HIDDEN BENEATH OUR FEET:
The Story of Sewerage in Leeds

by

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To
past and present staff of Leeds City Council's Main Drainage organisation

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I. KING CHOLERA

In the early years of the Nineteenth Century most of the area presently occupied by Leeds City was still characterised by rural tranquility. Miles of rolling pastures and woodland separated Sheepscar from Seacroft Village. Viewed from the fields to the west of Wellington Bridge however, the Leeds of the 1830's presented an industrial panorama dominated by textile mills. The skyline bristled with tall chimneys belching their smoke and attendant lung diseases onto a largely helpless population.

The factory owners and middle classes lived to the west and on the hillsides of Woodhouse or Headingley - protected from the swirling smog by the prevailing westerly winds.

Crowded into the terraces and tenements in the heart of the township were the working classes. As a consequence of the furious expansion of industry, the population of Leeds had increased from 53,000 in 1801 to 123,000 in 1831. To cater for this influx of people unscrupulous landowners had crammed dwellings into every imaginable nook and cranny. Very few of the streets and yards were paved or drained. The result was that only in dry weather could the inhabitants venture forth without sinking ankle deep in mud. Domestic and human waste would be deposited in the street: sometimes in designated middenheaps, which would be cleared by scavengers - sometimes not. Stagnant pools in the streets were a common feature and at times the stench was unbearable. The insanitary conditions in the street inevitably spilled into the dwellings.

> "*The surface of these streets*", wrote a local doctor, Robert Baker, "*is considerably elevated by accumulated ashes and filth, untouched by any scavenger; they form the nuclei of disease exhaled from a thousand sources. Here and there stagnant water, and channels so offensive that they have been declared to be unbearable, lie under the doorways of the uncomplaining poor; and privies so laden with ashes and excrementitious matter, as to be unusable, prevail, till the streets themselves become offensive from deposits of this description: in short there is generally pervading these localities a want of the common conveniences of life*."

It was from these quarters that the Cholera sprang, during the national epidemic of 1832. The first victim in Leeds - in May of that year - was the two year old child of a weaver living in a 5 metre square cottage in Blue Bell Fold (near Marsh Lane) - "a small and dirty cul de sac, containing about 20 houses, inhabited by poor families", according to the Leeds Board of Health. Not without reason was the disease called 'King Cholera' - having more the aspect of an almighty curse than a plain disease. It had spread rapidly since the first case was recorded in Sunderland. The victims would be afflicted by a violent pain in the stomach, followed by diarrhoea, sickness and death. Seven hundred people in Leeds died of Cholera over a six month period.

Soon after the 1832 Cholera outbreak, Robert Baker wrote a detailed report on the marked geographical pattern to the disease in Leeds. Worst hit were the poor areas to the East of the town centre. There was shown to be a clear link between the disease and poor drainage. The report was sent to the Home Secretary in London, but appears to have been promptly shelved.

Cholera struck again within two years. Although centred in the working class areas, the middle and upper classes were smitten too. It is easy to understand their panic: Cholera was like a mad dog - no one could be sure where it would pounce. Disease was not yet understood; the germ theory had not yet been propounded (it was commonly thought that disease was transmitted by smells, or ‘miasmas’); Koch's discovery of the Cholera bacillus had yet to be made. Most of the cures and preventative measures current at the time were 'quack' remedies.

Following a suggestion in Parliament, a National Fast Day was held on 21st March 1832, as a day of atonement, for the sins which had presumably invited the scourge of Cholera.

To working-class radicals this was the height of hypocrisy. In response the National Union of the Working Classes mounted a demonstration of 120,000 in London to protest against the Government's handling of the crisis. The radical viewpoint was expressed by Henry Hetherington in the "Poor Man's Guardian" (18/2/1832):

"*The Cholera has arrived amongst us, and this, among other blessings, we have to lay at the door of our ’glorious constitution’, for it is a disease begotten of that poverty and wretchedness which are occasioned by the wealth and luxury of the few to whom only the constitution belongs*."

The Government was **frightened** into establishing a Commission of Enquiry into the circumstances leading to such epidemics.

The resulting report of Edwin Chadwick on "The Sanitary Condition of the Labouring Classes" (1842) was a best-seller. It's central thesis was the same as Baker's earlier report. Indeed, Chadwick included Baker's statistical map of Leeds (fig.1) and wrote:

> "*By the inspection of the map of Leeds which Mr.Baker has prepared at my request to show the localities of epidemic diseases, it will be perceived that they ... fall on the uncleansed and close streets and wards occupied by the labouring classes and that the track of the Cholera is nearly identical with the track of the fever. It will also be observed that in the badly cleansed and badly drained wards to the right of the map, the proportional mortality is nearly double that which prevails in the better conditioned districts to the left.*"

In the 1845 ‘Report of Commissioners of Enquiry into the State of Large Towns and Populous Districts’, James Smith described the Holbeck and Hunslet districts in the following terms:

> *“ as from the want of proper sewerage there are no house-drains, the slops and refuse from the houses are thrown upon the surface of the streets, which are in many places thereby raised some feet above the original level. All over this district the dunghills, ash-pits, and privies have been set down without any order, in some places encroaching upon the streets, and in the courts the filth often covering almost the whole area.”* Of Leeds in general, he said, *“There are sewers in a few of the principal streets, but in the greater number of streets and alleys there is no provision whatever for drainage or sewerage.”*

Even where drainage was available, it left a great deal to be desired. It was common in the early-Victorian towns for the sewers to be chiefly flat-bottomed passages and conduits, laid in a piecemeal fashion, with inadequate gradients. These sewers were totally unsuitable for the mixture of rainwater, waste-water and excrement which they received. The flat-bottoms and shallow slopes ensured that they soon became choked up with noxious accumulations. The putrefying organic material deposited in this manner, gave rise to poisonous gases such as methane, which would often find its way into the houses through untrapped drains. Even the wealthy houses were affected, according to evidence given to a House of Commons Committee in 1834, but it was the servants sleeping in the 'lower rooms' who took the brunt of the resulting ill health!

Regular removal of the large quantities of sewer deposits was a real head-ache. Mr. John Roe, Civil Engineer to the Holborn and Finsbury Commission of Sewers, explained the usual method in a statement given to Chadwick's Enquiry:

> "*... the streets were opened at a great expense and obstruction ....; men descend, scoop up the deposit into pails, which are raised by a windlass to the surface, and laid there until the carts come; it is laid there until it is carted away, sometimes for several hours, to the public annoyance and prejudice. The contract price for removal from the old sewers without manholes was 11s. per cubic yard of slop removed; where they have manholes it was 6s.10d. per cubic yard.*"

No wonder, with removal being such a chore, the deposits were allowed to remain for 5 to 10 years in the sewers.

In Roe's own area great strides had been taken in organising the sewerage system on an entirely superior basis: the outlets had been made low enough to enable all the outlying areas to be drained with sufficiently steep sewers and the sewers had curved bottoms to reduce the rate of deposition. Moreover, Roe's plan of flushing the sewers and carrying off all the refuse by water had been adopted. The cost of sewer cleaning in Holborn and Finsbury was consequently reduced from £12,000 per year to £600.

Amongst public health agitators, there was a growing conviction that this 'water-borne' sanitation represented the way forward. An essential requirement for this to be implemented effectively however, was that every house had a reliable supply of water, which could be used for flushing away soil matter. There was no way in which Leeds of the 1830's could boast such a supply: The Leeds water supply was an entirely class-based affair.

Leeds was one of the first towns in Britain to have a piped water supply to houses. It came into operation in 1694 and was designed by the engineers George Sorocold and Henry Gilbert. A water wheel built near Leeds Bridge, Lower Briggate, pumped water from the River Aire through 2½ kilometres of 75mm diameter lead pipes to a storage reservoir - or 'cistern' - in Wade Lane, whence it served the wealthier inhabitants in a town of 7,000. The only materials available for pipes at that time were either lead or the bored trunks of elm trees. Sixty years later, when the total population had risen to approximately 17,000, new works were built at Pitt Fall Mills, near The Calls. In the 1790's three storage reservoirs were built near Albion Street.

In the early years of the nineteenth century the waterworks company was supplying about 2,000 houses. Most of the inhabitants of Leeds relied instead on wells, boreholes, water-carriers and the River Aire. Water-carriers it should be noted charged up to two shillings per week for their services. For many people, this was a sum almost as much as their total weekly rent for accommodation. The River Aire by 1830 however, was completely unsafe for drinking. According to Charles Fowler in the 'Leeds Intelligencer' (21/8/1841), it was:

> "*..charged with the contents of about 200 water closets and similar places, a great number of common drains, the drainings from dunghills, the Infirmary (dead leeches, poultices for patients, etc), slaughter houses, chemical soap, gas, dung, dyehouses and manufacturies, spent blue and black dye, pig manure, old urine wash, with all sorts of decomposed animal and vegetable substances from an extent of drainage between Armley Mills to the Kings Mill amounting to about 30,000,000 gallons per annum of the mass of filth with which the river is loaded.*"

Small wonder that the death rate in Leeds rose from 20.7 per thousand in 1831 to 27.2 per thousand in 1841. The average life expectancy in Leeds, according to figures given by Chadwick, was as follows:

Gentry	-	44 years
Tradesmen	-	27 years
Workmen	-	19 years

The Leeds Waterworks Company discontinued its use of the Aire for drinking water in 1841 and used instead, as a temporary supply, the water leaking into the partially complete tunnel linking Leeds with the proposed Eccup reservoir. For most people however, a wholesome water supply was still beyond reach: in 1842 the number of Leeds houses with a piped water supply was still only 3000. By 1852, when the Waterworks Company was bought by Leeds Corporation (for £¼m), the number of connected properties had risen to 22,732.

II. THE IMPROVEMENT OF LEEDS

Prior to the 1832 Cholera very few streets in Leeds were drained. The few sewers which did exist had been built privately and discharged either directly to the River Aire at Leeds Bridge or to Addle Beck - the 'Ganges of Lady Lane' - and thence to the River (see fig.2).

Impelled by a growing movement for Improvement, the newly formed Borough Council promoted a series of local Acts of Parliament. As far as sewerage was concerned, the Leeds Improvement Act 1842 was epoch-making. Section 153 of the Act stated:

> "*It shall be lawful for the Council from time to time to cause such common sewers, drains, vaults, culverts, watercourses, wells and pumps as they may think necessary to be made and constructed in or under any streets within the limits of this Act*."

Various proposals were considered for using the new powers in order to provide a comprehensive sewerage system. In particular, three rival plans were presented to the Council during the course of 1844-45 by Thomas Walker (the Borough Engineer), Captain Vetch, R.E., and the Leeds based engineer John Wignall Leather.

Walker's plan was distinguished by his scant regard for all the arguments about the condition of the River Aire. His report proposed "*... conveying the drainage along the natural hollows, direct into the river, its natural channel*". He claimed that "*it is altogether impossible to cleanse the River Aire of its impurities, and that no proof whatever can be adduced that the present polluted state of the River Aire has been injurious to the public health*". In keeping with this outlook, Walker's plans showed no less than seven new sewer outfalls to the Aire - all close to the town centre.

Both Vetch and Leather proposed deep main sewers parallel to the river, picking up (or intercepting) subsidiary shallow sewers from the various streets, and discharging to the river well downstream from the town. Vetch envisaged a 'manure farm' close to the outfall, by means of which a revenue of £10,000 per annum could be raised by usage of a portion of the sewage for agricultural purposes. There were severe misgivings among others however about the viability of his plans for sewage utilisation, given the assumed toxic effect of some of the dyers' wastes in the sewage and the advent of cheap Peruvian guano as an agricultural fertiliser. There was also some doubt about the possibility of getting agreement from private landowners to some of his proposed sewer routes.

Leather's scheme, which avoided these uncertainties and led the sewage untreated to the Aire, was adopted by the Council in June 1846 (see fig.3).

In his report of February 1845 on the "Means of Providing an Effectual Sewerage System for the Town of Leeds", Leather set out seven explicit general principles or conditions which he felt were "*essential to a sound system of sewerage*" and which he had incorporated in his scheme (see Appendix 1).

In these conditions were embodied the principal recommendations in Chadwick's 1842 Report - namely, that sanitation should be hydraulic, arterial and water-borne. This meant that ideally water had to be piped to every house to flush away the excrement (via a 'water-closet'). This water would then carry the sewage away in sewers of curved cross-section (rather than the brick arches which were then prevalent).

The cross-sections of Leather's proposed sewers were generally egg-shaped. This was in accord with the recommendations of Chadwick's technical advisor, John Roe, engineer to the Holborn and Finsbury Commission of Sewers. The egg-shape was intended to give relatively high velocities at low flows and thus improve the scouring action or self-cleansing behaviour of the pipes.

It is interesting to note that the appropriate size for the pipes was a subject of great contention at the time. Rival sets of flow tables were available, which gave vast differences in capacities.

Leather insisted that none of the existing sewers could be incorporated in the scheme. The condition of the Marsh Lane sewer, described by Captain Vetch, was thought to be typical: "*2 feet wide, 3 feet high, flat at top and bottom, the sides were built of dry stones full of large interstices, affording an extensive harbourage for rats, and permitting the liquid filth to soak through whatever ground was porous*."

It was recommended that individual houses be connected to the street sewers with the relatively new glazed earthenware pipes (150 to 225mm in diameter).

Despite the Council decision in 1846 to adopt the new sewerage scheme, various factors combined to produce delays. Firstly, agreement was still needed from the Aire and Calder Navigation Company, whose rights over the River Aire and its tributaries would be affected. Secondly, a borrowing limit of £100,000 was imposed on the Council by the 1842 Improvement Act and half of this sum had already been used on other projects. Thirdly, agreement was needed from the owner of the Temple Newsam estate to site the main outfall sewer on his land.

It took 2 years to sort out these difficulties, but by then a downturn in the economy and in company profits had increased the lobby against the levying of a sewerage rate. Motions to proceed were lost in the Council meetings in January and February 1849. The fresh outbreak of Cholera in October 1849 however, in which 2000 died in Leeds, may have helped to concentrate minds: The Streets Committee authorised the first contracts for construction work to be let in 1850. Leather's scheme was completed at a total cost of £137,000 by 1855.

The part played by the new breed of mapmaker in enabling the scheme was indispensable. Up to the commencement of the Nineteenth Century very few reliable maps or plans of the Township of Leeds were available. Yet the visionary civil engineering feats of the Industrial Revolution needed the skills of the surveyor as never before.

Accurate scale plans were essential for the construction of new communications - canals, railways and turnpike roads. Plans were needed for the use of the new official bodies such as the Local

Boards of Health and the Poor Law Commissioners. Plans were needed too for the public sewer and waterworks schemes.

It is thought that the first plan of Leeds drawn from an accurate survey was that of Netlam and Giles in 1815. Figure 2, which is Charles Fowler's 1821 plan, appears to have been based on Netlam and Giles' plan. Not until 1850 did the Ordnance Survey produce plans of Leeds (60 inch to 1 mile plans 1:1056 scale - based on a survey done in 1847 by Capt.R.E.Tucker). The earliest comprehensive public sewer records held in Leeds were superimposed on the 1850 O.S. sheets (see reproduction here).

III. A STILL-BORN PROGENY ?

Over the next 10 years Leeds Council spent about £10,000 per annum on extensions to the new sewerage system. Private property owners however did not seem to be responding with much enthusiasm to the new amenity. In December 1854 the Streets Committee noted that there had been very few applications for the connection of house drains to the new sewers. In May 1857, the same committee advertised a decision not to sewer any street unless two-thirds of property owners in the street agreed to connect to the sewer.

The slow rate of improvement of sanitary conditions, despite the new sewers, is illustrated by the continuing rarity of the flushing water-closet system in Leeds:

YEAR	Number of WC's
1856	1,005
1860	1,628
1865	3,221
1870	6,000

In 1870 an estimated 30,000 privies were still in use in the Borough of Leeds. The middensteads - great piles of human dung - were still a feature of the Leeds streets. Writing in 1874, in his "Report on the Sanitary State of Leeds", J.Netten Radcliffe described a middenstead in Wellington Yard "*which measures 21 feet long by 5 feet 10 inches broad, and which is 6 feet deep below the surface of the ground. Into this middenstead there fell not long ago a half tipsy man, plunging deep into the revolting filth, and there, suffocated, he lay until, days afterwards, discovered by the scavengers*."

The lack of an effective piped water supply was no longer a constraint on the spread of the WC. The water supply undertaking, upon becoming a municipally owned utility in 1852, had works consisting of a Storage Reservoir at Eccup (capacity 1.1 million cubic metres); a Service Reservoir at Weetwood and one at Woodhouse Moor. After municipalisation large extensions were made, including filter beds at Headingley (1860) and a pumping station at Arthington on the River Wharfe.

In September 1866 Edward Filliter, the Council's Engineer, could report to his employers that "*the present supply of water is derived chiefly from the River Wharfe at Arthington (whence you have Parliamentary powers to pump 6 million gallons per day), and partly from the small gathering ground about the Eccup Reservoir, with certain springs thereto*."

Average consumption, he pointed out, was currently 4.5 million gallons per day. However "*should your consumption attain even 6 millions of gallons per day before a new scheme is actually in operation, you will become dependent upon the Eccup gathering ground, and, if a stoppage by* *accident or for ordinary repair should happen to one of your pumping engines at Arthington, much uneasiness might justly arise among the inhabitants, especially among your large consumers.*"

The piped water supply had freed industry from the banks of the river. As a result, the needs of industry played no small role in forcing the pace of development of the water supply.

Year	Average gross daily consumption (litres)	Number of houses supplied
1856	7,255,000	30,996
1860	11,520,000	35,447
1865	20,034,000	46,305

Table of Annual Water Consumption in Leeds

To help meet the increased requirements three new impounding reservoirs were built: Fewston, Swinsty and Lindley Wood in the Washburn Valley 15 miles north of Leeds. By 1883, 78,600 houses were supplied with piped water.

In the 1870's, not before time, the Sanitary Committee began a campaign against the "abominable middenstead and cesspool". By 1889 there were 28,000 WC's in Leeds and by 1902 only 15,000 of the 100,000 tenants supplied with water had no WC.

Although the WC was becoming the norm, it was not without its opponents. For a long time it faced bitter competition from the earth-closet. In the earth-closet system, each deposit of faeces would be covered by an automatically measured amount of dry earth. The earth was a natural deodorant and disinfectant and could be re-used. In the densely populated towns however it was not a practical, hygienic proposition.

IV. TREATMENT

Leather's sewerage scheme dealt exclusively with the townships of Leeds, Hunslet and Holbeck. In the late 1860's however, major extensions of the sewerage network were planned, linking it to Armley, Wortley, Headingley, Chapel Allerton and Potternewton.

These extensions did not always receive unanimous acclaim. The extension into Headingley, in particular, met with vocal opposition. A number of influential residents wanted the cheaper option: draining directly to the River Aire, upstream of central Leeds

The plans also stirred up great opposition from landowners adjacent to the Aire downstream of Leeds, who feared even worse pollution of the river. Conditions were already bad. In August 1865, Francis Darwin, the Chairman of the West Riding Magistrates, had cause to visit the main outfall location. He was aghast at what he saw: *"On arriving at the place where the sewage of Leeds is cast into the river, I certainly was very much astonished. I observed human excrement and carcasses of dogs and cats, and I may say I never saw anything so frightful in my life; every eddy of the stream was manifestly full of human excrement of the most terrible kind"*.

In December 1869 a Chancery injunction was obtained, restraining the Council from discharging any more sewage to the Aire, until it had been sufficiently purified and deodorized as not to be, or create a nuisance, or become injurious to the public health.

Under this pressure the Council's Streets Committee reached agreement with the owner of Temple Newsam estate for the sale of more land, upon which to build a sewage treatment works at Knostrop.

Many rival schemes were proposed for the 107 hectare site. In 1877 the Streets Committee chose a lime precipitation process as the cheapest and most effective of the methods proposed. This method was used, more or less unchanged, for the next 30 years.

The West Riding Rivers Board, which was constituted in 1893, brought pressure on the Corporation in the mid 1890's to improve the quality of the effluent. Consequently, five new precipitation tanks were constructed in 1897, bringing the total tank capacity to 28.6 million litres (fig.4). This improvement however brought additional problems: more sludge was thus produced, as more suspended solids were removed from the sewage, and yet the area of lagoons available for drying the sludge correspondingly decreased. The accumulation of sludge became a worry and also the impetus for further developments - as will be shown.

The construction of the Knostrop Treatment Works enabled the extension of the sewerage system to proceed once again. In the period between 1877 and 1900, approximately £600,000 was spent by the Council on sewerage and drainage. Construction proceeded at 193 km of sewer per decade.

V. THE STORM WATER PROBLEM

When the main sewers of John Wignall Leather's scheme were designed, very few streets in the areas served were paved and the population of Leeds was only of the order of 160,000. By the early 1880's the population of the Borough had leapt to more than 300,000, numerous streets had been paved, and the sewerage system had been extended to many of the outlying townships. So thoroughly was the area being drained of surface water during rain storms, that the principal intercepting sewer was completely unable to cope. The result was that many premises lying in the lower levels of the town were subject to an increasing frequency of back-flooding during heavy rainfalls. Something had to be done - and yet it was out of the question to provide sewers big enough to conduct all the storm water to Knostrop.

The Borough Engineer of the time, Thomas Hewson, proposed a solution to the Streets and Sewerage Committee of the Council in June 1883. In his "Report on Leeds Intercepting Sewers and Disposal of Rainfall" Hewson suggested that no more than two volumes of rainwater to every one volume of foul sewage should be allowed to enter the Intercepting Sewers. This would prevent them flowing more than two-thirds full for the foreseeable future and would be achieved by a system of storm overflows. He explained the principle of operation as follows:

> "*Intercepting sewers receive along their routes at irregular intervals, the main and street sewers running right and left from them. On the main and street sewers, arrangements of leaping weirs as storm overflows or diverters of the rainfall from them to the becks, would be made. These should be so remote, laterally from the intercepting sewer, as to reach an altitude on the main or street sewer above the highest flood level of the beck, and so prevent the beck storm water from flowing into the sewer. They would have two outlets to discharge into, one near, for when the flow was sluggish, and one farther off, for when the rainfall increased the flow and velocity so as to carry it over the first opening*."

The general arrangement of the proposed leaping weir storm overflows was as shown in fig.5.

The Local Government Board, set up in 1871 by Disraeli, was the central authority responsible for sewage and sewage disposal. Apparently, one of the Board's "requirements" was that storm overflows should not come into operation until a flow equal to six times the dry-weather flow was being conveyed to the sewage works for treatment. Hewson's two of rainfall to one of sewage was consistent with this, since in his calculations he assumed that at peak flow the foul sewage flowed at twice the average daily rate (i.e. 230 litres per head per day, compared with an average of 115 litres per head per day).

Of course, this temporary 'overflow' expedient tackled only the tip of the iceberg. Conditions in some parts of Leeds still gave testimony to what life could be like without proper surface water drainage and street paving. Take for example the situation in Thornhill Road (Upper Wortley), as described by an irate correspondent of the "Yorkshire Post" in late 1890:

> "... *It is perfect cruelty to animals to attempt passing along this road with a load. A number of minor accidents have already taken place, such as sacks of flour falling off waggons,*

> *carts upset, horses sticking completely fast and having to be pulled out with extraneous aids*"

At least Hewson - the Borough and Sewerage Engineer of the time - and his contemporaries were a little better equipped than their predecessors, as regards hydraulic theory. Discussion of the proposed measures for dealing with excess storm flow, did not involve all the arguments about pipe capacities, which plagued earlier engineers.

By the 1890's, relatively reliable flow tables were being used. Experiments by Darcy, Bazin and others, provided the basis for the popular formulae of Kutter or Crimp and Bruges. Tables published by the latter pair in 1897 were used well into the 1970s for assessing old egg-shaped sewers.

In addition to overflows, Hewson also suggested that a separate system of surface water drainage could be introduced for the low-lying areas of Leeds. This idea was not to be acted on however until some seventy years had passed.

VI. HIGH LEVEL TREATMENT

In 1900 the Council, anxious to extend its sewage treatment facilities, because of increasing sludge drying problems (due to lack of space), agreed to purchase 800 hectares of Gateforth Estate, near Selby, for £85,000 and to promote a local Act of Parliament for sewage disposal there. The sewage was to be given preliminary treatment at Knostrop and then conveyed by conduit 21 km to Gateforth. The Bill however was defeated in the House of Lords.

Taking stock of alternative approaches, the Sewerage Committee received a report in May 1906 from the Sewerage Engineer, Mr.G.A.Hart, which made recommendations for a sewage disposal scheme situated on the Temple Newsam Estate, at Thorpe Stapleton, adjacent to the existing Knostrop works. His report agreed with a previous report of experts (Messrs. Strachan, Chatterton and Midgley Taylor in 1904) that the sewage disposal scheme should provide for an ultimate population of 600,000 persons, with a sewage flow of 180 litres per head per day in dry weather - compared with the existing population of 456,000, with a sewage flow of 163 litres per head per day.

The proposed treatment scheme involved the following processes: "*(1) chemical precipitation of the sewage, to be followed by (2) subsequent filtration on percolating bacteria beds, (3) the pressing of the sludge into solid cake, to be followed by its ultimate disposal on the low lying land available*".

One serious problem with the existing treatment works at Knostrop was the low-lying nature of the site relative to the river level. The main outfall sewer crossed under the Aire at South Accommodation Road and its invert level at Knostrop corresponded to the dry-weather level of the Aire at that point (17.83m above Ordnance Datum). Consequently the sewage had to be pumped up before it could receive any treatment in settling tanks. This pumping also had to take account of the fact that the River Aire at Knostrop was estimated to rise by about 4.25m in time of flood.

The proposed treatment works was to be constructed on higher land which would allow an improved system of purification to take place entirely under the force of gravity. The additional pumping costs involved in taking the sewage from the existing main outfall sewer to the new High Level tanks would have been considerable. A bold plan involved in the new scheme however, was the construction of a new, 'High Level', Intercepting Sewer - 11km long - which would intercept the sewage from the more elevated, northern parts of the town and bring it directly to the new works without pumping. This sewer, which would progress from Morris Lane, Kirkstall to the new High Level tanks at Thorpe Stapleton, would receive sewage from 190,000 persons out of a total population of 456,000 (see fig.6).

The total cost of the scheme in capital outlay was expected to be £1,269,000, of which £163,000 would be for the new intercepting sewers. The running costs were put at £30,250 per annum.

Legal action against the Council by the West Riding Rivers Board in 1907 gave added reason to go ahead with Hart's scheme. The case brought by the Rivers Board was tried before Mr.Justice Grantham on 30th July 1907 and resulted in an Order of the Court to the effect that the dry weather flow from the Knostrop works should not contain suspended solids in greater ratio than 11 parts per 100,000. The Corporation was allowed 12 months to carry out the necessary remodelling of the treatment works. The terms of the Order also required the Corporation to obtain Parliamentary Powers for a new sewage purification scheme. As chance would have it, the owner of Templenewsam Estate (who had resisted the extension of the sewage works) died and the Council was able to purchase 240 hectares from the new owner (the Hon.E.F.Lindley Wood).

When the necessary Parliamentary Powers to proceed were obtained, by means of the Leeds Corporation Act in 1908, it was anticipated that High Level Sewage Disposal Works would be fully operational by 1918. The First World War cut across these plans. At the outbreak of hostilities in 1914, four years after they had commenced, construction works at Thorpe Stapleton were suspended and did not recommence until 1919. Work on the sewer was suspended between 1916 and 1922. By late 1925 the bulk of the work had been completed, but, due to the increased cost of all materials and wages in the wake of the war, the estimated total cost had gone up to £2,128,000.

The High Level Intercepting Sewer itself was an ambitious engineering project. For about 7/8 of its length it was constructed in tunnel, sometimes at great depths: in Pontefract Lane the depth to invert was 34m. The size of the sewer varied from a barrel 2.44m in diameter at the lower end, to an egg-shaped sewer 1.14m by 0.76m in size at the upper end. Under The Headrow and Upper Briggate it was 1.52m in diameter. Seven million bricks were utilised in its construction.

Treacherous ground conditions were encountered along some parts of the route, that would be taxing even with modern tunnelling equipment and methods. As the High Level Sewer construction progressed under the Leeds to Selby railway line - which then belonged to the LNER Company - the strata encountered were seen to be grossly contorted. At about 5.5m below the sewer foundation, old coal workings were discovered. These had been abandoned and filled with an ineffective packing, locally known as "*gob*". Poisonous gases emanated from this material, which was of unknown composition, and caused illness among the miners.

Subsidence was so severe that special measures had to be taken to provide a safe foundation for the new sewer: 31 concrete piers were sunk down to the level of the undisturbed strata, at 3.8m intervals, with a concrete semi-circular arch between each pair of piers. Thus, the 2.13m diameter sewer construction took place on top of something akin to an underground viaduct.

The Sewerage Engineer in charge of the scheme was scathing in his comments on some of the efforts of earlier schemes. Of an 1850 vintage sewer encountered in Regent Street, he said, "*It had been constructed in a heading, apparently by some person who either suffered from extremely defective vision or who was constantly under the influence of liquor, since it was no unusual thing to find it suddenly swinging out of line six inches in a distance of six feet*."

Changed construction techniques in the parts of the High Level Sewer constructed after the First World War, compared with before, reflected the technological advances of the time. Before 1916 the motive power was entirely steam: steam cranes for hoisting up the shafts; steam pumps; steam driven air compressors and fans. By 1925 however, steam cranes had been largely replaced petrol winches; air compressors were petrol driven and many pumps and fans used electric power.

Almost a quarter of a century after the scheme was conceived, the last brick of the High Level Intercepting Sewer was laid, by Alderman Noon, in February 1927. To distinguish it from the new High Level Sewer, the original Intercepting Sewer of the 1850's, which still carried the greater part of the City's waste water to the old Knostrop Works, became known as the Low Level Sewer.

Whilst the High Level scheme was being conceived, a substantial deteriorating length of the Low Level Sewer underwent a major transformation. Between Globe Road and Kidacre Street, Leather's original 1.68m by 1.37m egg-shape sewer was converted by replacement of its upper half with a large arch. The resulting shape was similar to that used in the remarkable sewer system of Paris - the setting of many dramas, from the fictional world of "Les Misérables" to the perilous world of the Resistance Movement in World War 2. The Parisian sewers were navigable on foot and by boat, but there is no record of boating in the Leeds sewers!

Almost fifty years later, when the benching in the 'Paris' sections of the Low Level Sewer beneath Water Lane, Great Wilson Street and Meadow Lane began to collapse, it was time to replace the lower half. This was a major challenge, since the work had to proceed ***within*** the sewer, whilst coping with live flows. Thanks to the ingenious methods used, no blockage was created. Nevertheless, for the duration of the work, the City engineer took out a special insurance policy against consequential flooding of local industry!

The York Street Subway

By the turn of the Century, so many cables, ducts and pipes were being placed in the highway that the constant digging of trenches was becoming a nuisance. The Sewerage Department joined in an experiment whereby all the utilities of the Corporation (sewerage, gas, water and electricity supply) laid their apparatus in a single subway, at the side of the highway. The York Street subway, 2.1m high and 2.4m wide, constructed in 1903, was the first example. There is no clear record of why the idea didn't catch on.

VII. A MATTER OF ECONOMICS

The story of sewerage in Leeds is inevitably intertwined with that of the wider social and economic developments. The rate of progress with public and estate sewer construction in the city was dependent on many external factors, as can be seen from the graph below.

Sewer construction work formed the basis of some unemployment relief schemes (in the Hawksworth Valley for example) during the depressed years of the early 1920s. The widespread industrial struggles of the 1920's too had their reflection amongst the Sewerage Engineer's employees at Knostrop.

The 1921/22 Annual Report of the Sewerage Committee recorded that "*from 2/4/21 to 7/7/21 (both days inclusive) all treatment was suspended in consequence of a general strike of workmen*." Amazingly, the Council's General Purposes Committee report for the same year noted that "*During the period under review no cases of withdrawal of labour were reported of any of the workpeople employed in Corporation Departments*." ! Can it really have escaped this Committee's notice that all the city's sewage had been flowing totally untreated into the river for a fifth of the year?

Notwithstanding lapses such as this, the sewerage system had become an indispensable part of the economic infrastructure. Industrial use accounted for a significant portion of the dry weather flow taken for treatment. By 1938, out of a total dry weather flow of 88.28 million litres per day going for treatment, 24.33 million litres was attributable to industry. The make up of this volume is shown in the following Table:

Type of Industry or Trade	Litres/Day
Tanners, Curriers, Fellmongers	2,209,400
Piece & Wool Scouring/Dyeing	12,499,200
Chemical Manufacturers	394,600
Oil, Soap, Tallow & Candles	431,400
Breweries & Vinegar Manufacturers	3,315,900
Slaughter House & Casing	343,200
Garages	229,100
Laundries	2,425,300
Unclassified Trades	2,485,800
TOTAL	**24,333,900**

Table of Industrial Effluents to the Sewers (1938)

Neighbouring Bradford was more fortunate than Leeds in the industrial composition of its sewage. During World War I Bradford's Esholt Treatment Works actually ran at a profit on the basis of selling the clear grease (removed from the sewage "*by the joint agencies of steam and pressure*") which emanated from dirty wool, cleaned with tons of soap. In 1935/36 Bradford's receipts from the sale of grease were £37,940. For the same year the working costs at Knostrop were £48,967.

> *"The return we get is not to be measured in terms of £.s.d., but in the cleansing of our river, and, still more, in the better health of the citizens of Leeds."*
>
> - Councillor Bretherick (Chairman, Leeds Corporation Sewerage Committee), speaking in July 1933 after a visit to Knostrop Sewage Works.

VIII. TIME FOR RENEWAL

The sort of rainstorm which produces the most intense flows from any water-producing catchment is usually assumed to be a rainstorm which has a duration roughly equal to the time taken for the water falling on its farthest reaches to arrive at the outlet of the catchment. This being so, the artificial catchments created by modern urban sewer networks and becks, are worst affected by short, sharp storms. The convective thunderstorms of summer months fit the bill more than the long, steady rainfalls of winter frontal systems.

The Summer of 1948 in Leeds provided ample demonstration of this fact. Flooding was extensive, especially in the Gipton and Meanwood Valleys. The City Engineer, Mr.D.Currie, was asked to prepare a detailed survey of the main drainage of the city - by now comprising 1370km of sewers - with a view to fundamental remedial action. Such was the pace of post-war housing development in the city, that he at first was hampered by the fact that many of his staff were being diverted to deal with the design and construction of housing estate sewers.

The long-awaited report appeared in 1955 and revealed, in Currie's words, that "*not only is the present sewerage system overloaded but, more serious, sections of the most important sewers in the city are reaching the end of their lives and in places are breaking up*". It was exactly 100 years since the completion of Leather's scheme. His principal intercepting sewer, known as the Low Level Sewer, had developed alarming distortions along its whole length. In 1950 a complete collapse of the sewer took place in the Hunslet railway goods yard, necessitating a major diversion.

The sewerage engineer's worst nightmare!

At 14.00 hours on 13th January 1950 an urgent message was received from the Low Level Sewage Works that flow to the works had virtually ceased! This created near panic in the Sewerage Department. The Low Level Sewer was one of the largest in the city, 2.36m by 2.44m, carrying 90 million litres per day in dry weather and up to 360 million litres per day in rainfall. There could only be one explanation: the sewer had collapsed and a major emergency had been created.

According to Currie, "*this sewer [formed] the outfall for more than one-third of the area of the City, including many of the large industrial factories, and if heavy rainfall occurred before the blockage could be cleared, it was extremely likely that extensive flooding would be experienced, resulting in possible dislocation of these industries with many workers thrown idle and subsequent heavy claims for compensation upon the Corporation.*"

It took seven days and seven nights of frantic investigation before the precise location of the collapse was pinpointed: 9.4m beneath the loading bay in Hunslet railway goods station. In the meantime, sewer workers were dispatched to all 38 overflows in the catchment, with instructions to divert sewage into streams, in a bid to reduce flows arriving at the blockage. The country was scoured for high-capacity pumps, available at short notice. By January 21st, the combined capacity of all the pumps installed in a temporary sump upstream of the blockage was 85 million litres per day! Fortunately the weather remained fair. Before April 1951, a major diversion sewer had been designed and constructed.

In 1958 the 1.37m by 1.07m section from Globe Road to Wellington Street had reached a critical stage and needed emergency repairs (see fig.7). The potential dangers in collapses of major sewers are evident when it is realised that this short length of the Low Level Sewer passed underneath more than 40 railway tracks, 3 heavily trafficked roads, the River Aire and the Leeds and Liverpool Canal!

In addition to having structural problems, the Low Level Sewer was seriously overloaded with sewage flows. Before Hewson's rising overflows, installed over 50 years previously, could operate to relieve the flow, the sewer had to build up water levels to a depth considerably exceeding the height of the sewer itself. Not only did this extra weight of water put undue stresses on the structural fabric of the sewer, it also introduced pressures which could cause the sewage to find its way through flaws in the brickwork of the sewer. Thus the surrounding subsoil was contaminated. Since the Low Level Sewer frequently passed close under water mains, public health was thereby put at risk. Currie's report therefore proposed the abandonment of the old rising overflows.

The report highlighted also the need for either replacement or renewal of the Low Level Sewer. Just like Hewson before him however, Currie had to decide how to deal with the large increases in flow which had occurred since the time when the sewer was originally constructed. It would have cost £1.5m (at 1955 prices) to construct a new sewer large enough to convey all the sewage to Knostrop.

SEPARATE WAYS

Instead a £1.15m scheme was proposed, and adopted, which involved a new departure in sewerage policy for the city: a separate system of drainage for rainwater. Currie proposed to construct a new, 6.4km long, Low Level Sewer (or reconstruct the old sewer) which would cater for six times the dry weather flow from those areas which could be overflowed by gravity, but only the foul flow from most of the remaining low-lying areas. He proposed that the bulk of the rain or surface water from the latter areas should be taken into new surface-water-only sewers - in other words, a **separate sewerage system**.

This separate system approach meant that the low-lying areas involved would have to be re-sewered. These areas were generally old and decaying: ripe for redevelopment. Re-sewering on the separate system would take place as and when redevelopment took place. To allow ease of distinction, foul sewers were to be of clay pipes and surface water sewers of concrete. The first area to be treated in this manner was the Swarcliffe Council Estate.

A spin-off benefit from the new policy would be that rain-water, at least from the redevelopment areas, could be discharged relatively unpolluted to the becks and the River Aire. It would not have been first mixed with foul sewage, as was the case with the combined (foul and surface water) sewage which predominated in the other parts of the city. The costs of treating and pumping contaminated surface water at Knostrop would also be reduced.

The pace of development on the northern side of the city since the completion of the High Level Sewer in 1925 was so great that this sewer too was considerably overloaded by 1955. A series of overflow modifications and reconstructions was proposed in order to reduce flows in the High Level Sewer. Associated with these measures were various major flood relief sewers and culverts in the Meanwood Valley, Gipton Valley, Sheepscar, Alwoodley and many more parts of the city.

Currie's plan inaugurated the largest spate of sewer construction which Leeds has witnessed in recent decades.

IX. THE BURDEN OF MAINTENANCE

By the late 1960's the sewerage system of Leeds comprised more than 2600km of sewers and 50 thousand manholes. These and various types of ancillary structures, such as two hundred storm sewage overflow chambers and several dozen pumping stations, demanded ever increasing resources for their maintenance.

There had to be constant vigilance to prevent the prolonged accumulation of silt, grit and organic material in the sewerage system. Virtually every ancillary structure demanded a regular visit from a maintenance gang. Each day of the week sewermen were at work beneath the city streets clearing blockages, de-silting or carrying out repair work. Although safety standards had improved markedly since the Nineteenth Century, the work was still hazardous by any standards. A horrifying reminder of this was given in 1965 when Thomas Griffin, a 53 year old sewerman employed by Leeds Corporation, was working down a sewer, trying to remove a blockage. He accidentally fell and in an instant was swept away by the force of the flow. Colleagues above ground frantically raced along the route of the sewer lifting manhole covers in desperate efforts to get ahead of Mr.Griffin. All to no avail: his body was later discovered on the screens at Knostrop Sewage Works - three kilometres away. A verdict of accidental drowning was delivered at the Coroner's inquest.

Exceptionally dry weather brings a different kind of hazard for sewer-workers: the sluggish nature of the flow in the sewers increases the rate of deposition of organic material. The decomposition of the deposited wastes gives rise to poisonous or explosive gases, such as methane or hydrogen sulphide. Every sewer gang would keep a lamp similar to the miner's Davy lamp to detect methane. Also, they carried a small cage containing a piece of paper soaked in lead acetate for the detection of hydrogen sulphide: in the presence of the gas the paper would turn from white to black. Hydrogen sulphide, which is frequently present in sewers, has the unmistakeable smell of bad eggs and it might be thought that unaided human nostrils would suffice for its detection. Unfortunately, after only a brief exposure to hydrogen sulphide, the sense of smell is numbed. Longer exposure causes loss of consciousness.

By the 1980's the sewer gangs in Leeds were equipped with modern electronic equipment for the detection of toxic and explosive gases or oxygen deficiency. They also now carry compressed air cylinders and breathing masks for use in emergencies. Nevertheless, the work still needs great care.

One further danger of sewer work should not go without mention. Rats! It is well known that the sewers harbour rats. It is not as well known that the principal danger from rats is not physical attack, but their urine. Leptospirosis, or Weil's Disease, can be contracted from contaminated rats' urine present in the sewage. If it is not identified quickly and treated accordingly, Weil's Disease can prove fatal. Sewer workers are especially at risk, and therefore strict rules of cleanliness are observed.

Whilst better hydraulic design of sewers in the 1950's and 1960's may have led to a decrease in the accumulation of toxic gases, another development was producing the opposite effect. The increasing number of automatic pumping stations being installed on the sewer network meant that sewage was travelling longer distances and staying in the sewers for longer periods. In the process of breaking down or putrefying the organic matter in the sewage, the bacteria involved used up much of the dissolved oxygen present in the waste water. When the sewage is then conveyed into an enclosed pumping main, without contact with the air, the bacteria which need oxygen gradually cease activity. A different type of process then comes into play - involving anaerobic bacteria, which can manage without oxygen. A by-product of their activity however is the deadly hydrogen sulphide. Sewage which has undergone this process is said to be *septic* and is commonly jet black in colour.

This septic sewage can cause obnoxious bad-egg smells to emerge from the manholes, as well as creating extra dangers below ground.

A further product of septicity is sulphuric acid, which dissolves the cement in concrete sewer pipes or in the mortar of brick sewers. Corrosion of this nature usually occurs immediately downstream of septic pumping mains, before dilution with fresher sewage has been able to take place. Thus, it could be that wear and tear of some of the sewers in Leeds, as elsewhere, will have been brought about not by age but by 'progress' in the form of pumping stations.

The oldest sewage pumping station, currently operating in Leeds (excluding those at treatment works) is at Shadwell. Built in 1922, it functioned on the basis of triple ram pumps, driven via belts from a gas engine, until the early 1960s, when it was upgraded by the installation of electric pumps. All the others were built in the last 40 years or so.

It has been estimated that about one fifth of the sewer mileage in Yorkshire was constructed before 1914. Even after the sewer collapses in Leeds in the 1950's however, insufficient was done to monitor the condition of important old sewers in the city. Too few resources were available.

Not that monitoring and inspection would always be an easy task! Some of the larger trunk sewers in Leeds cannot be entered safely, even in dry weather, so high are the flows. Inspection is only possible, if at all, during the small hours of the morning.

Sewer flows in dry weather do not remain constant throughout the day. Reflecting the fluctuation of water consumption at different times of the day, sewer flows usually reach a peak sometime around mid-day and a further peak in the early evening (see fig.8). During the hours after midnight flows are generally very low and a significant portion of flow, especially in the older parts of the sewer system, is due to infiltration of ground water through leaking joints or defects in the sewer structure.

X. THE END OF MUNICIPAL OWNERSHIP

In 1974 the one and a quarter century period of municipal ownership of the city's sewerage came to an end. Simultaneously with the implementation of Local Government Reorganisation, which created the Leeds Metropolitan District, the Sewerage, Sewage Treatment and Water Supply functions were handed over, with all related assets, to the newly formed Yorkshire Water Authority. The Water Act, 1973, provided for the Leeds City Council to maintain the sewerage system and design new works on the Water Authority's behalf - i.e. as an Agent of the YWA. This gave City Councillors some sort of influence on sewerage policy, but the strategic priorities were set by the YWA Board, on which Leeds Councillors had only indirect representation. In the early 1980's the Conservative Government completely reorganised the ruling bodies of the Regional Water Authorities and, removing all local authority representation, thus completed the severance of sewerage from municipal control.

With Local Government Reorganisation, Leeds City Council's administrative boundary was significantly extended: many outlying villages, Rural and Urban Districts were absorbed. These Districts usually had their own sewage treatment works. There were now 28 sewage treatment works within the Leeds District, many of which were in a poor state of repair. Partly to overcome the problem of disrepair and partly to economise on running costs, the new Authority started a long term process of centralising sewage treatment by abandoning the outlying treatment works and pumping their sewage into branches of the former Leeds City sewers, whence it could gravitate to Knostrop.

First to go as a result of this trend was the Stourton Sewage Works of the former Rothwell UDC. At the beginning of the Century, the Stourton Works was a model cited in text-books for its use of the 'Leeds bed' type of filter, but it had now fallen into disrepair. In its place was built in 1977/78 an automatically controlled sewage pumping station. An interesting feature of this station is its two metre diameter screw pump - a device invented by Archimedes more than 2200 years ago!

Much of the major sewer construction in Leeds since 1974 has been located in the areas which prior to Reorganisation were independent of the City: Horsforth UD, Otley UD, Wetherby RD, Garforth UD, Pudsey UD, Rothwell UD and Morley MB. This reflected the facts that most of the visible sewer problems in the former Leeds BC had been solved and many of the outlying areas had piecemeal, inadequate or decaying sewer systems.

New techniques of inspection however began to uncover fresh problems, before they became visible on the ground or from manholes. The City's engineers embarked on a vast programme of closed circuit TV inspection of sewer conditions. Miniature TV cameras, travelling along even the smallest sewers, could highlight potential trouble *before* it progressed too far: partial sewer collapses, damage due to tree roots, leakage and excessive silting could be dealt with at an early stage. The future custodians of the City's sewerage would have no excuse for dangerous collapses of the kind which afflicted the trunk sewers in the 1950's.

Developments like this have steadily led to a marked change of emphasis in the work of drainage engineers throughout the country. 'Sewer Rehabilitation' - or renovation and repair - is now a cornerstone of sewerage policy.

New advances in hydraulic theory have also played their part in the new approach. These have resulted in a much better appreciation of the way our sewers behave under extreme flow conditions. Engineers have used computer models for many years for the assessment of the worst flows likely to be faced by sewerage networks. Until fairly recently however, these models were not sophisticated enough to take account of the effects of 'surcharging' in sewers. Sewer pipes were consequently designed with a specified probability of flowing 'just-full'.

For example, the YWA had a policy of designing trunk sewers so that they would probably flow 'just-full' approximately once every two years. No-one was able to say what margin of safety against flooding was implied by this criterion. Obviously, on the rarer occasions flows would be greater still and would surcharge the sewers so much that the sewage would build up in the manholes and escape over-ground. But how rare an event would this be?

In the mid-1980's, this problem had been overcome. Computer models started to be used in Leeds, as elsewhere, which could accurately predict the way in which water levels build up in manholes. An additional requirement became that sewers should be designed so that water levels are only likely to rise up manholes to ground level with a frequency of once in 50 years.

As a further result of technical progress, flows predicted by computers could be directly checked using solid-state electronic flow monitors. These monitors use advanced techniques to measure the flow rate in the sewers where they are installed. A reading is taken every 2 minutes or so and recorded on memory chips in an associated data logger. By these means, engineers can obtain a complete picture of the pattern of flows arising from any given rainstorm. The minute-by-minute progress of rainstorms too is measured similarly with equipment above ground.

In Leeds these new techniques have been deployed most effectively in examining the marked effect of coal mining subsidence on sewers in Rothwell and, subsequently, in developing the Leeds/Aire Sewerage and Sewage Treatment Strategy.

The Leeds/Aire Strategy really marked the culmination of the Yorkshire Water Authority's attempts to centralise sewage treatment for Leeds. Under this plan virtually all of the treatment works, except the central one at Knostrop, would be demolished. The sewage flows would either be pumped or discharged under gravity to Knostrop.

XI. PROFITS FROM SEWERS

The Conservative Government of Margaret Thatcher came to power in 1979 committed to reducing the size of the public sector in the UK economy.

Few people at the outset imagined that water and sewerage would be targetted for privatisation. The 'natural' monopoly of water resources and the draconian public health powers acquired by the water industry over the previous century seemed to make it an unlikely candidate.

Nevertheless, on 6th July 1989 a new Water Act was enacted. This resulted in the conversion of the water and sewerage undertakings into Public Limited Companies, preparatory to the sale of shares on the open market. On 1st September 1989 the majority of the property, rights and liabilities of the Yorkshire Water Authority were transferred to Yorkshire Water Services Ltd - a wholly owned subsidiary of Yorkshire Water Plc.

The provision of sewerage henceforth was to be a commercial undertaking - carried out for profit.

Because of the introduction of the profit motive, a new regulator - the Director General of Water Services - was appointed to oversee the water companies. The Director General and his department, OFWAT, were charged with ensuring that the new water companies carried out their functions properly and that 'customers' were not charged too much. The increasing use of the term 'customers', instead of 'the public', succinctly expressed the changed nature of the relationship between the water industry and those whom it served.

Certain of the former Water Authority's functions - such as pollution control, water resource management and flood alleviation - were handed to a newly created public body: the National Rivers Authority (NRA). Eventually, the NRA was merged into the Environment Agency.

For the time being, the Sewerage Agency Arrangement with Leeds City Council continued.

The policy of centralising sewage treatment also continued. The decade up to 1995 was characterised by the closure of many important sewage treatment works. The works at Ardsley Falls, Thorpe, Drighlington, Horsforth and Rodley were all replaced by pumping stations. Those at Houghside and Morley - whose site is now part of the White Rose shopping centre - were also closed, but their sewage was redirected without need for pumping. The Smalewell works at Pudsey is to be abandoned in 1998. Large scale improvements have taken place at Knostrop in order to accommodate the additional flows.

Sewage Works	*Year of Closure*
Ardsley Falls	1987
Thorpe	1987
Houghside	1987
Morley	1988

Ledsham	1990
Ledston Luck	1991
Ledston	1991
Horsforth	1991
Drighlington	1992
Rodley	1993
Smalewell	1998?

The advent of cheap microprocessor-based electronic systems during the same decade ensured that computerised control systems were at the heart of the new generation of pumping stations, which replaced some of the treatment works. To a large extent these stations are software controlled and to a modest degree have sufficient intelligence to diagnose simple problems and solve them without manual intervention. The parallel expansion of the Leeds Main Drainage telemetry system has given a means by which remote installations can phone for assistance if anything else goes wrong!

In January 1997 Yorkshire Water formally gave notice to the City Council that the Sewerage Arrangements were to be terminated on 31st December 1997. The same notice was also given to all other sewerage agents throughout the Yorkshire Water area. Operational responsibilities for the sewerage system were to be taken 'in-house' by Yorkshire Water. City Council staff engaged on this work would be transferred. The Council was given the option of entering a new agreement for designing new schemes, as a Consultant, and decided to take up this option. Thus, with little ceremony, the Council's pivotal role in the management of the Leeds sewerage system came to an end.

As this brief history has shown, municipal enterprise and strategic planning has been at the heart of sewerage provision for more than 150 years. In that time a vast network of sewers has been provided which deals daily with more than 200 thousand tonnes of foul sewage. During rainstorms the sewer flows are many times greater.

Probably three-quarters of a million people make use of the city's sewerage system every day, without giving it a second thought. Even so, much of our everyday life pre-supposes an effectual sewerage system: Not only the obvious things, like the flushing of a toilet and the running of a shower; but also, the less obvious things. Without a comprehensive sewerage system, the extensive network of metalled roads would not be possible. Without such roads, there would be no possibility of quick, convenient urban transport - such as buses or cars.

The composition of the sewage reflects the way we live and the nature of the city's economic base. It is interesting therefore to note the changes which the industrial composition of Leeds sewage has undergone.

Piece and wool scouring or dyeing represented 51% of flows[1] in 1938 but only 5.4% in 1996, showing the savage decline of a once important local industry. Laundries provided 10% of the

[1] *Trade flows in dry weather*

1938 flows for treatment, but the self-sufficient, washing machine owning citizens of today have caused the laundries and laundrettes to fall to less than 4%. Printing on the other hand, from being unclassified in the 1938 table given in Chapter VII, has soared to top of the current league table, with a full 14% of the flow.

XII. THE GREENING OF SEWERAGE

The story of sewerage in Leeds is far from complete. The future surely holds many fascinating possibilities. As a society we are becoming much more conscious of our obligation to protect and improve the natural environment. Undoubtedly, developments in drainage engineering will have a big part to play in fulfilling that obligation in Leeds.

We will need to clean up the becks by reducing our reliance on sewage overflows. Our children and grandchildren will perhaps find it hard to believe how long we clung to the crude reliefs, introduced by Hewson and others in the Nineteenth Century.

To enable overflows to be abandoned, drainage engineers will have to promote methods of controlling flows *at source*: Limit the amount of flow which unnecessarily enters the sewers and, in many instances, the need for an overflow will disappear. Rainwater from roofs can be collected in water-butts and used on gardens, rather than discharging into the sewers. The resulting savings in treated tap-water might also help to avoid the need for new reservoirs. With careful design and modern materials, many new roads, yards and car-parks can be made porous and thus help to replenish ground-water levels.

Maybe some foul flows will be kept out of the sewers too, as eco-friendly, composting lavatories catch on. Will the old earth-closet make a come-back in a modern, hi-tech guise?

The future drainage engineer in Leeds will probably seek assistance from '*real-time*' computer control, in order to keep more sewage *in* the sewers and *out of* the watercourses. Use of available capacity within the sewers can be optimised by linking automated valve systems and pumping installations to powerful computers and networks of weather or flow monitoring stations. Just as area traffic control systems have increased the through-put of urban road networks, there is a potential for real-time control to make better use of the sewers.

At the outset of our story, we saw how sanitary legislation was introduced to improve conditions within the cities. Now, the pressure is on to ensure that these improvements are not at the expense of the natural environment.

XIII. A FINAL WORD

When the Public Health Act, 1848, was introduced, the 'Times' called the Act "*a reckless invasion of property and liberty*". The same newspaper later stated that "*the English People would prefer to take the chance of Cholera, rather than be bullied into health*".

Happily, this barbaric attitude has long since disappeared - at least with regard to sanitation. Nowadays the sewers beneath our streets are taken for granted by most citizens: But vigilance is needed!

As the foregoing story of sewerage in Leeds has shown, an effectual sewerage system is undoubtedly one of the essential prerequisites for civilised life. If ever we were tempted not to safeguard and renew this inherited asset, society would surely be revisited with the epidemic diseases and squalor which plagued Victorian Leeds. Public Health Engineering has contributed immensely to improving the quality of life for the people of Leeds, relative to that of their forebears. If this brief pamphlet helps to explain some of those achievements, then its purpose will have been fulfilled

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David Sellers, October 1997.

APPENDIX 1

LEATHER'S DESIGN PHILOSOPHY

The conditions which Leather based his sewerage scheme on largely coincide with present day practice and were as follow:

1. That the sewers should be laid at such levels as will afford at all times an effectual underdrainage to every dwelling in the District.

2. That the Termini of the principal Branch Sewers should be laid at such levels as would admit of their being carried forward with competent inclination or slope to any extent to which there might seem a reasonable probability that further extensions would be required.

3. That the main Trunk and Principal Branch Sewers should be projected in such lines as would admit of the Minor Branch Sewers and Street Drains being carried up from them with constantly increasing declivity.

4. That the Minor Branch Sewers should be brought into the Principal Branch Sewers and the Principal Branch Sewers into the Main Trunk by the shortest practicable course, so as to secure the scouring effect of every accession of water as early as practicable.

5. That the Sewers should be of sufficient and only sufficient size or capacity to carry off all the water which would be likely to fall upon the surface they might have to drain; that the dimensions of the Sewers should (as far as practicable) be increased by gradual increments proportionate to the accessions of water which such Sewers might have to receive on their route from additional branches - so that the hydraulic mean depth and slope of the surface might be kept as nearly uniform as practicable and the whole system thus be kept in train.

6. That wherever a constant run of water can be had through a Main Sewer it is extremely desirable to secure it; - and where a constant run cannot be had, the means of obtaining an occasional scour should not be neglected.

7. That the Main Trunk Sewer ought to be taken to its Outfall in the most direct practicable course, consistent with economy - not only for the avoidance of angles, but in order to secure the full effect of the whole of the fall which circumstances may admit.

APPENDIX 2

THE LETTER OF THE LAW

1 The '**Leeds Improvement Act, 1842**' was the first of a series of privately promoted Parliamentary measures which gave the Council the power to construct common sewers and to carry out other drainage works. The powers obtained through this pioneering Act also enabled the Council to ensure that:

* No house could be built until its site was drained;

* The owner or occupier of any house, which was near to a Council sewer, had to connect to that sewer.

2 Following the second major Cholera outbreak, in 1847, the Government was propelled into the introduction of the '**Public Health Act, 1848**'. This Act created a General Board of Health (Edwin Chadwick was one of its three members). During its five years existence, the Board was empowered to provide sewerage systems for the water-borne collection of domestic waste. A Medical Officer of Health could also be appointed. Despite the patent need for public health schemes, the vested interests of landowners and others formed a vociferous lobby against the granting of the necessary powers to any public body. When the Board of Health was abolished, the 'Times' concluded that "*the English People would prefer to take the chance of Cholera, rather than be bullied into health*". The same newspaper called the 1848 Act "*a reckless invasion of property and liberty*". Even so, the Act was only mandatory in towns where the death rate was greater than 22 per thousand of population or where 10% of ratepayers petitioned for its adoption.

3 The '**Public Health Act, 1875**' was a measure of great significance on a national scale. So far as Leeds was concerned however, this Act was partly a consolidation of the existing legislation. It went further in that it allowed any local authority to carry sewers "*into, through, or under any lands whatsoever within their district*", provided that reasonable notice in writing was given to the owner or occupier. The 1875 Act also declared that all existing and future sewers within a Local Authority district would *belong* to that Local Authority - i.e. they would be **public sewers**. Exceptions were to be any sewers which had been constructed privately for profit.

Under the 1875 Act, urban authorities could, at their own desire, keep a map of sewerage in their districts.

4 The '**Rivers (Prevention of Pollution) Act, 1876**' prohibited the pollution of rivers by the discharge of sewage and other waste material. A possible weakness of this Act was that the local authorities which were made responsible for the enforcement of its provisions were often the very bodies which were causing the pollution, through the discharge of sewage. Furthermore, each local authority was apt to be interested in river quality only

within its own boundaries. The '**Local Government Act, 1888**' however, empowered county councils or joint committees of county councils to enforce the 1876 Act. The Yorkshire West Riding Rivers Board, set up in 1896, was more vigilant than most. It is sometimes remarked that the success of this body was at least partly due to the fact that its administrative boundary covered almost the whole of a natural catchment area.

5 The '**Public Health Act, 1936**', like the great 1875 Act before it, confirmed that sewerage and sewage disposal were to be administered by local authorities. It went further than merely *empowering* the local councils however: effective waste-water management was now required. The Act *required* local authorities to provide the necessary sewers for the 'effectual' drainage of their districts. This requirement embraced both foul sewage **and** surface water run-off.

The Act gave the occupier of any domestic premises the right to connect to the public sewers, but industrial effluent could only be discharged with the consent of the local authority.

The power of the local authority to lay sewers across any land was reinforced. Furthermore, any private person or company constructing a new sewer could be required to upsize or otherwise amend the design of this sewer if the local authority considered that such changes would benefit the sewerage system as a whole.

6 The '**Water Act, 1973**' created 10 Regional Water Authorities in England and Wales. These Authorities inherited the accumulated assets and responsibilities of local authorities and other public undertakings in the area of Water Supply, Sewerage and Sewage Disposal. These assets came from:-

* 29 River Authorities
* 157 Water Undertakings
* 1,393 Sewerage Undertakings

The Act obliged the Water Authorities to enter into Agency Agreements with the local authorities for the design, construction and operation of the sewerage system within the area of each local authority.

7 The '**Water Act, 1989**' required the functions and assets of the Water Authorities to be transferred to 10 Water Service Companies. The public water supply, sewerage and sewage treatment service was 'privatised'. This Act brought about a fundamental change in the basis upon which the sewerage function was to be administered. The provision of sewerage henceforth was to be a commercial undertaking - carried out for profit.

8 The '**Water Industry Act, 1991**' is the current primary legislation and simply brought together the various pieces of legislation and consolidated the 1989 Act.

THE AUTHOR

David Sellers is a chartered civil engineer who has been involved with designing sewerage, pumping stations and associated structures in Leeds for more than twenty years. Aware that the history of our sewerage inheritance is hidden even more effectively than the sewers themselves, he has tried to bring to light some of its milestones.