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“The Development of the Water-Supply to the Canterbury Plains, New Zealand.”

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IN a Paper entitled “Water-Supply and Irrigation of the Canterbury Plains,” contributed to the Proceedings¹ of the Institution in 1883, Mr. G. F. Ritso, Assoc. M. Inst. C.E., gave a comprehensive account of the enterprise up to 1883, and especially described the Malvern Water Works, the first public works for water-supply for agricultural and pastoral purposes in New Zealand. These works were initiated by the old Provincial Government, but they made small progress, and on that form of Government being abolished, the Author, in March 1877, being then in the Public Works Department of the General Government of New Zealand, and District Engineer for Canterbury, took over charge of all public works in that district, and amongst them the Malvern Water Works.

Since the publication of Mr. Ritso’s Paper the supply of water to the Canterbury Plains has been greatly developed, and as the Author has had to carry out large undertakings for that object, he proposes to give in the following Paper some details of the advance that has been made during the last 20 years.

First it must be noted that the term “irrigation,” applied to this scheme, is still a misnomer. Irrigation has been carried out on a small scale in places for many years; but, taking one year with another, it does not seem to have been successful enough to warrant its extension on a large scale. Commercially, it is still in the experimental stage. The fact is, that although in Canterbury the summers are generally too dry, the average rainfall of about 24 inches annually is barely low enough, and in occasional years, such as in the recent wet summer of 1902–1903, the difficulties attending the satisfactory disposal of the tail-water would cause irrigation-works to be a positive nuisance, especially to the

¹ Vol. lxxiv. p. 238.

low-lying lands near the sea. Also the great variety in size of the holdings and the patchy character of the soil in many localities, varying between rich alluvial mould and bare shingle, induce a mixed style of farming, thus rendering it difficult to devise a system of irrigation which would be equally acceptable to all the farmers in every season.

The commercial success of the Water Supply to the Canterbury Plains is due chiefly to the increased capacity of the land for carrying stock, and for keeping them in good condition. The easy access to water, as compared with that in the old days, when streams were 10 or 20 miles apart, has also rendered large areas profitable for cultivation, which would otherwise have remained in their native state. In the process of effecting these improvements the Canterbury Plains have, during the past 20 years, become covered with a perfect network of water-races. It is, indeed, a very poor and remote district where a Canterbury farmer may not, if he choose, obtain a running stream of water in every paddock. In 1883 Mr. Ritso estimated the area watered in Canterbury as about 500,000 acres, but this was a high estimate, and it included 300,000 acres in the Ashburton District, which was then sparsely settled, and the channels were some 4 or 5 miles apart. The holdings there are now much more numerous, and the paddocks smaller, so that the races have been made closer together, in order to water them effectively. Whereas the total length of races in Canterbury was then 300 to 400 miles, the total length of all the races there now is 3,500 miles, watering some 1,200,000 acres. The amount and cost of the water supplied to the various districts in 1903 are shown in the following Table, compiled from the official returns of the County Councils and Water-Supply Boards. It will be seen that the average cost per acre of the area served with water in Canterbury is 2s. 10½d., and that the total daily supply is 256 million gallons, distributed in 24 hours, equivalent to 470 cubic feet per second.

The two larger counties of Ashburton and Selwyn show a marked difference in the cost of their systems of races. The low capital cost per acre of races in the former is due to the very easy nature of the country, the plains being particularly uniform in their slope towards the sea, while the absence of any water-courses, except those of the rivers feeding the races, causes very little need for flumes or embankments. In the Ashley County, between the Waimakariri and Ashley Rivers, where for the past 5 years the Author has had charge of the construction and operation of the water-race system, the surface of the land is modified by downs, and

CANTERBURY WATER-RACES, NEW ZEALAND.

County.	Area Watered.	Length of Races.	Total Cost.	Cost per Acre Watered.	Amount of Water Distributed every 24 Hours.	Annual Charge for Use of Water.
	Acres.	Miles.	£.	s. d.	Gallons.	
Amuri	24,162	5½	4,800	3 11½	..	Races are maintained by an annual charge in proportion to the area watered.
Ashley	122,000	500	25,000	4 1	27,000,000	¾d. to 6d. per acre, in addition to special rates for interest on loans.
Selwyn	326,888	1,119	73,819	4 5	90,940,960	¾d. to £1 5s. per 100 acres.
Ashburton	586,000	1,350	43,300	1 5¾	86,000,000	£2 to £3 per mile of race.
Geraldine	71,212	260	9,010	2 6½	29,520,000	About 7d. per acre, including a rate for payment of principal and interest on loans and a rate for maintenance.
Levels	19,000	71	5,500	5 9½	6,480,000	1½d. per acre, and on part of area an interest rate of ¾d. in the pound on capital value.
Mackenzie	9,000	32	1,885	4 2½	7,516,800	2½d. per acre on part of district and 5d. in the pound on capital value in remainder of district.
Waimate	35,700	157	8,125	4 7	8,500,000	Races are maintained by an annual charge on the value of lands watered.
Total	1,193,962	3,543	171,439	2 10½	255,957,760	

intersected by the valleys of two small rivers, the Cust and the Eyre, besides numerous creeks and storm-water channels, which, although dry during the greater part of the year, require a large amount of fluming. The Malvern Water Works, already referred to, are chiefly responsible for the large sum of £73,819 set down to the Selwyn County, in which they are situated. Part of the money spent upon them, however, was to a certain extent for experimental purposes, and the other districts have derived benefit from the experience gained. These works also were originally constructed at the expense of the Government, while at the present time the races, although in a few cases made partly from Government grants in aid, are chiefly made at the cost of the settlers themselves, on whom rates are levied to provide interest on the necessary loans.

The Malvern Water Works, as originally designed, owed their supply to the water of the River Kowai being diverted, by a concrete dam across its bed, into a brick-lined tunnel, 1,012 yards in length, which enabled the river terrace to be pierced through, until the fall in the tunnel, being less than that of the surface of the open plains, allowed the channel to emerge on to their level. These works still furnish the largest daily volume of flow to any single head-race. The tunnel, however, has been allowed to get out of repair, and a heavy flood in March, 1902, damaged the dam. Instead of effecting costly repairs, the County Council of Selwyn decided to construct new headworks about a mile higher up the river, at a level which enabled them to dispense with a tunnel, and to substitute an open channel partly in sidelong cutting. The contracts for these works are now in progress. In the numerous head-races from the various rivers elsewhere, the dam and tunnel system has been superseded as being too costly. The Author carried out the headworks at the intake from the Waiau River for the Amuri County races, the tunnel for which was only 12 yards in length; the tunnel for the Waimakariri intake of the Ashley County is only 70 yards in length. In the intakes from the Rakaia, Ashburton, Selwyn and Rangitata Rivers also a tunnel is dispensed with, or a short culvert is substituted. The usual plan is to have a short block-cutting to conduct the flow to a channel benched out on the terrace face. In the big rivers damming is out of the question, and the engineer has to be content with obtaining for the site of the intake either solid rock or the shelter of some point or bluff of the terrace which happens to be naturally of a more permanent nature or composed of more compact material than the ordinary run of shingle terraces.

The two dangers to which an intake may be liable are, first, that the flood-waters may scour it out and undermine it; and second, in the larger rivers, the stream may desert it, and seek some other part of the river-bed, in which case it has to be trained back again by scooping channels through the shingle. In some cases a system of infiltration to the intake has been successfully adopted by sinking a perforated wooden chamber, 30 feet to 50 feet in length, surrounded by boulders, protected by an envelope of wire netting. The chamber is founded on piles, and is connected with a culvert through the bank or terrace. The piles have to be taken down below the level of the lowest scour in the river. In all cases sluice-gates are provided, and some of these automatically cut off the supply in case of a flood; attempts have been made to adjust the supply automatically for all pressures of water in the river, but as this variation of pressure in the big rivers is very large—in the North Waimakariri intake there has been 11 feet 8 inches of water on the sill of the intake, and the river there is $\frac{3}{4}$ mile in width—it is, in the Author's opinion, preferable to employ a resident care-taker to regulate the more important intakes and secure uniformity of flow. Also precautions have to be taken by him to prevent the inlet from getting choked by the ingress of shingle, and the general work of maintenance of the head-race is sufficient to keep him otherwise in constant employment. Where the levels permit of it, a bye-wash is constructed for returning the surplus water from the channel to the river, and in some cases a shingle-trap is provided to catch and intercept deposit, which can be excavated from time to time.

In the head-race of the Ashley district, on the northern bank of the Waimakariri River, the ordinary working flow is 30 to 40 cubic feet per second, the gradient is 4 feet per mile, and the channel is benched along a terrace face, with a slope of about 35° for 2 miles, when the race enters a block-cutting 18 feet in depth, and emerges on the open plain about $\frac{1}{2}$ mile lower down. A somewhat similar race, but providing an ordinary flow of about 12 cubic feet per second, exists upon the opposite terrace of this river, and supplies one of the Selwyn districts. This head-race emerges from a tunnel, about 8 chains in length, in the gorge. These examples have locations presenting rather more than the average difficulties; the work in the head-races from such rivers as the Selwyn and Ashburton is easier, the terraces being lower. This method of grading along the terraces, although involving a yearly charge for maintenance, such as the removal of slips and the repair of occasional damage from wash-outs or from the under-cutting action

of flood-water in the rivers, is, in general, more within the means of the settler than is the payment of interest-charges upon the heavy first cost of tunnelling.¹ The gradients of these main races vary between about 4 feet per mile and 8 feet per mile. The angle of slope varies between about 25° and 45° for ordinary shingle terraces. The North Waimakariri race is 5 feet in width at the bottom, with side-slopes of 1 to 1 for the greater part, and is 5 feet in depth; but the depth of water in it, or in any of the other open races, is seldom more than 3 feet. The outer banks are usually not less than 3 feet in width at the top. In fixing the dimensions and gradients of these main races when running full, the Author has found it suitable to assume a mean velocity of 2 feet per second. This velocity is sufficient to check the growth of weeds, but not enough to cause scour.

With regard to maintenance, it may be noted that the rivers of Canterbury flow, in general, from west to east. The expense of maintenance is greater on the northern side. In this hemisphere a terrace facing south has a shady aspect. It is also more exposed to the violence of the rain-storms, which blow from the south-west, than is a terrace having a northern or sunny aspect, and, worse still, it is more exposed to the action of frost. In the North Waimakariri head-race, there is more annual expense due to this than to any other cause. In mid-winter, about mid-day, when a thaw begins, the terrace seems alive with falling stones, which fall into and help to choke the race. A plan adopted with success in the construction of some head-races is to leave a level bench 6 or 8 feet in width on the terrace edge of the race, so that the fallen shingle may be mostly intercepted; it can thus be removed more cheaply and without having choked the race. An important point, which affects races of all kinds throughout Canterbury, is the amount of leakage which takes place. In the early days of water-races it was held by many that, owing to the porous nature of the shingle subsoil which prevails nearly everywhere, the water would disappear altogether. Afterwards, when it was found that the races had become "sealed" by the minute particles of clay brought down in suspension in the water from the rivers, it was argued that the races were thereby rendered quite water-tight, and they certainly appeared to hold their water and carry it long distances without any sudden diminution in its volume. Such diminution is, however, under

¹ These remarks apply only to races for watering stock, and not to races for "power" purposes, where any stoppage of the supply by slips, etc., would not be tolerated.

ordinary circumstances, very difficult to detect by the eye without careful measurement. In many parts of the plains, where the sub-soil is of a homogeneous nature, a race will run for miles without any sign of leakage, but the Author has satisfied himself from careful observation that there are many races which cross veins or patches of looser material such as shingle naturally washed clean when originally deposited by fluvial action. In these places it is not uncommon for a small race to lose half its volume, or indeed for the water to disappear altogether, but usually the water lost in any one place is not sufficient to enable the leak to be readily detected. That the fine matter carried in suspension when the rivers are in flood tends to render the channel water-tight is generally admitted; indeed it is the Author's ordinary experience that when the water is thus discoloured the amount of water required in a system of races is less, and the supply in the head-race which feeds them has to be regulated accordingly. For actually stanching leaks, however, a mixture of earth and gritty sand is necessary. The fine particles will run through the spaces between the stones unless this coarser medium be present to retain them. The Author has always found that when leaky spots are once detected they can be cured by cutting out the loose material and ramming in the material described. True clay capable of being puddled is very rare. For the side-slopes to continue water-tight they must be stable and not liable to be scoured by the flow of water; this can usually be effected by making them not steeper than 1 to 1 in cuttings, and $1\frac{1}{2}$ to 1 in embankments, but the velocity of flow must not be so great as to disturb the material. Provided the slopes of main races are stable, there is no advantage in excavating to a flatter slope than 1 to 1 in order to induce deposit, because the fine particles are not deposited, but penetrate the sides by hydrostatic pressure whatever the slope may be. Any deposit of coarse earth, moreover, would be only a proof that the race was being injured elsewhere above by scour. It may be taken as an axiom that wherever there is scour there is liability to loss of water, because the water-tight lining is thereby removed. This is exemplified by the fact that the water from an ordinary natural creek will in many cases disappear altogether into its shingle bed, but if diverted into a properly graded race, run through the same material, it will continue to flow for many miles lower down.

With regard to the distribution of the water, the problem of locating the main feeder-channels to the best advantage is much complicated by local conditions. It has often been maintained that for a new country the best policy is for the making of main

roads to precede settlement, and this practice is in vogue in some colonies. It might be urged, with still more force, that in a country naturally unwatered, or insufficiently watered, as most countries are, the making of water-races which supply the life-blood of settlement should not follow its occupation, but precede it. The main feeders could thus be laid out on ground that would command levels suitable for supplying the branch-feeders, and the branches from them, before the subdivision and enclosure of the land. Roads, moreover, can be made to deviate on to rising ground, but with water-races any slight deviation in that direction is soon limited by the earthwork involved. The law of New Zealand gives to County Councils and Water Supply Boards power to enforce the construction of water-races through any farm-lands, subject to the payment for the land, and compensation for severance or other damage, which may be assessed by a Court. The process, however, is tedious and expensive, and usually the water-rights are secured by a simple method, based upon a system of mutual concession and friendly arrangement among the farmers. If it were not so, the cost of satisfying claims and the technical legal difficulties, involving expenditure on lawyers and land-surveyors, would prevent most of the distributing-races from being made at all.

The branch races are usually simple in construction. They vary between 1 foot and 3 feet in bottom-width for the smaller branches, although the main branch-feeders may be any width up to 16 feet. They have flat side-slopes of about 2 to 1 for shallow work, and 1 to 1 if the cutting be over 18 inches in depth. Flat slopes are preferable for shallow branch races, as they are less liable to injury from stock when drinking. For the larger races the work is usually done by ploughing and scooping. For the smaller branches the ground is often ploughed two spits deep, and the earth is thrown up neatly on both sides of the race to an even slope by an implement drawn by four horses, or occasionally by a traction-engine. This implement is called a "side-wiper," and has a steel share, like the prow of a ship, with long steel mould-boards set at an angle and strongly framed together. The earthwork of these races costs £4 to £8 per mile, including embankments at low places. Falls, to break the velocity of these shallow races, are not often required, as, owing to the great friction of their sides and their low hydraulic mean depth, no scour is produced unless the fall of the ground exceed about 40 feet per mile, or the material be light and unstable. In the latter case, or if there be an abrupt fall in the ground, it is usually sufficient to

construct falls of boulders, hand-pitched and bedded on a layer of coarse shingle 1 foot in thickness. This is cheaper than concrete and serves the purpose equally well.

Sluice-gates are required for regulating the distribution at main junctions or forks, at places where they can be readily inspected, but for smaller junctions the sluices are objectionable, because when the sluice is raised, rubbish brought down the race is sucked down and constantly chokes the opening, necessitating frequent inspection and clearance. A better and cheaper plan is to provide stout weir-boards on edge, securely fixed, with a notch cut out to the required dimensions for affording the normal supply to the branch. Any ordinary rubbish brought down is soon forced over the weir by the pressure of the water behind it. Crossings of roads and farm-crossings are made either by fords or culverts. The former are more permanent and cheaper. When a ford is once formed with a good foundation of boulders covered with shingle and topped with broken metal, and has become consolidated, it requires very little repair. Culverts are constructed of timber or concrete; the latter, however, is generally too expensive. Earthenware pipes are not adapted to shallow races, because, unless covered with at least 18 inches thickness of earth, they are sure to become broken by wheel traffic.