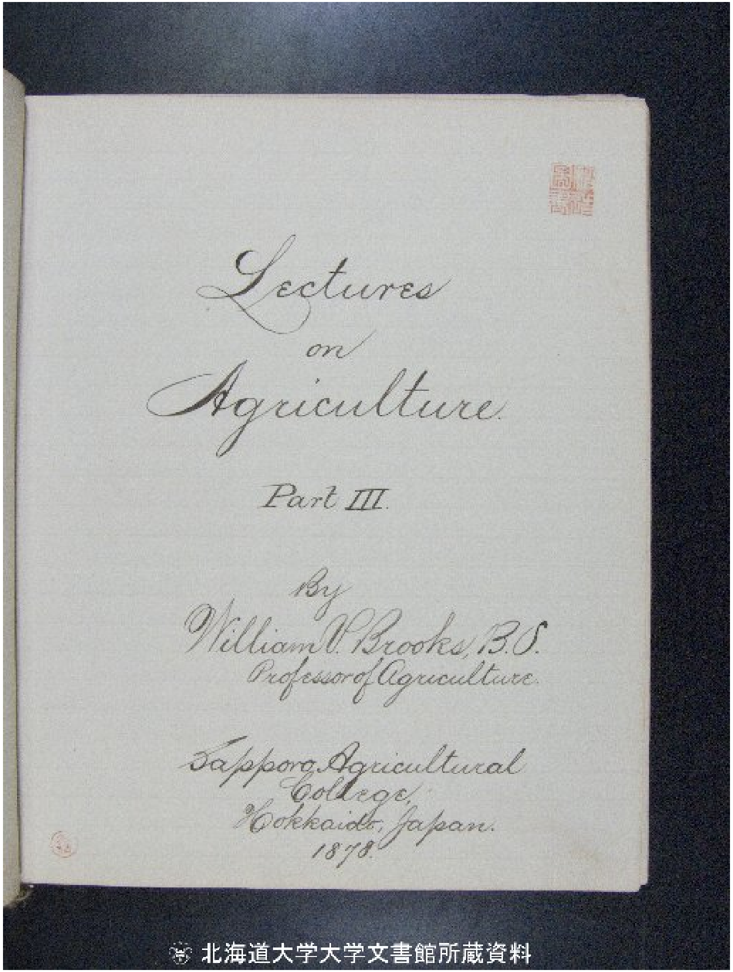


Lectures

on

Agriculture

Part III.

By

William P. Brooks, B. S.

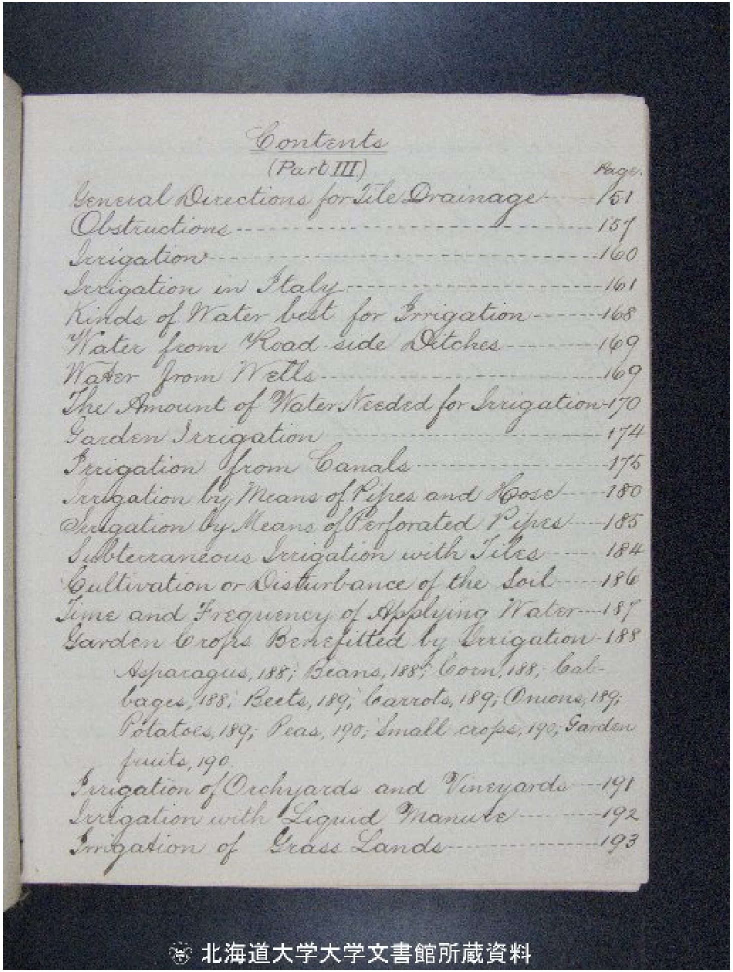
Professor of Agriculture

Sapporo Agricultural

College,

Hokkaido, Japan

1878.



Contents
(Part III)

Contents

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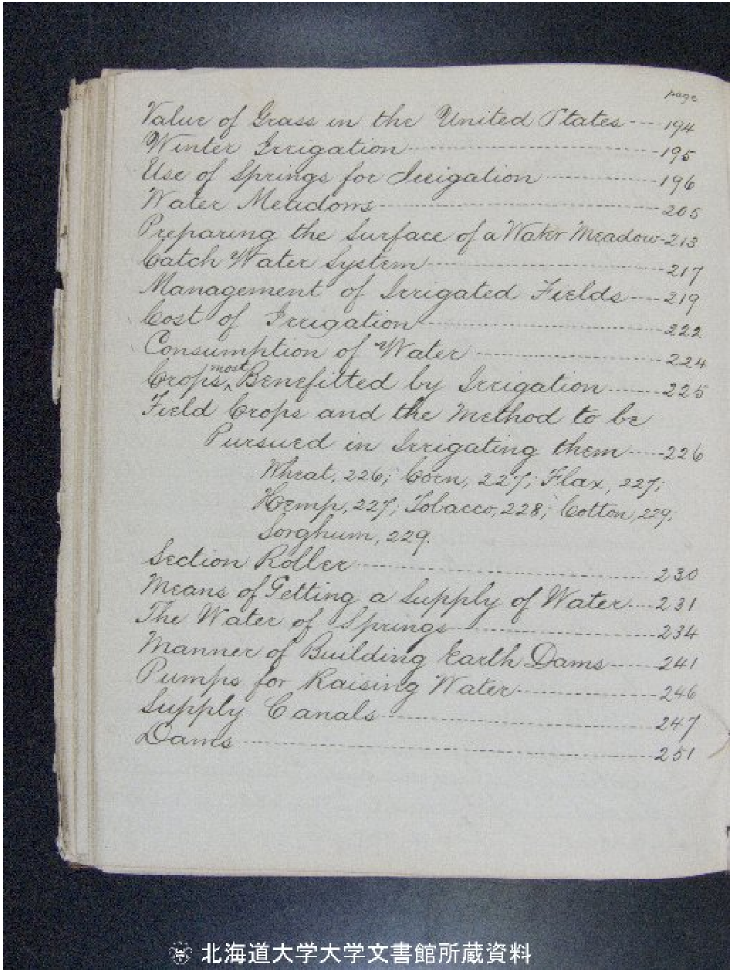

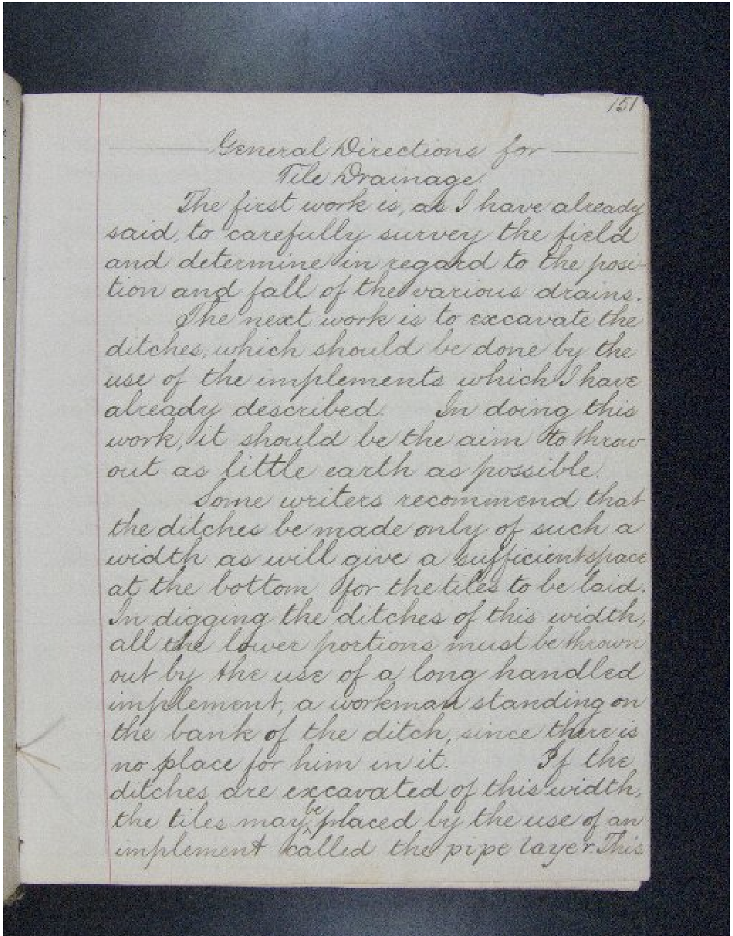
151

General Directions for
Tile Drainage

The first work is, as I have already said, to carefully survey the field and determine in regard to the position and fall of the various drains. The next work is to excavate the ditches, which should be done by the use of the implements which I have already described. In doing this work, it should be the aim to throw out as little earth as possible. Some writers recommend that the ditches be made only of such a width as will give a sufficient space at the bottom for the tiles to be laid. In digging the ditches of this width, all the lower portions must be thrown out by the use of a long handled implement, a workman standing on the bank of the ditch, since there is no place for him in it. If the ditches are excavated of this width, the tiles may be placed by the use of an implement called the pipe layer. This

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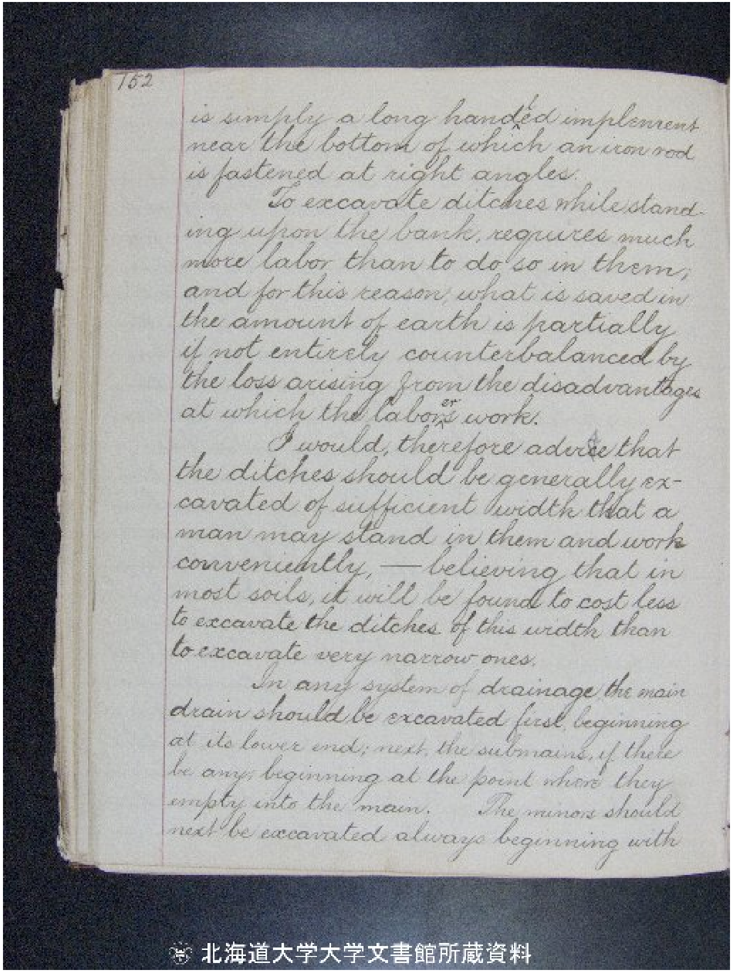
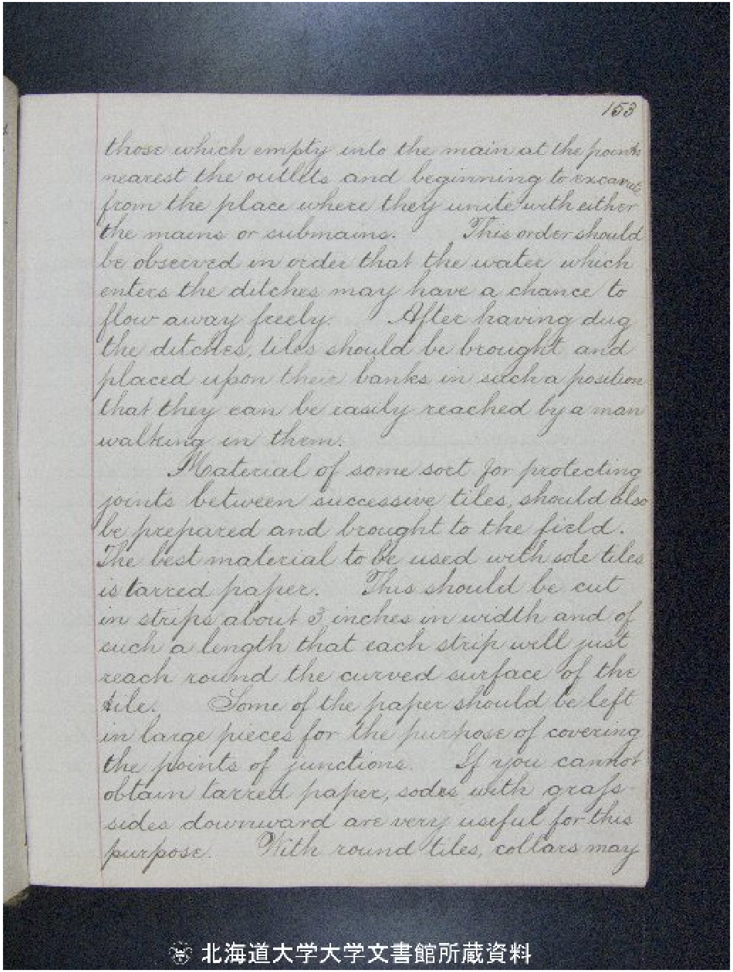


is simply a long handled implement near the bottom of which an iron rod is fastened at right angles.

To excavate ditches while standing upon the bank, requires much more labor than to do so in them; and for this reason, what is saved in the amount of earth is partially if not entirely counterbalanced by the loss arising from the disadvantages at which the laborers work.

I would, therefore advise that the ditches should be generally excavated of sufficient width that a man may stand in them and work conveniently, —— believing that in most soils, it will be found to cost less to excavate the ditches of this width than to excavate very narrow ones.

In any system of drainage the main drain should be excavated first beginning at its lower end; next, the submains, if there be any, beginning at the point where they empty into the main. The minors should next be excavated always beginning with



153

those which empty into the main at the points nearest the outlets and beginning to excavate from the place where they unite with either the mains or submains. This order should be observed in order that the water which enters the ditches may have a chance to flow away freely. After having dug the ditches, tiles should be brought and placed upon their banks in such a position that they can be easily reached by a man walking in them.

Material of some sort for protecting joints between successive tiles, should also be prepared and brought to the field. The best material to be used with sole tiles is tarred paper. This should be cut in strips about 3 inches in width and of such a length that each strip will just reach round the curved surface of the tile. Some of the paper should be left in large pieces for the purpose of covering the points of junctions. If you cannot obtain tarred paper, sodes with grass sides downward are very useful for this purpose. With round tiles, collars may

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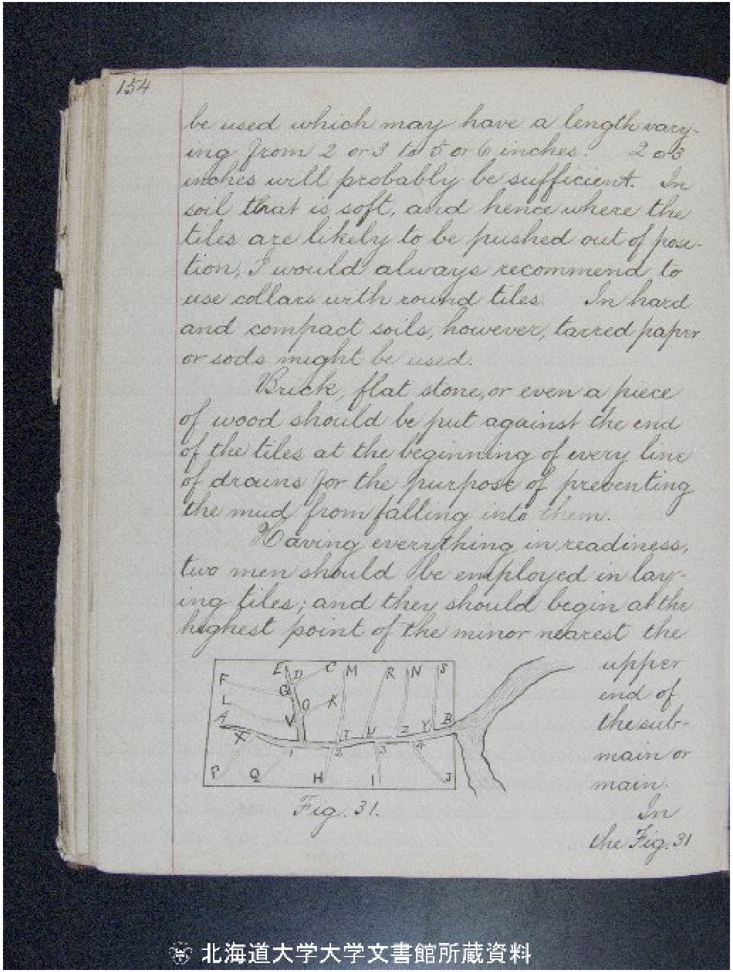
154

be used which may have a length varying from 2 or 3 to 5 or 6 inches. 2 or 3 inches will probably be sufficient. In soil that is soft, and hence where the tiles are likely to be pushed out of position, I would always recommend to use collars with round tiles. In hard and compact soils, however, tarred paper or sods might be used.

Brick, flat stone, or even a piece of wood should be put against the end of the tiles at the beginning of every line of drains for the purpose of preventing the mud from falling into them.

Having everything in readiness, two men should be employed in laying tiles; and they should begin at the highest point of the minor nearest the upper end of the sub-main or main.

Fig. 31.

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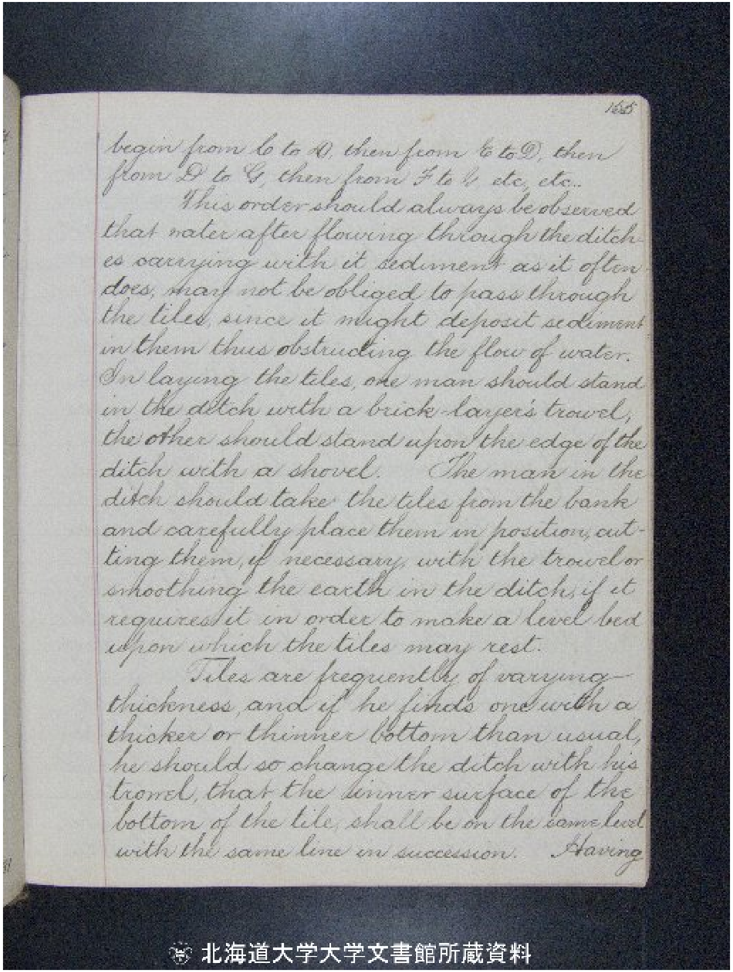
165

begin from C to D, then from E to D, then from D to G, then from F to C, etc, etc..

This order should always be observed that water after flowing through the ditches carrying with it sediment as it often does, may not be obliged to pass through the tiles, since it might deposit sediment in them thus obstructing the flow of water. In laying the tiles, one man should stand in the ditch with a brick-layer's trowel, the other should stand upon the edge of the ditch with a shovel. The man in the ditch should take the tiles from the bank and carefully place them in position, cutting them, if necessary, with the trowel or smoothing the earth in the ditch, if it requires it in order to make a level bed upon which the tiles may rest.

Tiles are frequently of varying thickness, and if he finds one with a thicker or thinner bottom than usual, he should so change the ditch with his trowel, that the inner surface of the bottom of the tile shall be on the same level with the same line in succession. Having

begin from C to D, then from E to D, then from G to Y, then from F to it etc., etc..

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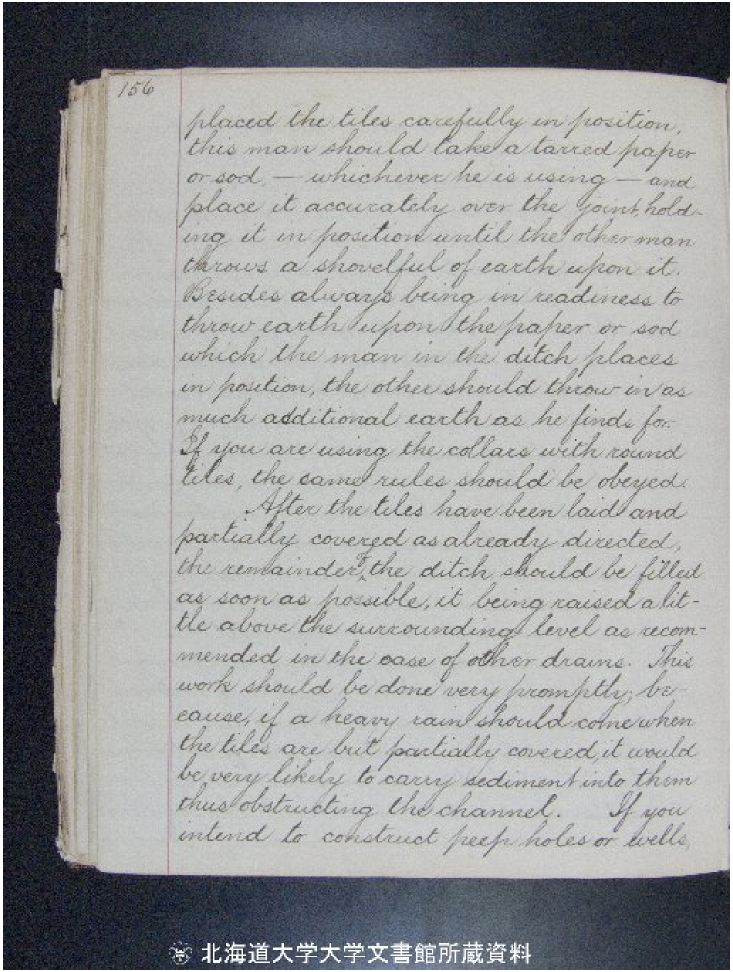
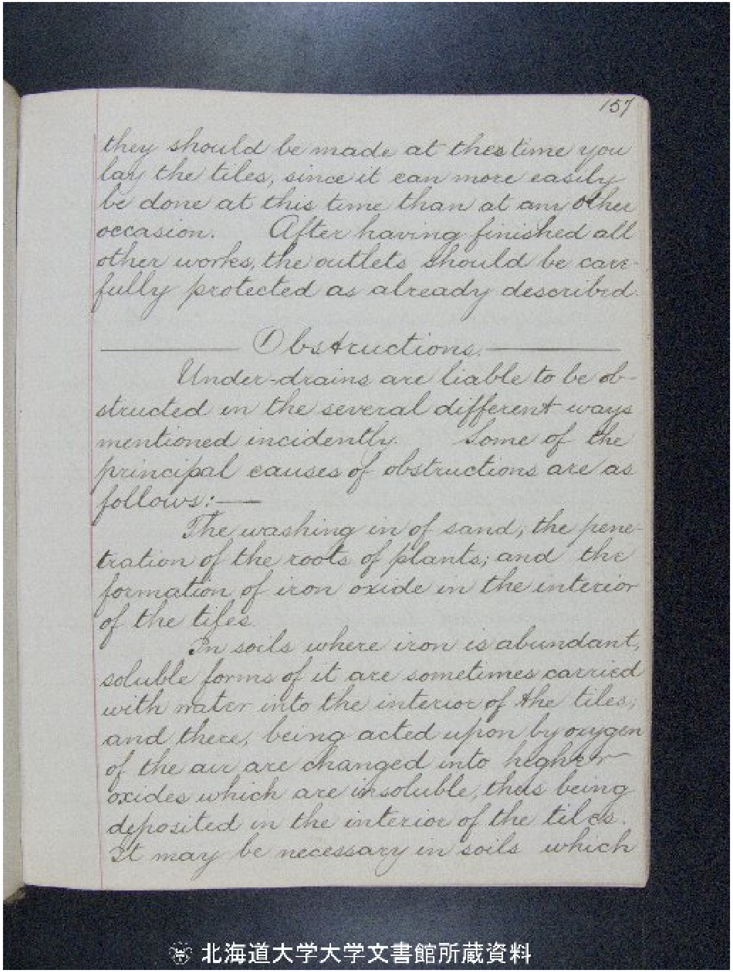


placed the tiles carefully in position, this man should take a tarred paper or sod, —— whichever he is using —— and place it accurately over the joint, holding it in position until the other man throws a shovelful of earth upon it. Besides always being in readiness to throw earth upon the paper or sod which the man in the ditch places in position, the other should throw in as much additional earth as he finds for. If you are using the collars with round tiles, the same rules should be obeyed.

After the tiles have been laid and partially covered as already directed, the remainder of the ditch should be filled as soon as possible, it being raised a little above the surrounding level as recommended in the case of other drains. This work should be done very promptly; because, if a heavy rain should come when the tiles are but partially covered, it would be very likely to carry sediment into them thus obstructing the channel. If you intend to construct peep holes or wells,



157

they should be made at the time you lay the tiles, since it can more easily be done at this time than at any other occasion. After having finished all other works, the outlets should be carefully protected as already described.

Obstructions.

Under-drains are liable to be obstructed in the several different ways mentioned incidently. Some of the principal causes of obstructions are as follows:—

The washing in of sand; the penetration of the roots of plants; and the formation of iron oxide in the interior of the tiles.

In soils where iron is abundant, soluble forms of it are sometimes carried with water into the interior of the tiles; and there, being acted upon by oxygen of the air are changed into higher oxides which are insoluble, thus being deposited in the interior of the tiles. It may be necessary in soils which

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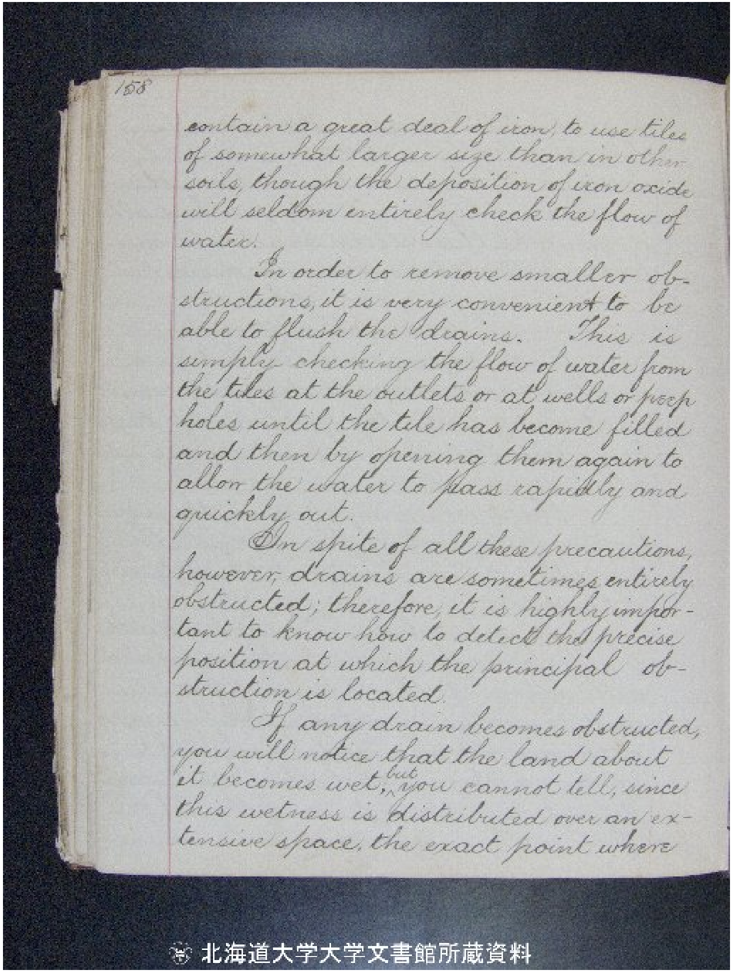

contain a great deal of iron, to use tiles of somewhat larger size than in other soils, though the deposition of iron oxide will seldom entirely check the flow of water.

In order to remove smaller obstructions, it is very convenient to be able to flush the drains. This is simply checking the flow of water from the tiles at the outlets or at wells or peep holes until the tile has become filled and then by opening them again to allow the water to pass rapidly and quickly out.

In spite of all these precautions, however, drains are sometimes entirely obstructed; therefore, it is highly important to know how to detect the precise position at which the principal obstruction is located.

If any drain becomes obstructed, you will notice that the land about it becomes wet, but you cannot tell, since this wetness is distributed over an extensive space, the exact point where

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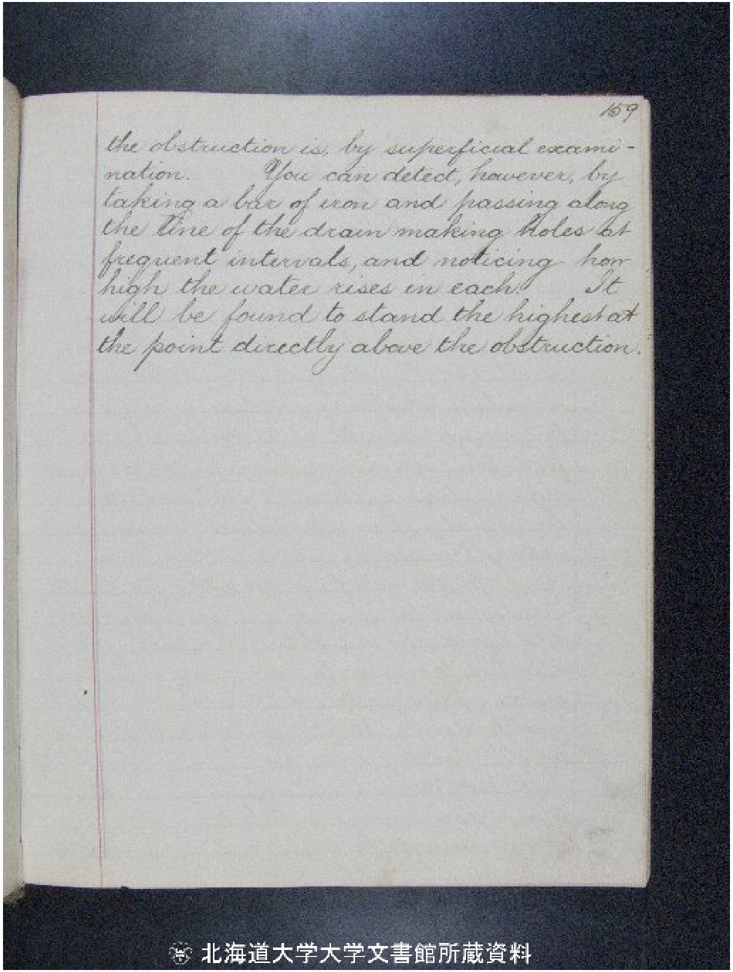
159

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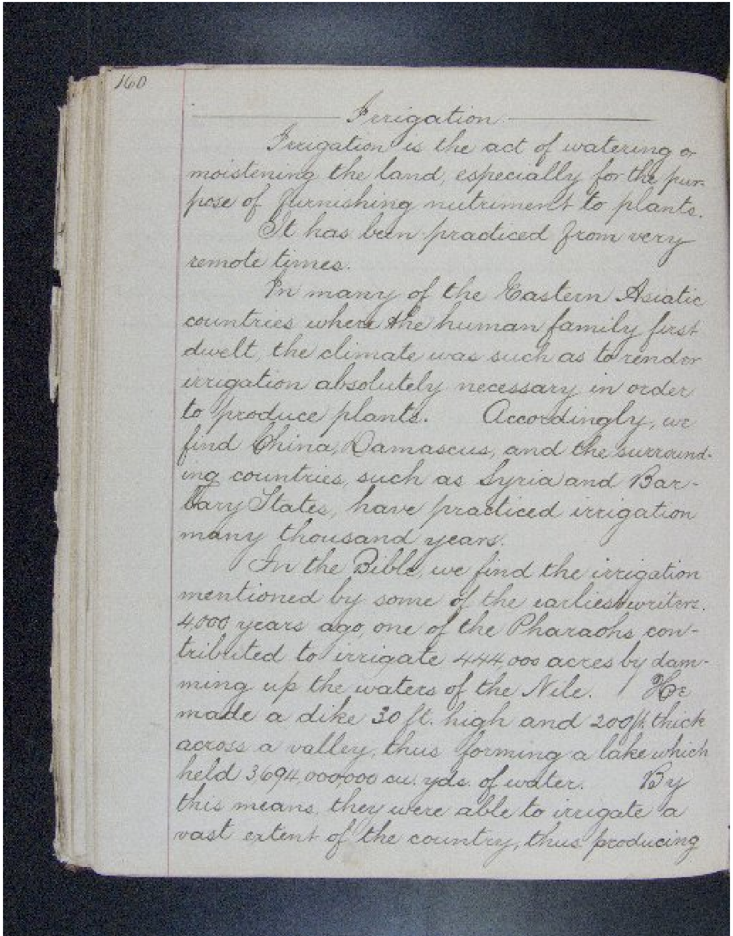

160

Irrigation

Irrigation is the act of watering or moistening the land, especially for the purpose of furnishing nutriment to plants.

It has been practiced from very remote times.

In many of the Eastern Asiatic countries where the human family first dwelt, the climate was such as to render irrigation absolutely necessary in order to produce plants. Accordingly, we find China, Damascus, and the surrounding countries, such as Syria and Barbary States, have practiced irrigation many thousand years.

In the Bible, we find the irrigation mentioned by some of the earliest writers. 4,000 years ago, one of the Pharaohs contributed to irrigate 444,000 acres by damming up the waters of the Nile. He made a dike 30 ft. high and 200 ft. thick across a valley, thus forming a lake which held 3694,000,000 cu. yds. of water. By this means they were able to irrigate a vast extent of the country, thus producing

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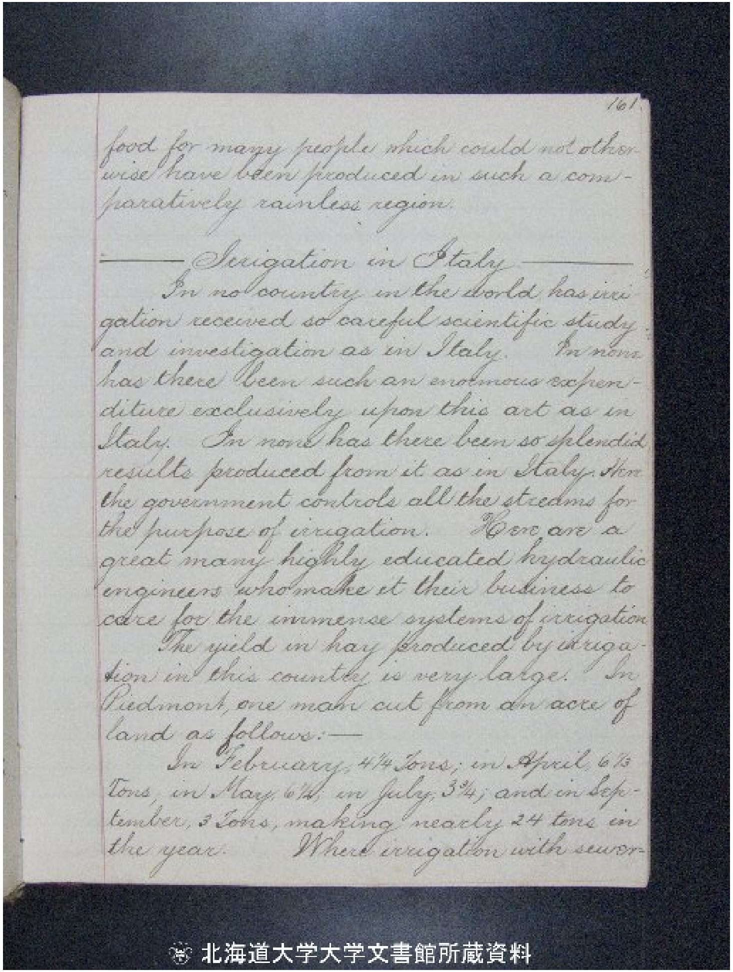
161

food for mazy people which could not otherwise have been produced in such a comparatively rainless region.

—— Irrigation in Italy ——

In no country in the world has irrigation received so careful scientific study and investigation as in Italy. In none has there been such an enormous expenditure exclusively upon this art as in Italy. In none has there been so splendid results produced from it as in Italy. Here the government controls all the streams for the purpose of irrigation. Here are a great many highly educated hydraulic engineers who make it their business to care for the immense systems of irrigation.

The yield in hay produced by irrigation in this country is very large. In Piedmont, one man out from an acre of land as follows:—

In February, 4¼ Tons; in April, 6⅓ Tons, in May, 6½, in July, 3¾; and in September, 3 Tons, making nearly 24 tons in the year. Where irrigation with sewer-

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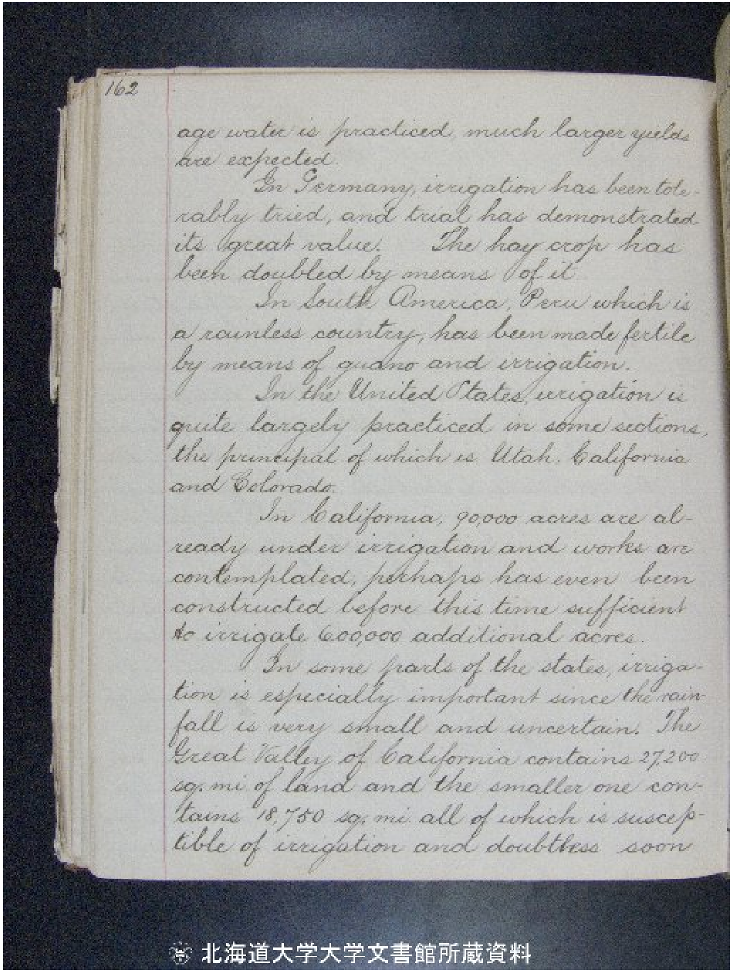
162

age water is practiced much larger yields are expected.

In Germany, irrigation has been tolerably tried, and trial has demonstrated its great value. The hay crop has been doubled by means of it.

In South America, Peru which is a rainless country, has been made fertile by means of guano and irrigation.

In the United States, irrigation is quite largely practiced in some sections, the principal of which is Utah. California and Colorado.

In California, 90,000 acres are already under irrigation and works are contemplated, perhaps has even been constructed before this time sufficient to irrigate 600,000 additional acres.

In some parts of the states, irrigation is especially important since the rainfall is very small and uncertain. The Great Valley of California contains 27,200 sq. mi of land and the smaller one contains 18,750 sq. mi. all of which is susceptible of irrigation and doubtless soon

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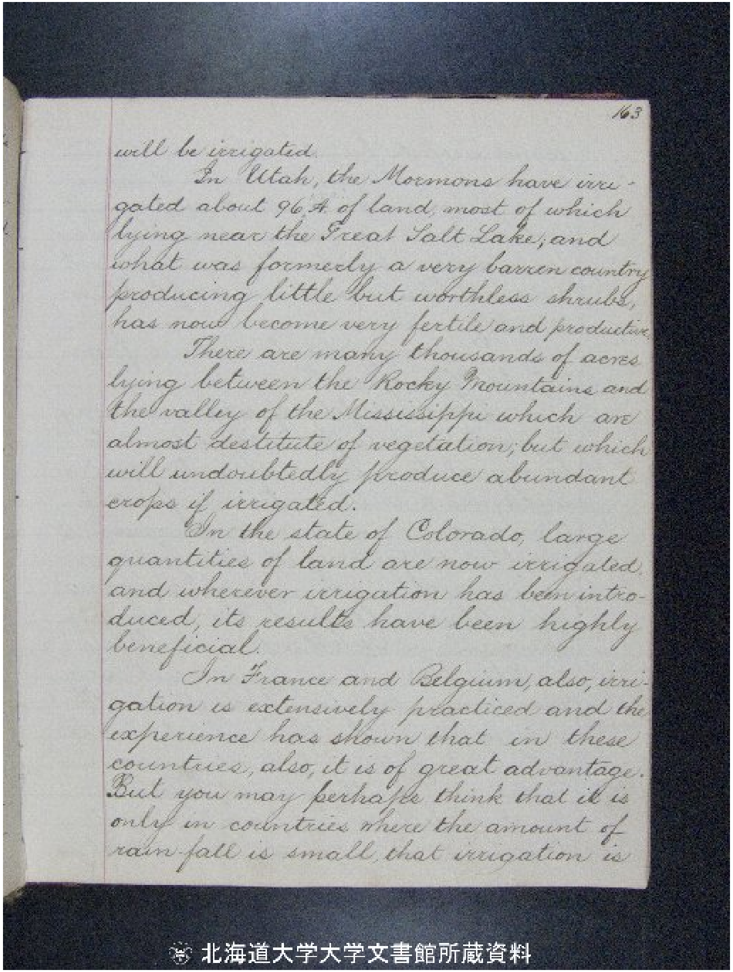
163

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In Utah, the Mormons have irri-
gated about 96 A of land, most of which
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There are many thousands of acres
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In the state of Colorado, large
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In France and Belgium, also, irri-
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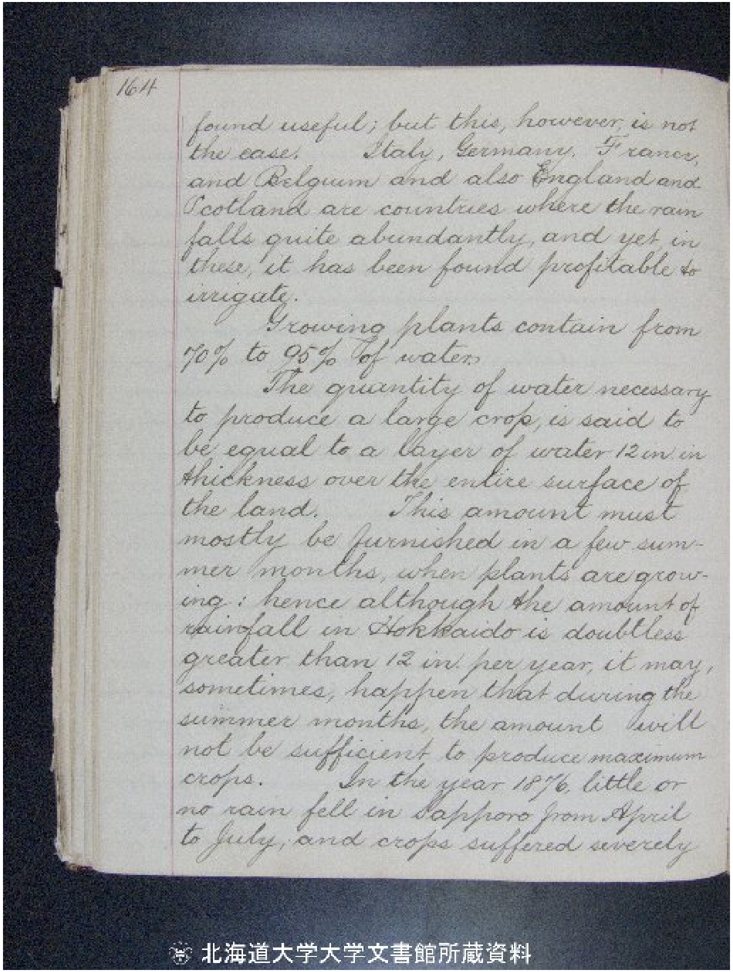
164

found useful; but this, however, is not the case. Italy, Germany, France, and Belgium and also England and Scotland are countries where the rain falls quite abundantly, and yet in these, it has been found profitable to irrigate.

Growing plants contain from 70% to 95% of water.

The quantity of water necessary to produce a large crop, is said to be equal to a layer of water 12 in in thickness over the entire surface of the land. This amount must mostly be furnished in a few summer months, when plants are growing: hence although the amount of rainfall in Hokkaido is doubtless greater than 12 in per year, it may, sometimes, happen that during the summer months, the amount will not be sufficient to produce maximum crops. In the year 1876, little or no rain fell in Sapporo from April to July; and crops suffered severely

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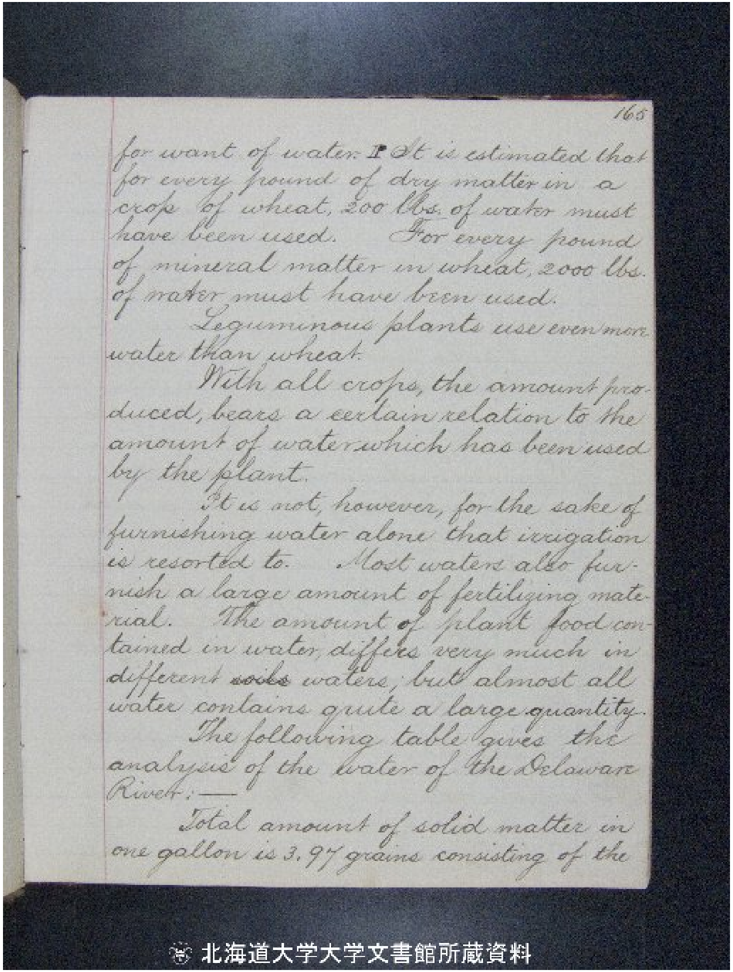


for want of water. Ⅱ It is estimated that for every pound of dry matter in a crop of wheat, 200 lbs. of water must have been used. For every pound of mineral matter in wheat, 2000 lbs. of mater must have been used.

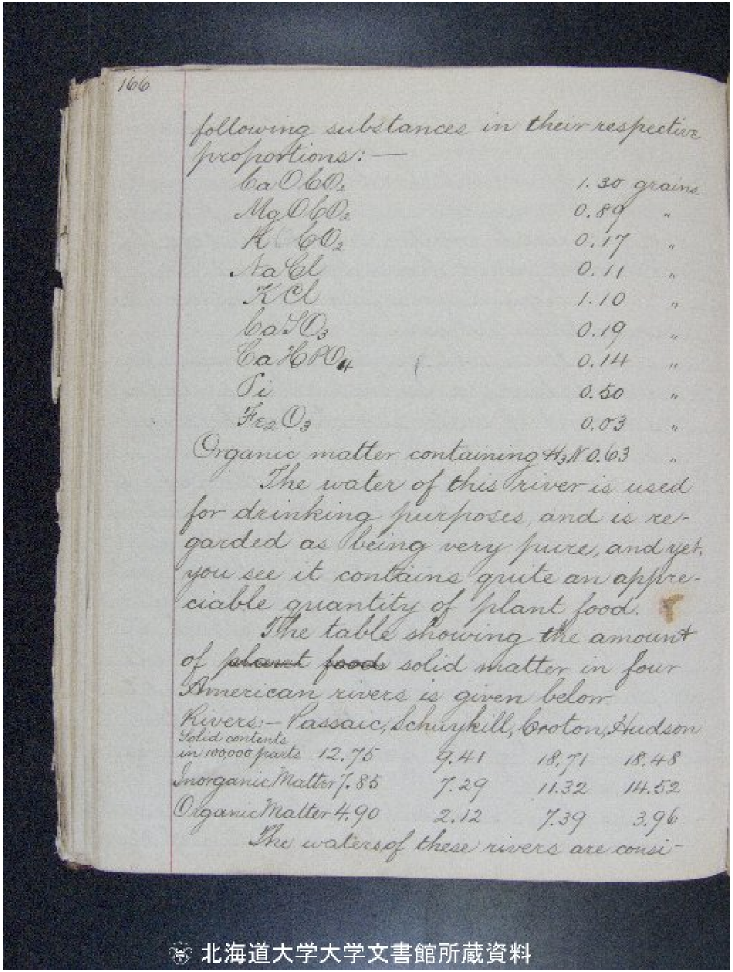
Leguminous plants use even more water than wheat.

With all crops, the amount produced, bears a certain relation to the amount of water which has been used by the plant.

It is not, however, for the sake of furnishing water alone that irrigation is resorted to. Most waters also furnish a large amount of fertilizing material. The amount of plant food contained in water differs very much in different waters; but almost all water contains quite a large quantity.

The following table gives the analysis of the water of the Delaware River: —

Total amount of solid matter in one gallon is 3.97 grains consisting of the



following substances in their respective proportions: ——

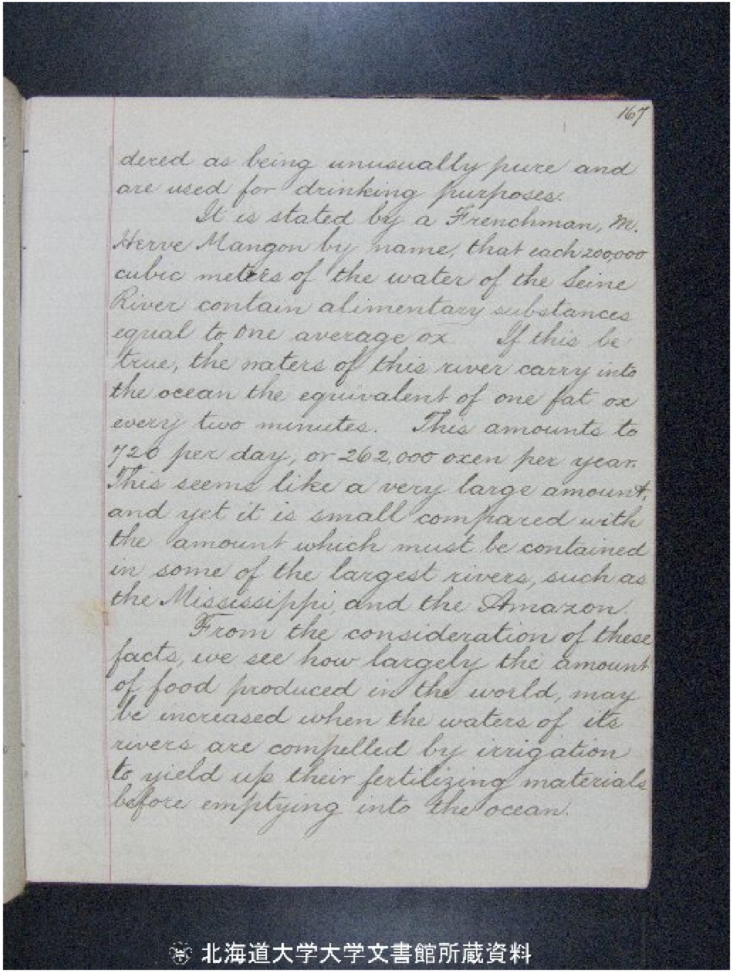
CaOCO2	1.30 grains
$MgOCO_2$	0.89 〃
$K\ CO_2$	0.17 〃
NaCl	0.11 〃
KCl	1.10 〃
$CaGO_3$	0.19 〃
$CaHPO_4$	0.14 〃
Si	0.50 〃
Fe_2O_3	0.03 〃
Organic matter containing H_3N	0.63 〃

The water of this river is used for drinking purposes and is regarded as being very pure, and yet, you see it contains quite an appreciable quantity of plant food.

The table showing the amount of solid matter in four American rivers is given below.

Rivers: ——	Passaic,	Schuylkill,	Croton,	Hudson
Solid contents in 100,000 parts	12.75	9.41	18.71	18.48
Inorganic Matter	7.85	7.29	11.32	14.52
Organic Matter	4.9	2.12	7.39	3.96

The waters of these rivers are considered


167
dered as being unusually pure and are used for drinking purposes.
It is stated by a Frenchman, M. Herve Mangon by name, that each 200,000 cubic meters of the water of the Seine River contain alimentary substances equal to one average ox. If this be true, the waters of this river carry into the ocean the equivalent of one fat ox every two minutes. This amounts to 720 per day, or 262,000 oxen per year. This seems like a very large amount, and yet it is small compared with the amount which must be contained in some of the largest rivers, such as the Mississippi and the Amazon.
From the consideration of these facts, we see how largely the amount of food produced in the world, may be increased when the waters of its rivers are compelled by irrigation to yield up their fertilizing materials before emptying into the ocean.

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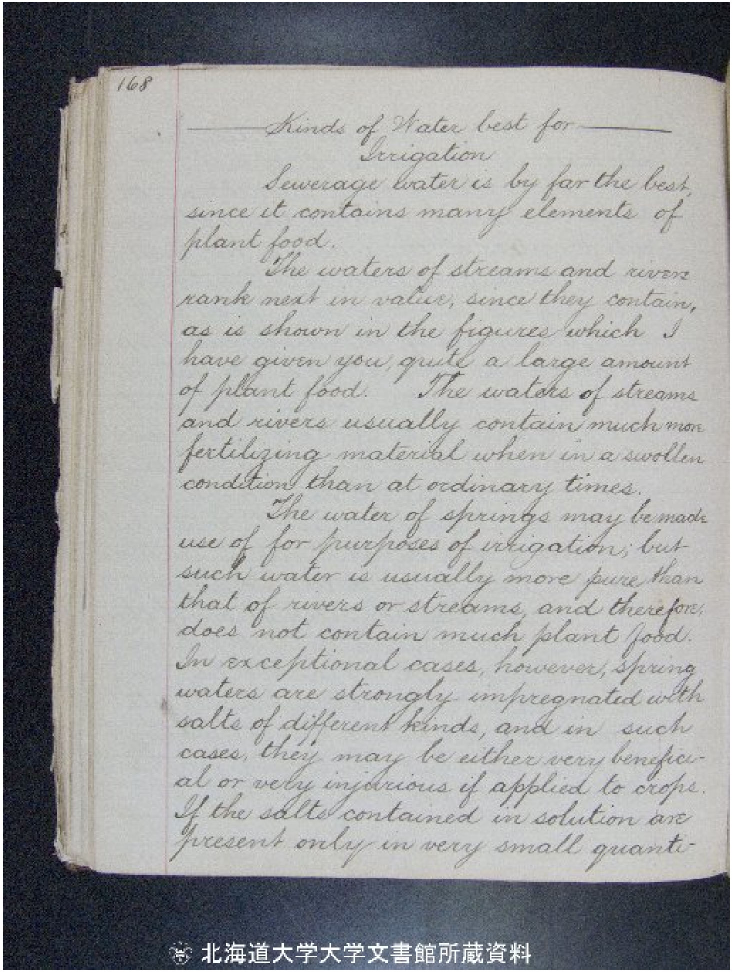
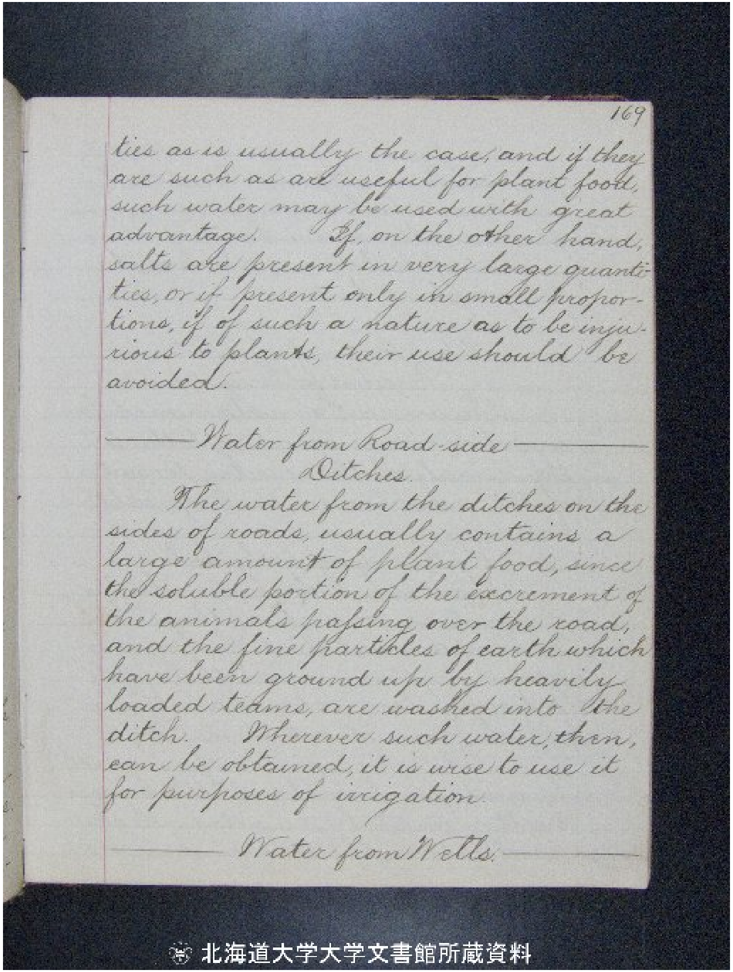


Kinds of Water best for Irrigation

Sewerage water is by far the best, since it contains many elements of plant food.

The waters of streams and rivers rank next in value, since they contain, as is shown in the figures which I have given you, quite a large amount of plant food. The waters of streams and rivers usually contain much more fertilizing material when in a swollen condition than at ordinary times.

The water of springs may be made use of for purposes of irrigation, but such water is usually more pure than that of rivers or streams, and there fore, does not contain much plant food. In exceptional cases, however, spring waters are strongly impregnated with salts of different kinds, and in such cases, they may be either very beneficial or very injurious of applied to crops. If the salts contained in solution are present only in very small quantities



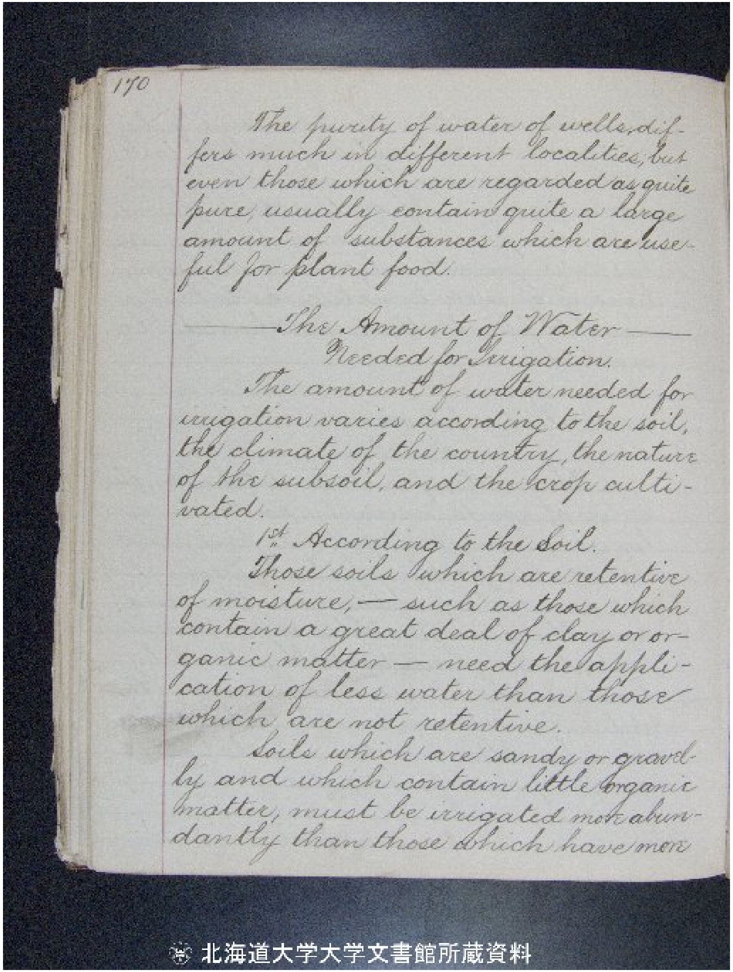
as is usually the case, and if they are such as are useful for plant food, such water may be used with great advantage. If, on the other hand, salts are present in very large quantities, or if present only in small proportions, if of such a nature as to be injurious to plants, their use should be avoided.

——— Water from Road-side ———

Ditches.

The water from the ditches on the sides of roads, usually contains a large amount of plant food, since the soluble portion of the excrement of the animals passing over the road, and the fine particles of earth which have been ground up by heavily loaded teams, are washed into the ditch. Wherever such water, then, can be obtained, it is wise to use it for purposes of irrigation.

——— Water from Wells ———



170

The purity of water of wells differs much in different localities, but even those which are regarded as quite pure, usually contain quite a large amount of substances which are useful for plant food.

——The Amount of Water——
Needed for Irrigation.

The amount of water needed for irrigation varies according to the soil, the climate of the country, the nature of the subsoil, and the crop cultivated.

1st According to the Soil.

Those soils which are retentive of moisture, — such as those which contain a great deal of clay or organic matter — need the application of less water than those which are not retentive.

Soils which are sandy or gravelly and which contain little organic matter, must be irrigated more abundantly than those which have more

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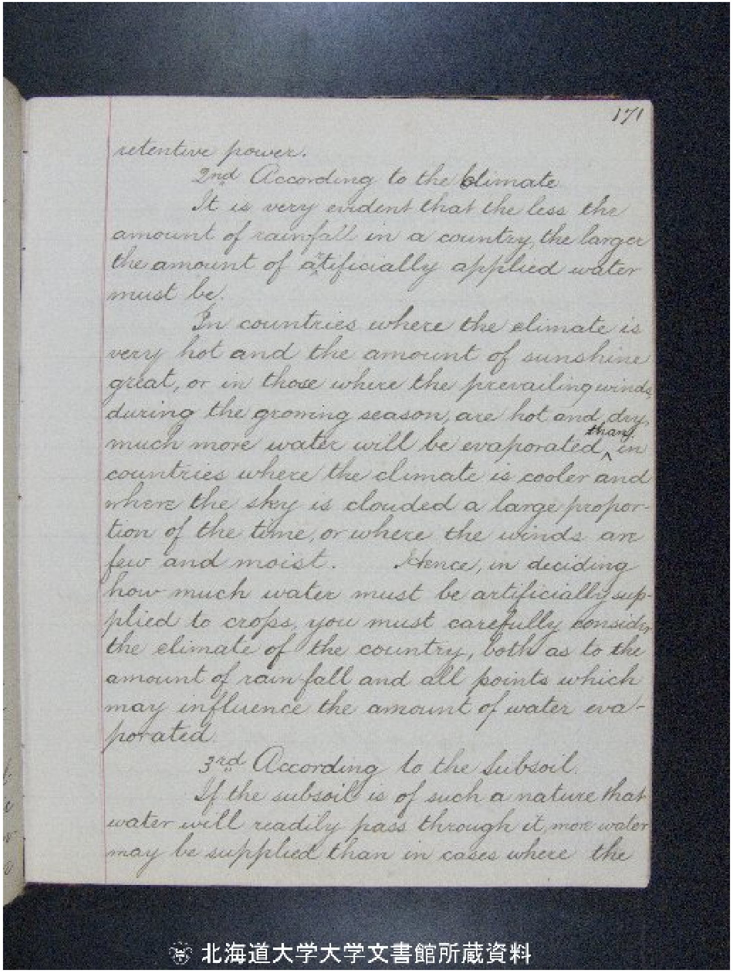
171

retentive power.

2nd According to the Climate

It is very evident that the less the amount of rainfall in a country, the larger the amount of artificially applied water must be.

In countries where the climate is very hot and the amount of sunshine great, or in those where the prevailing winds during the growing season, are hot and dry, much more water will be evaporated than in countries where the climate is cooler and where the sky is clouded a large proportion of the time, or where the winds an few and moist. Hence, in deciding how much water must be artificially supplied to crops, you must carefully consider the climate of the country, both as to the amount of rain-fall and all points which may influence the amount of water evaporated.

3rd According to the Subsoil.

If the subsoil is of such a nature that water will readily pass through it more water may be supplied than in cases where the

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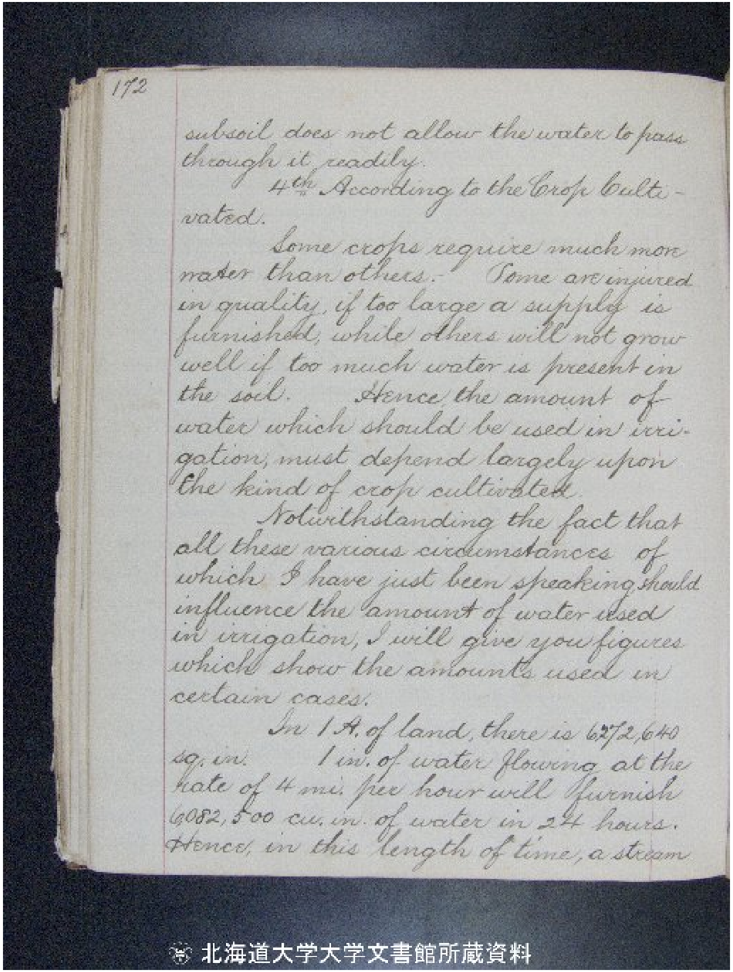

172

subsoil does not allow the water to pass through it readily.

4th According to the Crop Cultivated.

Some crops require much more water than others. Some are injured in quality, if too large a supply is furnished, while others will not grow well if too much water is present in the soil. Hence the amount of water which should be used in irrigation, must depend largely upon the kind of crop cultivated.

Notwithstanding the fact that all these various circumstances of which I have just been speaking should influence the amount of water used in irrigation, I will give you figures which show the amounts used in certain cases.

In 1 A. of land, there is 6272,640 sq. in. 1 in. of water flowing at the rate of 4 mi. per hour will furnish 6082,500 cu. in. of water in 24 hours. Hence, in this length of time, a stream

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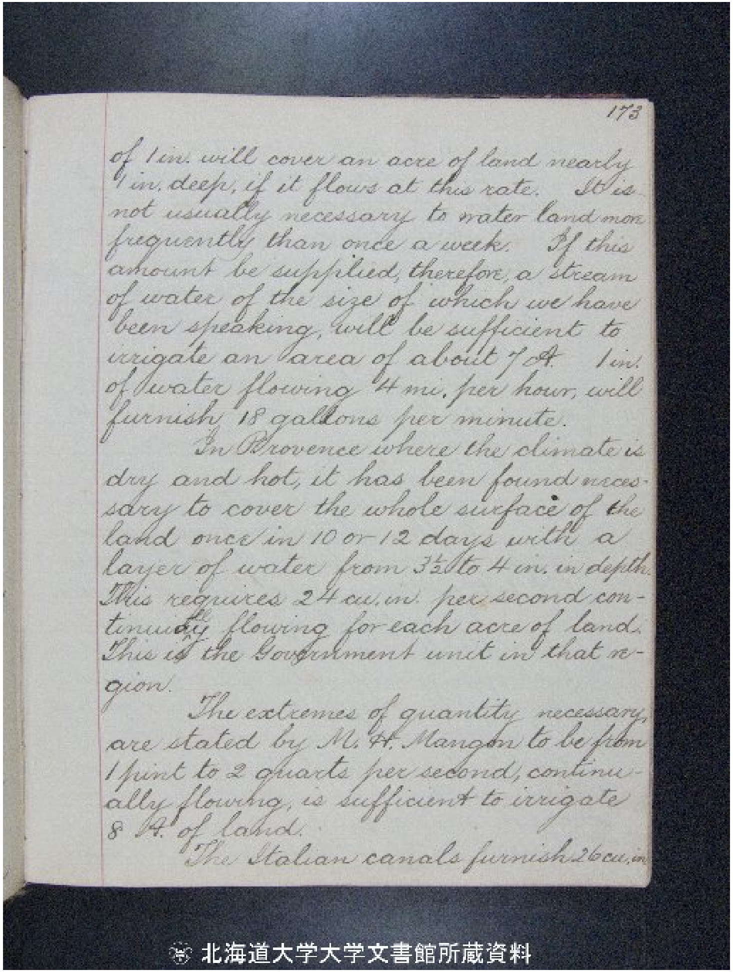

173

of 1 in. will cover an acre of land nearly 1 in. deep, if it flows at this rate. It is not usually necessary to water land more frequently than once a week. If this amount be supplied, therefore, a stream of water of the size of which we have been speaking, will be sufficient to irrigate an area of about 7 A. 1 in. of water flowing 4 mi. per hour, will furnish 18 gallons per minute.

In Provence where the climate is dry and hot, it has been found necessary to cover the whole surface of the land once in 10 or 12 days with a layer of water from 3½ to 4 in. in depth. This requires 24 cu. in. per second continually flowing for each acre of land. This is the Government unit in that region.

The extremes of quantity necessary, are stated by M. H. Mangon to be from 1 pint to 2 quarts per second, continually flowing, is sufficient to irrigate 8 A. of land.

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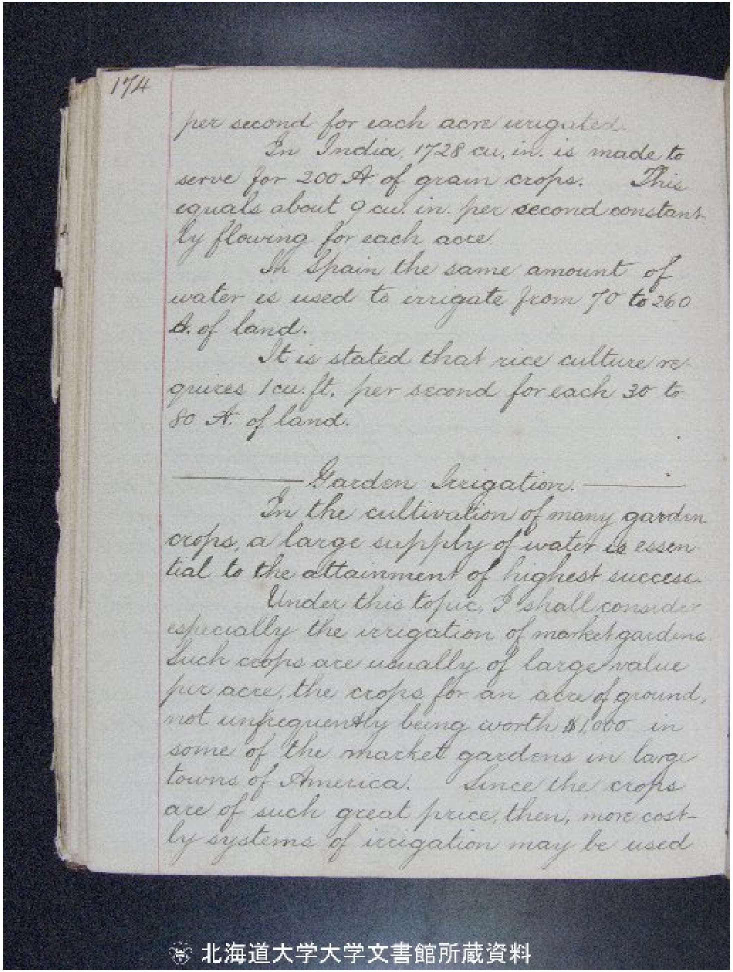

174

per second for each acre irrigated.

In India, 1728 cu. in. is made to serve for 200 A of grain crops. This equals about 9 cu. in. per second constantly flowing for each acre

In Spain the same amount of water is used to irrigate from 70 to 260 A. of land.

It is stated that rice culture requires 1 cu. ft. per second for each 30 to 80 A. of land.

——— Garden Irrigation. ———

In the cultivation of many garden crops, a large supply of water is essential to the attainment of highest success.

Under this topic, I shall consider especially the irrigation of market gardens. Such crops are usually of large value per acre, the crops for an acre of ground, not unfrequently being worth $1,000 in some of the market gardens in large towns of America. Since the crops are of such great price, then, more costly systems of irrigation may be used

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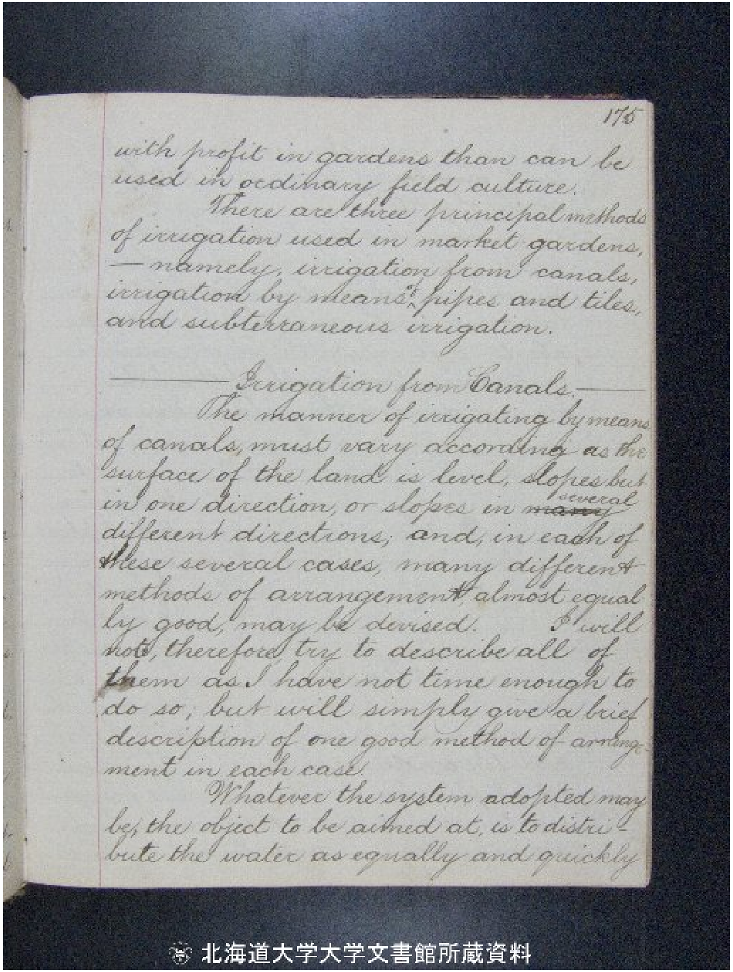
175

with profit in gardens than can be used in ordinary field culture.

There are three principal methods of irrigation used in market gardens, — namely, irrigation from canals, irrigation by means of pipes and tiles, and subterraneous irrigation.

—— Irrigation from Canals. ——

The manner of irrigating by means of canals, must vary according as the surface of the land is level, slopes but in one direction, or slopes in ~~many~~ several different directions, and, in each of these several cases, many different methods of arrangement almost equally good, may be devised. I will not, therefore try to describe all of them as I have not time enough to do so, but will simply give a brief description of one good method of arrangement in each case.

Whatever the system adopted may be, the object to be aimed at, is to distribute the water as equally and quickly

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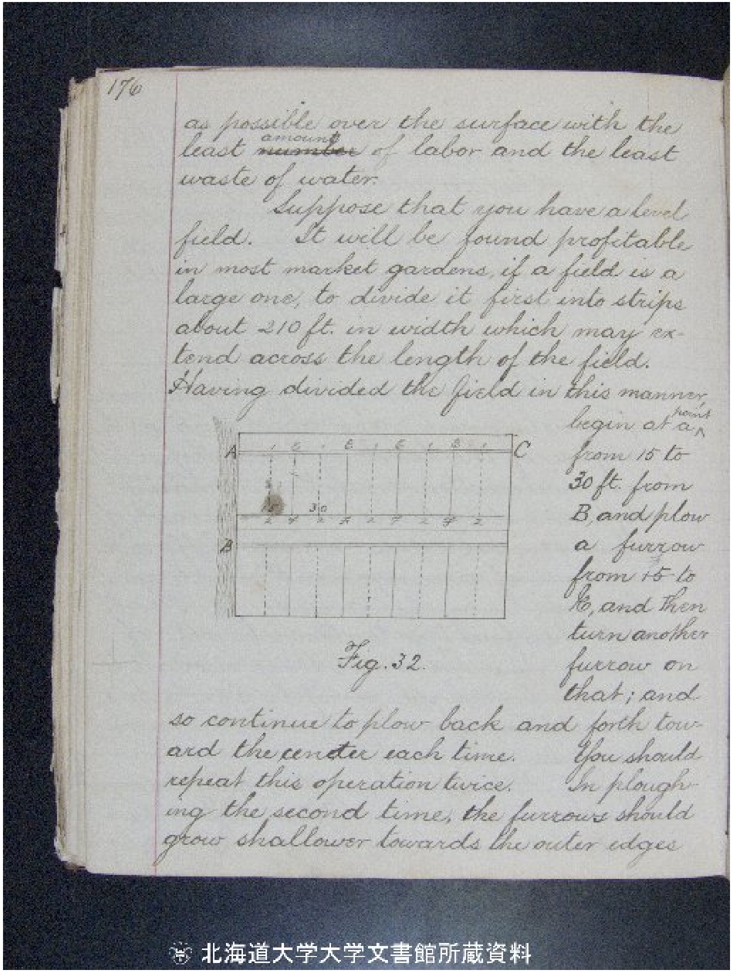

176

as possible over the surface with the least ~~number~~ amount of labor and the least waste of water.

Suppose that you have a level field. It will be found profitable in most market gardens, if a field is a large one, to divide it first into strips about 210 ft. in width which may extend across the length of the field. Having divided the field in this manner begin at a point from 15 to 30 ft. from B, and plow a furrow from 15 to E, and then turn another furrow on that; and so continue to plow back and forth toward the center each time. You should repeat this operation twice. In ploughing the second time, the furrows should grow shallower towards the outer edges

Fig. 32.

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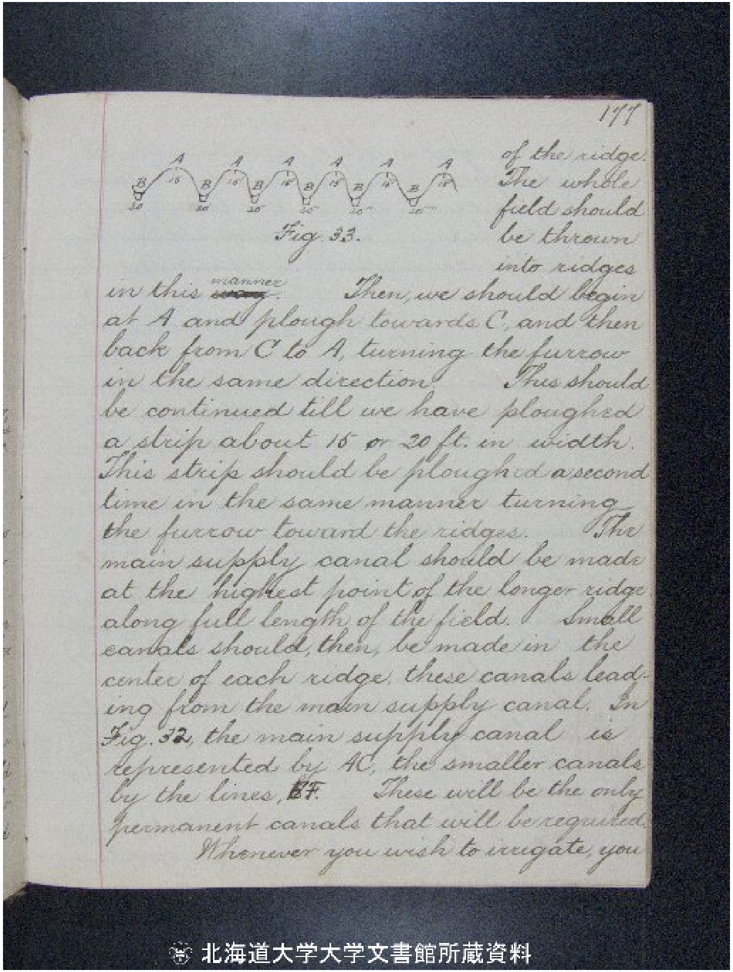

177

Fig. 33.

of the ridge. The whole field should be thrown into ridges in this manner. Then, we should begin at A and plough towards C, and then back from C to A, turning the furrow in the same direction. This should be continued till we have ploughed a strip about 15 or 20 ft. in width. This strip should be ploughed a second time in the same manner turning the furrow toward the ridges. The main supply canal should be made at the highest point of the longer ridge along full length of the field. Small canals should, then, be made in the center of each ridge, these canals leading from the main supply canal. In Fig. 32, the main supply canal is represented by AC, the smaller canals by the lines, EF. These will be the only permanent canals that will be required.
Whenever you wish to irrigate, you

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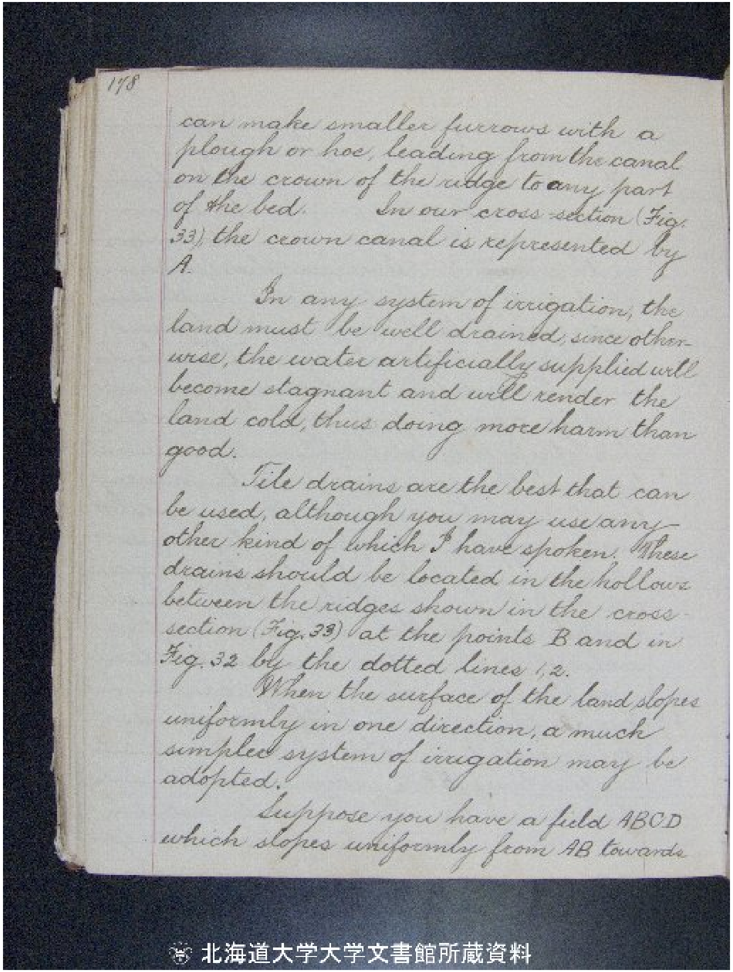
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can make smaller furrows with a plough or hoe, leading from the canal on the crown of the ridge to any part of the bed. In our cross-section (Fig. 33) the crown canal is represented by A.

In any system of irrigation, the land must be well drained, since otherwise the water artificially supplied will become stagnant and will render the land cold, thus doing more harm than good.

Tile drains are the best that can be used, although you may use any other kind of which I have spoken. These drains should be located in the hollows between the ridges shown in the cross section (Fig. 33) at the points B and in Fig. 32 by the dotted lines 1, 2.

When the surface of the land slopes uniformly in one direction, a much simpler system of irrigation may be adopted.

Suppose you have a field ABCD which slopes uniformly from AB towards

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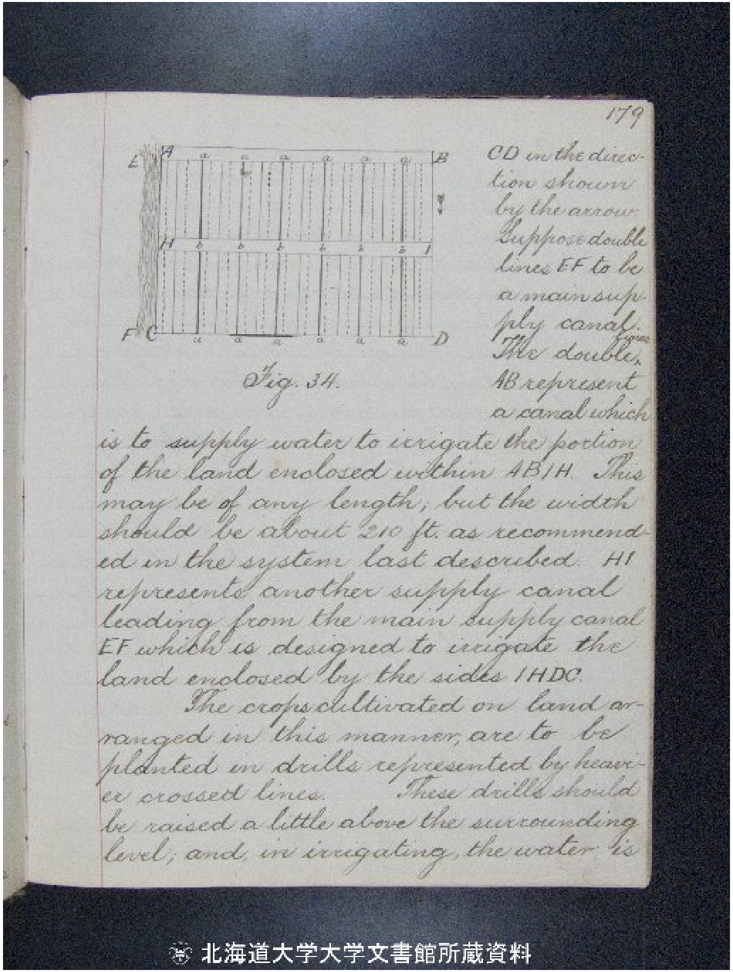
179

CD in the direction shown by the arrow Suppose double lines EF to be a main supply canal. The double lines AB represent a canal which is to supply water to irrigate the portion of the land enclosed within AB/H. This may be of any length, but the width should be about 210 ft. as recommended in the system last described. H1 represents another supply canal leading from the main supply canal EF which is designed to irrigate the land enclosed by the sides 1HDC.

The crops cultivated on land arranged in this manner, are to be planted in drills represented by heavier crossed lines. These drills should be raised a little above the surrounding level, and in irrigating, the water is

Fig. 34.

Fig.34

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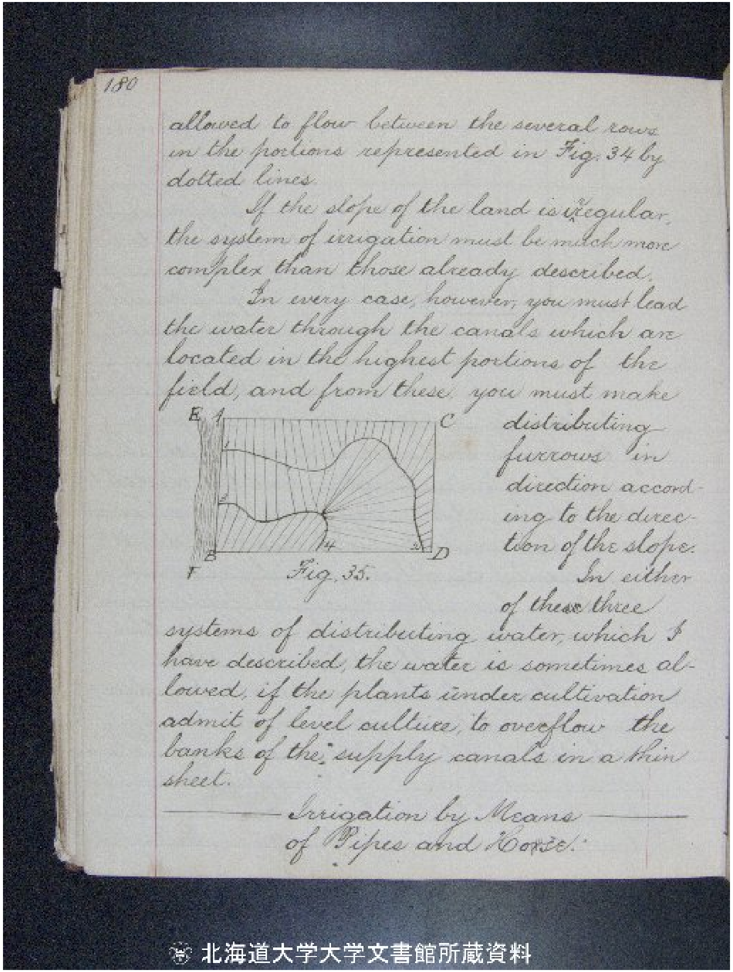

allowed to flow between the several rows in the portions represented in Fig. 34 by dotted lines.
If the slope of the land is irregular, the system of irrigation must be much more complex than those already described.
In every case, however, you must lead the water through the canals which are located in the highest portions of the field, and from these you must make distributing furrows in direction according to the direction of the slope.

Fig. 35.
In either of these three systems of distributing water, which I have described, the water is sometimes allowed, if the plants under cultivation admit of level culture, to overflow the banks of the supply canals in a thin sheet.
—— Irrigation by Means ——
of Pipes and Hose.

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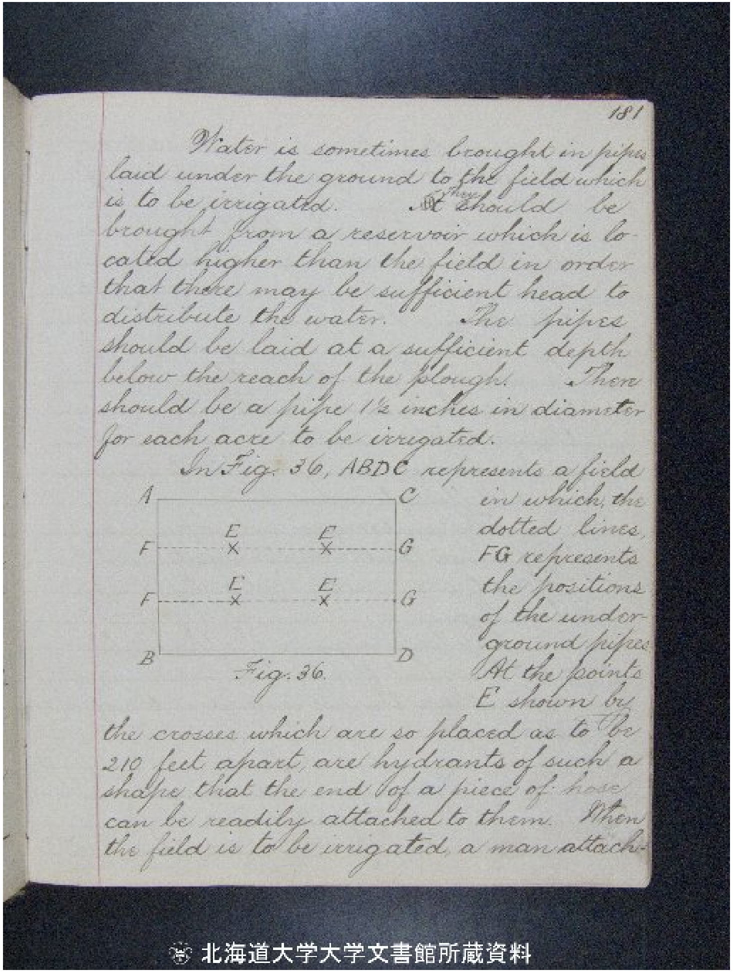
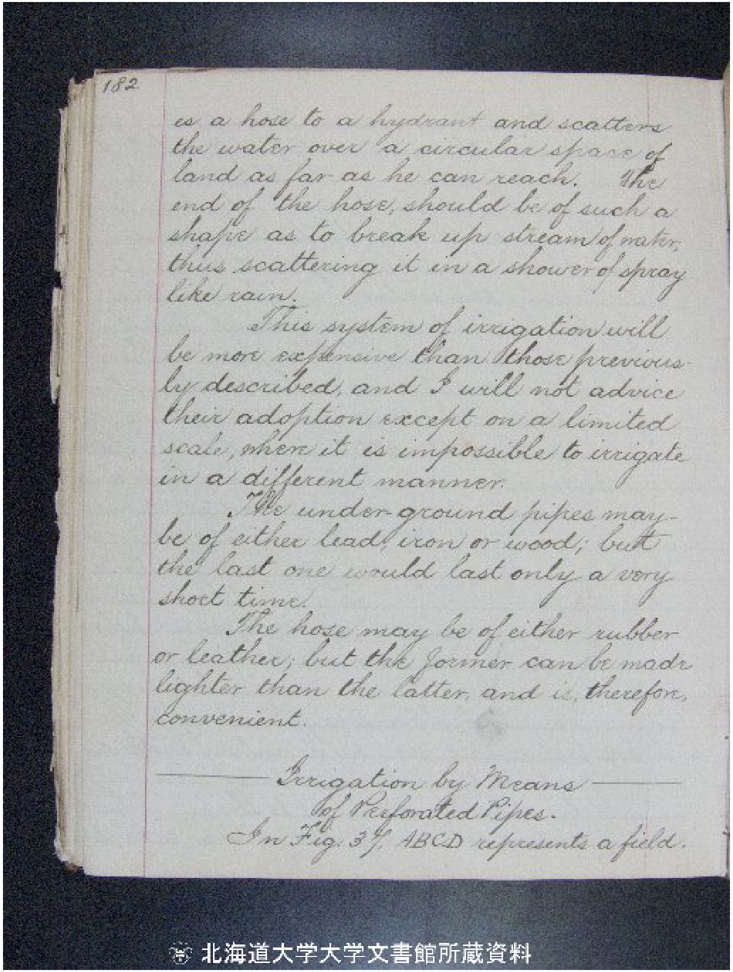


Water is sometimes brought in pipes laid under the ground to the field which is to be irrigated. They should be brought from a reservoir which is located higher than the field in order that there may be sufficient head to distribute the water. The pipes should be laid at a sufficient depth below the reach of the plough. Then should be a pipe 1 1/2 inches in diameter for each acre to be irrigated.

Fig.36

In Fig. 36, ABCD represents a field in which, the dotted lines, FG represents the positions of the under ground pipes. At the points E shown by the crosses which are so placed as to be 210 feet apart, are hydrants of such a shape that the end of a piece of hose can be readily attached to them. When the field is to be irrigated a man attaches



182

is a hose to a hydrant and scatters the water over a circular space of land as far as he can reach. The end of the hose, should be of such a shape as to break up stream of mater, thus scattering it in a shower of spray like rain.

This system of irrigation will be more expensive than those previous-ly described, and I will not advice their adoption except on a limited scale, when it is impossible to irrigate in a different manner.

The under-ground pipes may be of either lead, iron or wood; but the last one would last only a very short time.

The hose may be of either rubber or leather; but the former can be made lighter than the latter, and is, therefore, convenient.

——— Irrigation by Means ———
of Perforated Pipes.

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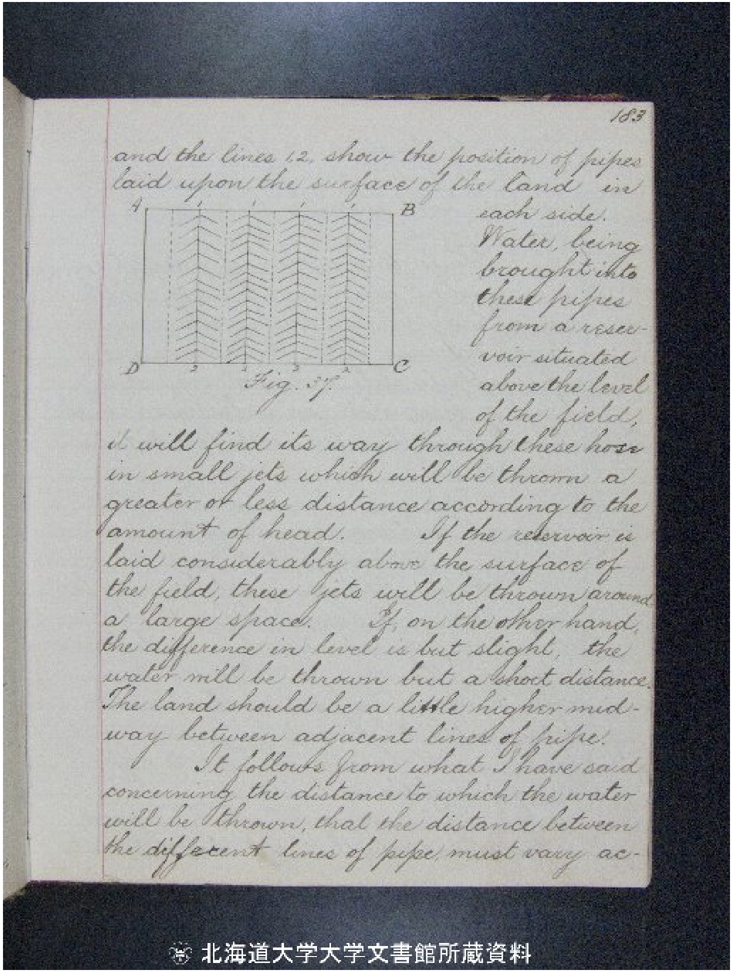

183

and the lines 1,2, show the position of pipes laid upon the surface of the land in each side. Water, being brought into these pipes from a reservoir situated above the level of the field, it will find its way through these hose in small jets which will be thrown a greater or less distance according to the amount of head. If the reservoir is laid considerably above the surface of the field, these jets will be thrown around a large space. If, on the other hand, the difference in level is but slight, the water will be thrown but a short distance. The land should be a little higher midway between adjacent lines of pipe.

It follows from what I have said concerning the distance to which the water will be thrown, that the distance between the different lines of pipe must vary ac-

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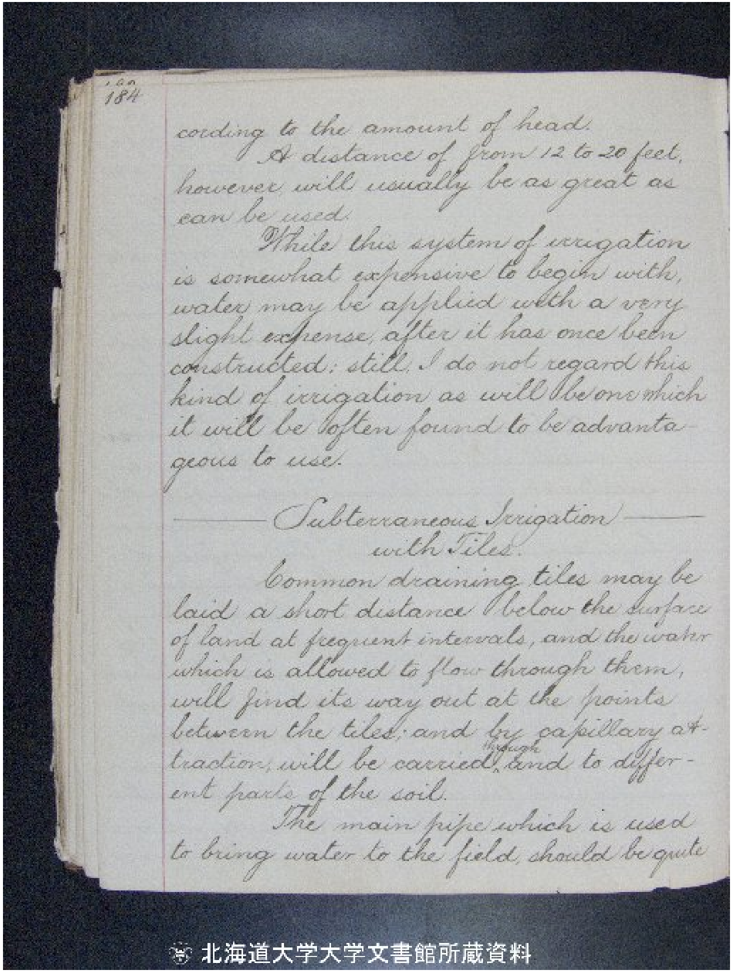

184

cording to the amount of head. A distance of from 12 to 20 feet, however will usually be as great as can be used.

While this system of irrigation is somewhat expensive to begin with, water may be applied with a very slight expense, after it has once been constructed; still, I do not regard this kind of irrigation as will be one which it will be often found to be advantageous to use.

— Subterraneous Irrigation —
with Tiles.

Common draining tiles may be laid a short distance below the surface of land at frequent intervals, and the water which is allowed to flow through them, will find its way out at the points between the tiles; and by capillary attraction, will be carried through and to different parts of the soil.

The main pipe which is used to bring water to the field, should be quite

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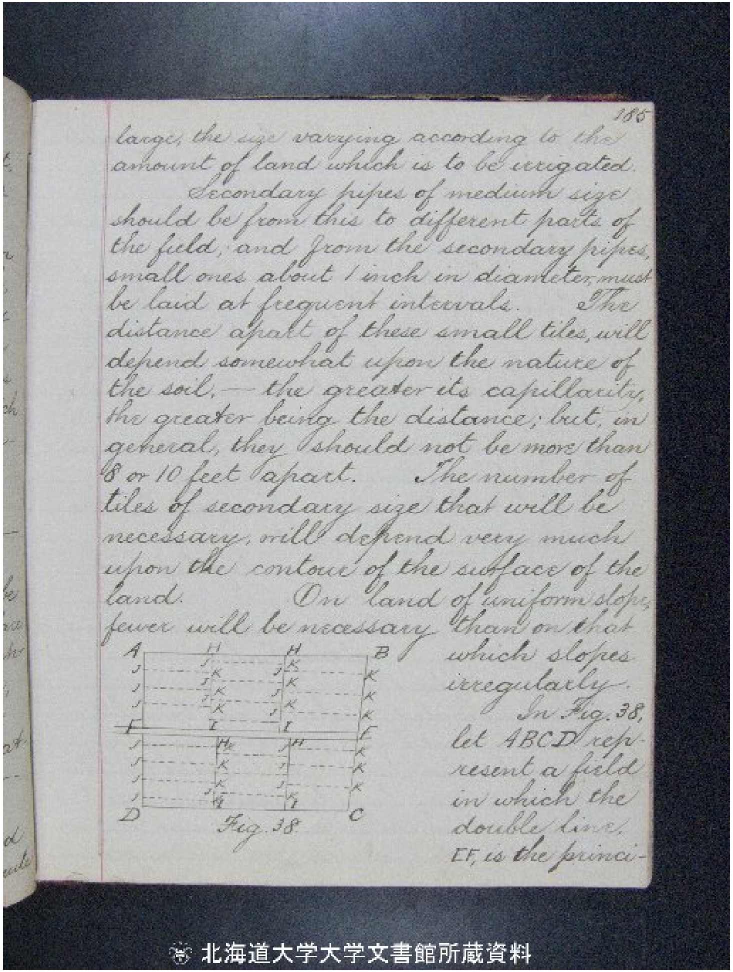
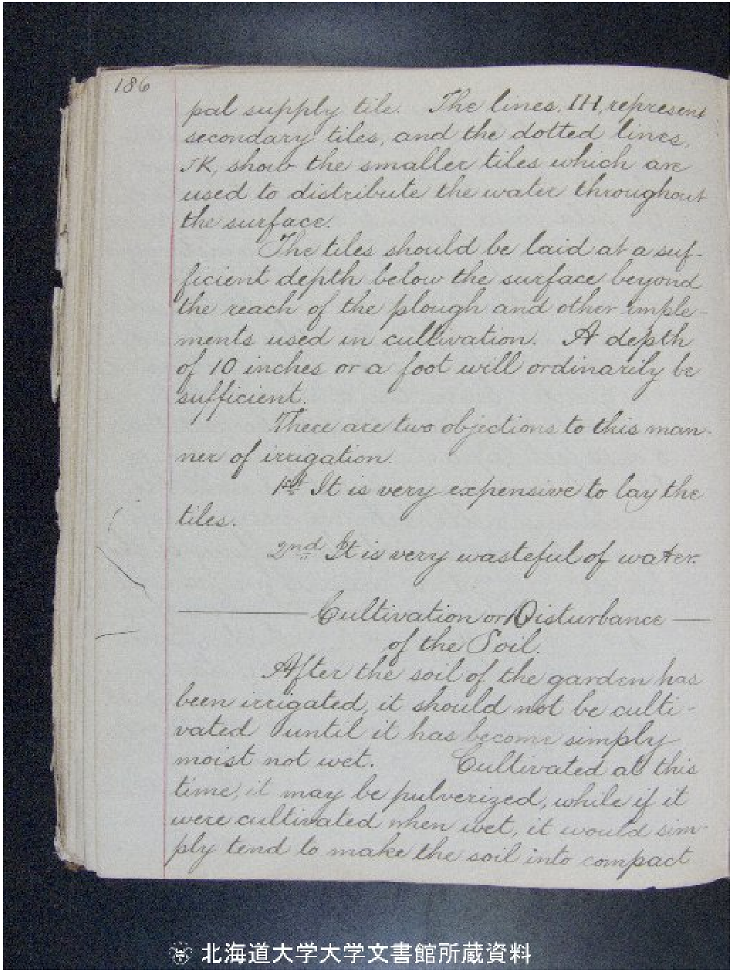


large, the size varying according to the amount of land which is to be irrigated.

Secondary pipes of medium size should be from this to different parts of the field, and from the secondary pipes, small ones about 1 inch in diameter, must be laid at frequent intervals. The distance apart of these small tiles, will depend somewhat upon the nature of the soil. — the greater its capillarity, the greater being the distance; but in general, they should not be more than 8 or 10 feet apart. The number of tiles of secondary size that will be necessary, will depend very much upon the contour of the surface of the land. On land of uniform slope, fewer will be necessary than on that which slopes irregularly.

Fig.38

In Fig.38, let ABCD represent a field in which the double line, EF, is the principal



186

pal supply tile. The lines, IH, represent secondary tiles, and the dotted lines, JK, show the smaller tiles which are used to distribute the water throughout the surface.

The tiles should be laid at a sufficient depth below the surface beyond the reach of the plough and other implements used in cultivation. A depth of 10 inches or a foot will ordinarily be sufficient.

There are two objections to this manner of irrigation.

1st It is very expensive to lay the tiles.

2nd It is very wasteful of water.

Cultivation or Disturbance of the Soil.

After the soil of the garden has been irrigated, it should not be cultivated until it has become simply moist not wet. Cultivated at this time, it may be pulverized, while if it were cultivated when wet, it would simply tend to make the soil into compact

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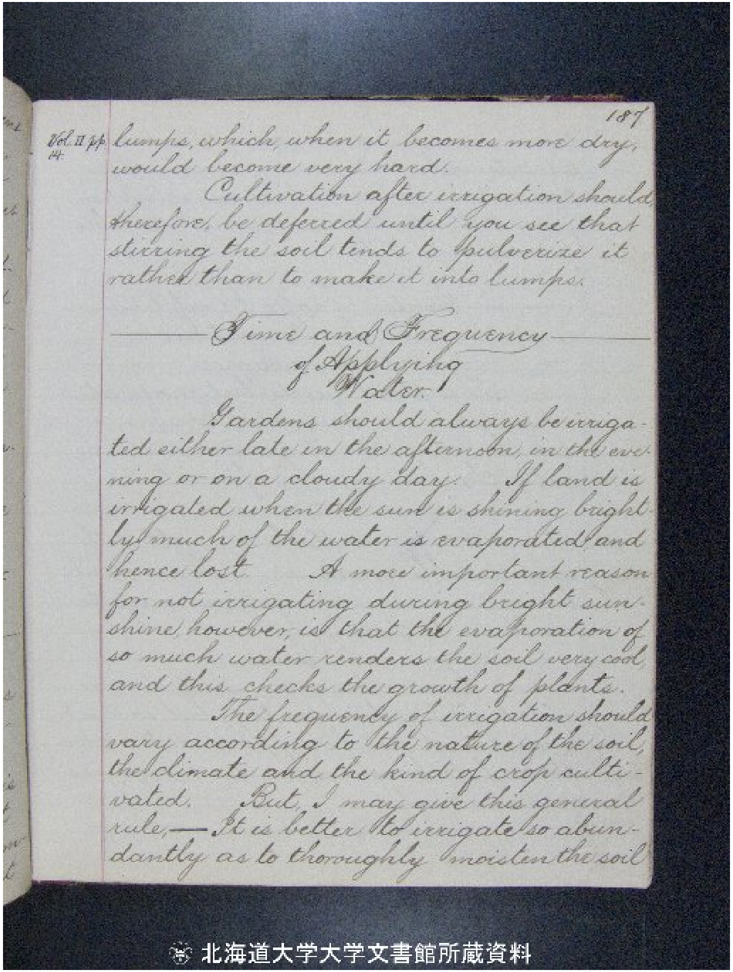
——— Cultivation or Disturbance ——— of the Soil.

After the soil of the garden has been irrigated it should not be cultivated until it has become simply moist not wet. Cultivated at this time, it may be pulverized, while if it were cultivated when wet, it would simply tend to make the soil into compact


187

Vol. II pp. 14

lumps, which when it becomes more dry, would become very hard.

Cultivation after irrigation should, therefore, be deferred until you see that stirring the soil tends to pulverize it rather than to make it into lumps.

—— Time and Frequency ——
of Applying
Water.

Gardens should always be irrigated either late in the afternoon, in the evening or on a cloudy day. If land is irrigated when the sun is shining brightly much of the water is evaporated and hence lost. A more important reason for not irrigating during bright sunshine however, is that the evaporation of so much water renders the soil very cool and this checks the growth of plants.

The frequency of irrigation should vary according to the nature of the soil, the climate and the kind of crop cultivated. But, I may give this general rule,— It is better to irrigate so abundantly as to thoroughly moisten the soil

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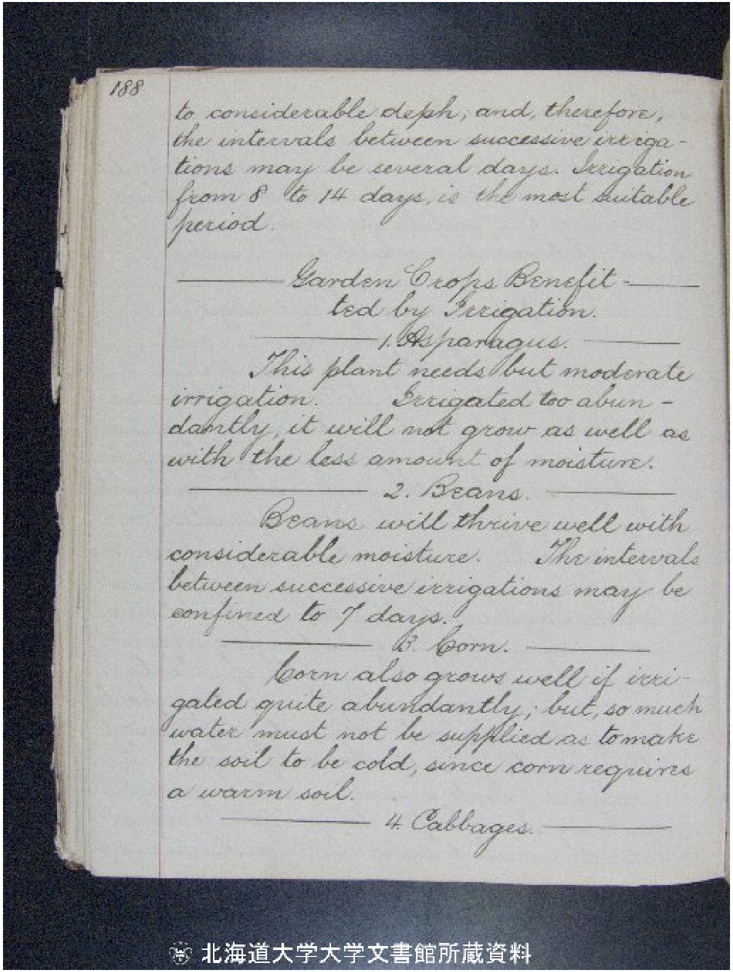

188

to considerable deph, and, therefore,
the intervals between successive irriga-
tions may be several days. Irrigation
from 8 to 14 days, is the most suitable
period.

Garden Crops Benefit-
ted by Irrigation.

1. Asparagus.

This plant needs but moderate
irrigation. Irrigated too abun-
dantly, it will not grow as well as
with the less amount of moisture.

2. Beans.

Beans will thrive well with
considerable moisture. The intervals
between successive irrigations may be
confined to 7 days.

3. Corn.

Corn also grows well if irri-
gated quite abundantly; but, so much
water must not be supplied as to make
the soil to be cold, since corn requires
a warm soil.

4. Cabbages.

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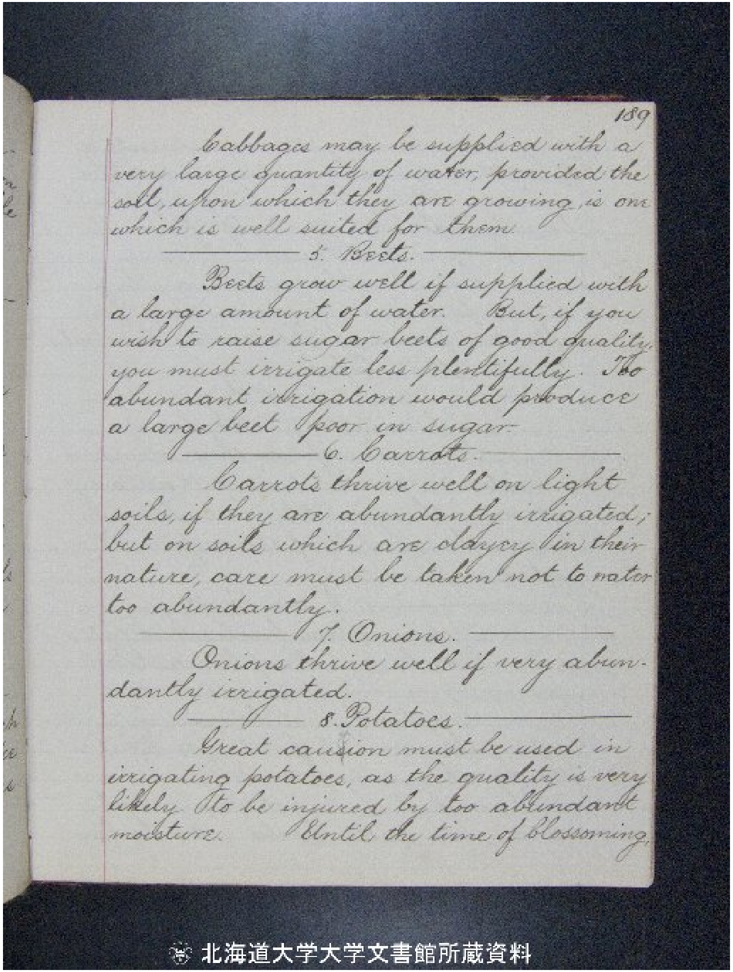


Cabbages may be supplied with a very large quantity of water, provided the soil, upon which they are growing, is one which is well suited for them.

——— 5. Beets. ———

Beets grow well if supplied with a large amount of water. But, if you wish to raise sugar beets of good quality, you must irrigate less plentifully. Too abundant irrigation would produce a large beet poor in sugar.

——— 6. Carrots. ———

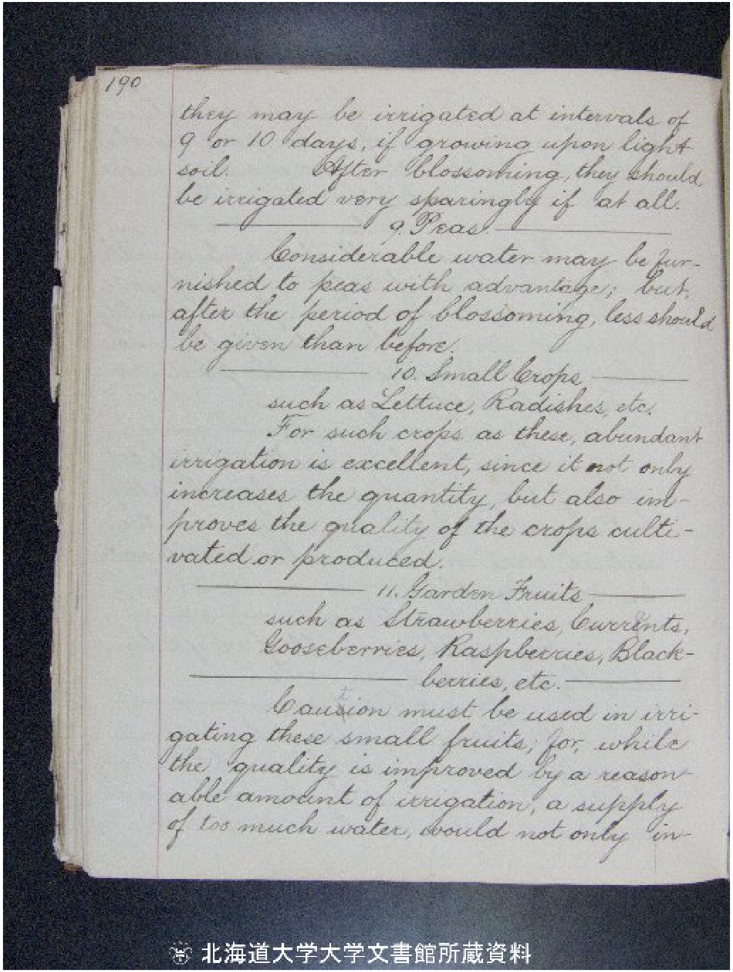
Carrots thrive well on light soils, if they are abundantly irrigated; but on soils which are clayey in their nature, care must be taken not to mater too abundantly.

——— 7. Onions. ———

Onions thrive well if very abundantly irrigated.

——— 8. Potatoes. ———

Great caution must be used in irrigating potatoes, as the quality is very likely to be injured by too abundant moisture. Until the time of blossoming,



they may be irrigated at intervals of 9 or 10 days, if growing upon light soil. After blossoming, they should be irrigated very sparingly if at all.

——— 9. Peas. ———

Considerable water may be furnished to peas with advantage; but, after the period of blossoming, less should be given than before.

——— 10. Small crops ———

such as Lettuce, Radishes, etc.

For such crops as these, abundant irrigation is excellent, since it not only increases the quantity, but also improves the quality of the crops cultivated or produced.

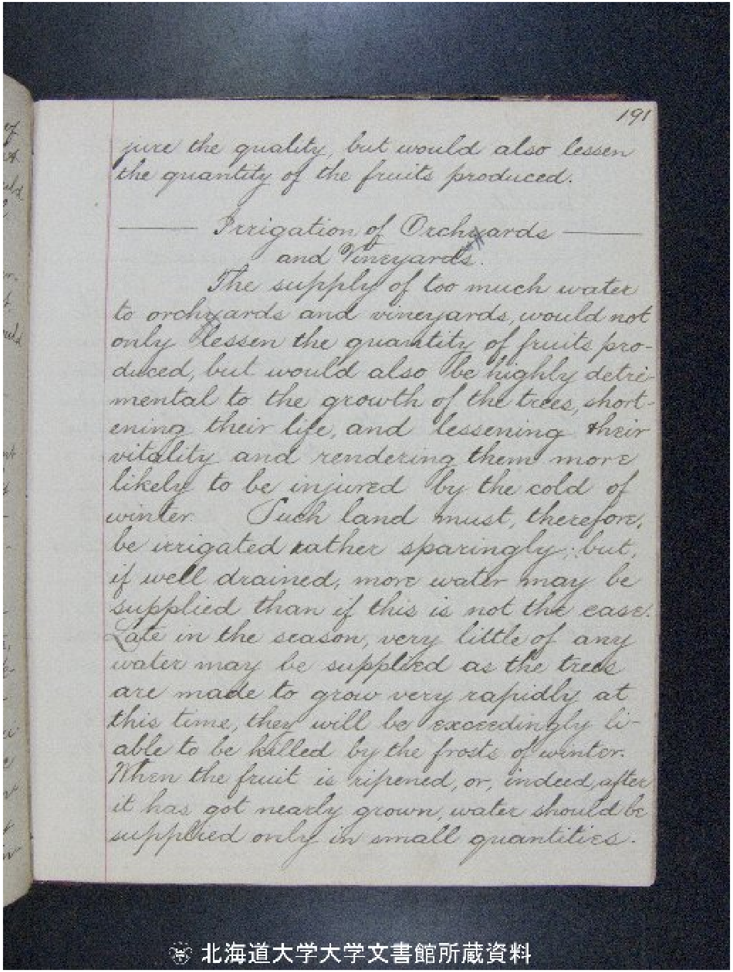
——— 11. Garden fruits ———

such as Strawberries, Currants,

Gooseberries, Raspberries, Black-

——— berries, etc. ———

Caution must be used in irrigating these small fruits, for, while the quality is improved by a reasonable amount of irrigation, a supply of too much water, would not only injure



191

jure the quality, but would also lessen the quantity of the fruits produced.

—— Irrigation of Orchards ——
and Vineyards.

The supply of too much water to orchards and vineyards, would not only lessen the quantity of fruits produced, but would also be highly detrimental to the growth of the trees, shortening their life, and lessening their vitality and rendering them more likely to be injured by the cold of winter. Such land must, therefore, be irrigated rather sparingly; but, if well drained, more water may be supplied than if this is not the case. Late in the season, very little of any water may be supplied as the trees are made to grow very rapidly at this time, they will be exceedingly liable to be killed by the frosts of winter. When the fruit is ripened, or, indeed, after it has got nearly grown, water should be supplied only in small quantities.

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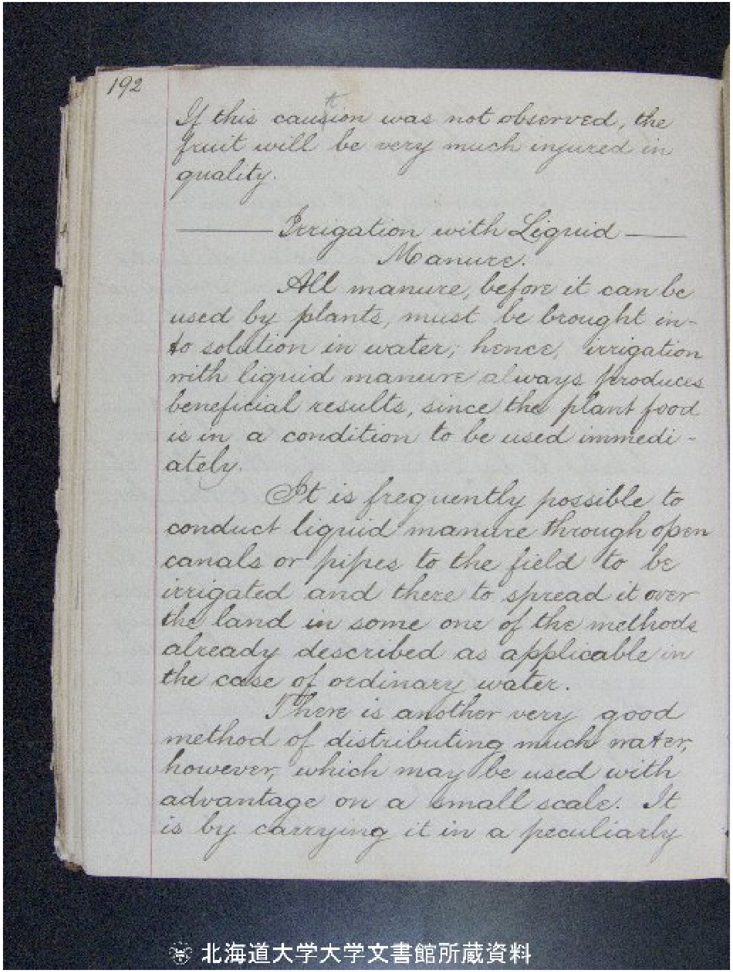
192

If this caution was not observed, the fruit will be very much injured in quality.

——— Irrigation with Liquid ———
Manure.

All manure, before it can be used by plants, must be brought into solution in water; hence, irrigation with liquid manure always produces beneficial results, since the plant food is in a condition to be used immediately.

It is frequently possible to conduct liquid manure through open canals or pipes to the field to be irrigated and there to spread it over the land in some one of the methods already described as applicable in the case of ordinary water.

There is another very good method of distributing much water, however, which may be used with advantage on a small scale. It is by carrying it in a peculiarly

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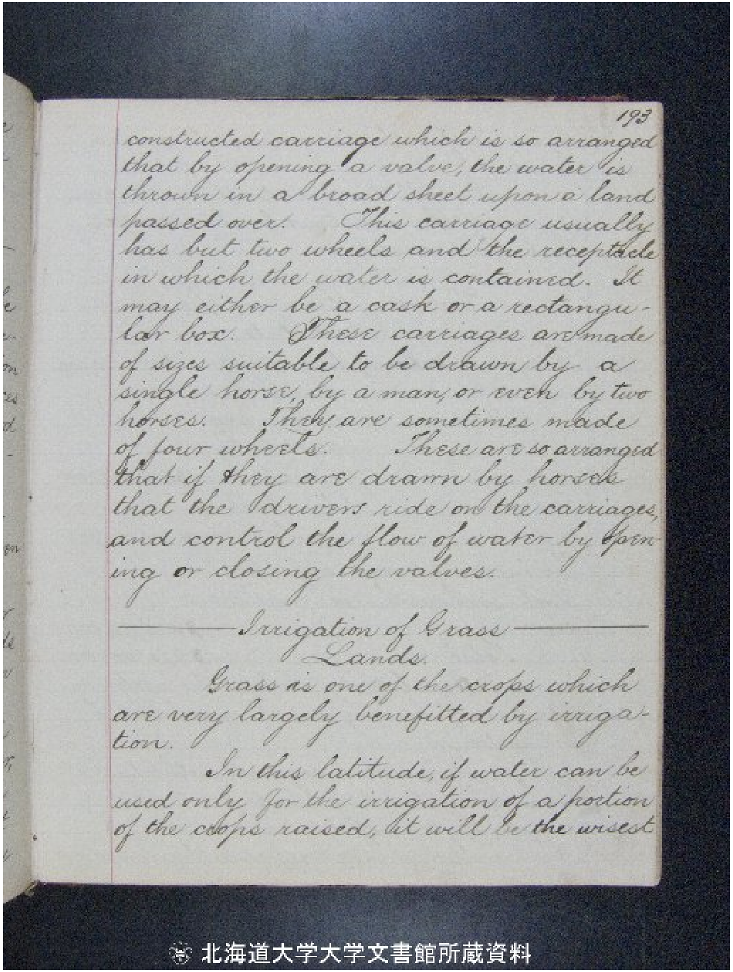

193

constructed carriage which is so arranged that by opening a valve, the water is thrown in a broad sheet upon a land passed over. This carriage usually has but two wheels and the receptacle in which the water is contained. It may either be a cask or a rectangular box. These carriages are made of sizes suitable to be drawn by a single horse, by a man, or even by two horses. They are sometimes made of four wheels. These are so arranged that if they are drawn by horses that the drivers ride on the carriages, and control the flow of water by opening or closing the valves.

Irrigation of Grass Lands.

Grass is one of the crops which are very largely benefitted by irrigation.

In this latitude, if water can be used only for the irrigation of a portion of the crops raised, it will be the wisest

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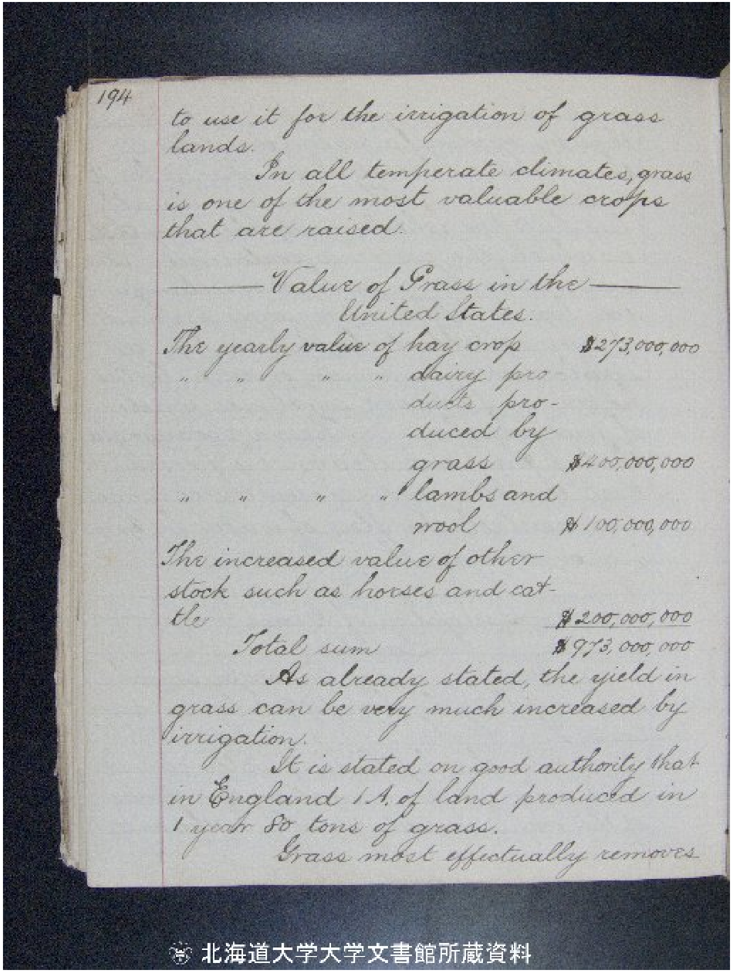
194
to use it for the irrigation of grass lands.
In all temperate climates, grass is one of the most valuable crops that are raised.
—— Value of Grass in the —— United States.
The yearly value of hay crop $273,000,000
" " " " dairy products produced by grass $400,000,000
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The increased value of other stock such as horses and cattle $200,000,000
Total sum $973,000,000
As already stated, the yield in grass can be very much increased by irrigation.
It is stated on good authority that in England 1 A. of land produced in 1 year 80 tons of grass.
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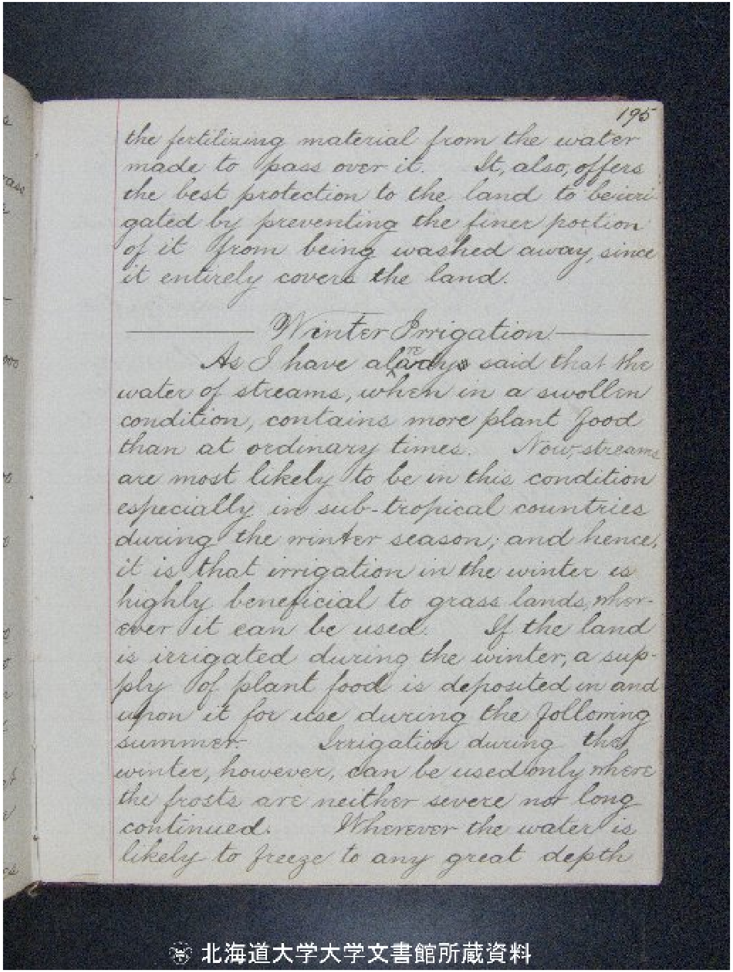
195

the fertilizing material from the water made to pass over it. It, also, offers the best protection to the land to be irrigated by preventing the finer portion of it from being washed away, since it entirely covers the land.

——— Winter Irrigation ———

As I have already said that the water of streams, when in a swollen condition, contains more plant food than at ordinary times. Now, streams are most likely to be in this condition especially in sub-tropical countries during the winter season; and hence, it is that irrigation in the winter is highly beneficial to grass lands, wherever it can be used. If the land is irrigated during the winter, a supply of plant food is deposited in and upon it for use during the following summer. Irrigation during the winter, however, can be used only where the frosts are neither severe nor long continued. Wherever the water is likely to freeze to any great depth

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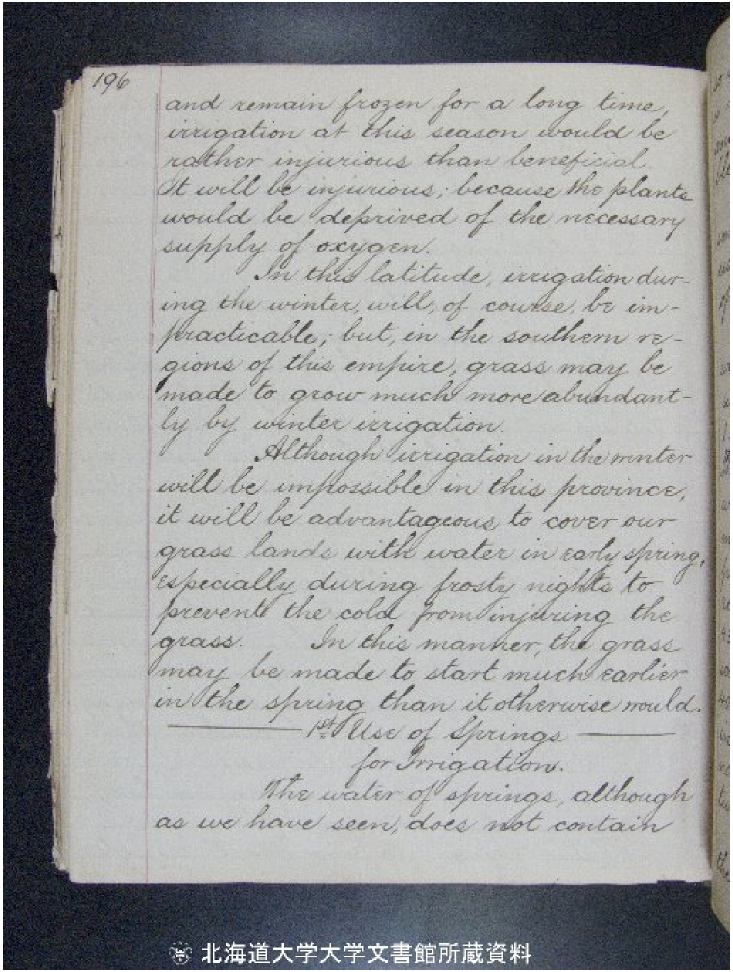
196

and remain frozen for a long time, irrigation at this season would be rather injurious than beneficial. It will be injurious; because the plants would be deprived of the necessary supply of oxygen.

In this latitude, irrigation during the winter, will, of course, be impracticable; but, in the southern regions of this empire, grass may be made to grow much more abundantly by winter irrigation.

Although irrigation in the winter will be impossible in this province, it will be advantageous to cover our grass lands with water in early spring, especially during frosty nights to prevent the cold from injuring the grass. In this manner, the grass may be made to start much earlier in the spring than it otherwise would.

——— 1st Use of Springs ———
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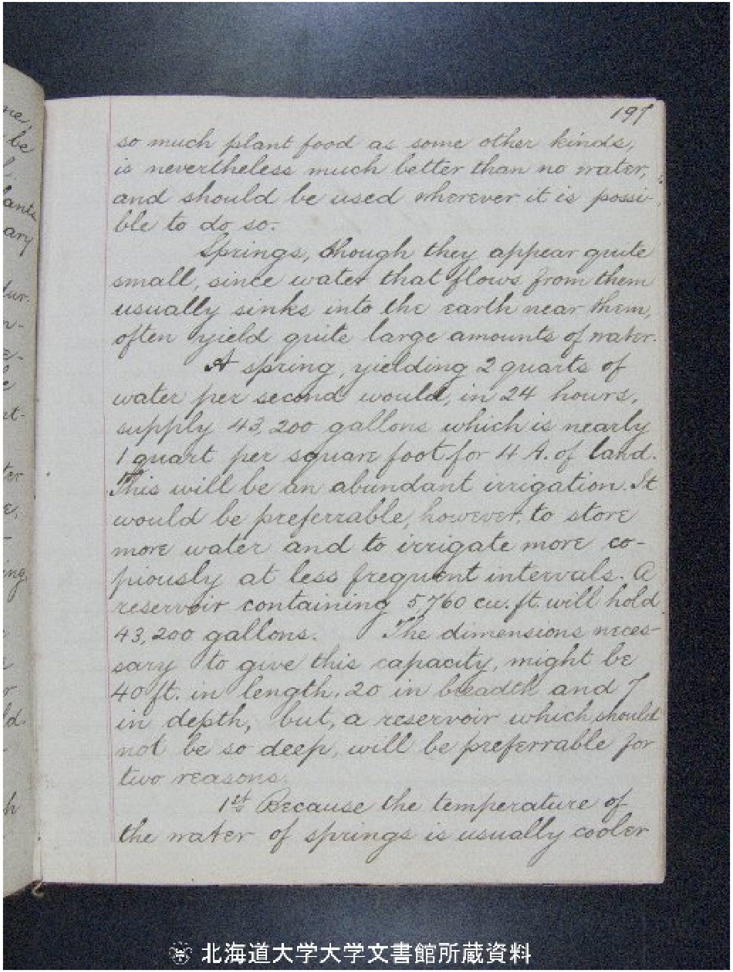
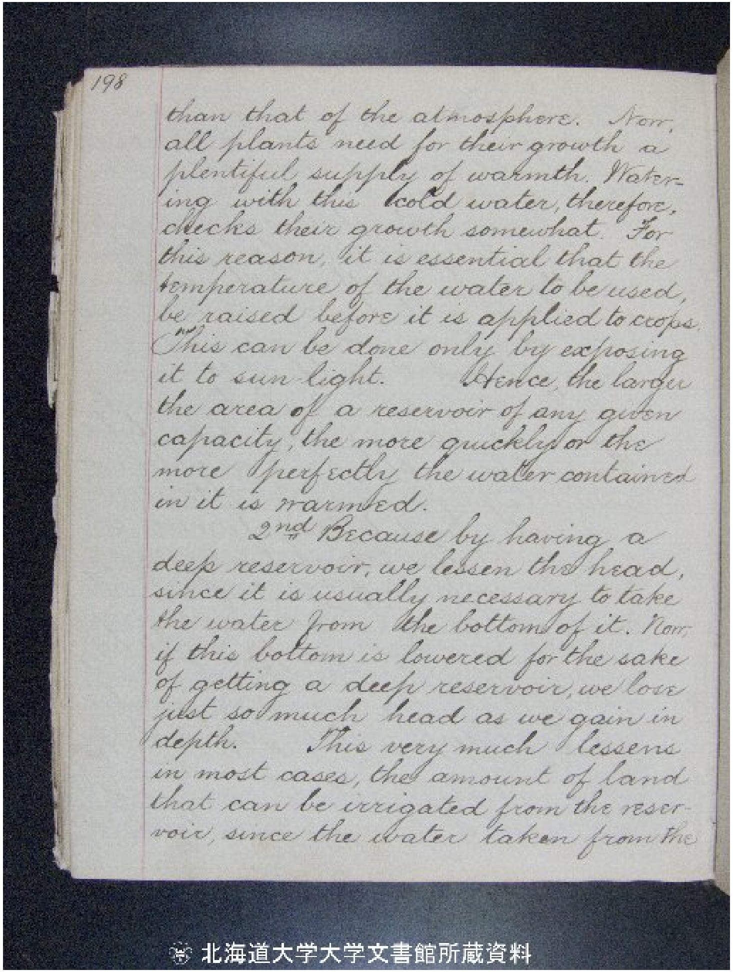


so much plant food as some other kinds, is nevertheless much better than no water, and should be used wherever it is possible to do so.

Springs, though they appear quite small, since water that flows from them usually sinks into the earth near them, often yield quite large amounts of water.

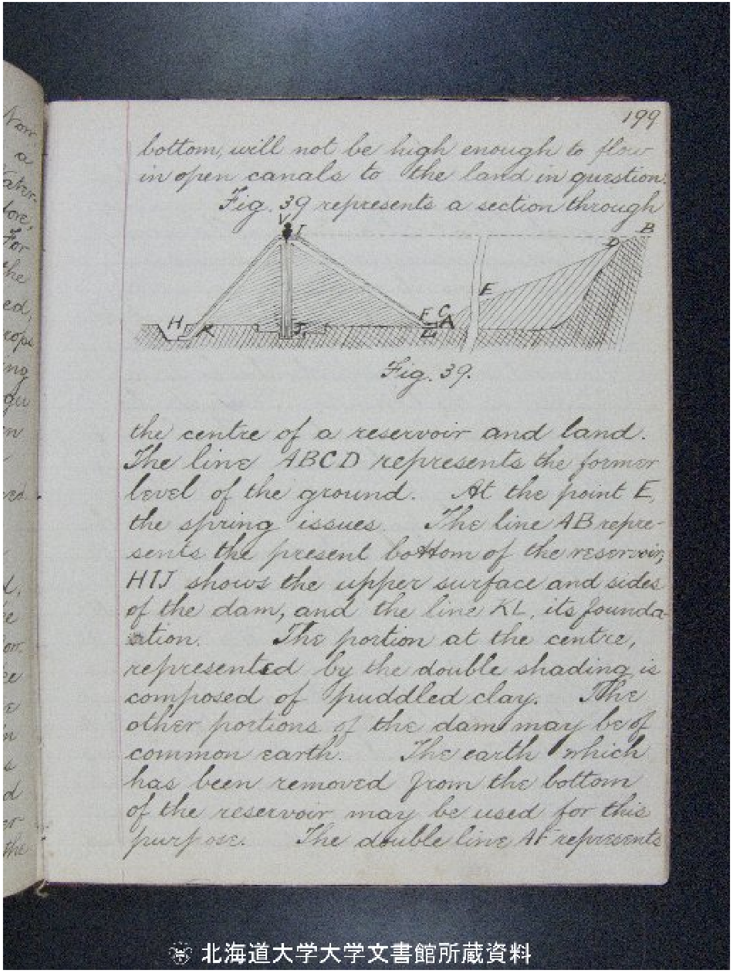
A spring, yielding 2 quarts of water per second would, in 24 hours, supply 43,200 gallons which is nearly 1 quart per square foot for 4 A. of land. This will be an abundant irrigation. It would be preferrable, however, to store mare water and to irrigate more copiously at less frequent intervals. A reservoir containing 5,760 cu. ft. will hold 43,200 gallons. The dimensions necessary to give this capacity, might be 40 ft. in length, 20 in breadth and 7 in depth, but, a reservoir which should not be so deep, will be preferrable for two reasons.

1st Because the temperature of the water of springs is usually cooler



than that of the atmosphere. Now, all plants need for their growth a plentiful supply of warmth. Watering with this cold water, therefore, checks their growth somewhat. For this reason, it is essential that the temperature of the water to be used, be raised before it is applied to crops. This can be done only by exposing it to sun-light. Hence, the larger the area of a reservoir of any given capacity, the more quickly or the more perfectly the water contained in it is warmed.

2nd Because by having a deep reservoir, we lessen the head, since it is usually necessary to take the water from the bottom of it. Now, if this bottom is lowered for the sake of getting a deep reservoir, we lose just so much head as we again in depth. This very much lessens in most cases, the amount of land that can be irrigated from the reservoir, since the water taken from the



199

bottom, will not be high enough to flow in open canals to the land in question.

Fig. 39 represents a section through

Fig. 39.

the centre of a reservoir and land. The line ABCD represents the former level of the ground. At the point E, the spring issues. The line AB represents the present bottom of the reservoir, HIJ shows the upper surface and sides of the dam, and the line KL, its foundation. The portion at the centre, represented by the double shading is composed of puddled clay. The other portions of the dam may be of common earth. The earth which has been removed from the bottom of the reservoir may be used for this purpose. The double line AF represents

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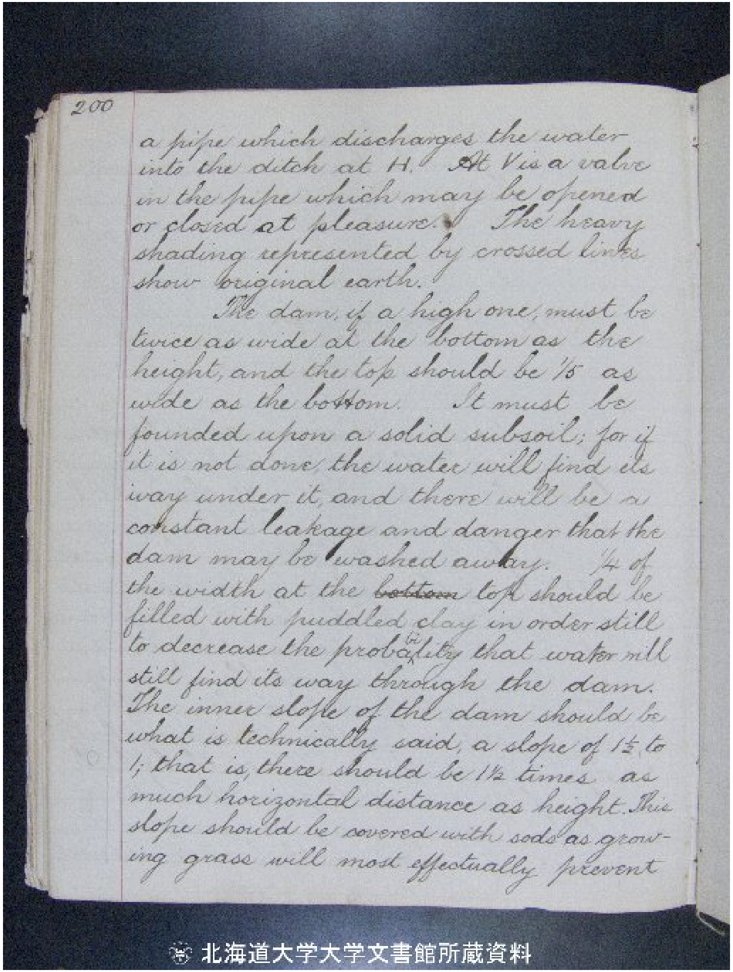
200
a pipe which discharges the water
into the ditch at H. At V is a valve
in the pipe which may be opened
or closed at pleasure. The heavy
shading represented by crossed lines
show original earth.
The dam, if a high one, must be
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The inner slope of the dam should be
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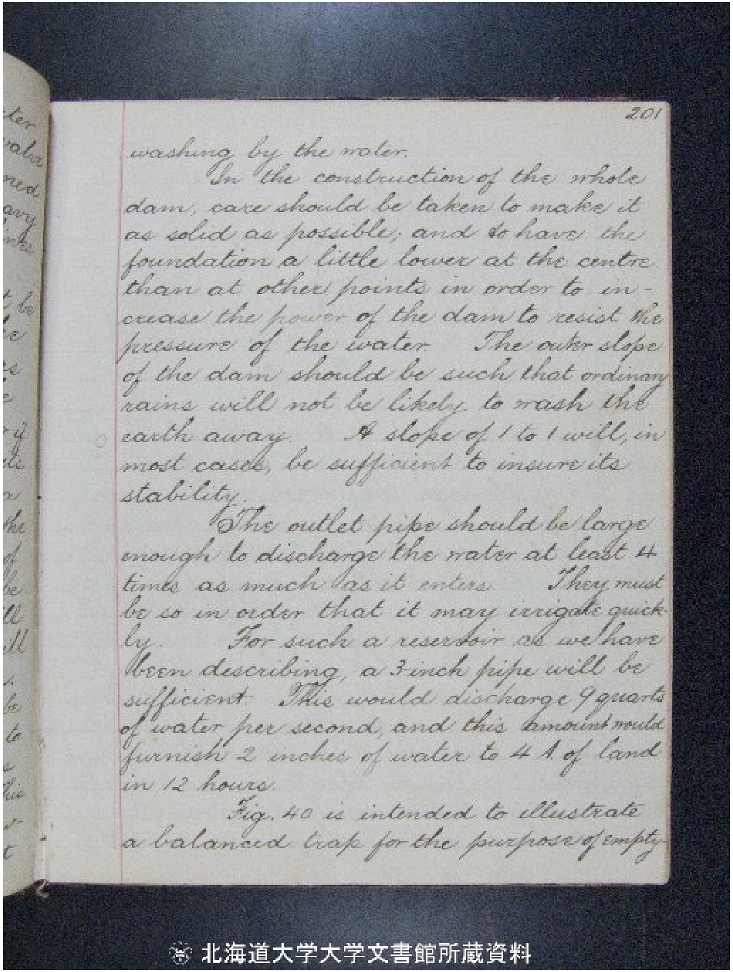
201

washing by the water.

In the construction of the whole dam, care should be taken to make it as solid as possible; and to have the foundation a little lower at the centre than at other points in order to increase the power of the dam to resist the pressure of the water. The outer slope of the dam should be such that ordinary rains will not be likely to wash the earth away. A slope of 1 to 1 will, in most cases, be sufficient to insure its stability.

The outlet pipe should be large enough to discharge the water at least 4 times as much as it enters. They must be so in order that it may irrigate quickly. For such a reservoir as we have been describing, a 3-inch pipe will be sufficient. This would discharge 9 quarts of water per second, and this amount would furnish 2 inches of water to 4 A. of land in 12 hours.

Fig. 40 is intended to illustrate a balanced trap for the purpose of empty-

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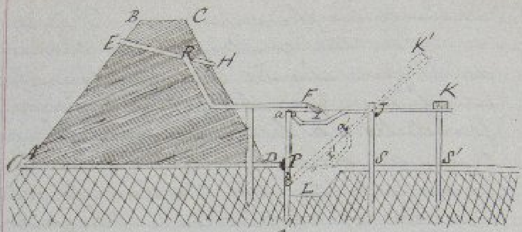
202

Fig. 40

ing a reservoir automatically.

ABCD is a dam; OP, a pipe running through the bottom of the dam emptying into the canal, L; EF, a pipe leading from a point near the top of the dam; and HR, an escape pipe leading from EF. At I is a box which is hinged at J. At the other end of the rod is a weight, K, which is sufficient, when there is no water in the box, to cause its end to rest upon a support, S'. ab represents a rod which is hinged at b. At the place on this rod which is opposite the mouth of the pipe OP is a leather or rubber cushion, which, when the

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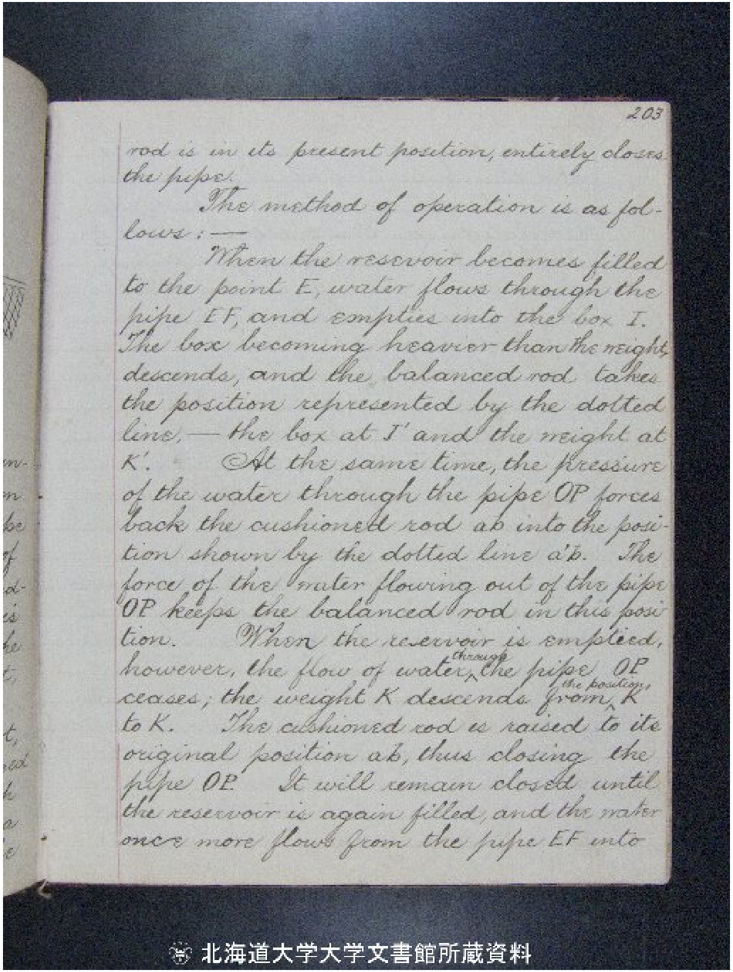

203

rod is in its present position, entirely closes the pipe.

The method of operation is as follows: —

When the reservoir becomes filled to the point E, water flows through the pipe EF, and empties into the box I. The box becoming heavier than the weight, descends, and the balanced rod takes the position represented by the dotted line, — the box at I' and the weight at K'. At the same time, the pressure of the water through the pipe OP forces back the cushioned rod ab into the position shown by the dotted line a'b. The force of the water flowing out of the pipe OP keeps the balanced rod in this position. When the reservoir is emptied, however, the flow of water through the pipe OP ceases; the weight K descends from the position K' to K. The cushioned rod is raised to its original position ab, thus closing the pipe OP. It will remain closed until the reservoir is again filled, and the water once more flows from the pipe EF into

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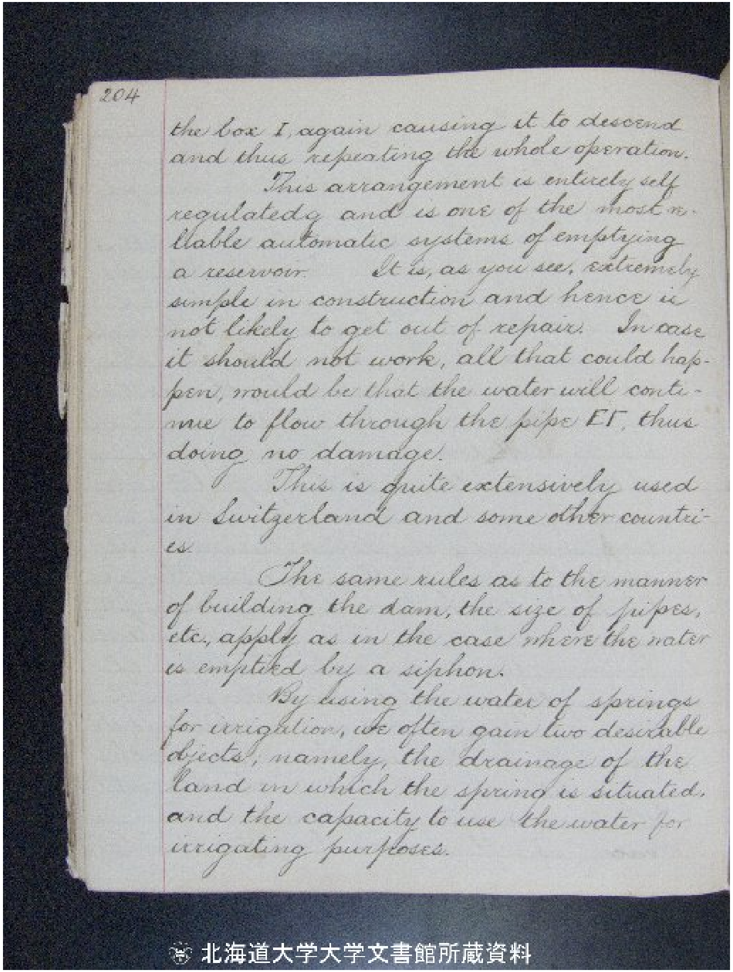
204
the box I, again causing it to descend and thus repeating the whole operation.
This arrangement is entirely self regulatedg and is one of the most reliable automatic systems of emptying a reservoir. It is, as you see, extremely simple in construction and hence is not likely to get out of repair. In case it should not work, all that could happen, would be that the water will continue to flow through the pipe EF, thus doing no damage.
This is quite extensively used in Switzerland and some other countries.
The same rules as to the manner of building the dam, the size of pipes, etc., apply as in the case where the water is emptied by a siphon.
By using the water of springs for irrigation, we often gain two desirable objects, namely, the drainage of the land in which the spring is situated, and the capacity to use the water for irrigating purposes.

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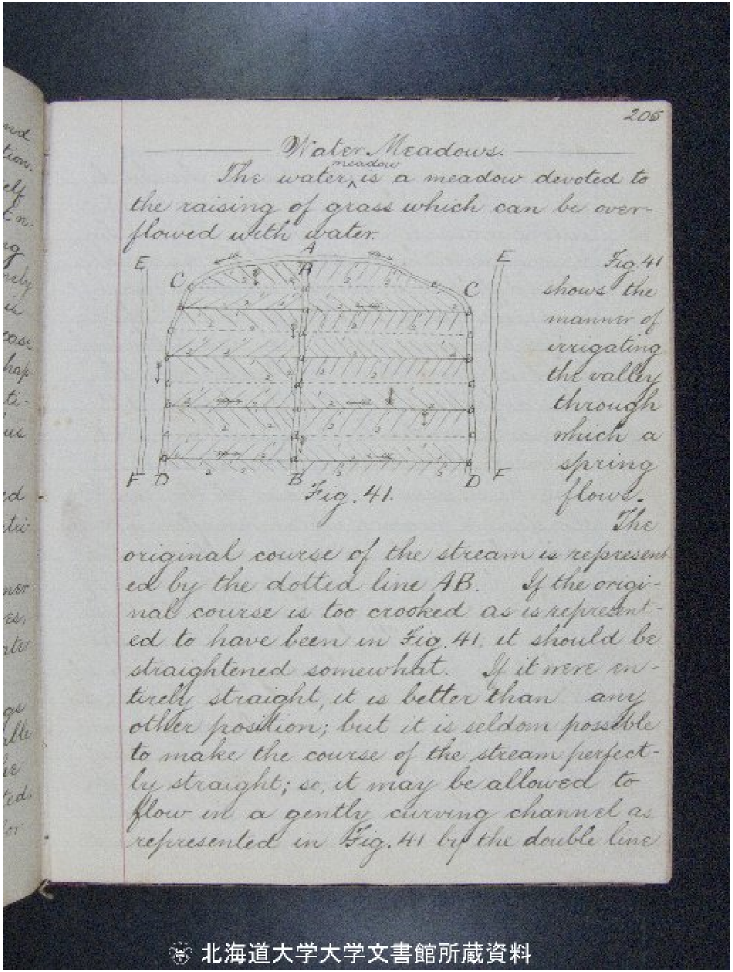
This is quite extensively used in Switzerland and some other countries.

The same rules as to the manner of building the dam, the size of pipes, etc., apply as in the case where the water is emptied by a siphon.

By using the water of springs for irrigation, we often gain two desirable objects, namely, the drainage of the land in which the spring is situated, and the capacity to use the water for irrigating purposes.


206

Water Meadows.

The water meadow is a meadow devoted to the raising of grass which can be overflowed with water.

Fig. 41.

Fig. 41 shows the manner of irrigating the valley through which a spring flows.

The original course of the stream is represented by the dotted line AB. If the original course is too crooked as is represented to have been in Fig. 41. it should be straightened somewhat. If it were entirely straight, it is better than any other position; but it is seldom possible to make the course of the stream perfectly straight; so, it may be allowed to flow in a gently curving channel as represented in Fig. 41 by the double line

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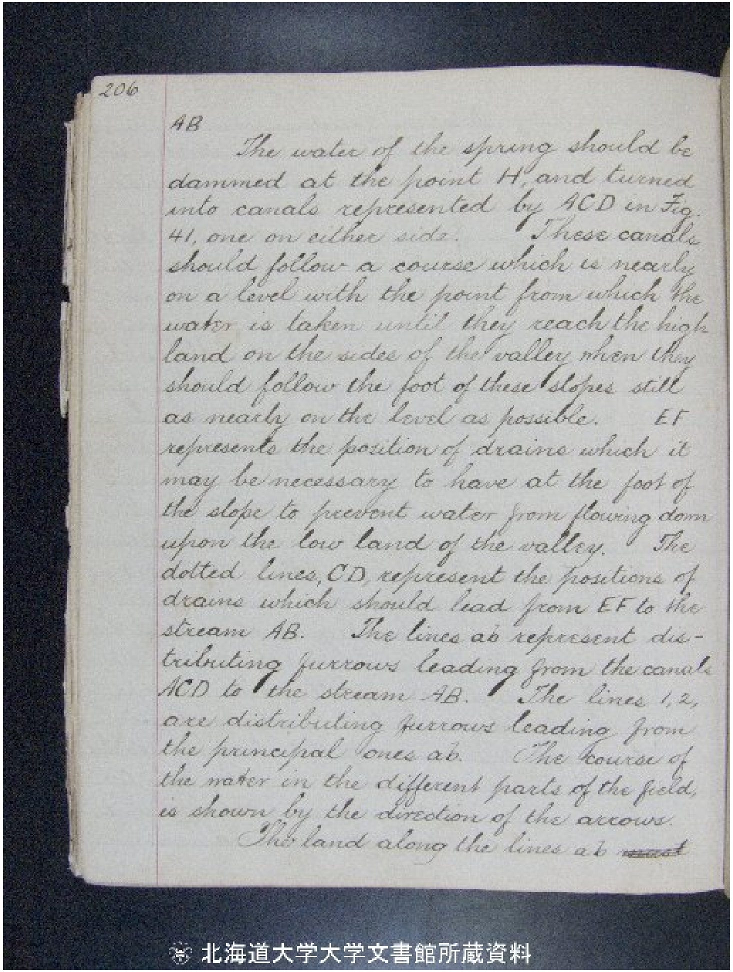
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AB

The water of the spring should be dammed at the point H, and turned into canals represented by ACD in Fig. 41, one on either side. These canals should follow a course which is nearly on a level with the point from which the water is taken until they reach the high land on the sides of the valley when they should follow the foot of these slopes still as nearly on the level as possible. EF represents the position of drains which it may be necessary to have at the foot of the slope to prevent water from flowing down upon the low land of the valley. The dotted lines, CD, represent the positions of drains which should lead from EF to the stream AB. The lines ab represent distributing furrows leading from the canals ACD to the stream AB. The lines 1, 2, are distributing furrows leading from the principal ones ab. The course of the water in the different parts of the field is shown by the direction of the arrows.

The land along the lines ab

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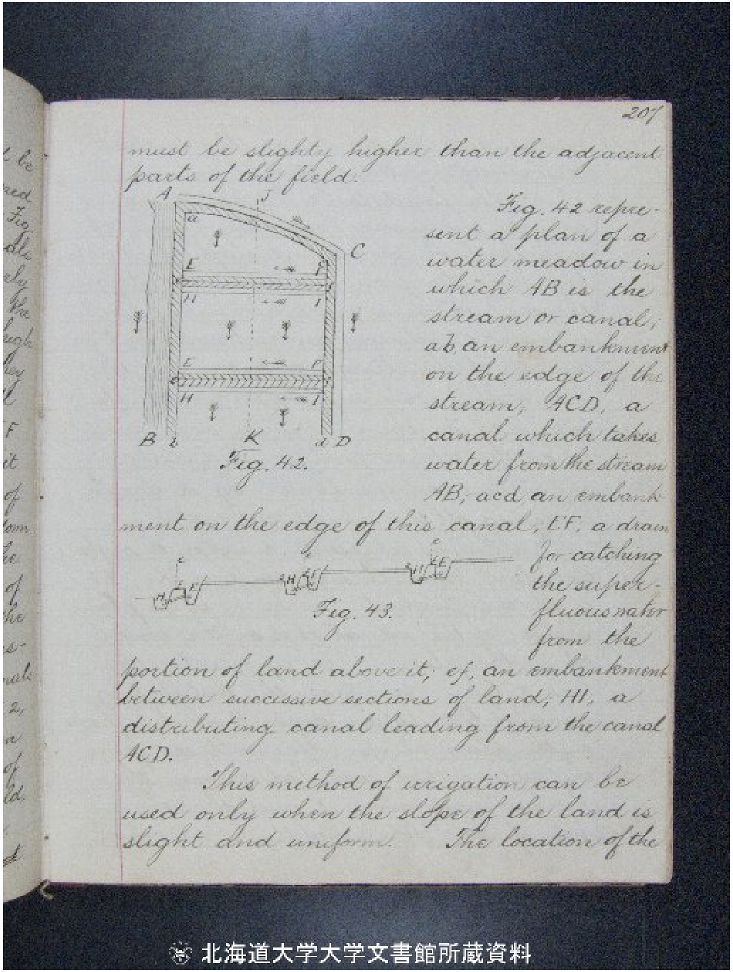


must be slighty higher than the adjacent parts of the field.

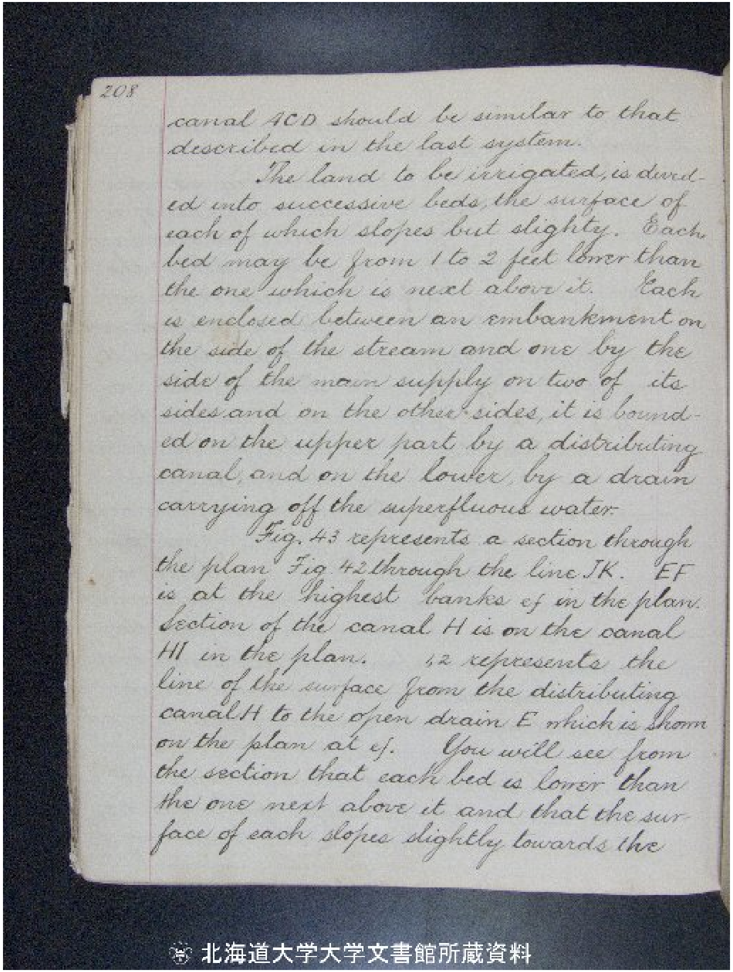
Fig.42

Fig. 42 represent a plan of a water meadow in which AB is the stream or canal, a b, an embanknrent on the edge of the stream; ACD, a canal which takes water from the stream AB; acd, an embankment on the edge of this, canal, EF, a drain for catching

Fig.43

the superfluous water from the portion of land above it, ef, an embankment between successive sections of land, HI, a distributing canal leading from the canal ACD.

This method of irrigation can be used only when the slope of the land is slight and uniform. The location of the



208

canal ACD should be similar to that described in the last system.

The land to be irrigated, is divided into successive beds, the surface of each of which slopes but slighty. Each bed may be from 1 to 2 feet lower than the one which is next above it. Each is enclosed between an embankment on the side of the stream and one by the side of the main supply on two of its sides and on the other sides, it is bounded on the upper part by a distributing canal, and on the lower by a drain carrying off the superfluous water.

Fig. 43 represents a section through the plan Fig 42 through the line JK. EF is at the highest banks ef in the plan. Section of the canal H is on the canal HI in the plan. 1,2 represents the line of the surface from the distributing canal H to the open drain E which is shown on the plan at ef. You will see from the section that each bed is lower than the one next above it and that the surface of each slopes slightly towards the

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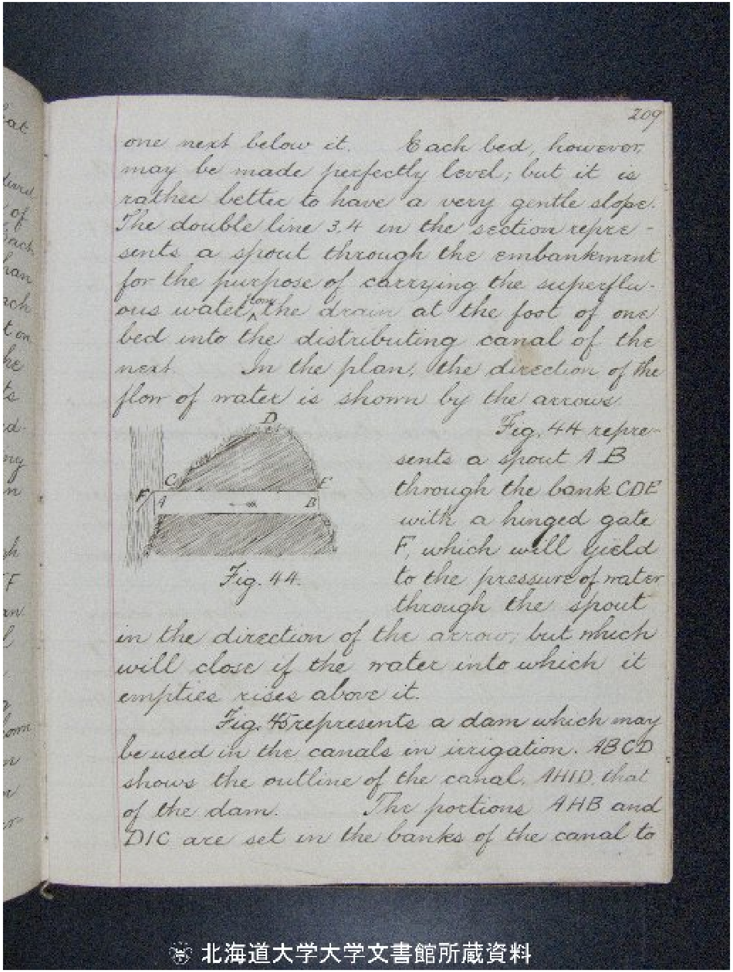
209

one next below it. Each bed, however, may be made perfectly level; but it is rather better to have a very gentle slope. The double line 3.4 in the section represents a spout through the embankment for the purpose of carrying the superfluous water from the drain at the foot of one bed into the distributing canal of the next. In the plan, the direction of the flow of water is shown by the arrows.

Fig. 44 represents a spout AB through the bank CDE with a hinged gate F, which will yield to the pressure of water through the spout in the direction of the arrow, but which will close if the water into which it empties rises above it.

Fig. 44.

Fig. 45 represents a dam which may be used in the canals in irrigation. ABCD shows the outline of the canal, AHID that of the dam. The portions AHB and DIC are set in the banks of the canal to

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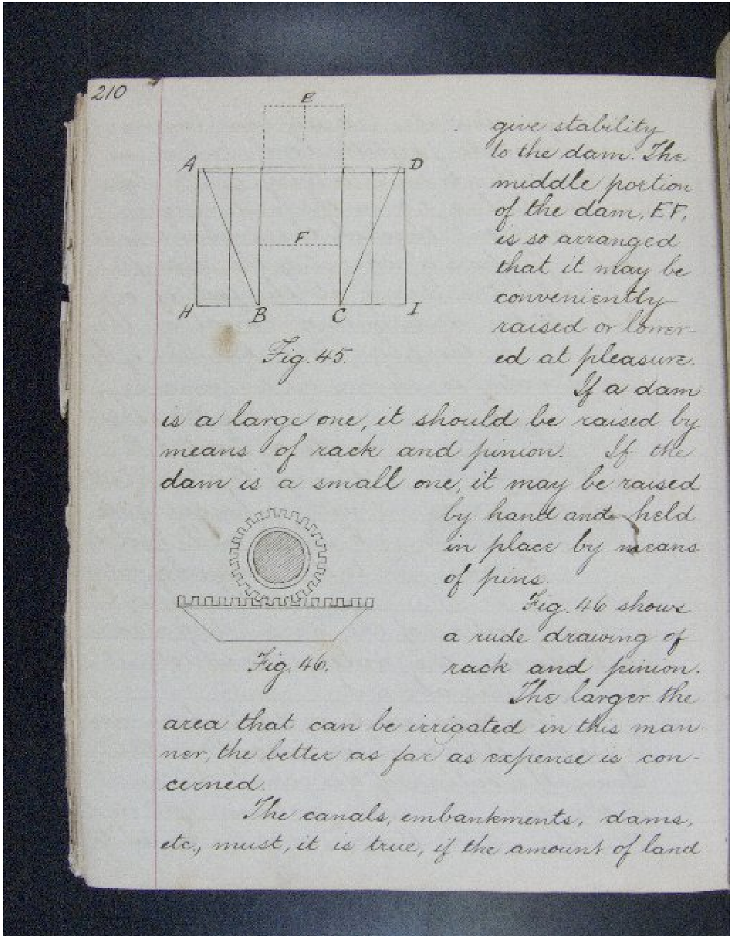


Fig.45

give stability to the dam. The middle portion of the dam, EF, is so arranged that it may be conveniently raised or lowered at pleasure.

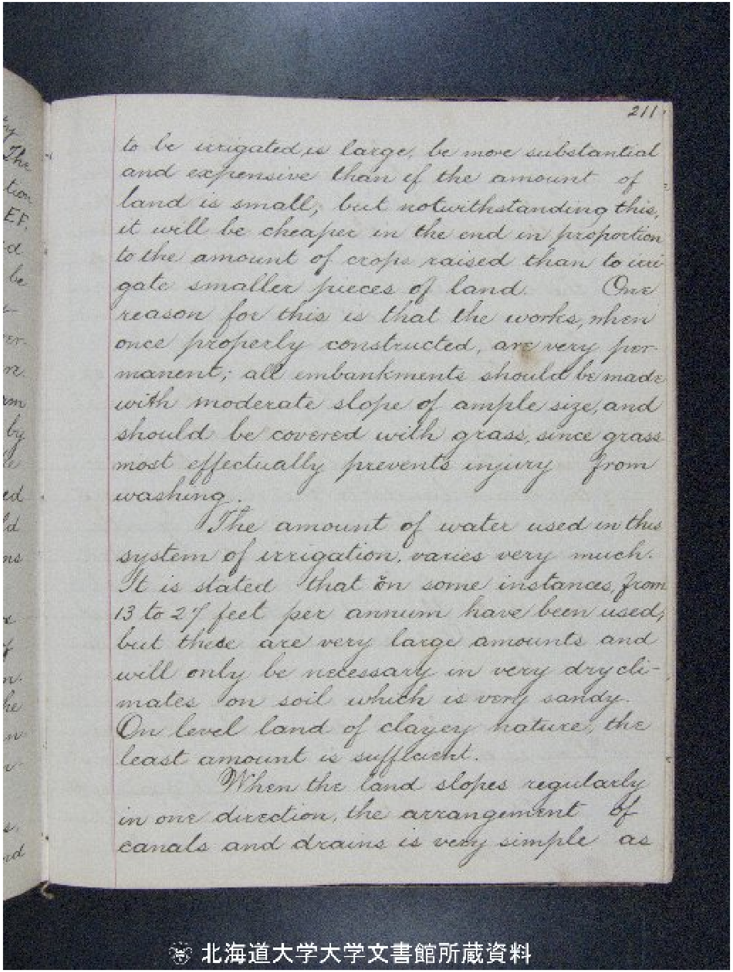
If a dam is a large one, it should be raised by means of rack and pinion. If the dam is a small one, it may be raised by hand and held in place by means of pins.

Fig.46

Fig. 46 shows a rude drawing of rack and pinion.

The larger the area that can be irrigated in this manner, the better as far as expense is concerned.

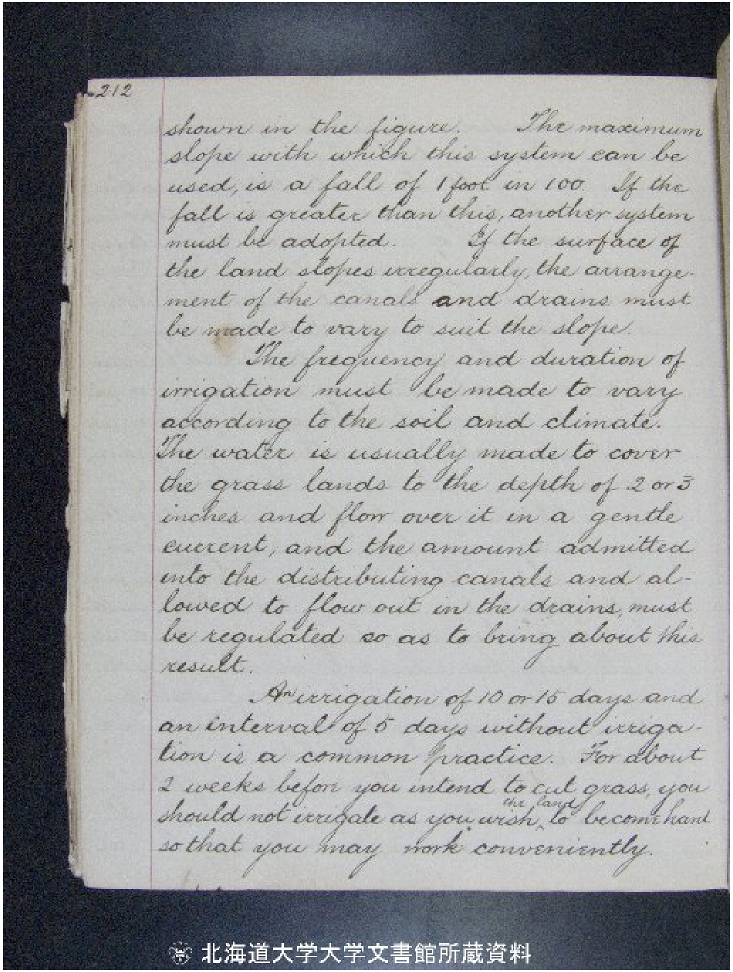
The canals, embankments, dams, etc., must, it is true, if the amount of land



to be irrigated is large, be more substantial and expensive than if the amount of land is small; but notwithstanding this, it will be cheaper in the end in proportion to the amount of crops raised than to irrigate smaller pieces of land. One reason for this is that the works, when once properly constructed, are very permanent; all embankments should be made with moderate slope of ample size, and should be covered with grass, since grass most effectually prevents injury from washing.

The amount of water used in this system of irrigation, varies very much. It is stated that in some instances, from13 to 27 feet per annum have been used, but these are very large amounts and will only be necessary in very dry climates on soil which is very sandy. One level land of clayey nature, the least amount is sufficient.

When the land slopes regularly in one direction, the arrangement of canals and drains is very simple as


212

shown in the figure. The maximum slope with which this system can be used, is a fall of 1 foot in 100. If the fall is greater than this, another system must be adopted. If the surface of the land slopes irregularly, the arrangement of the canals and drains must be made to vary to suit the slope.

The frequency and duration of irrigation must be made to vary according to the soil and climate. The water is usually made to cover the grass lands to the depth of 2 or 3 inches and flow over it in a gentle current, and the amount admitted into the distributing canals and allowed to flow out in the drains, must be regulated so as to bring about this result.

An irrigation of 10 or 15 days and an interval of 5 days without irrigation is a common practice. For about 2 weeks befor you intend to cut grass, you should not irrigate as you wish the land to become hard so that you may work conveniently.

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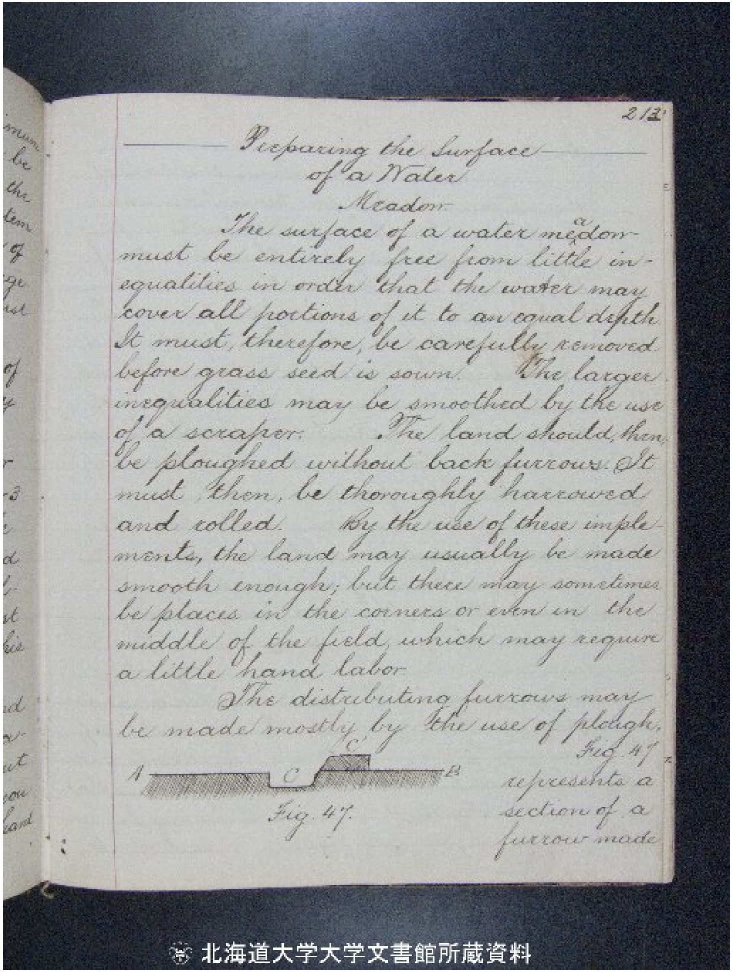


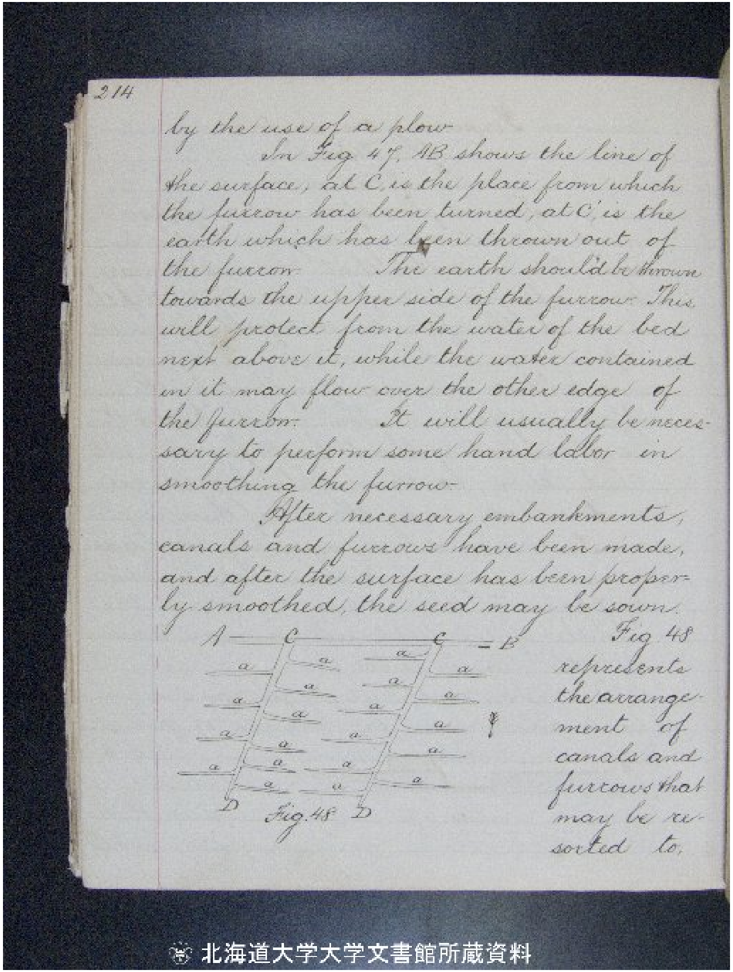
Preparing the Surface of a Water Meadow.

The surface of a water meadow must be entirely free from little inequalities in order that the water may cover all portions of it to an equal depth. It must, therefore, be carefully removed before grass seed is sown. The larger inequalities may be smoothed by the use of a scraper. The land should, them; be ploughed without back furrows It must then, be thoroughly harrowed and rolled. By the use of these implements, the land may usually be made smooth enough; but there may sometimes be places in the corners or even in the middle of the field, which may require a little hand labor.

The distributing furrows may be made mostly by the use of plough.

Fig.47

Fig. 47 represents a section of a furrow made


214

by the use of a plow.
In Fig 47, AB shows the line of the surface, at C, is the place from which the furrow has been turned, at C' is the earth which has been thrown out of the furrow. The earth should be thrown towards the upper side of the furrow. This will protect from the water of the bed next above it, while the water contained in it may flow over the other edge of the furrow. It will usually be necessary to perform some hand labor in smoothing the furrow.
After necessary embankments, canals and furrows have been made, and after the surface has been properly smoothed, the seed may be sown.

Fig 48 represents the arrangement of canals and furrows that may be resorted to,

Fig. 48

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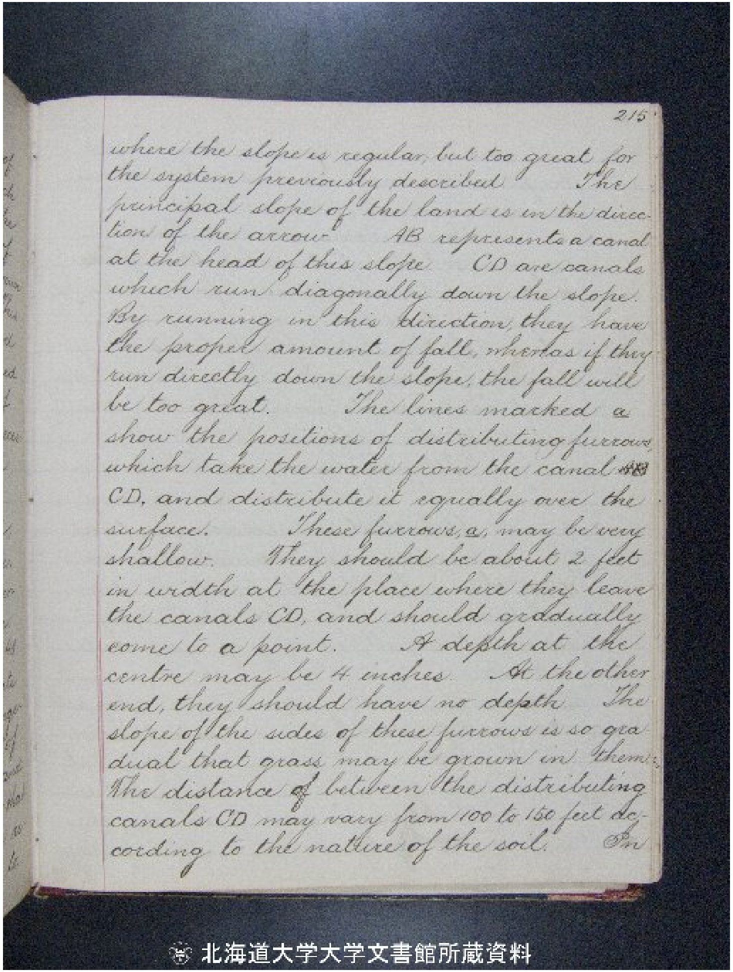
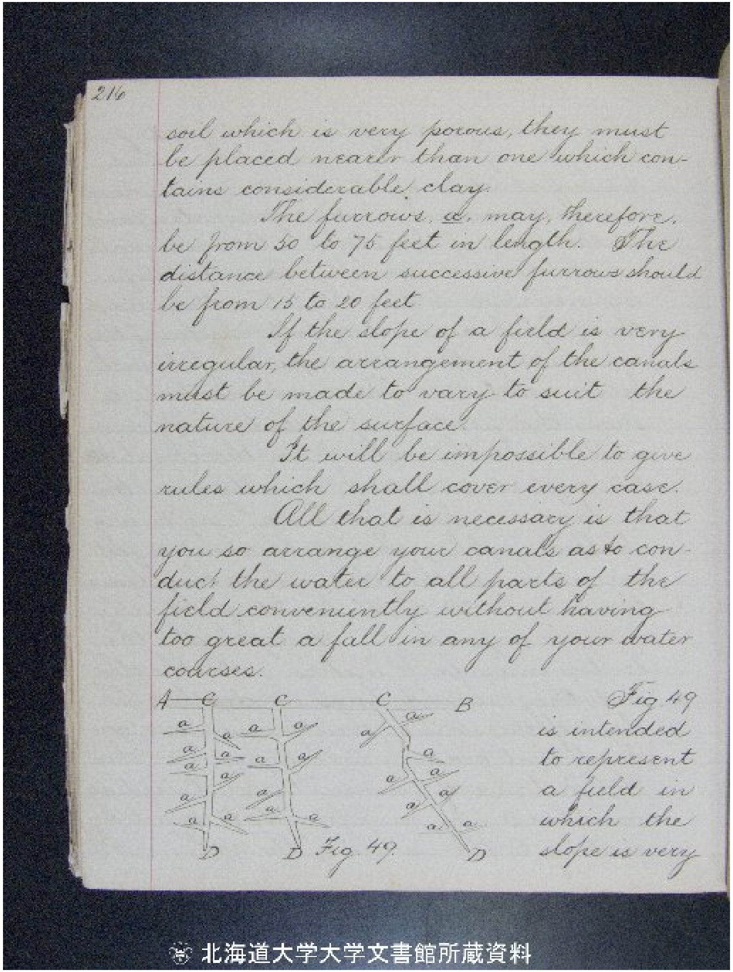


where the slop is regular, but too great for the system previously described. The principal slope of the land is in the direction of the arrow. AB represents a canal at the head of this slope. CD are canals which run diagonally down the slope. By running in this direction, they have the propel amount of fall, whereas if they run directly down the slope, the fall will be too great. The lines marked <u>a</u> show the positions of distributing furrows, which take the water from the canal CD, and distribute it equally over the surface. These furrows, <u>a</u>, may be very shallow. They should be about 2 feet in width at the place where they leave the canals CD, and should gradually come to a point. A depth at the centre may be may be 4 inches. At the other end, they should have no depth. The slope of the sides of these furrows is so gradual that grass may be grown in them. The distance between the distributing canals CD may vary from 100 to 150 feet according to the nature of the soil. In



216

soil which is very porous, they must be placed nearer than one which contains considerable clay.

The furrows, a, may, therefore, be from 50 to 75 feet in length. The distance between successive furrows should be from 15 to 20 feet

If the slope of a field is very irregular, the arrangement of the canals must be made to vary to suit the nature of the surface.

It will be impossible to give rules which shall cover every case.

All that is necessary is that you so arrange your canals as to conduct the water to all parts of the field conveniently without having too great a fall in any of your water courses.

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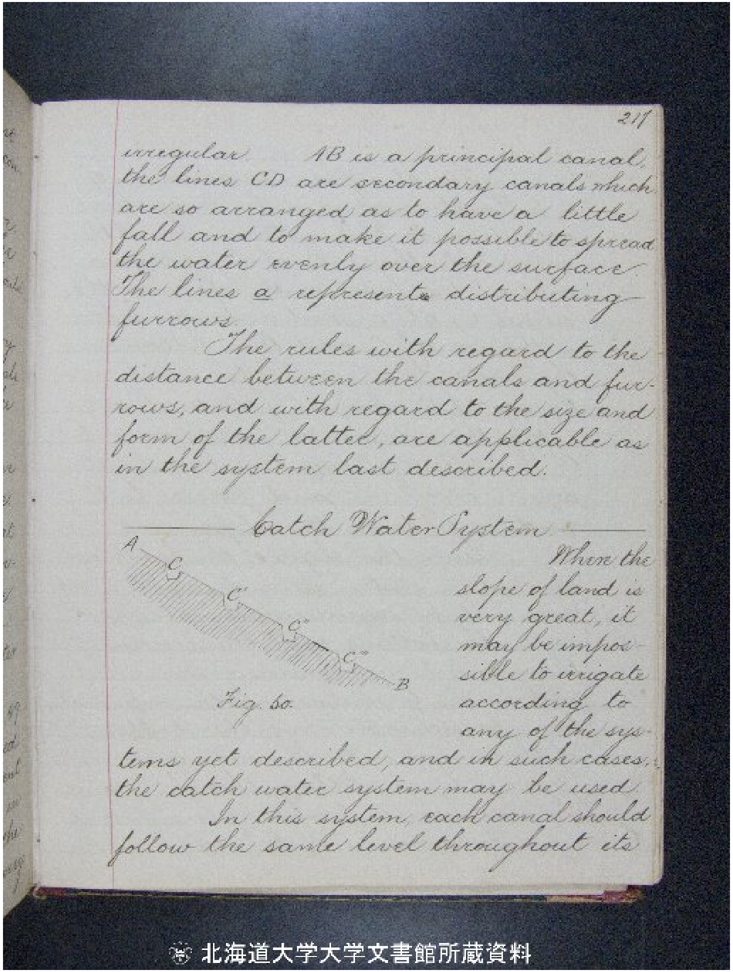


irregular. AB is a principal canal the lines CD are secondary canals which are so arranged as to have a little fall and to make it possible to spread the water evenly over the surface. The lines a represent distributing furrows.

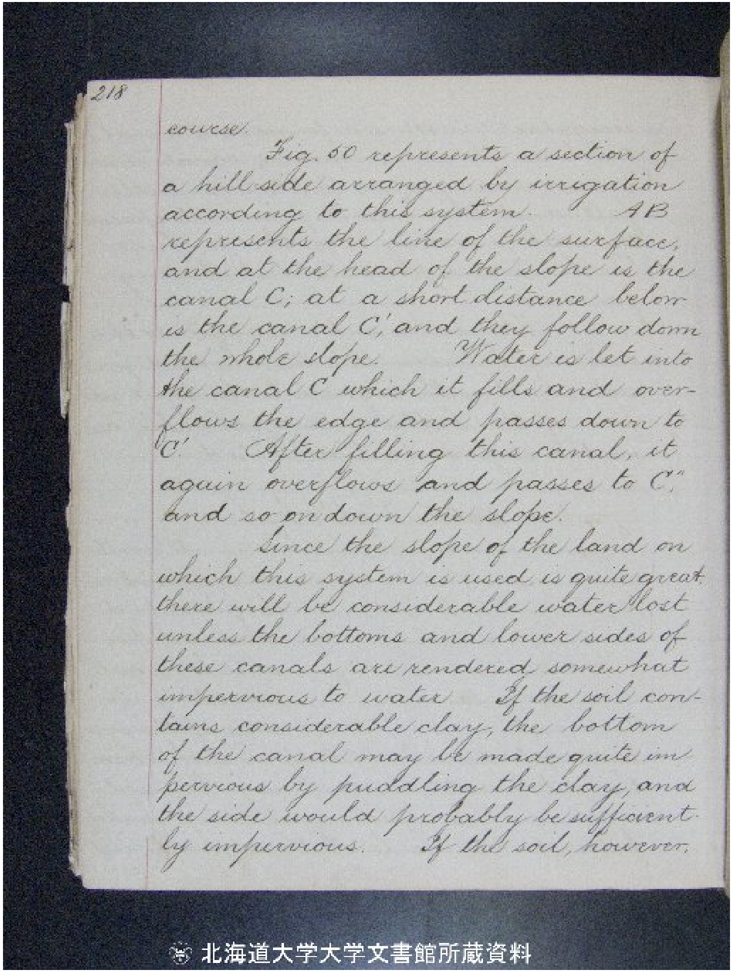
The rules with regard to the distance between the canals and furrows, and with regard to the size and form of the latter, are applicable as in the system last described.

——— Catch Water System ———

Fig.50

Where the slope of land is very great, it may be impossible to irrigate according to any of the systems yet described, and in such cases, the catch water system may be used.

In this system, each canal should follow the same level throughout its


218

course.
Fig. 50 represents a section of a hill-side arranged by irrigation according to this system. AB represents the line of the surface, and at the head of the slope is the canal C; at a short distance below is the canal C', and they follow down the whole slope. Water is let into the canal C which it fills and overflows the edge and passes down to C'. After filling this canal, it again overflows and passes to C'' and so on down the slope.
Since the slope of the land on which this system is used is quite great there will be considerable water lost unless the bottoms and lower sides of these canals are rendered somewhat impervious to water. If the soil contains considerable clay, the bottom of the canal may be made quite impervious by puddling the clay, and the side would probably be sufficiently impervious. If the soil, however,

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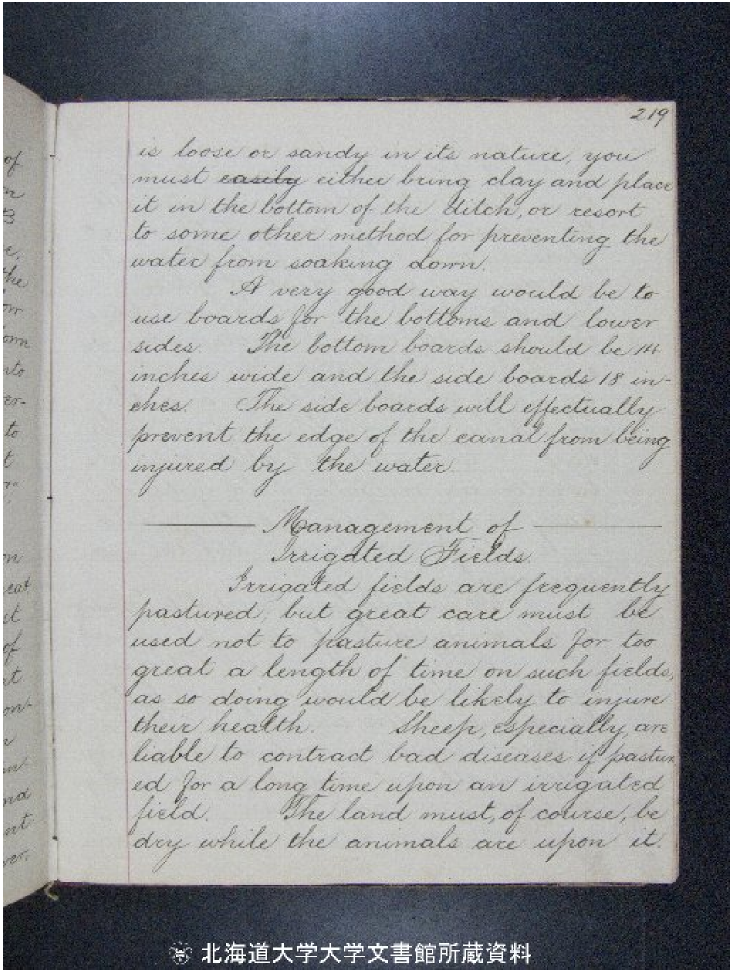

219

is loose or sandy in its nature, you must ~~easily~~ either bring clay and place it in the bottom of the ditch, or resort to some other method for preventing the water from soaking down.

A very good way would be to use boards for the bottoms and lower sides. The bottom boards should be 14 inches wide and the side boards 18 inches. The side boards will effectually prevent the edge of the canal from being injured by the water.

Management of Irrigated Fields

Irrigated fields are frequently pastured, but great care must be used not to pasture animals for too great a length of time on such fields, as so doing would be likely to injure their health. Sheep, especially, are liable to contract bad diseases if pastured for a long time upon an irrigated field. The land must, of course, be dry while the animals are upon it.

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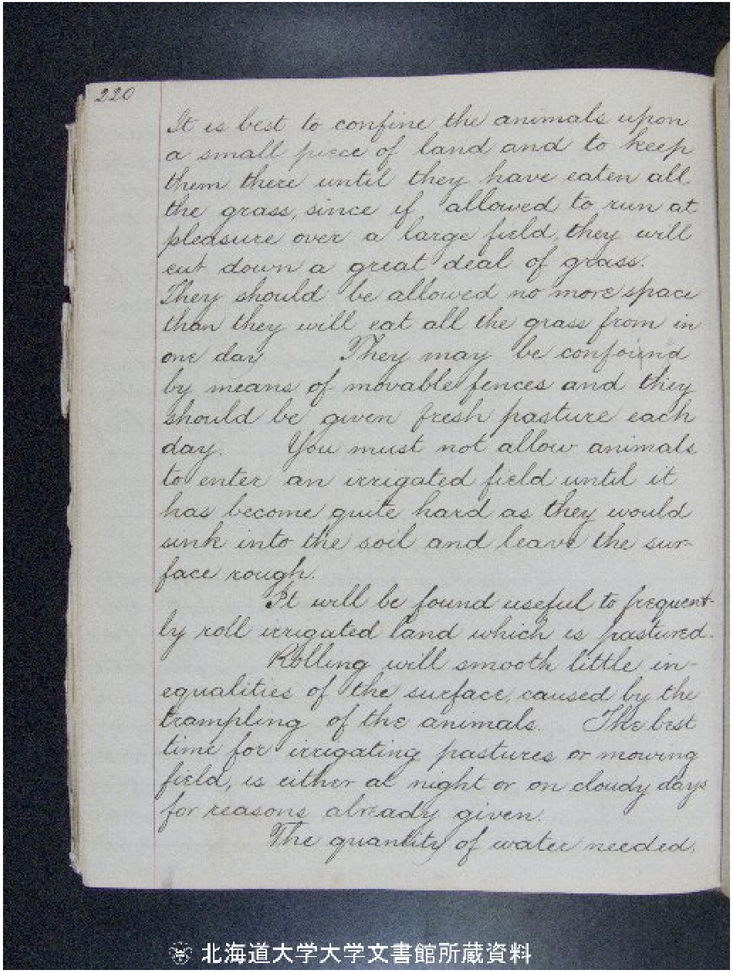
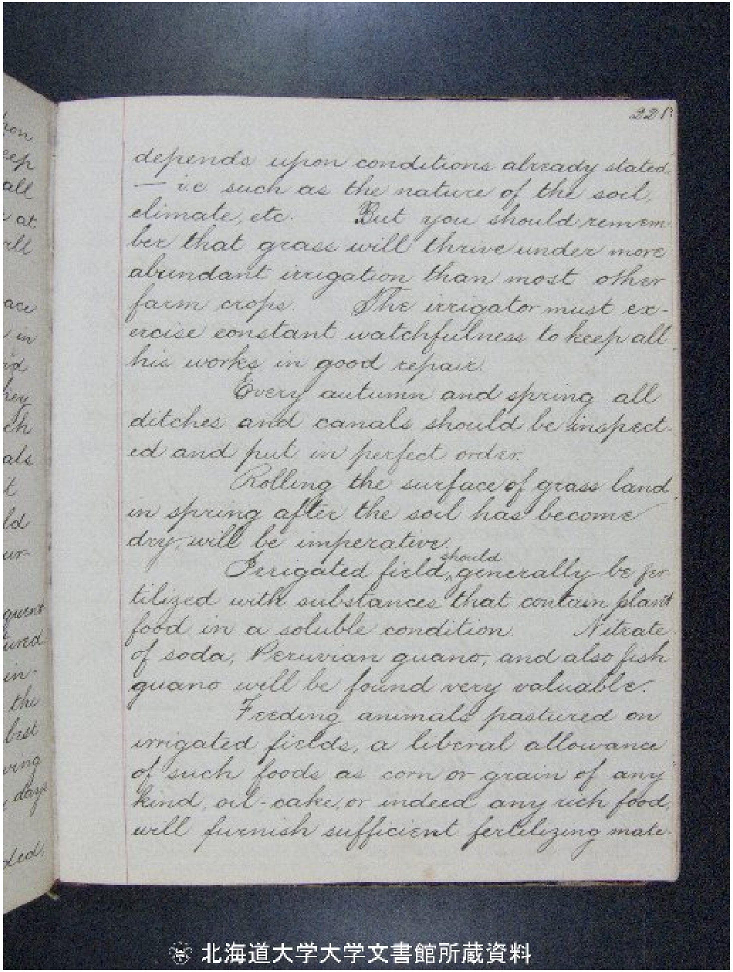


It is best to confine the animals upon a small piece of land and to keep them there until they have eaten all the grass, since ifallowed to run at pleasure over a large field, they will cut down a great deal of grass. They should be allowed no more space than they will eat all the grass from in one day. They may be confound by means of movable fences and they should be given fresh pasture each day. You must not allow animals to enter an irrigated field until it has become quite hard as they would sink into the soil and leave the surface rough.

It will be found useful to frequently roll irrigated land which is pastured.

Rolling will smooth little inequalities of the surface, caused by the trampling of the animals. The best time for irrigating pastures or mowing field, is either at night or on cloudy days for reasons already given.

The quantity of water needed,



221

depends upon conditions already stated — i.e. such as the nature of the soil climate, etc. But you should remember that grass will thrive under more abundant irrigation than most other farm crops. The irrigator must exercise constant watchfulness to keep all his works in good repair.

Every autumn and spring all ditches and canals should be inspected and put in perfect order.

Rolling the surface of grass land in spring after the soil has become dry, will be imperative.

Irrigated field should generally be fertilized with substances that contain plant food in a soluble condition. Nitrate of soda, Peruvian guano, and also fish guano will be found very valuable.

Feeding animals pastured on irrigated fields, a liberal allowance of such foods as corn or grain of any kind, oil-cake, or indeed any rich food, will furnish sufficient fertilizing mate-

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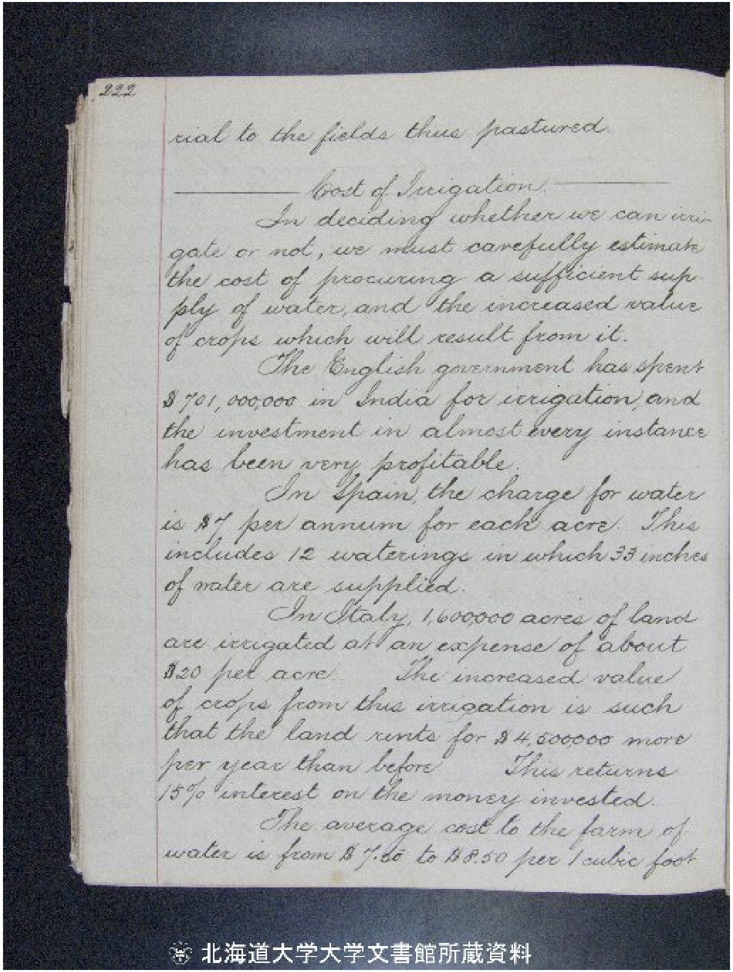

222

rial to the fields thus pastured.

——— Cost of Irrigation. ———

In deciding whether we can irrigate or not, we must carefully estimate the cost of procuring a sufficient supply of water, and the increased value of crops which will result from it.

The English government has spent $701,000,000 in India for irrigation, and the investment in almost every instance has been very profitable.

In Spain, the charge for water is $7 per annum for each acre. This includes 12 waterings in which 33 inches of water are supplied.

In Italy, 1,600000 acres of land are irrigated at an expense of about $20 per acre. The increased value of crops from this irrigation is such that the land rents for $4,500000 more per year than before. This returns 15% interest on the money invested.

The average cost to the farm of water is from $7.50 to $8.50 per 1 cubic foot

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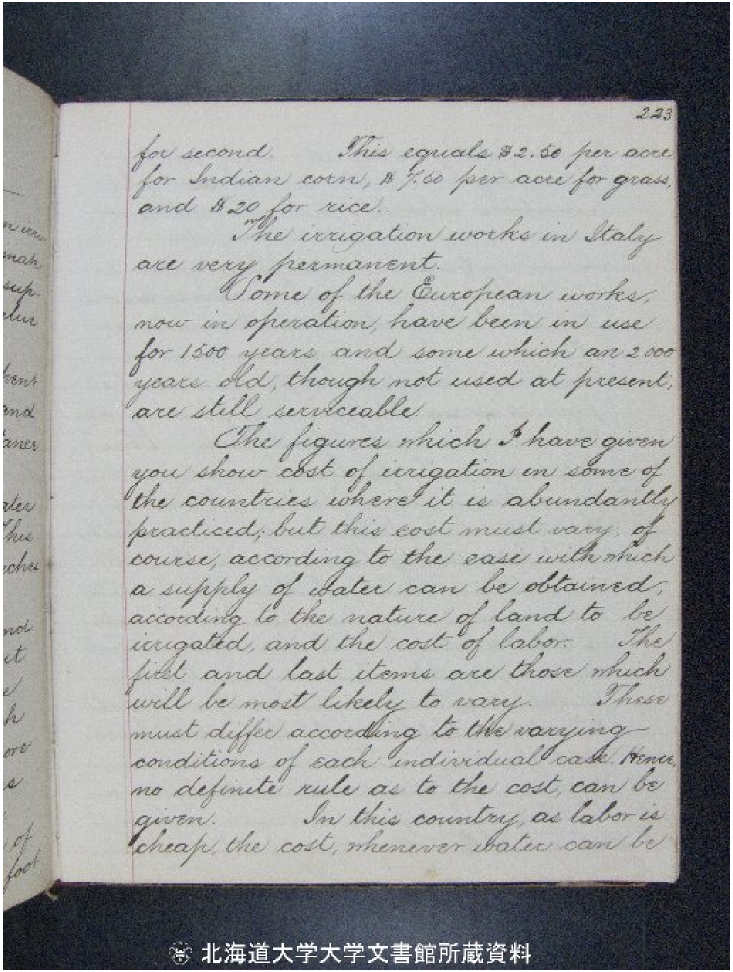
223

for second. This equals $2.50 per acre for Indian corn, $7.50 per acre for grass, and $20 for rice.

The irrigation works in Italy are very permanent.

Some of the European works, now in operation, have been in use for 1500 years and some which are 2000 years old, though not used at present, are still serviceable.

The figures which I have given you show cost of irrigation in some of the countries where it is abundantly practiced; but this cost must vary of course, according to the ease with which a supply of water can be obtained, according to the nature of land to be irrigated, and the cost of labor. The first and last items are those which will be most likely to vary. These must differ according to the varying conditions of each individual case. Hence, no definite rule as to the cost, can be given. In this country, as labor is cheap, the cost, whenever water can be

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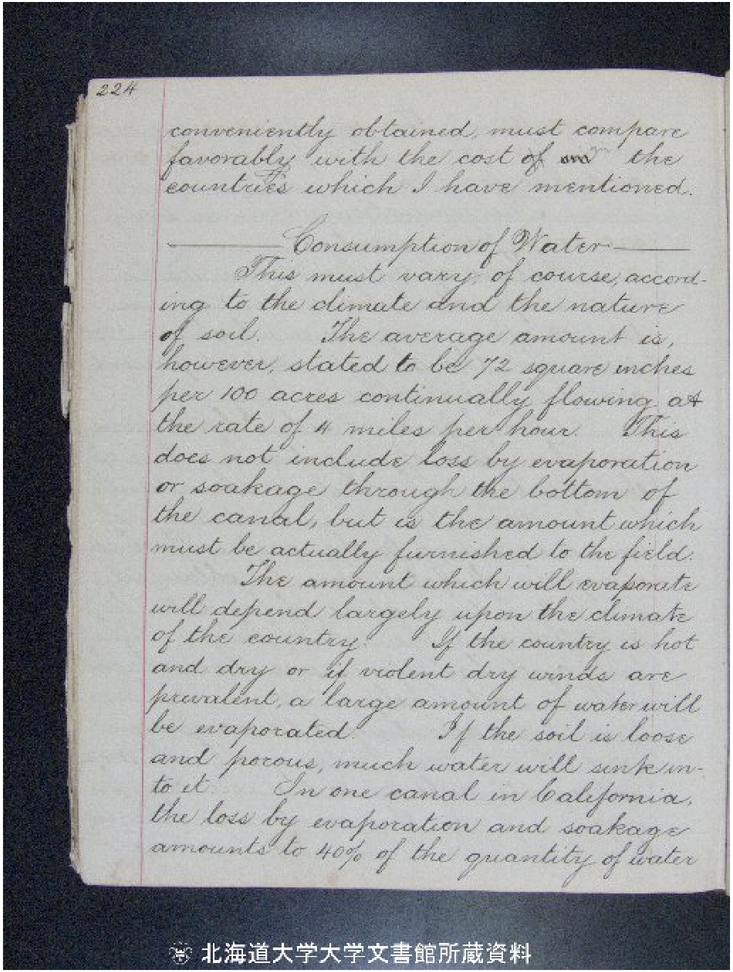
224

conveniently obtained, must compare favorably with the cost of ~~an~~ the countries which I have mentioned.

—— Consumption of Water ——

This must vary, of course, according to the climate and the nature of soil. The average amount is, however, stated to be 72 square inches per 100 acres continually flowing at the rate of 4 miles per hour. This does not include loss by evaporation or soakage through the bottom of the canal, but is the amount which must be actually furnished to the field.

The amount which will evaporate will depend largely upon the climate of the country. If the country is hot and dry or if violent dry winds are prevalent, a large amount of water will be evaporated. If the soil is loose and porous, much water will sink into it. In one canal in California, the loss by evaporation and soakage amounts to 40% of the quantity of water

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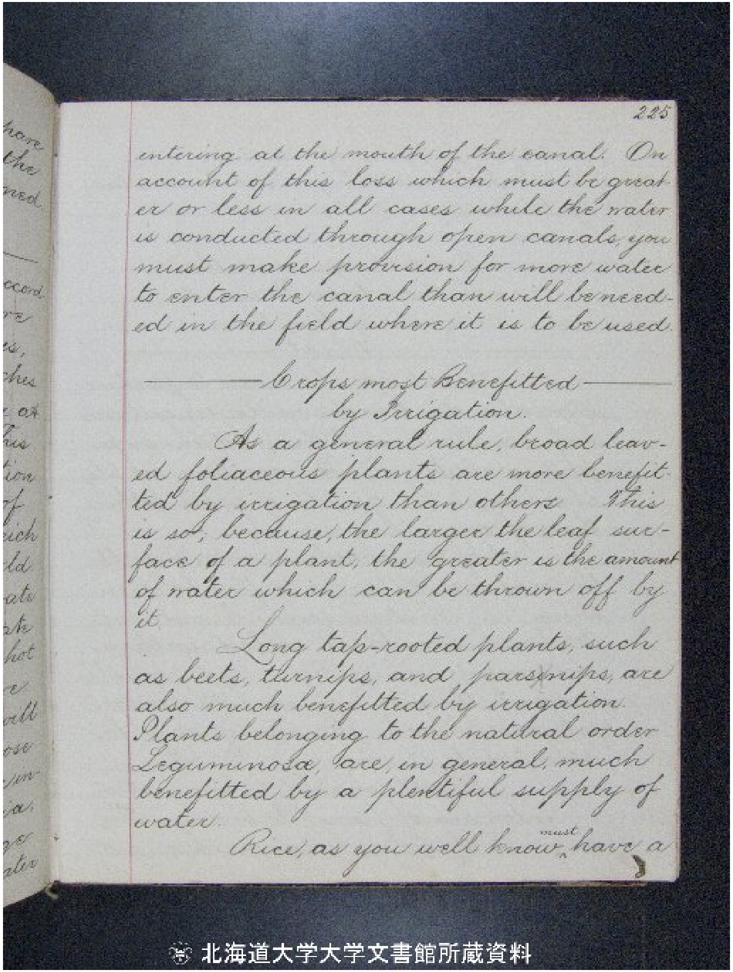


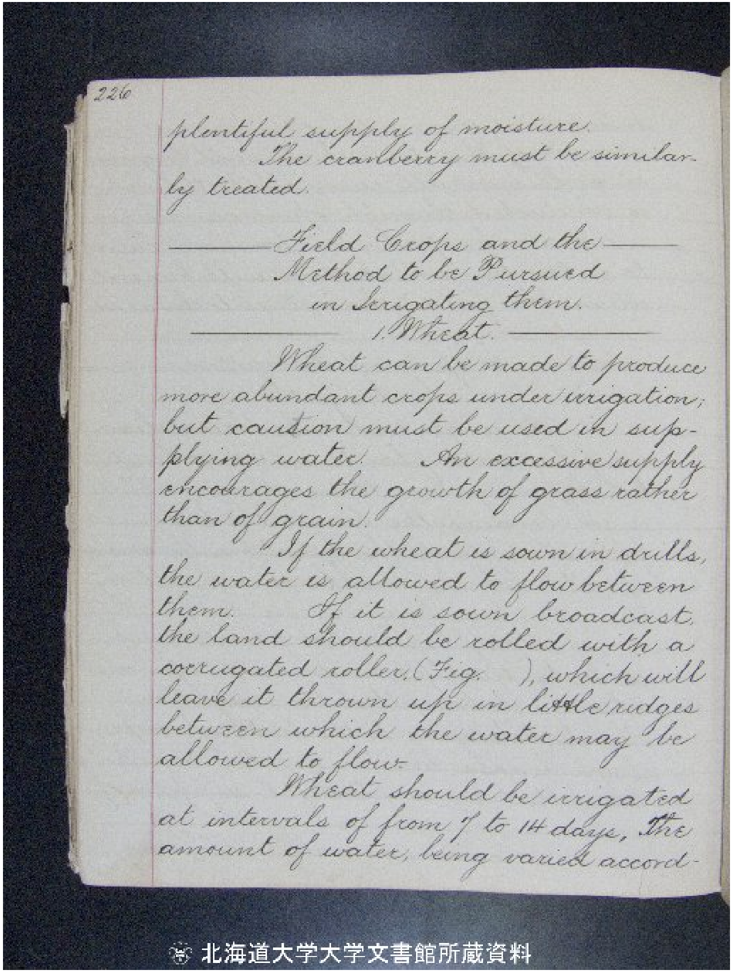
entering at the mouth of the canal. On account of this loss which must be greater or less in all cases while the water is conducted through open canals, you must make provision for more water to enter the canal than will be needed in the field where it is to be used.

———— Crops most Benefitted ———— by Irrigation

As a general rule, broad leaved foliaceous plants are more benefitted by irrigation than others. This is so; because, the larger the leaf surface of a plant, the greater is the amount of water which can be thrown off by it.

Longtap-rooted plants, such as beets, turnips, and parsnips, are also much benefitted by irrigation. Plants belonging to the natural order Leguminosa, are in general, much benefitted by a plentiful supply of water.

Rice, as you well know must have a



226

plentiful supply of moisture.
The cranberry must be similarly treated.

Field Crops and the Method to be Pursued in Irrigating them.

1. Wheat.

Wheat can be made to produce more abundant crops under irrigation; but caution must be used in supplying water. An excessive supply encourages the growth of grass rather than of grain.

If the wheat is sown in drills, the water is allowed to flow between them. If it is sown broadcast, the land should be rolled with a corrugated roller, (Fig.), which will leave it thrown up in little ridges between which the water may be allowed to flow.

Wheat should be irrigated at intervals of from 7 to 14 days, the amount of water, being varied accord-

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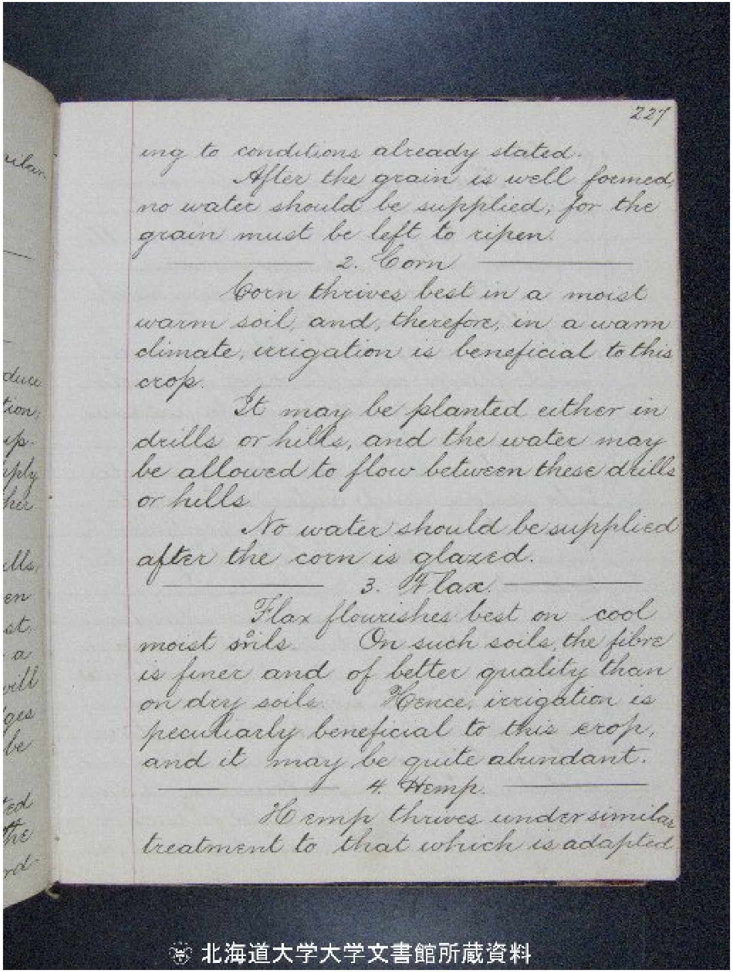
227

ing to conditions already stated.

After the grain is well formed, no water should be supplied, for the grain must be left to ripen.

2. Corn

Corn thrives best in a moist warm soil, and, therefore, in a warm climate, irrigation is beneficial to this crop.

It may be planted either in drills or hills, and the water may be allowed to flow between these drills or hills.

No water should be supplied after the corn is glazed.

3. Flax

Flax flourishes best on cool moist soils. On such soils, the fibre is finer and of better quality than on dry soils. Hence, irrigation is peculiarly beneficial to this crop, and it may be quite abundant.

4. Hemp.

Hemp thrives under similar treatment to that which is adapted

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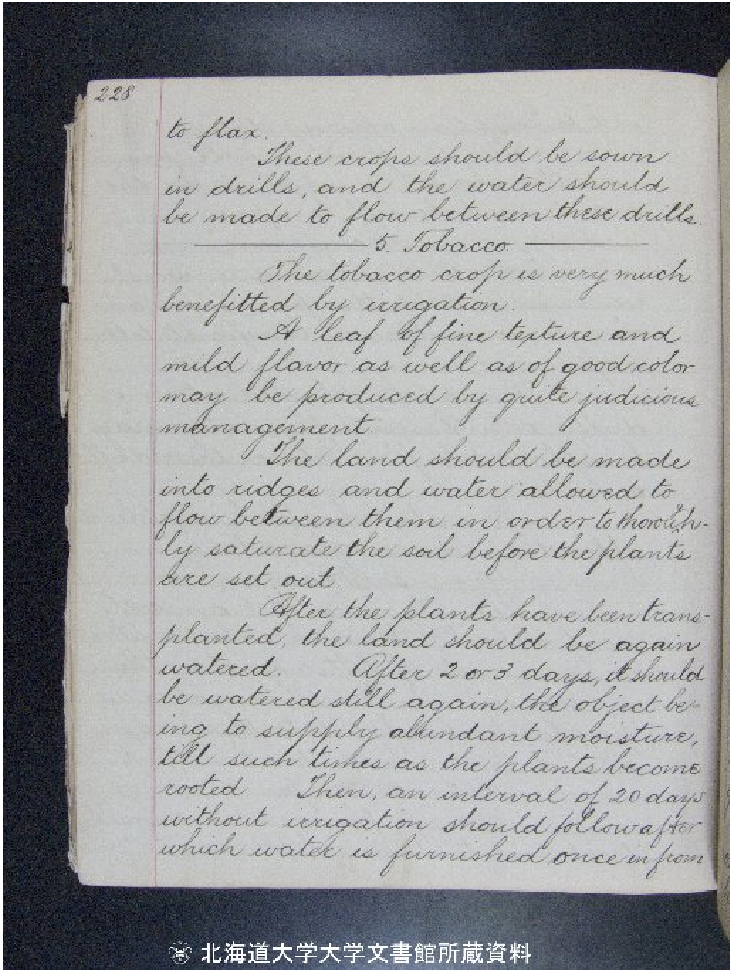

to flax.

These crops should be sown in drills, and the water should be made to flow between these drills.

5. Tobacco

The tobacco crop is very much benefitted by irrigation.

A leaf of fine texture and mild flavor as well as of good color may be produced by quite judicious management.

The land should be made into ridges and water allowed to flow between them in order to thoroughly saturate the soil before the plants are set out.

After the plants have been transplanted, the land should be again watered. After 2 or 3 days, it should be watered still again, the object being to supply abundant moisture, till such times as the plants become rooted. Then, an interval of 20 days without irrigation should follow after which water is furnished once in from

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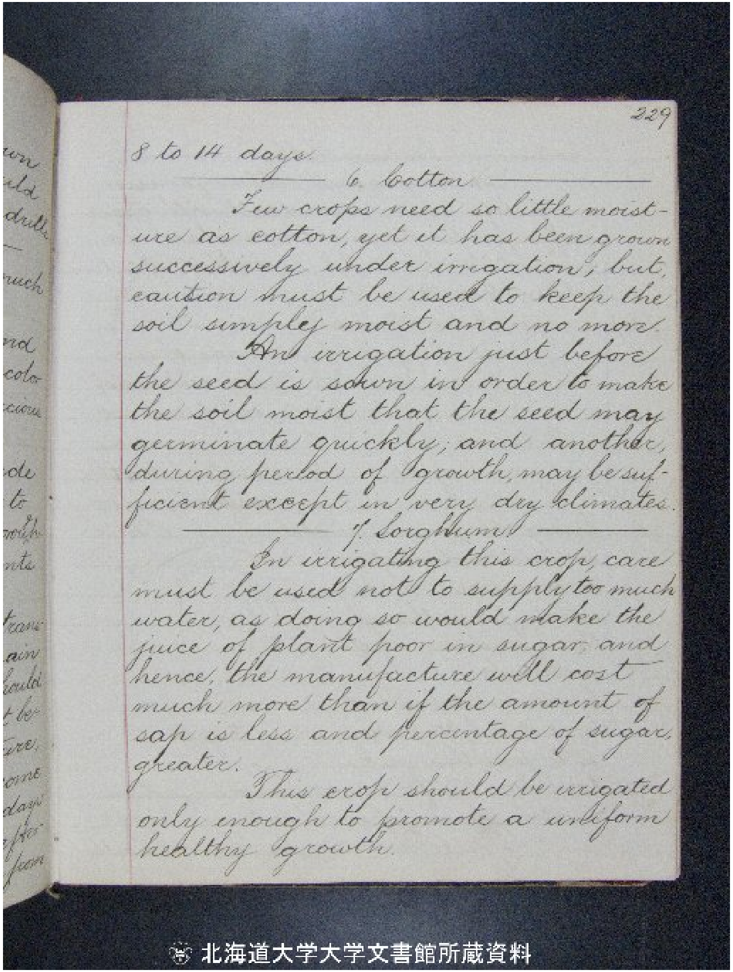
229

8 to 14 days.

6. Cotton

Few crops need so little moisture as cotton, yet it has been grown successively under irrigation, but, caution must be used to keep the soil simply moist and no more.

An irrigation just before the seed is sown in order to make the soil moist that the seed may germinate quickly, and another, during period of growth, may be sufficient except in very dry climates.

7. Sorghum

In irrigating this crop, care must be used not to supply too much water, as doing so would make the juice of plant poor in sugar, and hence, the manufacture will cost much more than if the amount of sap is less and percentage of sugar, greater.

This crop should be irrigated only enough to promote a uniform healthy growth.

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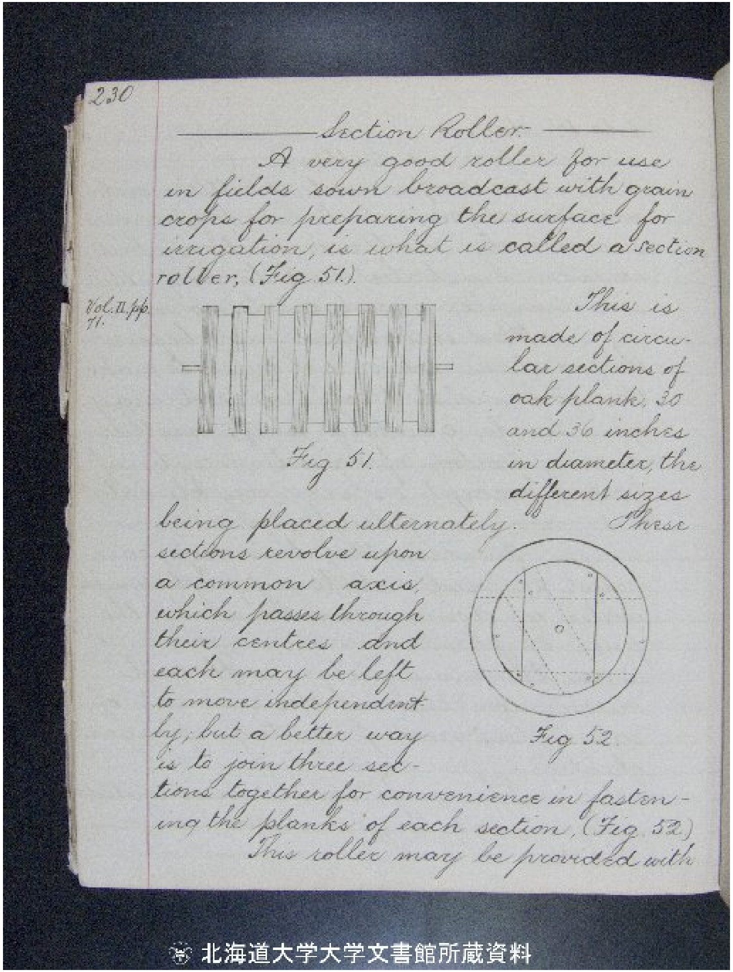

230

Vol. II pp. 71.

Section Roller.

A very good roller for use in fields sown broadcast with grain crops for preparing the surface for irrigation, is what is called a section roller, (Fig. 51).

Fig 51.

This is made of circular sections of oak plank, 30 and 36 inches in diameter, the different sizes being placed ulternately. These sections revolve upon a common axis, which passes through their centres and each may be left to move independent by; but a better way is to join three sections together for convenience in fastening the planks of each section, (Fig. 52)

Fig 52.

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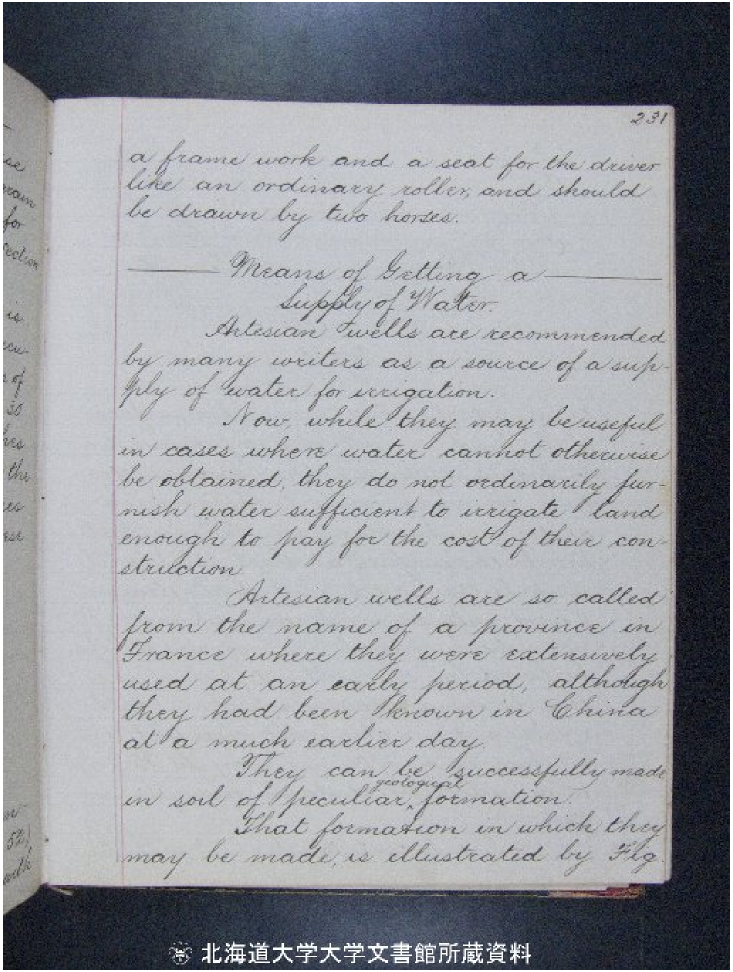

231

a frame work and a seat for the driver like an ordinary roller, and should be drawn by two horses.

Means of Getting a Supply of Water.

Artesian wells are recommended by many writers as a source of a supply of water for irrigation.

Now, while they may be useful in cases where water cannot otherwise be obtained, they do not ordinarily furnish water sufficient to irrigate land enough to pay for the cost of their construction.

Artesian wells are so called from the name of a province in France where they were extensively used at an early period, although they had been known in China at a much earlier day.

They can be successfully made in soil of peculiar geological formation.

That formation in which they may be made, is illustrated by Fig.

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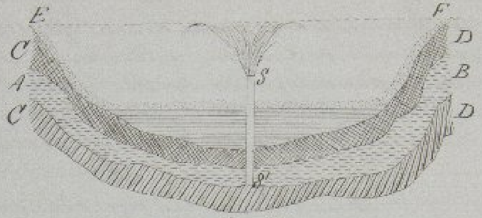

Fig. 53.

53 in which EF represents the surface of the land. CD are impervious strata between which is the pervious stratum AB which comes to the surface at the points A and B. Water, falling to the surface at these points, will sink to the lowest part of this stratum S' and will, in most cases, almost if not entirely fill it. If, now, a hole be bored in the valley till it strikes this pervious stratum which is full of water, the water will rise to the surface and ofttimes may be thrown a considerable distance above the surface.

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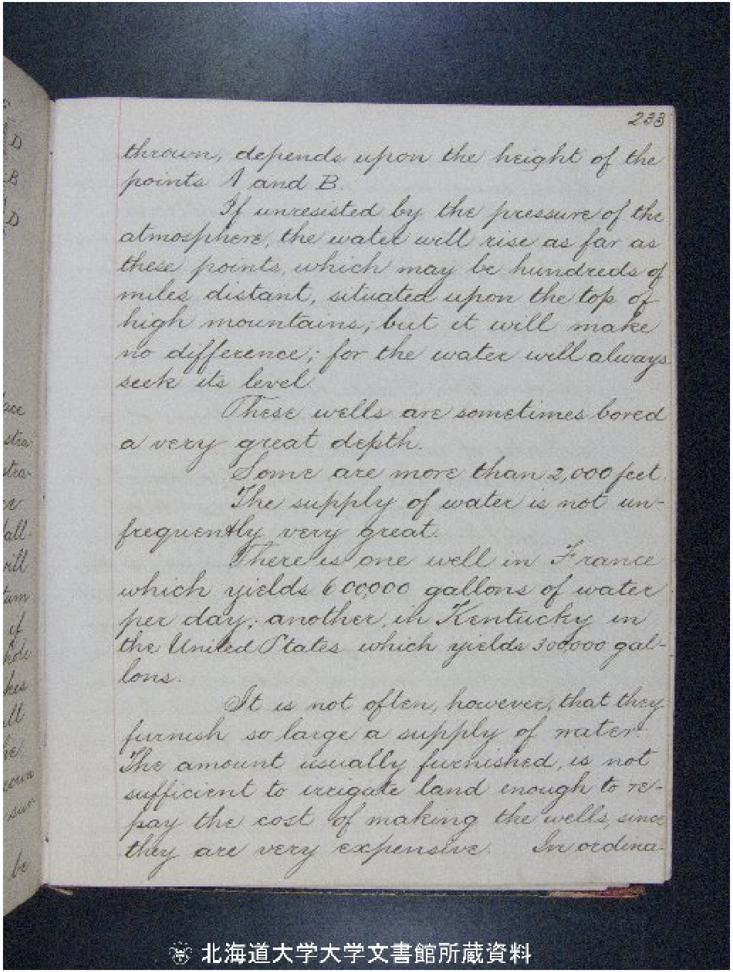
233

thrown, depends upon the height of the points A and B.

If unresisted by the pressure of the atmosphere, the water will rise as far as these points, which may be hundreds of miles distant, situated upon the top of high mountains; but it will make no difference; for the water will always seek its level.

These wells are sometimes bored a very great depth.

Some are more than 2,000 feet.

The supply of water is not un-frequently very great.

There is one well in France which yields 600,000 gallons of water per day, another in Kentucky in the United States which yields 300000 gallons.

It is not often, however, that they furnish so large a supply of mater. The amount usually furnished, is not sufficient to irrigate land enough to repay the cost of making the wells, since they are very expensive. In ordina-

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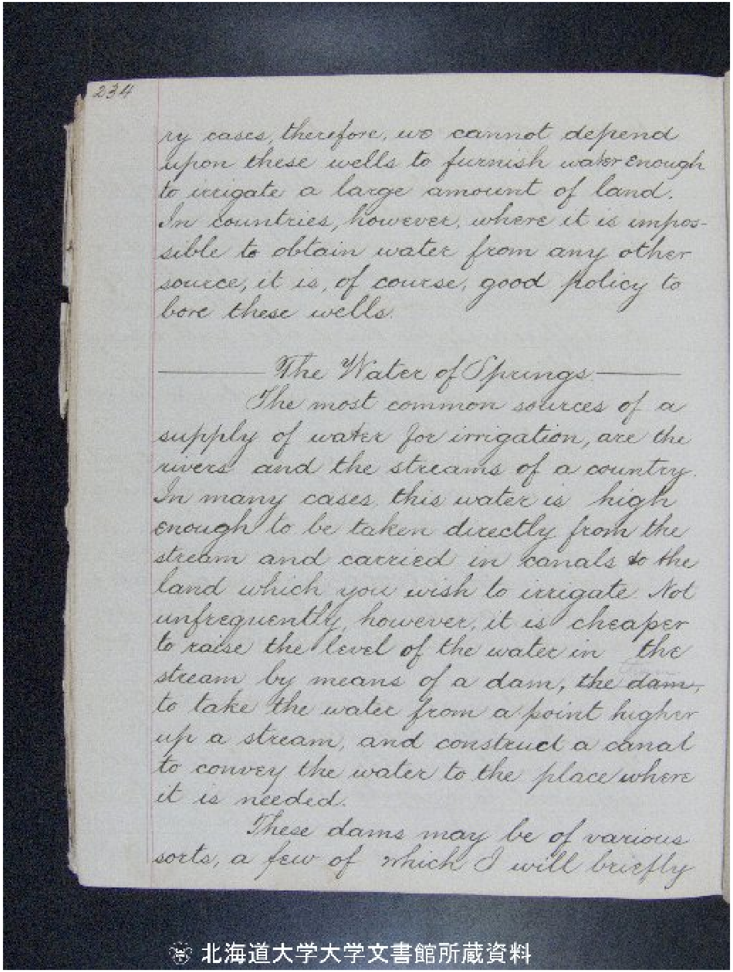
234

ry cases, therefore, we cannot depend upon these wells to furnish water enough to irrigate a large amount of land. In countries, however, where it is impossible to obtain water from any other source, it is, of course, good policy to bore these wells.

—— The Water of Springs ——

The most common sources of a supply of water for irrigation, are the rivers and the streams of a country. In many cases this water is high enough to be taken directly from the stream and carried in canals to the land which you wish to irrigate. Not unfrequently, however, it is cheaper to raise the level of the water in the stream by means of a dam, the dam, to take the water from a point higher up a stream, and construct a canal to convey the water to the place where it is needed.

These dams may be of various sorts, a few of which I will briefly

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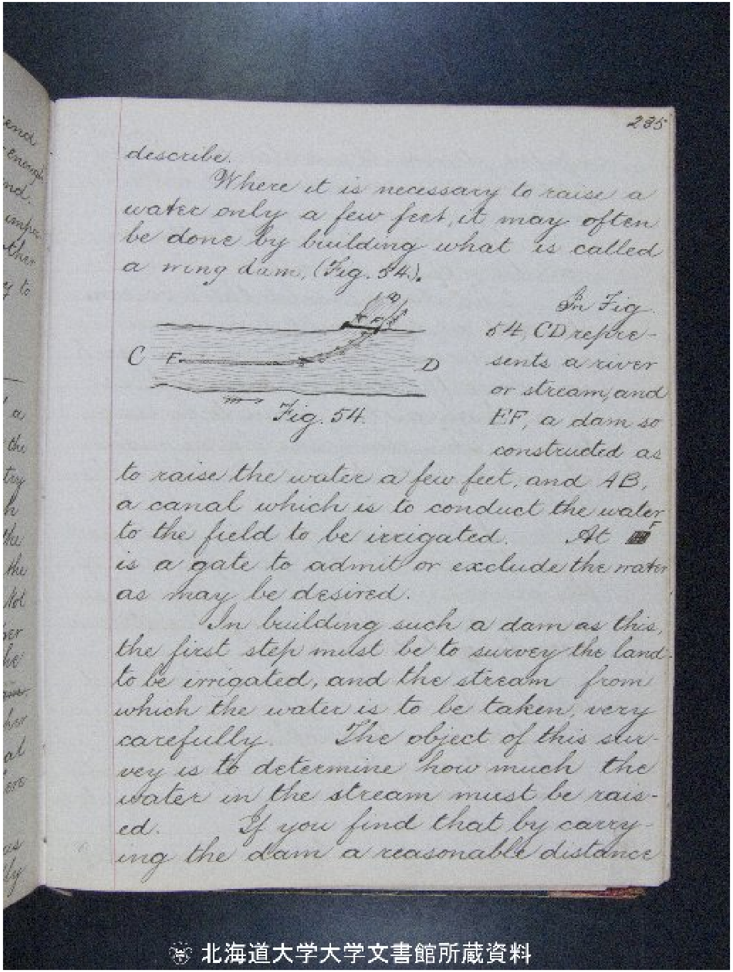

285

describe.
Where it is necessary to raise a water only a few feet, it may often be done by building what is called a wing dam. (Fig. 54).
In Fig. 54, CD represents a river or stream, and EF, a dam so constructed as to raise the water a few feet, and AB, a canal which is to conduct the water to the field to be irrigated. At F is a gate to admit or exclude the water as may be desired.
In building such a dam as this, the first step must be to survey the land to be irrigated, and the stream from which the water is to be taken, very carefully. The object of this survey is to determine how much the water in the stream must be raised. If you find that by carrying the dam a reasonable distance

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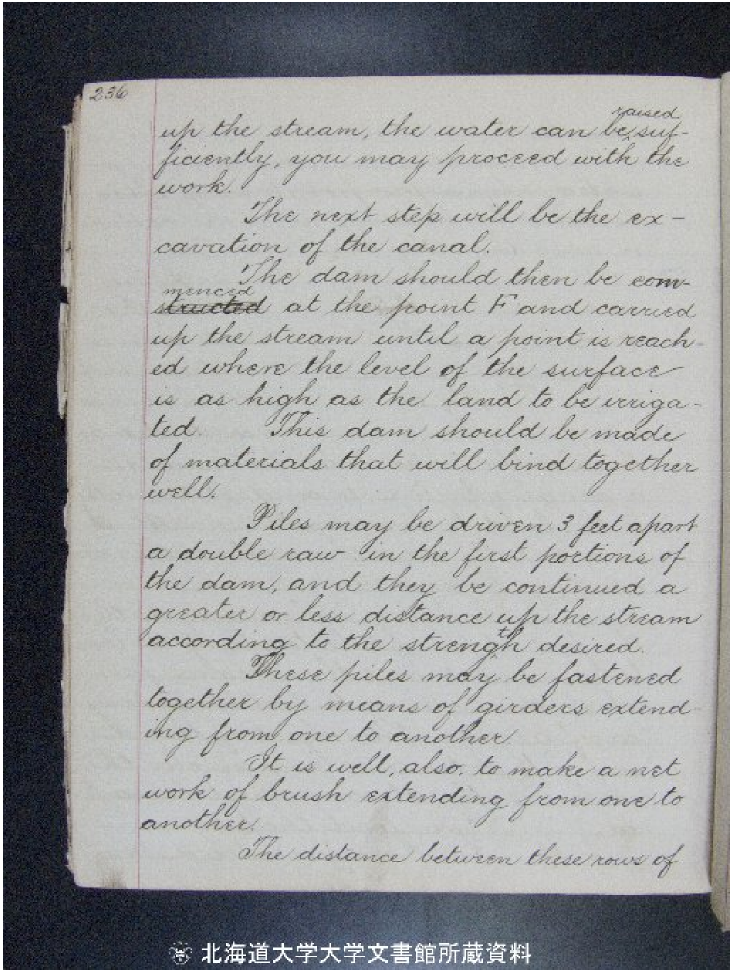
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up the stream, the water can be raised suf-
ficiently, you may proceed with the
work.
The next step will be the ex-
cavation of the canal.
The dam should then be com-
~~started~~ menced at the point F and carried
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Piles may be driven 3 feet apart
a double raw in the first portions of
the dam, and they be continued a
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These piles may be fastened
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The distance between these rows of

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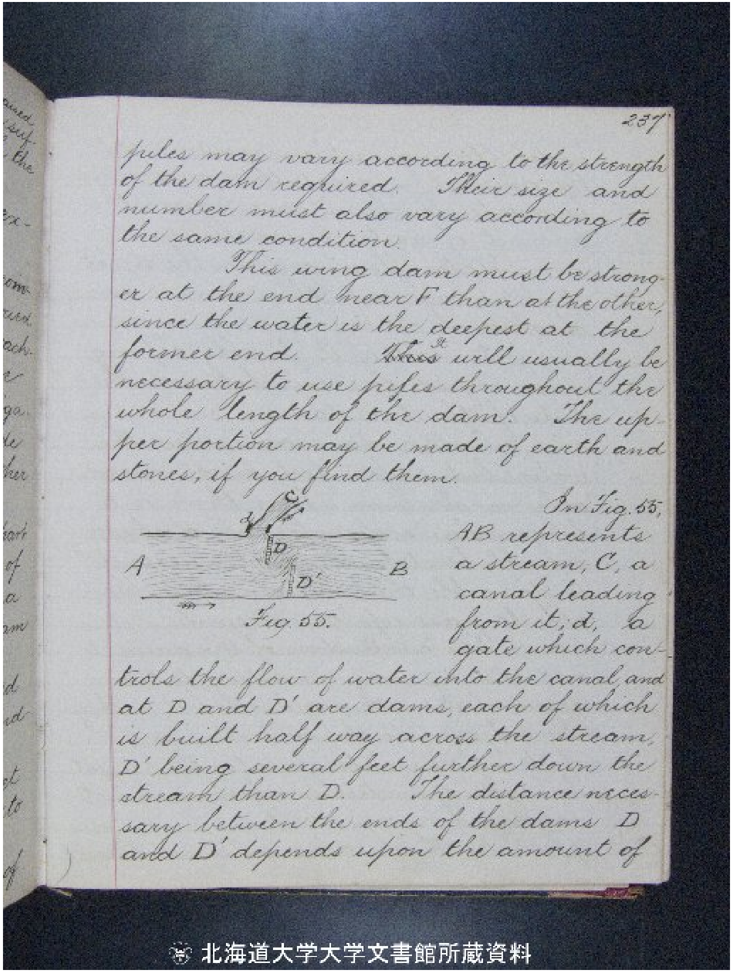

237

piles may vary according to the strength of the dam required. Their size and number must also vary according to the same condition.

This wing dam must be stronger at the end near F than at the other, since the water is the deepest at the former end. It will usually be necessary to use piles throughout the whole length of the dam. The upper portion may be made of earth and stones, if you find them.

In Fig. 55, AB represents a stream, C, a canal leading from it, d, a gate which controls the flow of water into the canal and at D and D' are dams, each of which is built half way across the stream, D' being several feet further down the stream than D. The distance necessary between the ends of the dams D and D' depends upon the amount of

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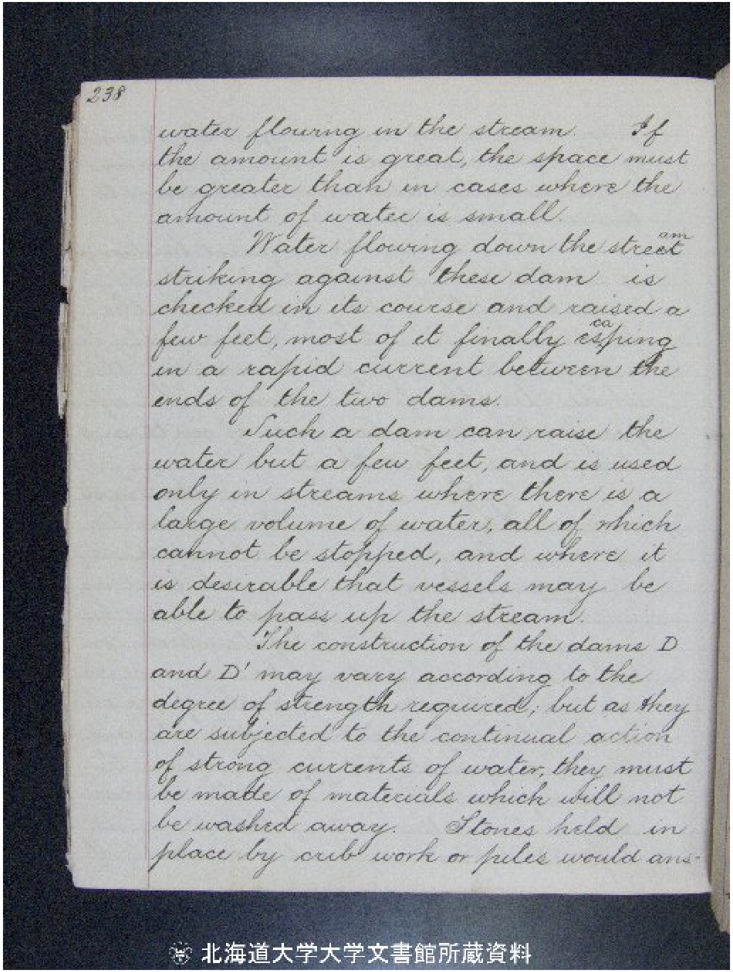

238

water flowing in the stream. If the amount is great, the space must be greater than in cases where the amount of water is small.

Water flowing down the stream striking against these dam is checked in its course and raised a few feet, most of it finally escaping in a rapid current between the ends of the two dams.

Such a dam can raise the water but a few feet, and is used only in streams where there is a large volume of water, all of which cannot be stopped, and where it is desirable that vessels may be able to pass up the stream.

The construction of the dams D and D' may vary according to the degree of strength required, but as they are subjected to the continual action of strong currents of water, they must be made of materials which will not be washed away. Stones held in place by crib work or piles would ans-

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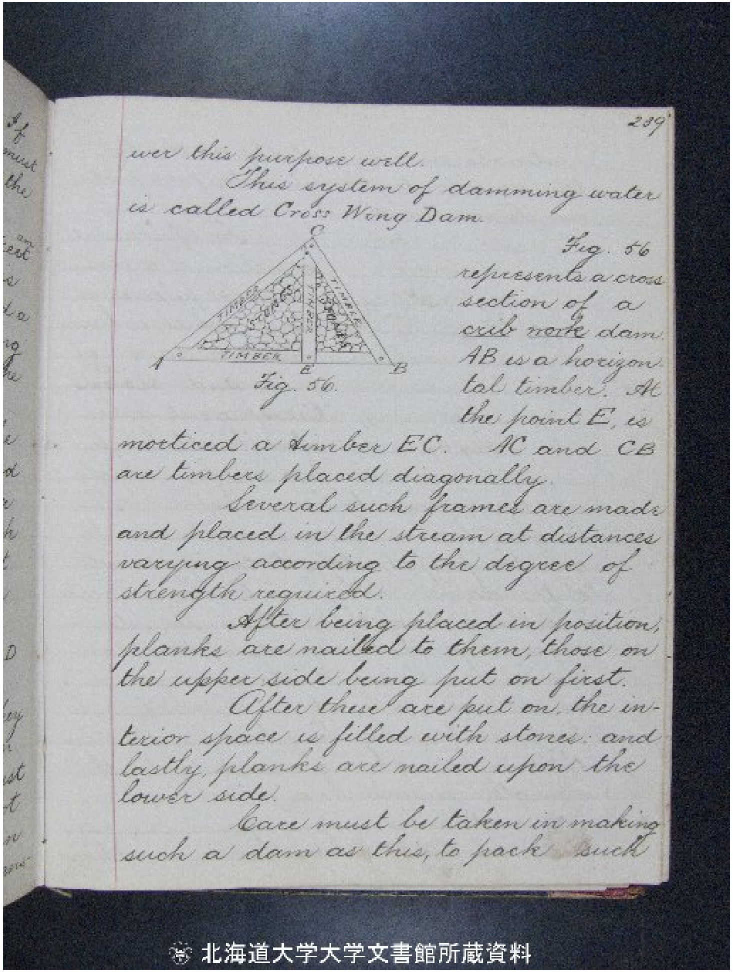

239

wer this purpose well.
This system of damming water is called Cross Wing Dam.

Fig. 56 represents a cross section of a crib work dam. AB is a horizontal timber. At the point E, is morticed a timber EC. AC and CB are timbers placed diagonally.

Several such frames are made and placed in the stream at distances varying according to the degree of strength required.

After being placed in position, planks are nailed to them, those on the upper side being put on first.

After these are put on, the interior space is filled with stones: and lastly, planks are nailed upon the lower side.

Care must be taken in making such a dam as this, to pack such

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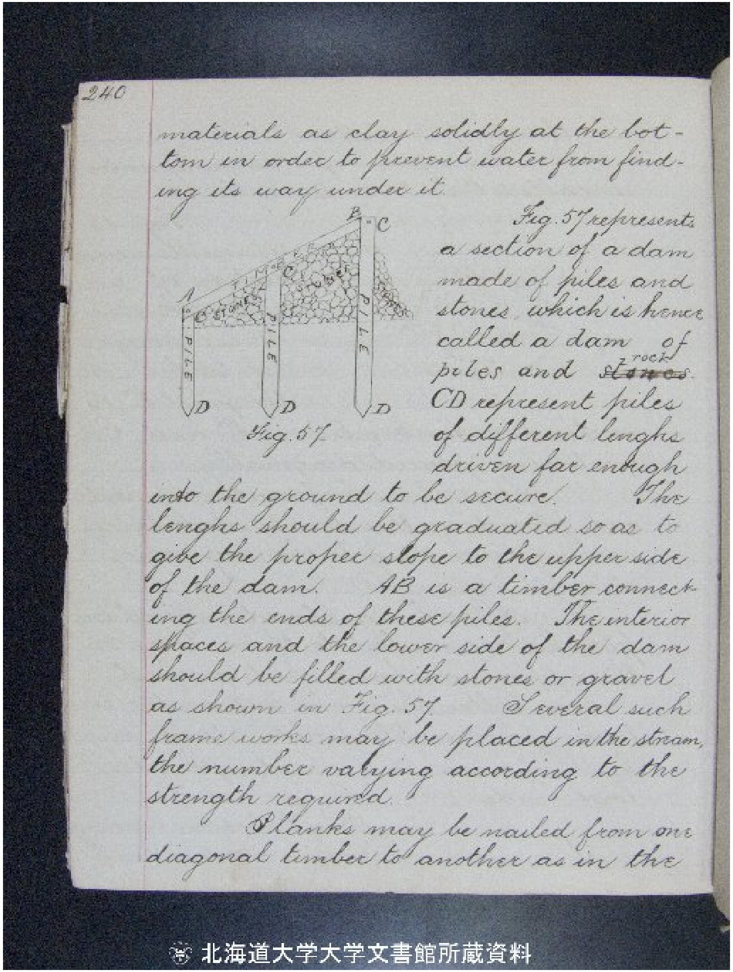

240

materials as clay solidly at the bottom in order to prevent water from finding its way under it.

Fig. 57 represents a section of a dam made of piles and stones which is hence called a dam of piles and ~~stones~~ rock. CD represent piles of different lenghs driven far enough into the ground to be secure. The lenghs should be graduated so as to gibe the proper slope to the upper side of the dam. AB is a timber connecting the ends of these piles. The interior spaces and the lower side of the dam should be filled with stones or gravel as shown in Fig. 57. Several such frame works may be placed in the stream, the number valying according to the strength required.

Blanks may be nailed from one diagonal timber to another as in the

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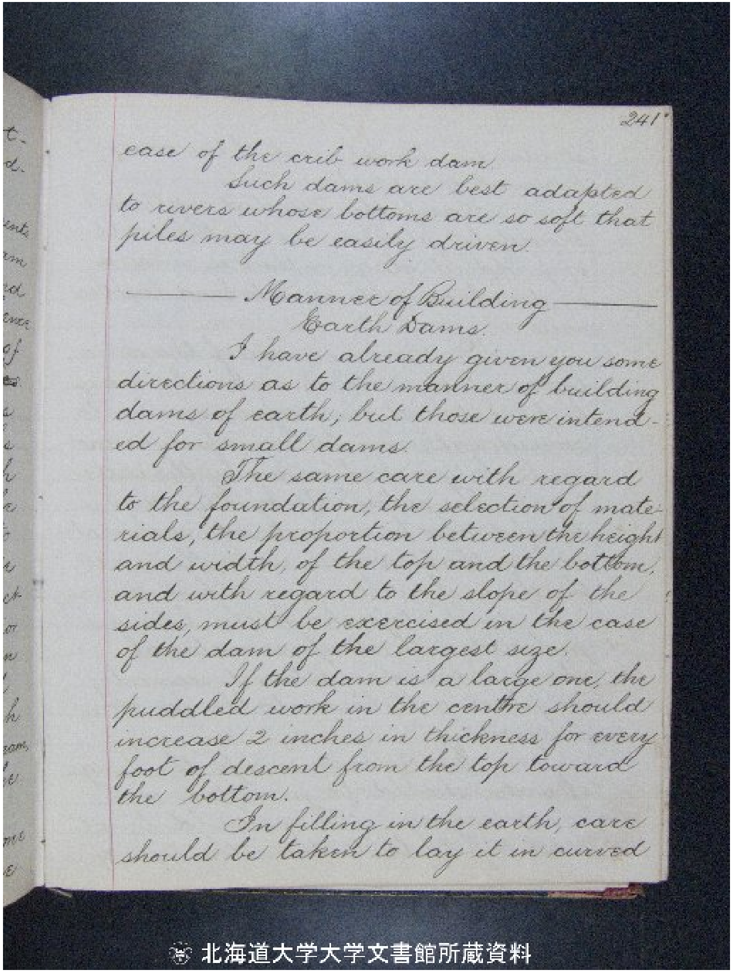
241

case of the crib work dam

Such dams are best adapted to rivers whose bottoms are so soft that piles may be easily driven.

Manner of Building Earth Dams.

I have already given you some directions as to the manner of building dams of earth, but those were intended for small dams.

The same care with regard to the foundation, the selection of materials, the proportion between the height and width, of the top and the bottom, and with regard to the slope of the sides, must be exercised in the case of the dam of the largest size.

If the dam is a large one, the puddled work in the centre should increase 2 inches in thickness for every foot of descent from the top toward the bottom.

In filling in the earth, care should be taken to lay it in curved

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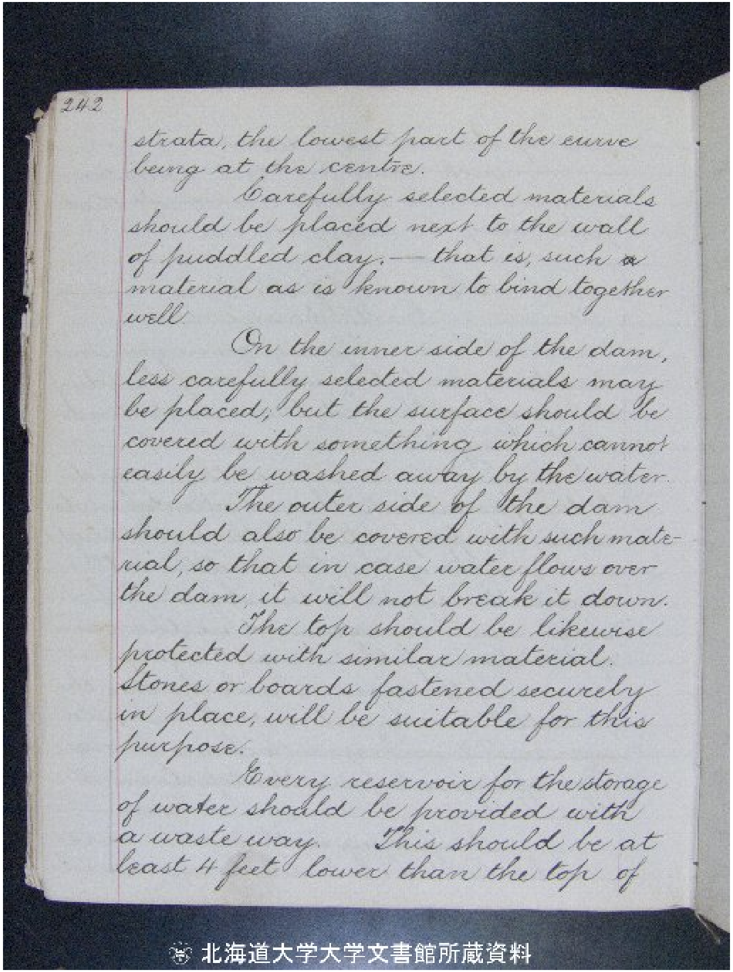

242

strata, the lowest part of the curve being at the centre.

Carefully selected materials should be placed next to the wall of puddled clay, — that is, such a material as is known to bind together well

On the inner side of the dam, less carefully selected materials may be placed, but the surface should be covered with something which cannot easily be washed away by the water.

The outer side of the dam should also be covered with such material, so that in case water flows over the dam it will not break it down.

The top should be likewise protected with similar material. Stones or boards fastened securely in place, will be suitable for this purpose.

Every reservoir for the storage of water should be provided with a waste way. This should be at least 4 feet lower than the top of

strata, the lowest part of the curve being at the centre.

Carefully selected materials should be placed next to the wall of puddled clay, — that is, such material as is known to bind together well.

On the inner side of the dam, less carefully selected materials may be placed, but the surface should be covered with something which cannot easily be washed away by the water.

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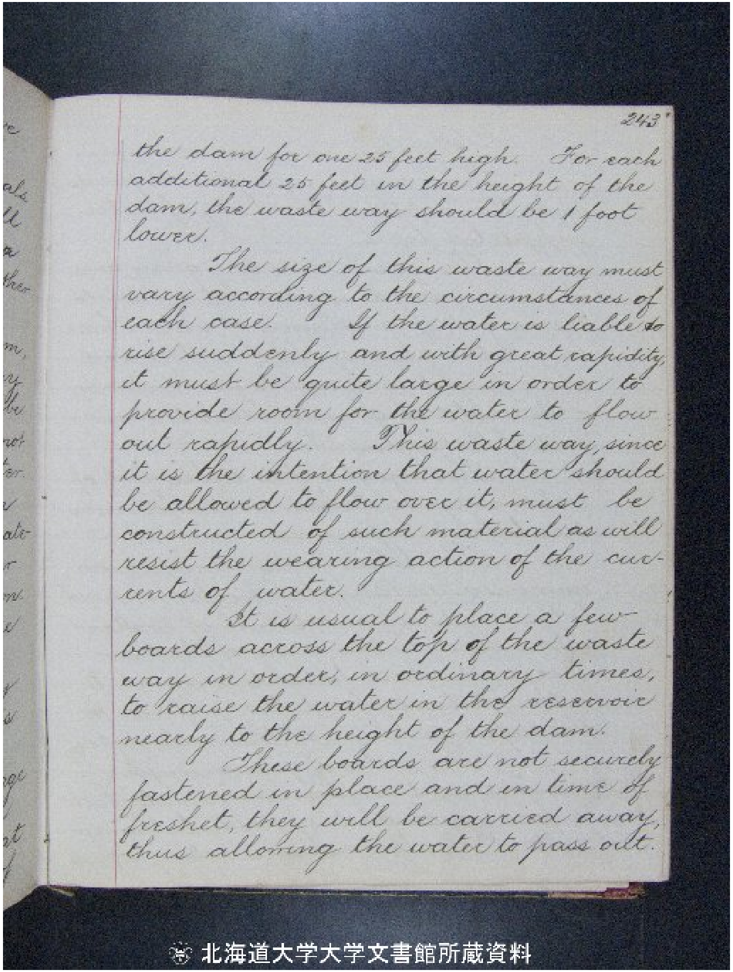
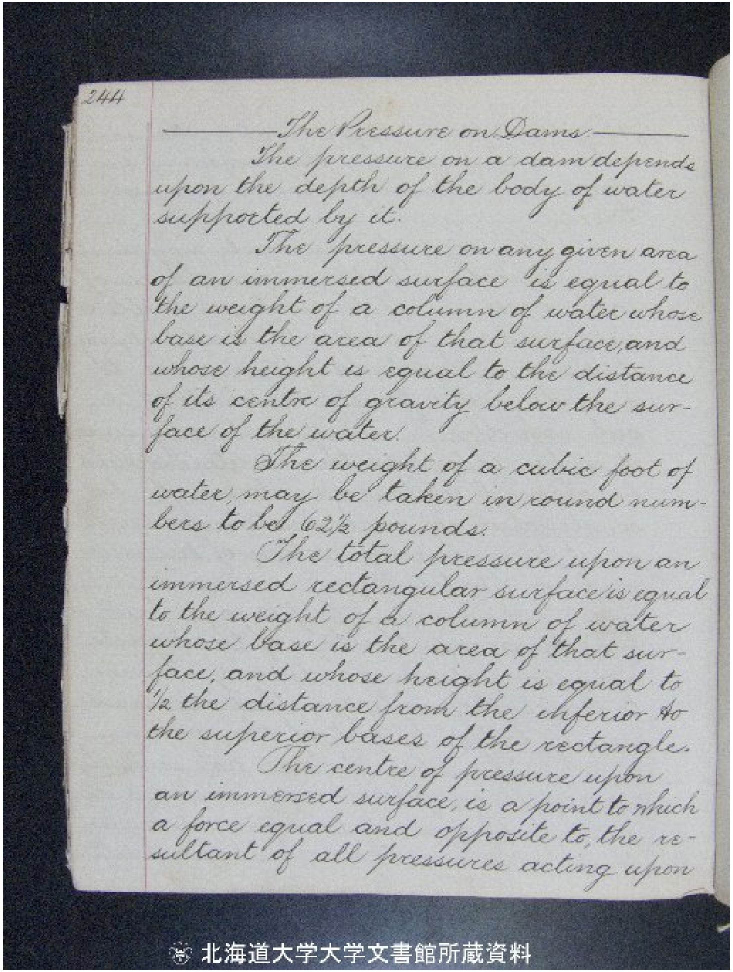


the dam for one 25 feet high. For each additional 25 feet in the height of the dam, the waste way should be 1 foot lower.

The size of this waste way must vary according to the circumstances of each case. If the water is liable to rise suddenly and with great rapidity, it must be quite large in order to provide room for the water to flow out rapidly. This waste way, since it is the intention that water should be allowed to flow over it, must be constructed of such material as will resist the wearing action of the currents of water.

It is usual to place a few boards across the top of the waste way in order, in ordinary times, to raise the water in the reservoir nearly to the height of the dam.

These boards are not securely fastened in place and in time of freshet, they will be carried away, thus allowing the water to pass out.


244

The Pressure on Dams

The pressure on a dam depends upon the depth of the body of water supported by it.

The pressure on any given area of an immersed surface is equal to the weight of a column of water whose base is the area of that surface, and whose height is equal to the distance of its centre of gravity below the surface of the water.

The weight of a cubic foot of water, may be taken in round numbers to be 62½ pounds.

The total pressure upon an immersed rectangular surface is equal to the weight of a column of water whose base is the area of that surface, and whose height is equal to ½ the distance from the inferior to the superior bases of the rectangle.

The centre of pressure upon an immersed surface, is a point to which a force equal and opposite to, the resultant of all pressures acting upon

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The weight of a cubic foot of water, may be taken in round numbers to be 6 1/2 pounds.

The total pressure upon an immersed rectangular surface is equal to the weight of a column of water whose base is the area of that surface, and whose height is equal to 1/2 the distance from the inferior to the superior bases of the rectangle.

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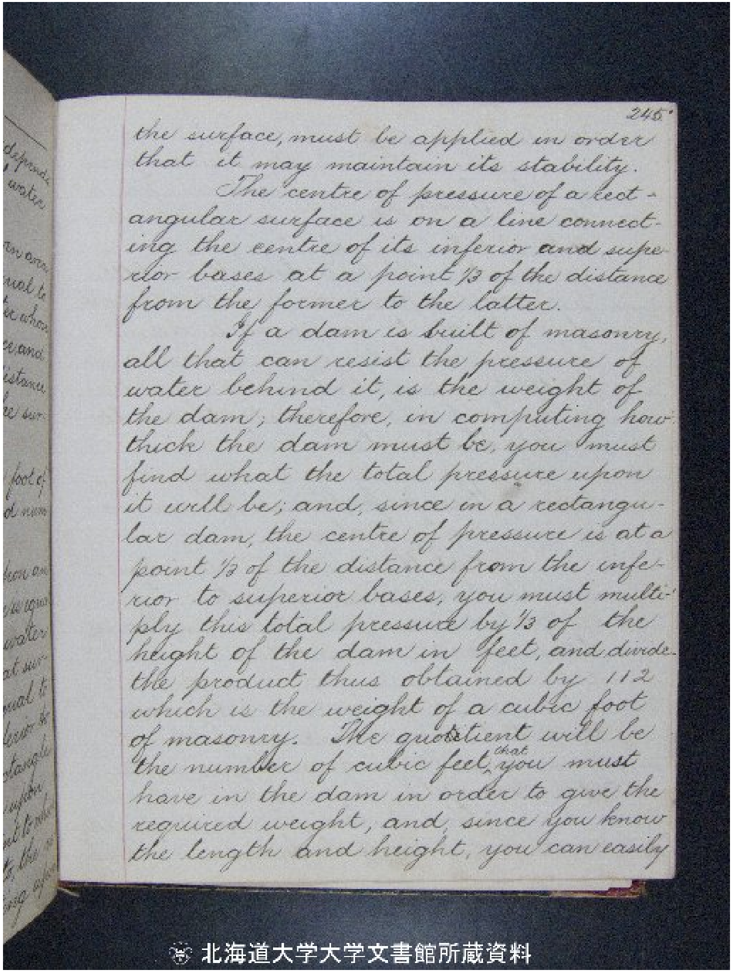

246

the surface, must be applied in order that it may maintain its stability.

The centre of pressure of a rectangular surface is on a line connecting the centre of its inferior and superior bases at a point ⅓ of the distance from the former to the latter.

If a dam is built of masonry, all that can resist the pressure of water behind it, is the weight of the dam; therefore, in computing how thick the dam must be, you must find what the total pressure upon it will be; and, since in a rectangular dam, the centre of pressure is at a point ⅓ of the distance from the inferior to superior bases, you must multiply this total pressure by ⅓ of the height of the dam in feet, and divide the product thus obtained by 112 which is the weight of a cubic foot of masonry. The quotient will be the number of cubic feet that you must have in the dam in order to give the required weight, and since you know the length and height, you can easily

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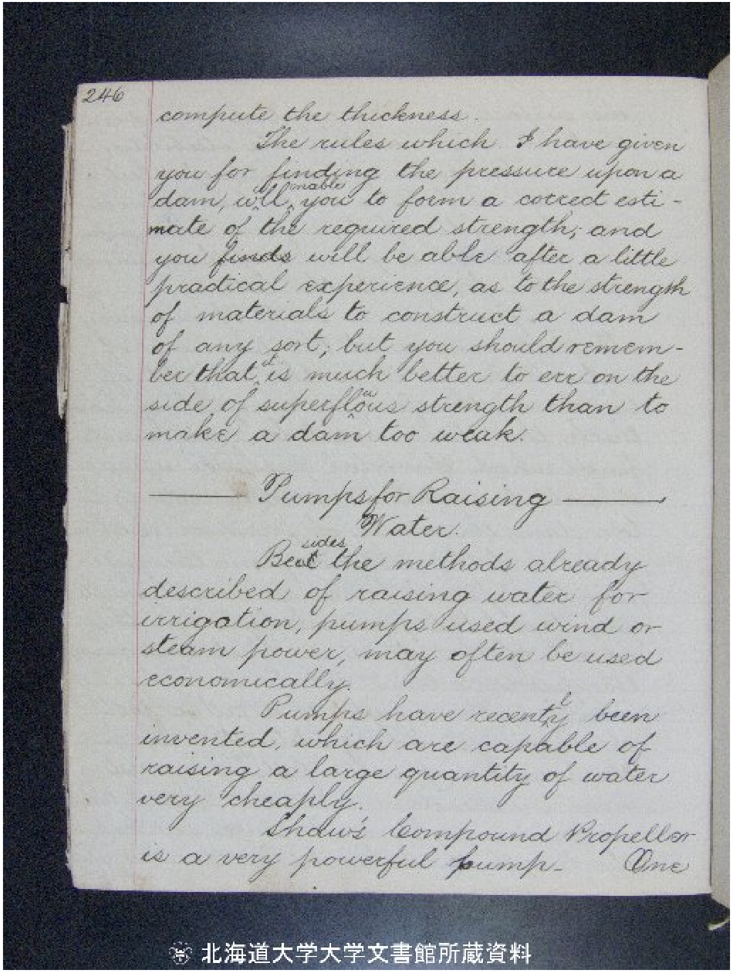
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compute the thickness.
The rules which I have given you for finding the pressure upon a dam, will enable you to form a correct estimate of the required strength; and you finds will be able after a little practical experience, as to the strength of materials to construct a dam of any sort; but you should remember that it is much better to err on the side of superflous strength than to make a dam too weak.
Pumps for Raising Water.
Besides the methods already described of raising water for irrigation, pumps used wind or steam power, may often be used economically.
Pumps have recently been invented, which are capable of raising a large quantity of water very cheaply.
Shaw's Compound Propellor is a very powerful pump. One

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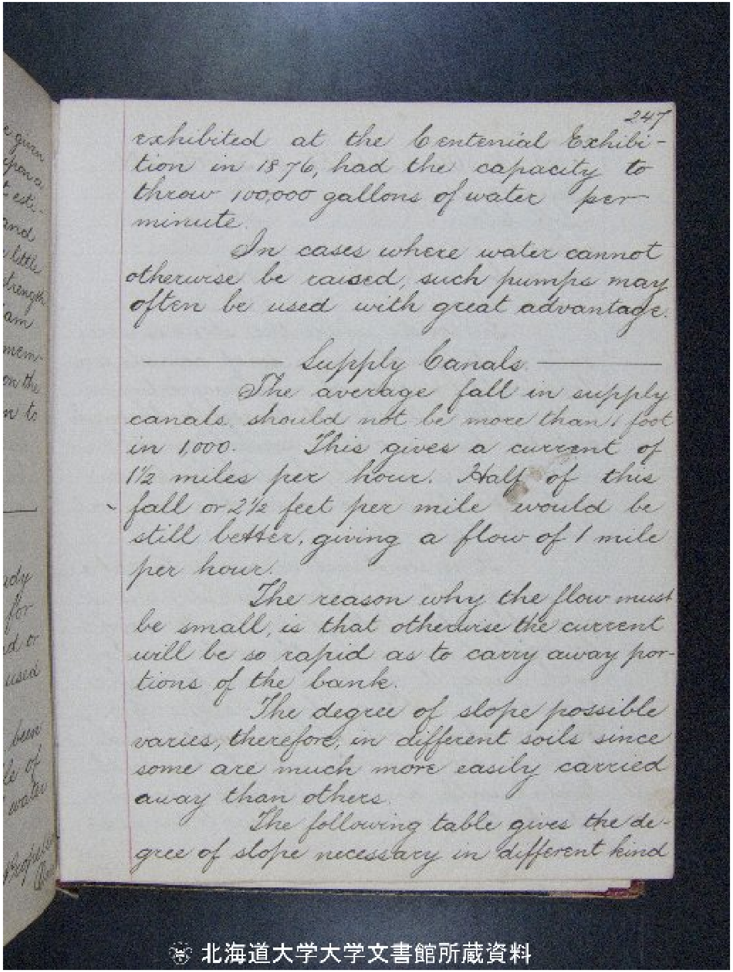

247

exhibited at the Centenial Exhibition in 1876, had the capacity to throw 100,000 gallons of water per minute.

In cases where water cannot otherwise be raised, such pumps may often be used with great advantage.

Supply Canals.

The average fall in supply canals should not be more than 1 foot in 1000. This gives a current of 1½ miles per hour. Half of this fall or 2½ feet per mile would be still better, giving a flow of 1 mile per hour.

The reason why the flow must be small, is that otherwise the current will be so rapid as to carry away portions of the bank.

The degree of slope possible varies, therefore, in different soils since some are much more easily carried away than others.

The following table gives the degree of slope necessary in different kind

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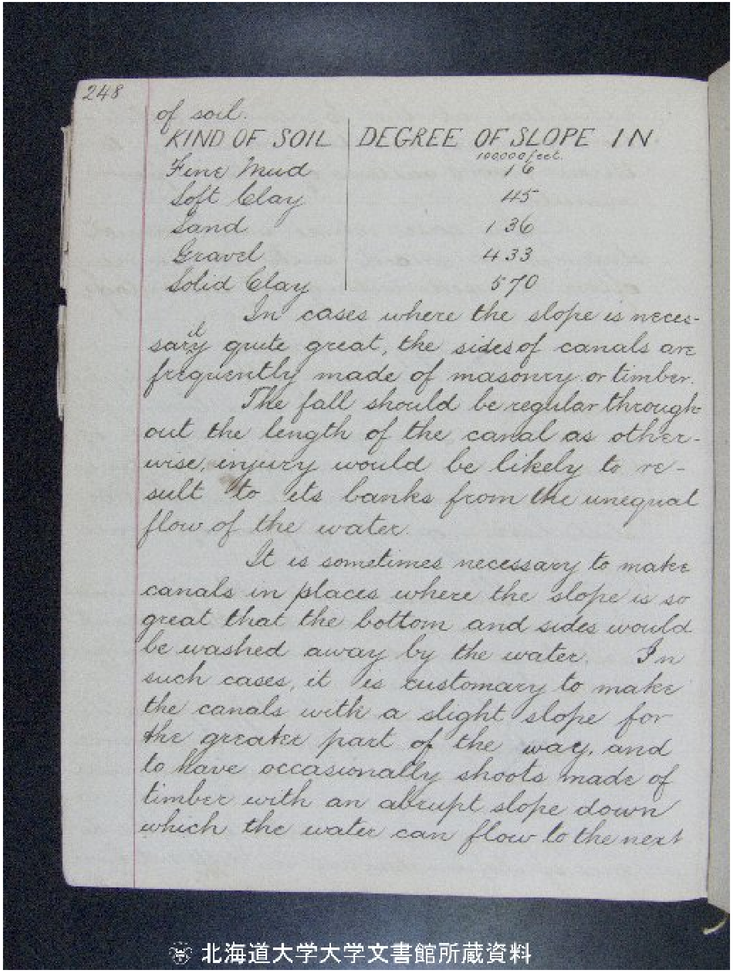
248

of soil.

KIND OF SOIL	DEGREE OF SLOPE IN 100000 feet.
Fine mud	16
Soft Clay	45
Sand	136
Gravel	433
Solid Clay	570

In cases where the slope is necessary it quite great, the sides of canals are frequently made of masonry or timber.

The fall should be regular through out the length of the canal as otherwise, injury would be likely to result to its banks from the unequal flow of the water.

It is sometimes necessary to make canals in places where the slope is so great that the bottom and sides would be washed away by the water. In such cases, it is customary to make the canals with a slight slope for the greater part of the way, and to have occasionally shoots made of timber with an abrupt slope down which the water can flow to the next

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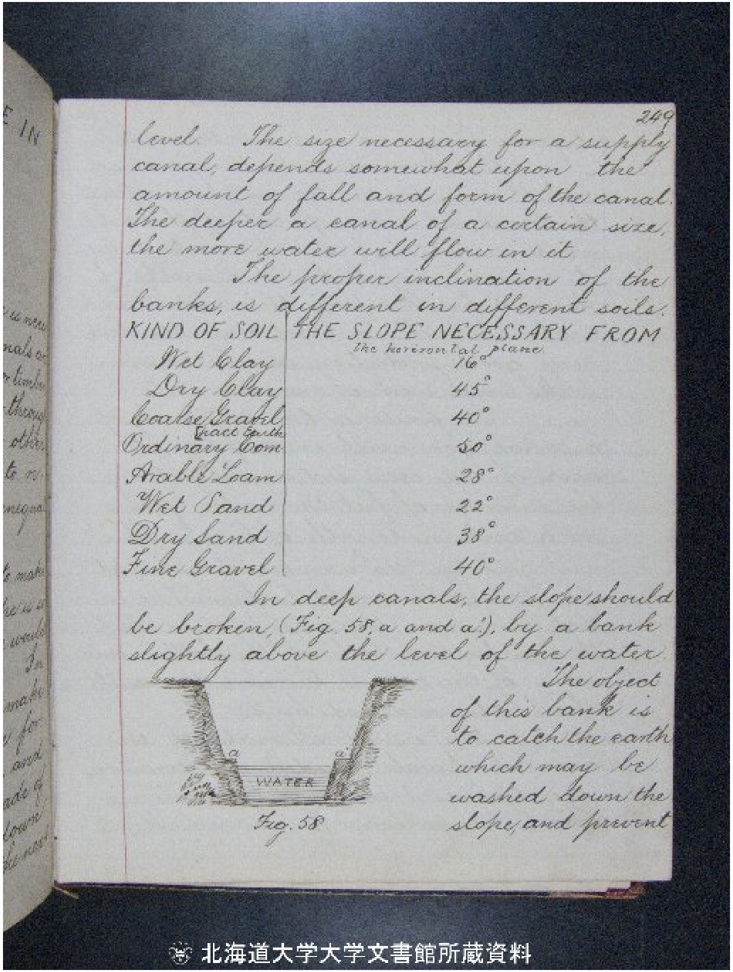

249

level. The size necessary for a supply canal, depends somewhat upon the amount of fall and form of the canal. The deeper a canal of a certain size, the more water will flow in it.

The proper inclination of the banks, is different in different soils.

KIND OF SOIL	THE SLOPE NECESSARY FROM the horizontal plane
Wet Clay	16°
Dry Clay	45°
Coarse Gravel	40°
Ordinary Compact Earth	50°
Arable Loam	28°
Wet Sand	22°
Dry Sand	38°
Fine Gravel	40°

In deep canals, the slope should be broken, (Fig. 58, a and a'), by a bank slightly above the level of the water. The object of this bank is to catch the earth which may be washed down the slope, and prevent

Fig. 58

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Fig.58

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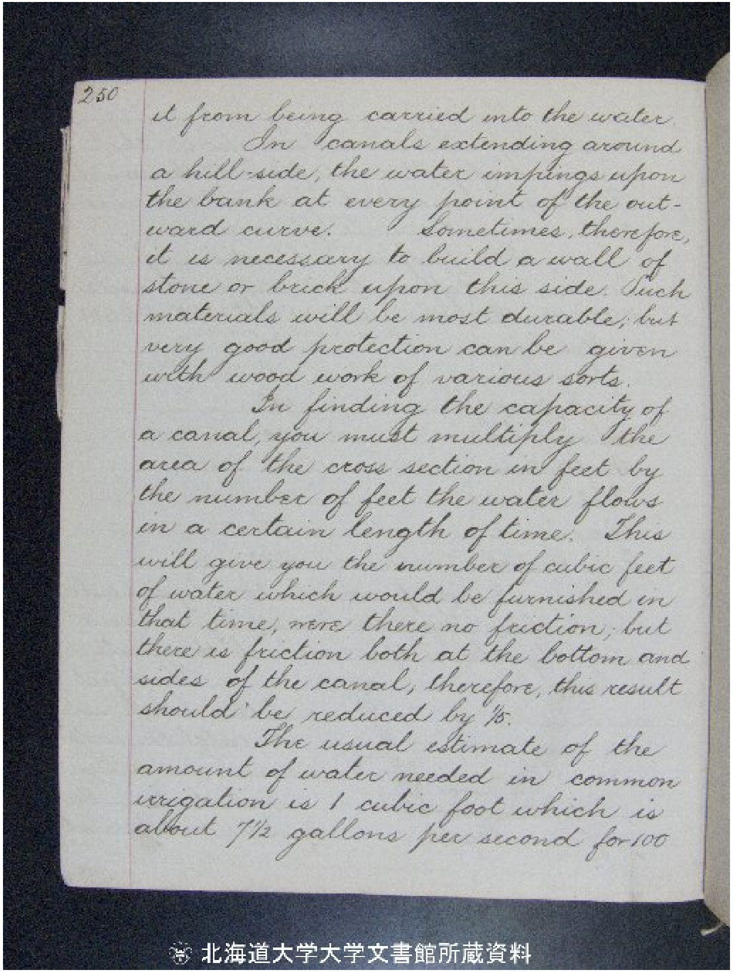
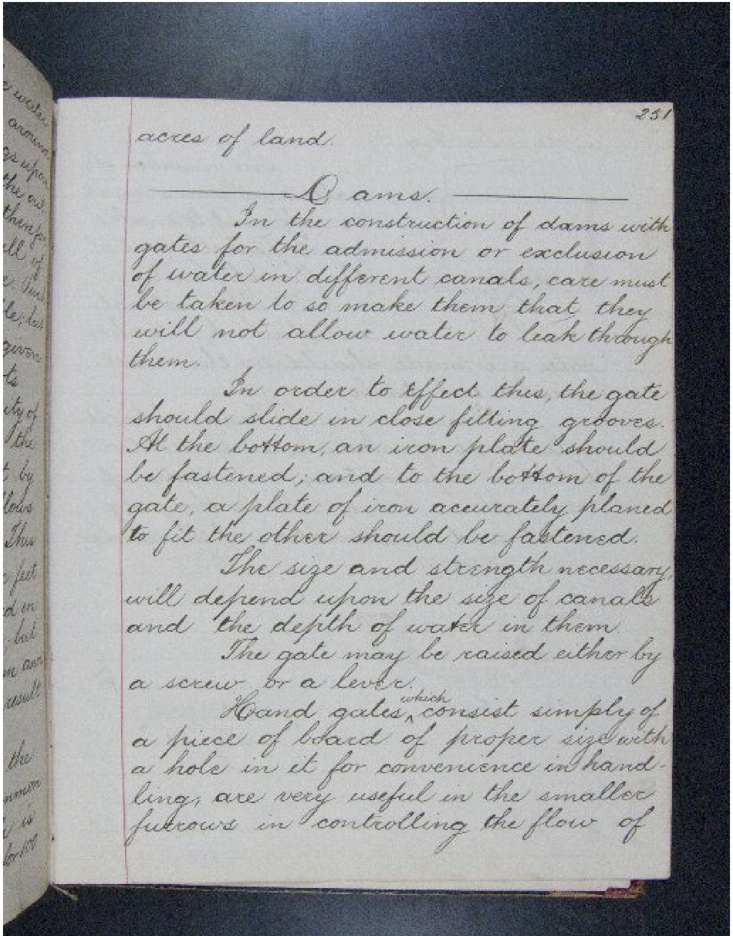


it from being carried into the water.

In canals extending around a hill-side, the water impings upon the bank at every point of the outward curve. Sometimes, there fore, it is necessary to build a wall of stone or brick upon this side. Such materials will be most durable; but very, good protection can be given with wood work of various sorts.

In finding the capacity of a canal, you must multiply the area of the cross section in feet by the number of feet the water flows in a certain length of time. This will give you the number of cubic feet of water which would be furnished in that time, mere there no friction; but there is friction both at the bottom and sides of the canal, therefore, this result should be reduced by 1/5.

The usual estimate of the amount of water needed in common irrigation is 1 cubic foot which is about 7 1/2 gallons per second for 100



231

acres of land.

Dams.

In the construction of dams with gates for the admission or exclusion of water in different canals, care must be taken to so make them that they will not allow water to leak through them.

In order to effect this, the gate should slide in close fitting grooves. At the bottom, an iron plate should be fastened; and to the bottom of the gate, a plate of iron accurately planed to fit the other should be fastened.

The size and strength necessary, will depend upon the size of canals and the depth of water in them.

The gate may be raised either by a screw or a lever.

Hand gates which consist simply of a piece of board of proper size with a hole in it for convenience in handling, are very useful in the smaller furrows in controlling the flow of

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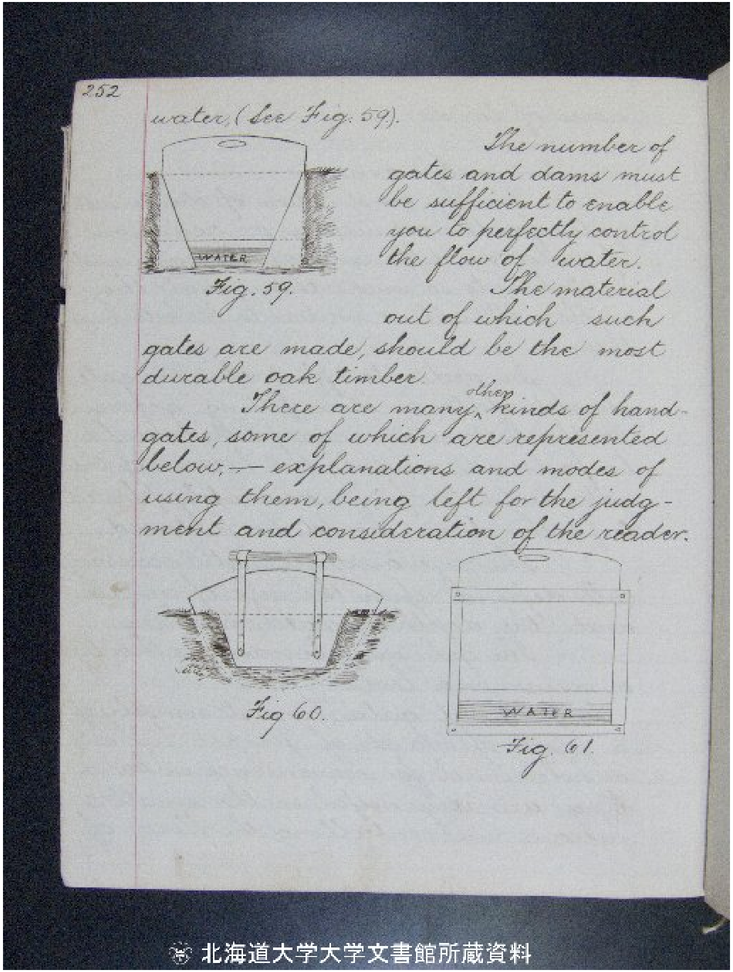
252

water, (See Fig. 59).

The number of gates and dams must be sufficient to enable you to perfectly control the flow of water.

The material out of which such gates are made, should be the most durable oak timber.

There are many other kinds of hand-gates, some of which are represented below, — explanations and modes of using them, being left for the judgment and consideration of the reader.

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Fig.60

Fig.61