand horses. On to the tops of the hills and into our very chambers is the liquid forced.

But what is the liquid, and whence is it obtained ? Some bright and pure from springs and wells, but most of doubtful hue and flavour drawn from a sewage-polluted stream, the instinctive appreciation of which cannot easily be set aside. Rome, with but few of the advantages which are at our disposal, did not stop to consider the great expense of fetching water, pure and clear, from the distant hills. Fortunately, however, there are to be found many modern examples of praiseworthy and happy selections of source, and also of thorough artificial purification.

But on the score of quantity what can be said ? In ancient Rome the daily consumption was at the rate of three hundred gallons for each individual, so liberal was the use of water for baths and fountains. In the present day thirty gallons are considered to be a wasteful quantity ; this is the change in the estimate of what is necessary for comfort and for health ; this is the progress of the last two thousand years.