

THE DRAINAGE OF THE FENS.

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The drainage of the Fens has engaged the attention of several generations of engineers, with the result that large areas of what was formerly morass have been converted into exceedingly fertile land. This result has been attained, in the first instance, by cutting large arterial drains which discharge the water into the rivers, all of which discharge into the Wash. The rivers which receive the waters from the Fens are the Witham, the Welland, the Nene, and the Ouse, and these rivers also drain uplands in the counties of Lincolnshire, Northamptonshire, Huntingdonshire, Cambridgeshire, and Norfolk. These rivers have from time to time been diverted and straightened, so that the waters are discharged into the sea much more rapidly than they formerly were.

Between the Fens and the sea there are marshes, the nature of the soil of which is quite different from that in the Fens. The soil of the latter is peat, showing a black colour on the surface, and is derived partly from the deposition of silt and soil carried down by the streams and floods, and partly by decaying vegetation and aqueous deposits over a long series of years. The soil of the

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marshes has been formed by a series of deposits of the sea. A cutting made through this soil will reveal the thickness of each successive deposit.

The improvements in the drainage of the Fens, or what might perhaps more correctly be called the reclamation of the Fens from their condition of morass, have resulted in a general lowering of the surface of both fen and marsh, as it does in all marsh lands, by the abstraction of the water and consequent shrinkage of the soil. A striking instance of this may be mentioned in what happened after the draining of Whittlesea Mere in the Middle Level of the Great Bedford Level. In 1851, engines and pumps were erected for the purpose of draining the Mere, and at the same time an iron post was sunk down into the ground for the purpose of observing the settlement. It was found necessary from time to time to lower the pumps owing to the depression of the land, and in 1876 new engines and pumps were erected to provide for the greater lift required, and the iron post was observed to be standing 8 feet out of the ground. At the present time the post stands 10 feet out of the ground.

While the settlement is in progress, a gradual silting up of the bed of the rivers is taking place, so that the difficulty of maintaining an efficient system of drainage is much increased, especially when it is considered that the surface of the fens and marshes is exceedingly flat, and that generally speaking the surface nearest the uplands and farthest away from the outlets, in some cases, perhaps, 20 to 30 miles, is in some parts 4 to 5 feet lower than it is nearer the point of discharge. And further, in some areas navigation is and must be maintained, and the interests of navigation and drainage are necessarily conflicting.

The uplands which on one side bound the Fens naturally discharge their waters into the fen drains, and, unless means are adopted to intercept the water from them, the fen land near the uplands is much flooded during excessive rains before the water can flow down to the outlets. It is, therefore, of the first importance to provide catch-water drains to intercept the upland water and to discharge them into the rivers if possible by a

separate channel. The Romans recognized this principle, and cut what is known as the Car Dyke, skirting the foot of the uplands all the way from Lincoln, past Bourne to the Nene near Peterborough. This Car Dyke is in existence still, but in many places has been neglected and has become more or less choked.

Nine consecutive wet years, 1875-1883, in South Lincolnshire forced the attention of the country to the necessity of making improvements in the drainage system in the Fens. In 1880-1882 a great improvement was made by a new cut at the outfall of the River Witham, so that the lower end of the river, instead of meandering through the sandbanks in the Wash, now discharges direct into Boston Deep, the result being that low-water level up to Boston was depressed about 4 feet, and a corresponding beneficial effect felt through a great part of the area which it drains in South Lincolnshire. But the excitement created by the condition produced by those wet seasons after a time died down, and no such continued heavy rains have occurred until the extraordinary downpour in August 1912. In the meantime the other rivers—the Welland, the Nene, and the Ouse—have been gradually silting up, and at the present time improvements in these rivers are urgently needed in order to obtain all the benefit of which the main drainage systems within their watersheds stand in need.

The condition of the gravitation outfalls is of course the first consideration in all drainage systems, but the Fens are dependent very largely in their interior economy upon pumping the water from the low-lying lands into the main outfall drains, especially where navigation must be maintained in those drains. At a time when, as often happens, the tides, blown up by the prevailing wind, reach an abnormal height and great falls of rain occur concurrently, the water is too high in the main drains to admit the water from the Fens by gravitation, resort must be had to pumping. Thus numerous pumping mills have been established in the interior districts of the Fens.

In the district drained by the South Forty Foot River—a great drain, with a fall of 3 inches in the mile, which discharges through the Black Sluice into the Witham below Boston and extends up to

Guthram Cote, a distance of about 21 miles, its course for the greater part of this length running nearly parallel with the hills which form the uplands, the drainage of the Fens which it traverses has hitherto depended on gravitation. Now, however, pumping engines in each fen are gradually being established.

The same conditions prevail on the left bank of the Trent below Gainsborough, for, although the lands are not strictly speaking fen lands, the conditions are much the same. Of late years several pumping engines have been established on that side of the river, because when freshets come down, the water in the river has been so high that for some days no water from the land could be discharged by gravitation into it.

The first form of pumping was by means of windmills and scoop-wheels, but although in many places scoop-wheels have been retained, the windmills have been superseded or supplemented by steam-engines. The scoop-wheel has in most cases been discarded for centrifugal pumps. In many cases in Norfolk the windmill is retained, but a portable steam-engine is used as an auxiliary.

The scoop-wheels, which sometimes vary from 36 to 50 feet in diameter, have only a low degree of efficiency, generally estimated at about 30 per cent. They have done good work, some of them with their engines having been at work for 60 years and upwards, but the expenditure of fuel in working them compared with present-day methods has been very large. In one case which the author was called upon to investigate, the consumption of coal used in the case of a wheel 36 feet in diameter, draining 9,000 acres, worked by a beam engine said to be 100 h.p., was 30 tons per week.

A comparison of the cost made at the time with the cost of other forms of power showed the following result:—

Present low-pressure engine	0·39	penny per b.h.p. per hour.
High-pressure condensing steam-engine	0·332	„ „ „ „ „
Gas-engine and suction-gas	0·272	„ „ „ „ „
Diesel oil-engine	0·119	„ „ „ „ „

In regard to the form of pumps, the centrifugal pump shows a much higher efficiency, namely, about 60 per cent. for low lifts, and

is more capable of dealing with variations in the lift than the old scoop-wheel.

There are two forms of centrifugal pumps, one invented by Appold and called the Appold pump or turbine pump and first manufactured by Messrs. Easton and Amos. The fan in this pump is placed horizontally at the bottom of the pump, and is worked by a vertical spindle by means of gearing at the upper end of the spindle. Within certain limits of lift, this pump has done excellent work. The advantage of it is that it cannot lose water, and although some danger of damage to the blades of the fan has been apprehended, necessitating its being lifted, the author has known them to be working for upwards of 35 years without any injury arising to them, and he has found this to be a common experience. Another advantage is that this pump lifts the water direct from the low level to the higher level, without, as in the case of the centrifugal pump, having to lift the water up to the level above the floor on which the pump is fixed, thus somewhat diminishing the power required. But it is only adapted for low lifts.

In the centrifugal pump which is now more commonly used, the fan is fixed vertically on a horizontal shaft. As it is now manufactured, it also does excellent work, and has been made capable of raising water to greater lifts than the Appold pump. But, as already mentioned, all the water must be lifted through a suction pipe up to the level of and through the pump, which is fixed on the engine-house floor. The lifts in the Fens vary from about 7 to 15 feet. The average cost of pumping in the South Level of the Great Bedford Level, as given by Mr. W. H. Wheeler, has been 16·25 pence per acre.

On the accompanying plans, Figs. 1 and 2 (pages 782-3), are shown the boundaries of the North and Middle Levels of the Bedford Level. The North Level has a taxable area of about 40,000 acres, and, in addition to this, about 36,000 acres form contributory areas draining into its outfall and contributing to the cost of maintenance. The Middle Level is a typical Fen district, and has a taxable area of 120,000 acres and the South Level about 140,000 acres. In

these Levels lie Fens known by name, and each Fen or combination of Fens is drained by engines and pump or scoop-wheels lifting the water into the main drains.

Embankments are formed for the most part along the sides of the main drains, so as to prevent the water in them overflowing the fens during heavy rains when the tide is up at the outlets.

In the line of most drains and rivers, embankments are formed at some distance away from the sides of the drains, leaving spaces or "washlands," which form reservoirs in times of flood. These "washlands" are maintained as grass lands, and the water flowing over them does no harm except perhaps when a flood occurs during hay harvest. Long lengths of these "washlands" are to be found between the old Bedford River and the Hundred Foot River in

FIG. 1.—*Boundary of the North Bedford Level.* (Adjoining Fig. 2.)
(Numbers indicate the altitudes in feet above the assumed mean level of the sea at Liverpool.)

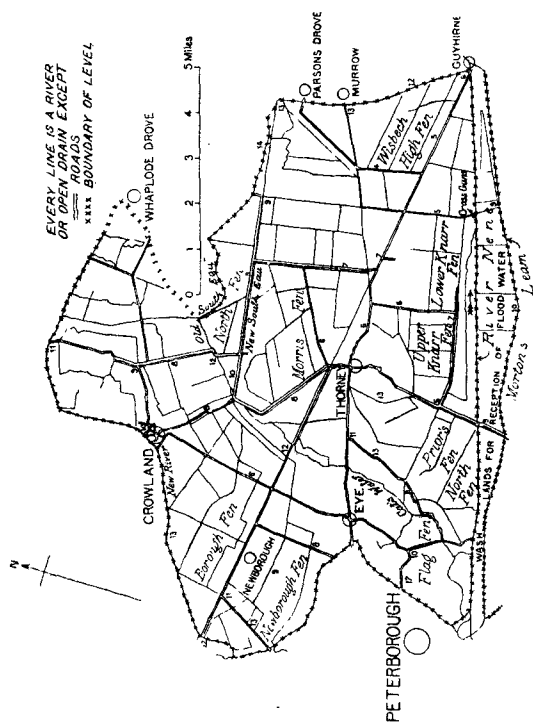
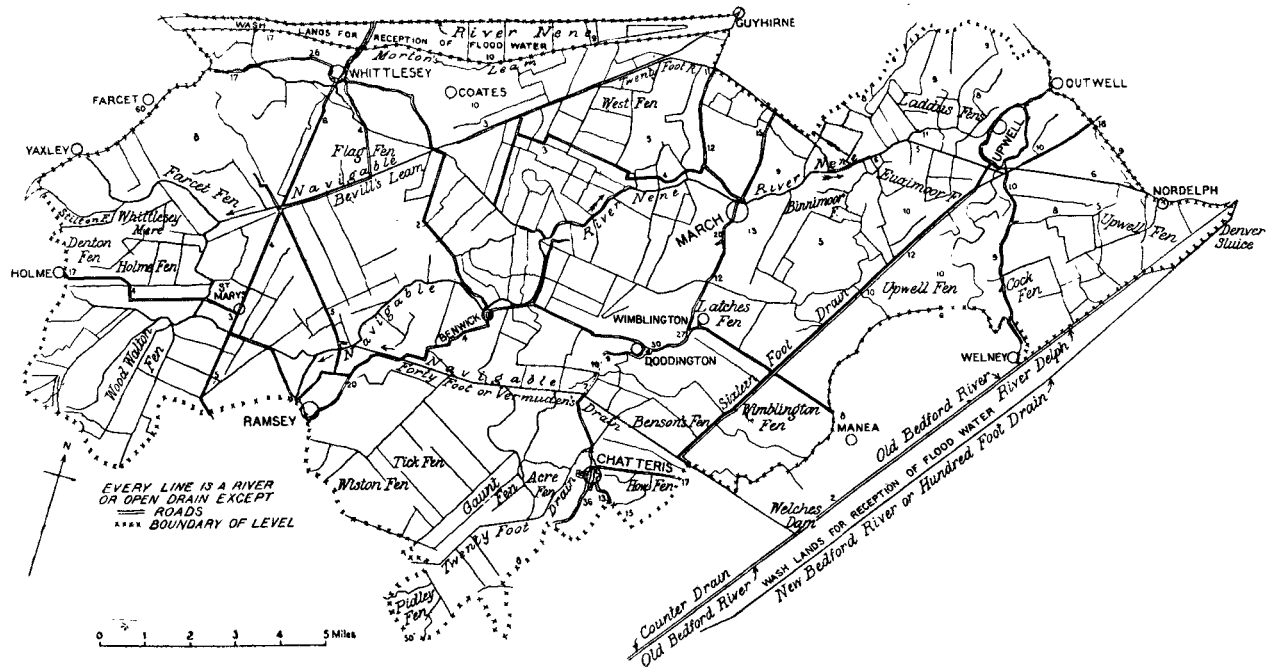


FIG. 2.—*Boundary of the Middle Bedford Level.* (Adjoining Fig. 1.)



the valley of the Ouse, and also between the Nene and Moreton's Leam in the Nene valley.

Many of these banks are made of material of a very poor kind for the purpose, owing to their situation on peat or light land, there being no good clay obtainable.

Breaches in these banks during flood times in various parts of the fens are of frequent occurrence, sometimes due to leaks through the banks and sometimes due to the water flowing over the top. The breaches cause a good deal of flooding of the fen land and consequent damage, and sometimes annoyance and disturbance between neighbours as to the liability for the maintenance of the banks.

A very serious breach in December 1910 occurred in the bank of the River Glen, causing the flooding of about 11,000 acres. The bank, which the author saw after it had been broken, was formed partly of peat and partly of light earth, and the land on which it stood was peat. After very heavy rains the water rose to such a height in the river that the bank could not withstand the pressure, and it gave way, leaving a breach 133 feet long and a hole in the middle of the breach, as is commonly the case, of about 13 to 14 feet deep below the bed of the river. The breach was narrowed to 40 feet by means of sacks of earth weighted down, and was ultimately closed by means of a cofferdam filled in with the best clay that could be found in the neighbourhood.

Having regard, as already pointed out, to the depression of the surface of the land, on the one hand, and the gradual silting up of the rivers on the other, the problem of the present day is how to provide for effectual drainage of the Fens and to prevent flooding of the land in times of excessive rainfall; and not only is it a question for the present time, but also for the future, because, as the land continues to settle and the rivers to silt up, the difficulty increases. There are two remedies, one by clearing out and deepening the beds of the rivers, and the other by pumping at the outfalls.

The outfalls of the drains discharge their water ultimately of course into the tideways. At each outfall of the principal areas

there are tidal sluices to prevent the tide flowing up the main drains. There are the Grand Sluice and the Black Sluice at Boston in the Witham, the North Level Sluice in the Nene, the St. Germans Sluice draining the Middle Level, and the Denver Sluice draining the South Level in the Ouse. When the tide rises, these sluices are closed, and when there are heavy floods in the rivers they sometimes remain closed for more than one tide, and this happens just at the time when the land inside is suffering from excess of water.

The rivers are quite capable of improvement, but only at very considerable cost, and further, in most of them there are many authorities which have jurisdiction over different portions of their lengths, so that it becomes extremely difficult to propound a scheme in which all these bodies will agree.

The other method is to pump the water at the outfalls into the tideway during times of excessive flood. This method would no doubt give relief, but it must be borne in mind that powerful engines would be required, and pumping would be necessary only for three or four months in the year, and in some cold dry winters might not be wanted. These are the considerations which must be weighed in each particular case, and no general rule can be laid down.

Several Bills were introduced into Parliament in 1877, 1878, 1879, and 1881, partly with the idea of establishing Conservancy Boards in the basins of rivers in which extensive flooding took place, but difficulties in the way of rating were the main reason which prevented their establishment.

The Paper is illustrated by 2 Figs. in the letterpress.

[*The Discussion on this Paper was combined with that on the Papers by Mr. Allen and Mr. Crocker, and commences on page 830.*]
