IMAGE EVALUATION
TEST TARGET (MT-3)

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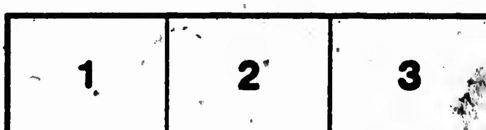

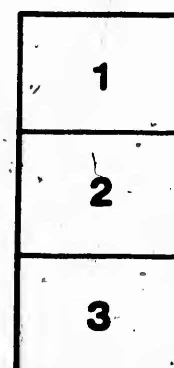

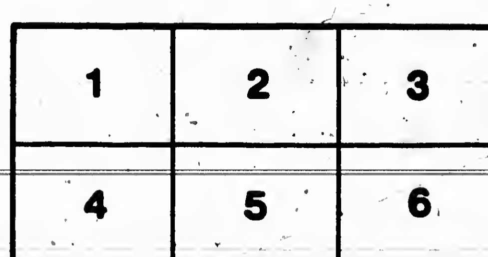

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Canadian Society of Civil Engineers.

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(*To be read on Thursday, the* 22nd Mar. 1894 (10th April))

IRRIGATION IN BRITISH COLUMBIA.

BY E. MOHUN, M. CAN. SOC. C. E.

The art of irrigation may claim to have been practised by the oldest branch of that profession which seeks to direct the great sources of power in nature for the use and service of man. Its origin is lost in the mists of antiquity, but the skill and knowledge of hydraulic laws possessed by the first civil engineers are attested by the ruins of the gigantic works construct ed by them in Egypt and Assyria. In the former we find the artificial Lake Mœris, two hundred and twenty-five miles in circumference, according to Herodotus, supposed to have been constructed by Amenemhat 3rd about 2380 B.C. The great Canal Bahr-Yoosup, 350 miles long, constructed under the Pharaohs, and repaired by Saladin. And the Sweet Water Canal attributed to Sesostris about 1400 B.C. In Assyria, Khammuragas, probably about 2000 B.C., is credited with the construction of numerous canals and the embankment of the Tigris.

About 600 B.C. Nebuchadnezzar embanked the Euphrates; cut canals to carry its overflow into the Tigris; excavated a reservoir, 40 miles square and thirty-five feet deep (Herodotus) to receive the waters of the former river, while its channel was being lined with brick; and constructed the far-famed Hanging Gardens of Babylon, on a series of arches at least 75 feet high a nd 400 Greek feet square. It is said that the water for their irrigation was raised from the Euphrates by an Archimedean screw. In China its history appears to be coeval with that of the Chinese Empire. In India in modern times the Imperial Government spent in ten years on irrigation no less a sum than £10,457,702 sterling. Of this amount £5,673,401 was expended in the North West Provinces, including the great works of the Ganges, the Eastern Jumna, the Agra, and the Lower Ganges canals; the area in the North West Provinces irrigated was 1,461,428 acres.

One of the most gigantic of modern irrigation schemes is proposed in Southern Idaho, and includes the construction of two great canals 300 and 280 miles long respectively, for the purpose of irrigating an estimated area of 4,500,000 acres. At the present day irrigation is in systematic use on every continent, and has proved of inestimable value in adding to the food supplies of the population of the globe.

In 1878 the author received instructions to report upon irrigation as practised in British Columbia for the information of the Dominion Government, and this paper is principally based upon the notes then taken; he would also bespeak the indulgence of the older members, when entering into details with which they are familiar, but to which, it may reasonably be assumed, some of the younger members have not probably devoted much attention. The main objects of the investigation were to ascertain how much water was required for crops, and whether the existing supplies were properly utilised.

THE MINER'S INCH.

As there will be frequent occasion to refer to the Miner's Inch, the standard measure of water both for mining and agriculture, it may be well before proceeding further to define it.

In California, the inch varies in different localities, and it means the amount which will pass through an orifice one inch square in a two inch plank with a certain head; the usual head is six inches above the top of the orifice. As, however, the depth of the orifice is sometimes made two inches, with a head varying from five to eight inches above it, it is obvious that the inch in California is not a fixed quantity in practice, and the writer believes there is no State law regulating it. Mr. Melville Attwood, a well-known mining engineer in San Francisco, informed the author that the inch recognized by the profession generally was 92 lbs. a minute. About sixteen years ago Mr. Amos Bowman, now of the Geological Survey of Canada, then in California, made a practical and admirable suggestion, namely, that an inch of water should mean 100 cubic feet an hour, or 2400 cubic feet a day. Had his suggestion been adopted, the matter would have been much simplified.

In 1878 the Mining Laws of British Columbia permitted the orifice to be ten inches or less in depth, with any head not more than seventeen inches above the *bottom* of the orifice. A few years later the author brought the matter to the notice of the Provincial Government; the following is now the definition according to the Land Act:—

"In measuring water in any ditch or sluice, the following rules shall be observed:—

"The water taken into a ditch or sluice shall be measured at the ditch or sluice head. No water shall be taken into a ditch or sluice except in a trough placed horizontally at the place at which the water enters it, and which trough shall be extended two feet beyond the orifice for the discharge of the water. One inch of water, or any multiple of one inch, shall mean half the quantity that will pass through an orifice two inches high by one or more inches wide, with a constant head of seven inches above the upper side of the orifice."

These dimensions and head were adopted as being as nearly as possible in accordance with the customary measurement. It is believed that this standard has since been adopted by the Dominion Government.

Taking the value of c. at 0.645 (Greenhill & Unwin), one inch $= 0.645 \sqrt{2gh} \times 0.01389 \times 43200 = 2536$ cubic feet a day. And for orifice of different depths with other heads the number of inches $= C \sqrt{h} \times 273.4 \times a$.

The construction of gauges has for a long time occupied the attention of the hydraulic engineers of Northern Italy; and the researches and experiments made by them, for the purpose of establishing a simple self-acting instrument of that description, led to the discovery of the following curious law of hydrodynamics, upon which is based the principle of the gauges used in Piedmont and Lombardy.

"It was ascertained that, in a vase constantly supplied, but divided into two portions by a diaphragm susceptible of being moved vertically with a discharging orifice on one side of the vase, a constant difference of level existed in the surfaces of the respective portions of the reservoir so long as the water flowed; and that this difference of level was greater in proportion as the opening of the diaphragm was less compared to that of the orifice. And it was also observed that if, by any change in the direction of the supply or the flow, the level were made to alter on either side of the diaphragm, the corresponding variations in the level upon the two sides continued always to be proportional to the respective difference of level first established." (Burnell.)

A sketch of one of these modules is shown in Plate V, Figure 1, in which the water is admitted into the regulating chamber A by the movable sluice b. The water is maintained at the proper height in the regulating chamber when discharging through the orifice O, by raising or lowering the sluice b. The chamber A is covered with a ceiling at the exact level of the required head (which is indicated by a gauge) to still the agitation of the entering water. The unit of measurement varies in different localities as follows:—

	Height of Orifice. ft.	Width of Orifice. ft.	Head above top of Orifice. ft.	Discharge in cubic feet a second.
Canal Lodi.........	1.12	0.12416	0.32	0.6165
Canal of Cremona.	1.31816	0.131	0.131	0.7225
Sardinian Module.	0.6562	0.6562	0.6562	2.046
Oncia Magistrale of Milan.........	0.655	0.3426	0.3294	0.866

In Spain a module giving very good results is in use on the Madrid Canal, Figure 2. Its construction, however, involves a serious loss of level between the canal and the irrigation ditch. This module consists of two chambers, one above the other; to the upper one the water has free access from the canal, in its floor, which is also the roof of the lower chamber; there is a circular sharp-edged orifice in a bronze plate, in which hangs a circular plug of varying diameter suspended from a float. The plug is so shaped that as the water in the upper chamber rises and falls and the float and plug with it, the free passage in the orifice

FIGURE I.

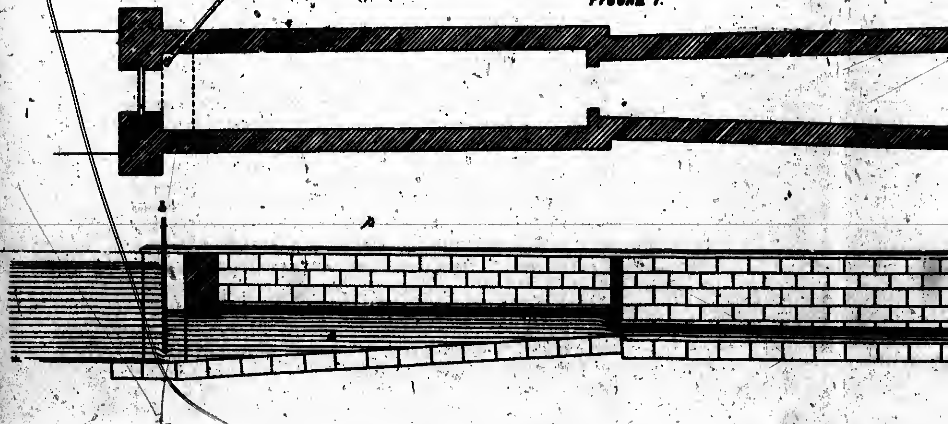
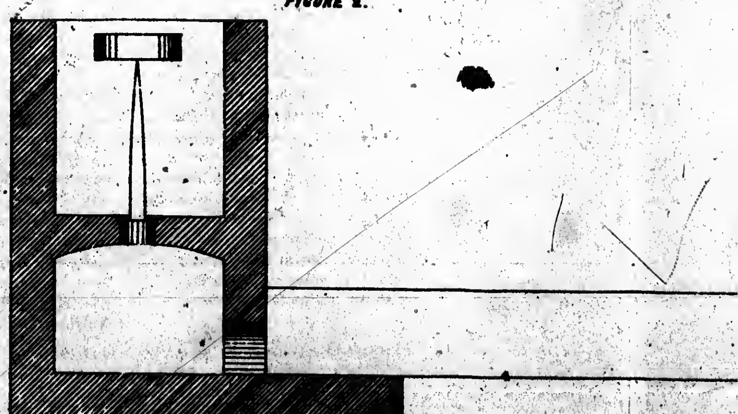


FIGURE 2.



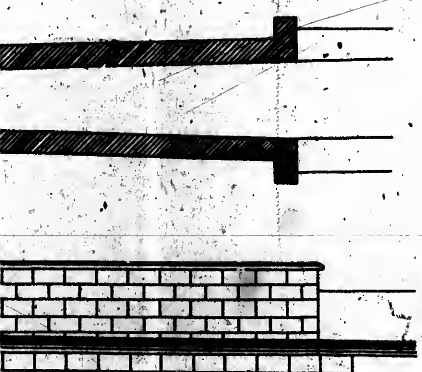
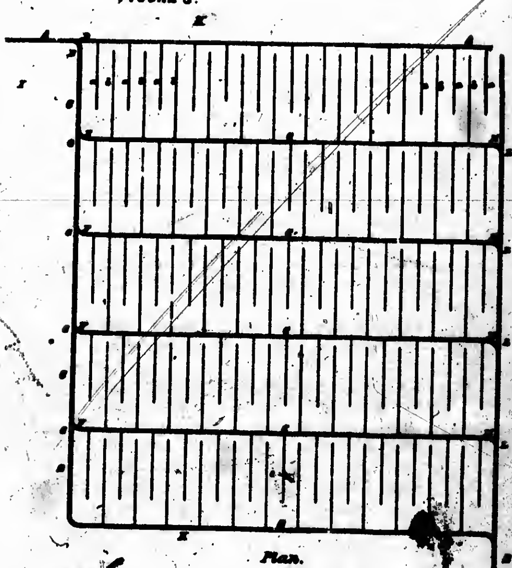


FIGURE 3.



Plan.

Cross Section on I.I.

Section on K.K.

is diminished or enlarged, so that the quantity discharged is uniform, though the head may vary. From the lower chamber the water is discharged through a culvert into the irrigation ditch.

An ingenious method of measurement has been proposed in England. In this module the orifices are in a sliding metal plate, connected by a link to a lever, attached at one end to a float in the regulating chamber, and so proportioned that the plate rises and falls with the float, maintaining the top of the orifice at a uniform depth below the surface of the water. Mr. Appold has also invented a module in which the water passes through a pipe having an enlarged chamber, in which swings a heavy pendulum, so proportioned that the discharging orifice diminishes as the pendulum under increased pressure approaches a horizontal position.

The general rules for irrigating crops, laid down by DeCandolle, are thus briefly enumerated by Dempsey:—

1st. That the water should be well aerated; the presence of atmospheric air is good, but that of carbonic acid gas much better; and it is desirable that the water should contain fertilising matters.

2nd. In the winter time there should be little irrigation, because the plants are then dormant, and water is then superabundant. In spring time water is usually abundant. In summer it is wanting; and at that time the water should be given in the evening.

3rd. The quantity of the water to be applied should be varied according

a. To the object of the culture:—When for leaves, more water should be given than when for flowers; less water should be given when for grains or fruits.

b. To the depths of the roots:—The application should be more frequent to the plants of which the roots are superficial; less frequent to deeper roots.

c. To the structure of the foliage:—Those which evaporate much (such as plants with large leaves) more frequently than perennial, or plants with thick leaves.

d. To the consistence of the stalks and of the roots:—Roots with fleshy fibres do not thrive if too abundantly watered; at the same time they are injured by dryness. Tuberculous or bulbous plants, or plants with fleshy leaves, can bear a long-continued dryness, and therefore infrequent, yet abundant, watering suits them well.

e. To the stage of vegetation:—It is important to bear in mind that young germinating plants require light and frequent waterings; those that are in the height of growth abundant waterings; and when the fruit or seed is being matured the waterings should be infrequent.

Those that have been transplanted require abundant watering.

f. To the nature of the soil, according to which the rules must be modified:—The lighter the soil the more frequent and plentiful must be the waterings. If it is a compact and clayey soil, less watering will be required.

g. To the state of the atmosphere:—It will be readily conceived that the watering must be more frequent when the temperature is high, the sky clear, and the air dry, and during drought.

Quantities necessary in Europe, Africa and Asia.

In connection with the subject it will be well to consider the quantities estimated to be necessary in different localities, when irrigation on an extensive scale is carried on; and Mr. Burnell gives the following figures:

Grau d'Arles	962	cubic feet per acre a day.
Haute Garonne	622	" " " " " "
Algeria	244	" " " " " "
Eastern Pyrenees	205	" " " " " "
East Indies	400	" " " " " "
South of France	1200	" " " " " "

The first and last of these quantities Mr. Burnell (and probably the reader will agree with him) considers excessive. He also states that the successful cultivation of rice is estimated to require 1440 cubic feet a day; but as rice is an essentially aquatic plant, requiring to be constantly immersed in water during its growth, while it cannot be cultivated with success north of the 46th parallel, its irrigation need not now be taken into consideration.

In that part of the Sahara which is contiguous to the French possessions in North Africa, much has been done in the way of irrigation, during the last few years, by means of artesian wells. Throughout the low-lying portions of the Algerian Sahara, there appears to be an abundance of subterranean waters, which only require an outlet to the surface to cause the wilderness to blossom as the rose. The first French well was bored in 1856, which yielded about 82 inches; and by the 1st October, 1885, there were in the Oued Rir, a valley about one hundred and twenty miles long, one hundred and fourteen artesian wells, and four hundred and ninety-two natural springs, yielding about 5,100 inches. Nor has this large flow affected the yield of the older wells. The "Société de Batna et du Sud Algerien," formed in 1881, in the first five years of its existence, sank seven wells yielding 527 inches, reclaimed one thousand acres of desert, planted more than fifty thousand date palms, constructed twenty-five miles of irrigation ditches, and built houses for the cultivators and Company's agents, and have already derived a revenue in round numbers of $100,000. (Chambers' Journal.)

SYSTEMS OF IRRIGATION.

In Lombardy the bedwork system of irrigation is generally adopted, in which the land to be irrigated is thrown up into ridges, the more compact the soil the wider the ridge; on the summit of the ridge is the shallow feeder or floating trough, from which the water is shed over the gently sloping sides of the ridge. The usual dimensions of the floating troughs are about 20 inches wide at their junctions with the conductors, and decrease in width to about 12 inches at their lower ends, they are generally about 70 yards long. The main conductor from which the floating troughs are supplied is usually but not necessarily at right angles to them, and the water is commonly turned off by closing the upper end of the floating trough with a sod. Between the ridges are small drains in which the superfluous water is collected and conveyed to a main drain, from which it is either again used to irrigate lower lying lands, or returned to the stream from which it was originally taken.

Figure 3 shews how with favourable natural contours a comparatively small amount of water can be of very considerable service.

In the Figure AA is the main conductor, BB the main drain, aa the floating troughs, bb the drains, cc are either conductors or drains according to circumstances, D, E, F, G, H & L, are hatches or sluices for the direction of the water. It is obvious that by opening or closing the hatches as circumstances dictate, the whole or any portions of the water can be directed to any particular section, and the superfluous water from one division used upon a lower one. In mountainous districts the main conductors have frequently a fall of 1 in 800; in the plains the fall usually is from 1 in 1500 to 1 in 3500.

In the catchwater system, extensively used in the water meadows of England, though generally considered inferior to the bed work, the water is conveyed along the side of a slope in a nearly level ditch without an outlet; as soon as the ditch is full, its contents begin to flow over the lower bank; at distances of about 30 feet, other level ditches on contour lines without outlets are formed, which collect and redistribute the water over the next lower area, when it is again caught and redistributed, until it finally reaches the lowest ditch, which is a drain.

A third method, that of sub-irrigation, has been employed both in England and in the United States, generally for the purpose of utilising and disposing without offence of liquid sewage. It has been received with favour by some persons, and has been adopted on free soils with apparent success, but as the liquid is distributed through the subsoil by underground pipes which are out of sight, the process is liable to objections which sanitarians cannot fail to recognize and appreciate.

The foremost of these objections is the fact that the distributing pipes must sooner or later become choked with the minute solid matters held by the liquid refuse in suspension, and when this is the case an "excrement sodden" condition of soil is produced. A stoppage can only be detected by positive signs of wetness on the surface, and not until the evils produced by exhalations from excrementitious matter may have gained an ascendency. Mr. Rogers Field has done much to overcome these objections. The drains by which he effects the distribution of the liquid consists of common agricultural drain pipes, laid some 10 or 12 inches below the surface upon a continuous bed of larger half pipes. This bed is not disturbed when the pipes are taken up to be cleaned, which ensures their being readily re-laid in true position. The sewage flows out of the joints into the soil and feeds the vegetation, and the concentrations of the flow, effected by the sudden discharge of a regulator or flush tank, with which the pipes are connected, forces the liquid rapidly along them.

In deference, however, to the wide experience of Mr. Rogers Field, and to the practical results obtained by Mr. Waring of Newport, U. S. A., who has adopted this means of sewage utilization in various instances in America, it is only right to append an extract from one of this last-named gentleman's letters on this subject.

In it he says: "I am carrying out the principles of sewage utilization here to some extent, not, however, in surface irrigation, but in the distribution of screened sewage by means of flush tanks of larger capacity, and of sub-irrigation by draining tiles laid about 10 inches below the surface of the ground. Some of this work dates back to 1869, and in one instance I have disposed in this manner of the sewage of a village of about 1500 inhabitants, and in another of the outflow of a prison producing about 30,000 gallons per day.

"In every instance the result has been most satisfactory, and I have large works of the same character now on hand." (Bailey-Denton.)

The sub-irrigation of drained land is also accomplished by closing the outlets of the drains, when the surface becomes too dry, and thus holding back the water in the soil, a very convenient method in land which has been over-drained. This system is in use to a considerable extent in Switzerland, and has been common in Persia for a great length of time. A system of irrigation known in England as "warping" is common in many countries; under this the land is flooded with water, having a large amount of mineral substances in suspension, the water being retained upon the land until the fertilizing matter has been deposited.

In British Columbia it has not been found practicable in many instances, owing mainly to the high price of labour, to properly prepare the surface for the reception of the water, and it is obvious that were such preparations made, a smaller quantity of water than is now in such cases used would be required, as we more nearly approached to its most economical distribution. In this province neither the bed-work nor catchwater systems have been adopted in their integrity. The more general method in use appears to be derived from the former. The ground is frequently formed in narrow ridges, and the water is carried in the hollows between them, instead of as in the bedwork system proper on top of them, and finds its way to the higher portions of the ridge by capillary attraction, so that in effect the lower part of the ridge is watered by surface and the upper part by sub-irrigation; a curious example of a combination of different principles. The method, however, appears a successful one. Grass crops are generally flooded to a depth of a few inches at each period of irrigation; the depth varies and depends mainly on the amount at the disposal of the agriculturist.

In California, where irrigation, under somewhat similar conditions of climate and soil as those which obtain in this province, has proved most successful, it is customary among the ditch companies to charge the farmer for one cubic foot of water a second,—34 inches,—for each one hundred and sixty acres under cultivation, equivalent to 540 cubic feet per acre a day, or a monthly rainfall of 4½ inches, of which it is estimated that not more than about ⅓ is actually absorbed.

The managing director of a company, engaged in extensive irrigating operations, stated in answer to enquiry: "In the San Joaquin Valley in the beginning of the farming season, a furrow is turned up all round the tract, thus forming a check, and the water is turned on until the land is so thoroughly saturated that it will absorb no more. This, with the few inches of rain that fall in the spring, is often enough to mature a crop of wheat, barley, etc. If not, then as the heads begin to fill out, that is six weeks or two months before maturity, the necessary amount of irrigation has to be applied."

It is obvious that such a method as this is only applicable to very level land. It is also to be remarked that there is no special irrigation system for grain in that state, the climate permitting this crop to be irrigated all the year round or nearly so.

Mr. Amos Bowman remarks as follows:

The quantity of water required to irrigate an acre varies considerably, depending chiefly upon the crop. Vines require very little; none after they are rooted. Other fruit requires irrigation. An inch of water running night and day will irrigate from one to ten acres for some products. For grass and clover, 10 inches, running three days in the week (of 24 hours each), would irrigate ten acres. Perhaps a constant flow of five inches to every ten acres would be near the mark, in other products one-half an inch to the acre.

The few results obtained by the writer, as examples of the quantity of water required to irrigate an acre, may be stated as follows:

For hay, one inch to half an inch per acre, running night and day.

For berries and newly planted vines, one half to one quarter inch per acre, running night and day.

For trees, one quarter to one tenth of an inch per acre, running night and day.

About 11 years ago a Mr. Pike sank an artesian well in the San Joaquin Valley, 268 feet deep, which it is stated cost between $400 and $500. The flow from this well was estimated at about 18,000 cubic feet a day, between 7 and 8 inches, and it was claimed to have successfully irrigated about 10 acres of barley, 5 acres of wheat, 5 acres of English peas, 2 acres of Chinese sugar cane, 4 acres of oat hay, 1½ acres of corn, besides a small orchard and vegetable garden, in all say from 28 to 30 acres; or approximately that one inch irrigated four acres of land. In California the extensive tracts of land which can be cultivated with the aid of irrigation encourage the formation by joint stock companies of irrigation ditches on too large a scale, and generally of too costly a character, to be undertaken by individuals.

Among them may be mentioned:

The Rodes Ditch............	length	about	10	miles,	cost	about	$10,000
Lower King's River Ditch.	"	"	13	"	"	"	$28,000
Last Chance Ditch..........	"	"	20	"	"	"	60,000
Mussel Slough Ditch........	"	"	60	"	"	"	60,000
The People's Ditch..........	"	"	45	"	"	"	100,000
The Settlers Ditch....	"	"	20	"	"	"	30,000
The Lake Side Ditch........	"	"	30	"	"	"	50,000

The foregoing are some only of the larger ditches. Since the date at which these notes were taken several very costly ones have been constructed, of which the author cannot give any details. During the past ten or twelve years considerable additions to the water supply for agriculture in California have been obtained from artesian wells.

IRRIGATING DISTRICT OF BRITISH COLUMBIA.

The district in this province in which irrigation is required may be roughly described as the elevated plateau lying between the Cascades and the Rocky Mountains. It is broken by smaller mountain ranges and spurs from the main chains; its elevation varying from about 800 to 3000 feet above the sea. The soil of the benches and terraces and irregular slopes of some of the valleys, which were once probably the bed of a large lake, is extremely fertile when cultivated, and has been described as composed of modified or redistributed drift, modern alluvium, etc., and is chiefly the product of the disintegration and rearrangement of the boulder clay, though mixed also with the detritus from local rocks since the glacial period, which has been carried down by rivers, when flowing at a higher level as they seem here to have flowed in the past. (See Geol. Sur. of Can. Rep.)

It appears that, at a greater elevation than about 2000 feet, summer frosts prevent successful cultivation as a general rule; though in some instances, owing to favourable local conditions, cultivation has proved remunerative of greater elevations. A curious instance of the uncertainty of obtaining a crop occurs at Douglas Lake, Nicola Valley; the Lake is 4 or 5 miles long at an elevation rather over 2000 feet, the soil at its head and foot appears identical, and the conditions seem precisely similiar, yet both whites and Indians agree that the crops at the head of the Lake are very uncertain, while at the foot they rarely fail.

IRRIGATION ESSENTIAL.

It must be understood that in the section of country referred to, with a few notable exceptions, such as the Spallumcheen Valley, cultivation cannot be successfully carried on without irrigation. This is usually applied three or four times in the season, commencing in April, at intervals of from twenty to thirty days.

The main stream of the Fraser and Thompson Rivers lie too far below the fertile benches in their valleys to render their boundless resources available except by pumping; this is unfortunate, for their waters contain an enormous amount of fertilizing matter in suspension. The principal supplies are derived from the smaller mountain streams, which generally attain their greatest volume in May, the month in the commencement of which the largest quantity is required; during the two succeeding months they fall very rapidly, and in dry summers there may be a scarcity towards the latter end of the irrigation season.

When it is practicable, which is rarely the case in British Columbia, to select from different sources of supply, the broad rule would appear to be that the water which has been longest exposed to the air is the best for the purpose, and it is on this ground that it is advisable to construct the main conductors wide and shallow; and though this form leads to a greater loss by evaporation, it also diminishes to an appreciable extent the lateral pressure on the banks. Water from lakes and large streams is generally of such a temperature as to be permitted to run without cessation; but when obtained from cold springs and short snow-fed streams, it is sometimes necessary to shut it off during the night. Authorities on this subject appear to consider that the best water for irrigation is obtained from artesian wells of considerable depth, on account of its temperature, and also on account of the mineral elements usually contained in it.

The artesian wells of Dakota are, perhaps, the most remarkable examples of their kind which have ever been opened, both as regards the pressure and the volume of the escaping water. More than one hundred wells, from 500 feet to 1,600 feet deep, are at present in successful operation in the district north of Yankton, and they yield a constant stream of water which is apparently never affected by any of the surrounding influences. The pressure of the water is abnormally high in many instances, and up to 180 lbs. per square inch has been registered by the gauges. (Industries.) Artesian wells have not yet been sunk in this province; the Provincial Government, however, last year commenced an experimental bore in the valley of the South Thompson River.

Mr. Bailey-Denton says:

In the "conclusions" arrived at by the "Rivers Pollution Commissioners," the average composition of "unpolluted waters" is given in the following form:

Results of analysis expressed in parts per 100,000.

Description.	Dissolved Matters.											No. of samples taken.
	Total solid impurities.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as nitrites or nitrates.	Total combined nitrogen.	Previous sewage or animal contamination.	Chloride.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	
Rain water	2.95	.070	.015	.029	.003	.042	42	.22	.4	.5	.3	39
Upland surface water..........	9.67	.322	.032	.002	.009	.042	10	1.13	1.5	4.3	5.4	195
Deep well w't'r	43.78	.061	.018	.012	.495	.522	4,743	5.11	15.8	9.2	25.0	157
Spring water...	28.20	.056	.013	.001	.383	.396	3,559	2.49	11.0	7.5	18.5	198
Average	....	.127	.019	.011	.222	.250	....	2.24	......	......	......	....

Without venturing to express an opinion upon the precise meaning of "previous sewage or animal contamination," the heading of one of the columns, these figures show an exceptionally large amount of fertilising matters in the waters from deep wells.

Temporary hardness is hardness due to calcic or magnesic carbonates, and can be got rid of by boiling the water.

Permanent hardness is hardness due to calcic or magnesic sulphates, and cannot be got rid of by boiling.

One grain of bicarbonate or sulphate of lime in a gallon of water is expressed as one degree of hardness per gallon.

It must not be inferred from previous remarks, that the table land of which we are speaking is badly watered for purposes other than those of irrigation. On the contrary, the whole surface of the country is dotted with lakes and traversed by streams, varying in size from the Fraser River to the tiniest rivulet, though frequently, from their positions and the large outlay required before they can be utilized, they are practically excluded from being classed among the available sources of supply.

RAINFALL.

The following table shews the rainfall in the irrigating and non-irrigating districts of British Columbia, during the irrigation season of 1877.

IRRIGATING DISTRICT.

Place.	April.	May.	June.	July.	Total.
Spence's Bridge..............	0.38	1.41	0.75	1.25	3.79
Cache Creek....................	1.03	1.10	1.35	1.22	4.70
Kamloops.........................	0.78	1.42	1.67	0.59	4.46
Okanagan	0.22	1.75	2.15	1.42	5.54

NON-IRRIGATING DISTRICT.

Place.	April.	May.	June.	July.	Total.
Spellamcheen.................	1.38	1.84	1.65	1.82	6.69
Hope	1.71	1.84	2.20	1.38	7.13
New Westminster............	1.55	1.62	2.65	1.03	6.85

The above table shews an average in the irrigating district of 137, and in the non-irrigating district of 205 cubic feet per acre a day, or half as much again in the latter case as in the former.

The years 1877 and 1878 were, however, dry seasons in the non-irrigating, though fully up to the average rainfall in the irrigating district. The mean rainfall in New Westminster for 14 years was for the above months, 3.18, 2.41, 2.42, and 1.67 respectively, equivalent to 288 cubic feet per acre a day. The rainfall in May, 1878, at Kamloops was 1.85 inches, equivalent to 216 cubic feet per acre a day, and it appeared to be the general opinion that with a similar rainfall during the season irrigation might, at all events to a very great extent, be dispensed with.

It must be remembered, however, that as art cannot compete with nature in the equable distribution of water, a larger quantity is required for artificial irrigation than would constitute an abundant rainfall. And it may further be observed that the rainfall which would constitute an ample supply for the generally retentive soils of the lower, would possibly prove inadequate for some of the soils of the upper country.

Further, in the irrigating district, a heavy precipitation is often the result of sudden and violent storms, the effect of which is sometimes more injurious than beneficial. An instance of this occurred on the 20th July, 1878, when a sudden storm burst on the Bonaparte Valley, with the result that several acres of cultivated land were covered with wash gravel, the crops destroyed, and that portion of the farm rendered worthless. It is obvious that such a storm would largely increase the registered rainfall, though its effects were simply disastrous. In the farming lands of the non-irrigating district, storms of this description are almost unknown, the rain falling more frequently and less violently, and with a corresponding increase of beneficial effect.

LOSSES OF WATER.

There are three principal heads under which the losses of water after leaving the reservoir or stream may be classified, namely :—

Loss by evaporation,

Loss by leakage in transit, and

Loss in distribution.

As regards the first there are no data derived from experiments in this province from which to deduce any conclusions. In California loss by evaporation does not appear to be taken into consideration.

On this point the following are the opinions of some eminent English engineers :—

Mr. Bateman places the loss by evaporation at from 9 to 16 inches, with an average of 12 inches.

Mr. Hemans allows from 12 to 14 inches.

Mr. Duncan estimates 11 or 12 inches as the constant loss at Liverpool, and found the loss varied little, even with considerable difference of rainfall.

Mr. [illegible] says: "Evaporation is more nearly 15 inches than any other quantity."

Careful experiments, extending over a period of 25 years, made in Hertfordshire, England, showed that with a mean annual rainfall of 26.609 inches, the mean percolation was 8.227 inches, and the mean loss by evaporation 18.382 inches.

Mr. Dempsey quotes the following results of experiments made in Yorkshire during five consecutive years: mean annual rainfall 24.6, mean annual percolation 4.82, which gives double the loss by evaporation recorded in Hertfordshire.

Dr. Dalton gives the following results: mean annual rainfall 33.56 inches, mean evaporation 25.158, and mean percolation 8.402.

By another set of observations quoted by Dempsey and also by Haskoll we have: mean annual rainfall 26.614, mean percolation 11.294, mean evaporation 15.32 inches.

To tabulate them we have

	Rainfall.	Evaporation.	Percolation.
1st...........................	26.609	18.382	8.227
2nd...........................	24.6	19.78	4.82
3rd...........................	33.56	25.158	8.402
4th...........................	26.614	15.32	11.294

The mean of these various independent observations would give rainfall 27.846 inches, evaporation 19.66, percolation 8.186, or in round numbers the loss by evaporation would be about seven-tenths, leaving about three-tenths of the whole rainfall for percolation.

These results, however, are for the entire year; during the summer months the evaporation is probably much greater.

The amount lost in transit by leakage and evaporation has, in some cases, been estimated at 50 per cent. of the amount entering at the head of the ditch. It is obvious that the quantity lost through these causes depends upon the construction, the length and exposure of the ditch. The loss by filtration may often be reduced by the construction of timber flumes when the soil is porous, and by throwing into the ditch at intervals small quantities of soil, which being first carried along in suspension, and then gradually deposited, assist the consolidation of the bottom and banks.

The main conductors are often necessarily carried along steep side hills, and around bluffs and across ravines in timber flumes. These ditches and flumes have generally been set out and constructed by their owners, and as a rule most successfully, though in some instances too great a gradient having been adopted, overfalls have been found necessary at intervals to reduce the velocity which threatened serious damage. In one or two instances when the water refused to disobey the laws of gravity and flow up hill, heavy losses have been the result to the unfortunate projectors.

The loss in distribution may be reduced to a minimum by the proper preparation of the surface for the reception, and by making adequate provision for the distribution of the water. No hard and fast rules can be laid down by which to estimate these losses, each case must be treated on its individual merits.

QUANTITY OF WATER.

It has been customary in this province to record and claim one inch of water per acre, or 2536 cubic feet per acre a day. As to the amount necessary, one cubic foot a second, or 34 inches, will cover four acres to a depth of over six inches in a day, which certainly appears to be a not unreasonably low estimate of the quantity required at each period of irrigation.

On this assumption, and that the land requires irrigating once in 25 days, 34 inches will irrigate one hundred acres of land, and 34 inches on 100 acres is equivalent to 864 cubic feet per acre a day. Judging from the quantities [illegible] by Mr. Burnell as required in Europe this amount should prove ample.

It is generally considered by engineers that from one-half to two-thirds of the whole quantity delivered is lost or wasted. Now the amount delivered at each period of irrigation on one four acre tract is 86,400 cubic feet, or 21,600 cubic feet per acre a day; deducting three-fourths of that amount for all losses, we have 5,400 cubic feet per acre at each period of irrigation, or a daily average throughout the irrigation season of 216 cubic feet per acre per day actually utilised, equivalent in round numbers to a monthly absorption of 1.8 inches of rain; as, however, it is doubtful if more than one-third of any rainfall is actually absorbed, this amount may fairly be taken as equivalent to from 5 to 6 inches of rainfall. With such a rainfall it is certain that irrigation would be unnecessary. If the superfluous water be utilized on lower lying lands, the result will be found to be an approximation to the Californian standard of one cubic foot a second for each one hundred and sixty acres under cultivation.

In the author's opinion 34 inches delivered upon the land will be found ample to irrigate from 100 to 150 acres of cereals or roots according to position and soil.

It is generally considered that grass requires a larger supply of water than grain; and in estimating that quantity we are again confronted by a total want of data in this province; but since it is known that rice needs 1440 cubic feet per acre a day, it would appear reasonable to assume an approximate mean, say 45 inches delivered on the ground, for each hundred acres of grass under cultivation.

In assuming these quantities it is thought that an ample margin has been left for all losses in distribution, and the author, though anxious not to under-estimate the quantity required, feels considerable doubt as to whether, with proper construction and handling, two-thirds of the amount would not prove sufficient.

To give an example of the enormous quantities supposed by some to be required: on a certain farm it was found that the main conductor close to the land to be irrigated had a velocity of 2.35 feet a second, with an area of 1.25 square feet, equal to a daily discharge of 253,800 cubic feet or 100 inches. It was stated that the season lasted ninety days, that the irrigated area comprised about 50 acres of grass and 30 acres of grain, that during sixty days the grass received the water and during thirty days the grain. We have then the astounding result, that throughout the season the grass received an average of 3,384, and the grain 2,820 cubic feet per acre a day, equivalent to over 26 inches of rainfall a month, or enough in ninety days to convert the whole area into a lake over 6½ feet deep. Probably not more than one-tenth was of actual service, and when compared with other results, you will doubtless conclude that in this case at least the supply exceeded the legitimate demand.

DRAINAGE.

In this province but little has been done, and in most cases, from the natural contour of the land and the character of the sub-soil, but little requires to be done for the purpose of removing the surplus irrigation water. When, however, it does not naturally and rapidly flow off, its drainage is as essential as its original introduction.

FALL OF MAIN CONDUCTORS.

It is apparent that the main conductors are frequently constructed with too heavy grades, and it is suggested that the velocity should not be greater than from 1 to 2 feet a second through earth, and 3 to 4 or 5 feet in timber flumes.

With regard to flow in open channels, Colonel Waring calls attention to a result he has observed in the flow of sewers in the following words:

"One principle is very apt to be disregarded in regulating the size of sewers; that is, that after water has once fairly entered a smooth conduit, having a fall or inclination towards its outlet, the rapidity of the flow is constantly accelerated up to a certain point, and the faster the stream runs the smaller it becomes; consequently, although the sewer may be quite full at its upper end, the increasing velocity soon reduces the size of the stream, and gives room for more water. It is found possible, in practice, to make constant additions to the volume of water flowing through a sewer by means of inlets entering at short intervals, and the aggregate area of the inlets is thus increased to very many times the area of the sewer itself."

The author has on two or three occasions observed results confirmatory to a certain extent of this statement, and would be glad to learn whether the point has attracted the attention of others, and how far it is available in practice. Except by Colonel Waring, he has never seen the matter referred to in any works of reference to which he has access, and though probably of not much practical importance in the construction of such channels as drainage and irrigation ditches, he would submit that it may prove a serious point for consideration in designing such costly subterranean works as sewers.

From the drawings accompanying this paper Plate V has been prepared.