WORK OF R.E. IN THE EUROPEAN WAR, 1914–19

WATER SUPPLY—EGYPT AND PALESTINE

THE

WORK OF THE ROYAL ENGINEERS

IN THE

EUROPEAN WAR, 1914–19.

WORK IN THE FIELD IN OTHER THEATRES OF WAR.

EGYPT AND PALESTINE.—WATER-SUPPLY.

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THE WORK OF THE ROYAL ENGINEERS IN THE EUROPEAN WAR, 1914-1919.

EGYPT AND PALESTINE.—WATER-SUPPLY.

CHAPTER I.

EGYPT, 1914–1918.

(*See Map* I.).

1. *Introduction.*—Egypt proper, the Nile Delta, draws all its water from that river. The delta is covered by a system of irrigation canals which carry the Nile water over the whole area, but, these canals are open to pollution from many sources, and are used as waterways for general traffic, with the result that the water is unfit for human consumption until purified. Even for washing purposes this water is condemned owing to the presence of bilharzia.

The Egyptian fellaheen appear to prefer the muddy and polluted liquid to pure water, and wash in it and drink of it after their ablutions, but in towns of any importance, waterworks have been installed where the water is filtered and purified before distribution.

Within the area indicated on *Map* I., pure water can be got from deep wells sunk into a layer of sand which lies about 150 feet below the general level of the delta. It is interesting to note that the water in these wells rises from the lower stratum and stands in the wells at about the level of the surface water of the neighbouring land. Thus, close alongside each other, there may be two wells, one a few feet deep collecting the impure subsoil water and a deep well tapping pure water lying in lower levels, but the surface of the water in both is at the same level.

Nearly all the land in the delta is irrigated, heavily cultivated, and swarms with mosquitoes. The soil is unsuitable for encampments. It has, therefore, been necessary to locate troops in Egypt as far as possible on vacant desert land. The largest concentrations of troops have naturally been in the vicinity of the principal towns :—Cairo, Alexandria, Ismailia, Port Said and Suez, where extensions of the town water-supply have generally met the requirements of the troops. The local water companies have in these cases given every possible assistance to the Army and have carried out considerable works. It has, however, also been necessary to form camps in Egypt outside the areas served by water companies (and even to supplement town supplies).

Three sources of supply were employed :—Deep well bores where possible ; Nile water from the irrigation canals where boring was not likely to be successful ; and condensers where all other sources failed.

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2. *Early Work.*—At Mena Camp, near the great Pyramids of Gizeh, up to 30,000 men were supplied with drinking and washing water from a 6-in. tube well sunk in the camp to a depth of about 120 ft., and water for horses was supplied from a shallow well alongside.

At Wardan, 40 miles north west of Cairo, on the edge of the Desert of Khanka ; 20 miles north east of Cairo at Tel-el-Kebir ; and at Belbeis, tube wells averaging 100 ft. to 150 ft. in depth have been used to supply troops. At Aboukir, north west of Alexandria, but beyond the limits of its water supply system, at Abu Sueir, and along the Suez Canal, it has been found necessary to instal filter plants, and purify water from the Sweet Water Canals. At Moascar Camp near Ismailia, the town supply has been supplemented by the provision of a new filter specially for use of the camp. A description of this filter will be found in *R.E. Professional Papers, 4th Series, Paper No.* 9.

A very great deal of work has been done in Egypt since 1914. The most important and permanent work carried out by the Army is at Alexandria and at the various aerodromes. Of these the following deserve special mention :—

(i.) Sidi Bishr. Water supply (10,000 gals.), night storage.
(ii.) Wardian. No. 2 Balloon Station.
(iii.) Mex A.O.D. 37,500 gals., reinforced concrete reservoir.
(iv.) Aboukir.
(v.) Amria.
(vi.) El Rimal and Abu Sueir.
(vii.) El Khanka.

3. *Condensers.*—At Sollum and Mersa Matruh on the Mediterranean coast, west of the delta, condensing machinery was erected to provide water to the garrisons.

While on the subject of condensers, it may be mentioned that during the war the following condensers were erected :—

Location.	Capacity in gals. per day.	Gals. per ton of coal consumed.
Mersa Matruh	6,720	—
Sollum	22,000	2,240
Quarantine	11,000	2,100
Mohamdiya	22,000	—

4. *Drainage.*—Connected closely with the provision of water was the disposal of sullage water in standing camps. Experience in Egypt has shown clearly, that even in what appears to be sandy desert land, it is no simple matter to arrange for the disposal of sullage water. The ground soon becomes waterlogged and sodden, and eventually it becomes necessary to provide a proper system of drainage.

Soakage pits of nearly every imaginable type were tried, but were always found unsatisfactory, except in camps near Alexandria. Here, in some camps, rough stone-lined wells sunk to the permanent level of the sub-soil water, which circulates freely in a stratum of sand, have proved satisfactory. Under these conditions, sullage water can be absorbed into the water lying under the surface, to an almost unlimited extent.

In every case, however, it was necessary to provide grease traps formed of a frame with a bottom of wire netting and filled with hay, or something of that kind, to intercept the grease.

In nearly all other standing camps, it was found necessary to connect the camps to an existing drainage system, or to provide a self-contained temporary system of drains, taking the sullage water away from the site of the camp.

CHAPTER II.

SUEZ CANAL AREA.

(*See Map* II.).

5. *Water Sources.*—The only reliable source of drinking water in the Suez Canal area is the Sweet Water Canal which flows from the Nile to Ismailia and thence south to Suez and north to Port Said. This water is, however, unfit for consumption unless properly treated and purified.

It is true that on the east side of the canal beyond Suez, the " Ayun Musa " or wells of Moses, yield a supply of water, but this is brackish and unpalatable. There are also a few scattered wells or " birs " of brackish water in the Sinai Desert, some rock cisterns in the Sinai foothills, and, in the winter, some pools in the beds of water courses or wadis, while further north, in the Katia oasis, water of unquestionable quality can always be got from shallow wells. A scattered Bedouin population normally lives on these supplies, and the Turkish Army which attempted the invasion of Egypt and reached the east bank of the Suez Canal in February, 1915, managed to subsist on them, but as supplies for an army they are inadequate.

During the period August, 1914 to November, 1915, the line of the Suez Canal was held by a force which seldom exceeded two infantry divisions. Posts were established on the east bank of the canal, covering bridges and ferries, from Suez to Port Said. Defence works had been constructed on the west bank. Reserves were held at Ismailia where they could be transferred by rail to any threatened point. The canal was patrolled by armed craft, and its eastern banks by the troops.

The troops relied for water on the water-supply system which had been installed by the Suez Canal Company at Suez, Ismailia, and Port Said, for the inhabitants of these towns ; and for shipping going through the canal.

This water was distributed to the various garrisons on the banks of the canal by water boats and barges, collected from the ports and by the Suez Canal Company's water tank steamer *Progrès*. At all posts, reservoirs or tanks were provided to store two days' supply of drinking water.

The following unimportant supplies to the east bank of the canal also existed from pre-war times :—

The quarantine station opposite Ismailia, drew filtered water through a 2-in. syphon under the Canal from that town, and the quarantine station at Kantara drew unfiltered water in a similar way direct from the Sweet Water Canal.

6. *Supply for Defence System.*—In November, 1915, a new situation developed.

The G.O.C. Force in Egypt, who had accompanied the Secretary of State for War on a tour to the Gallipoli front and Greece, cabled to Egypt from Athens on the 16th November that :—

> "The defence of the Canal must be taken up seriously and in depth. In anticipation, stores and materials for water-supply and roads, for trenches for either forward line trenches or posts, as may be decided after study of problem should be ordered. The work should not be delayed for want of material."

In the first instance, no information was available as to what number of troops would be allotted to the defences, nor had any line of defence been selected. In forming preliminary estimates of work and material required it was therefore necessary to assume a great deal, and acting on these assumptions, to order and purchase engineer stores and plant, and to commence work as far as was possible, in anticipation of probable requirements.

It was considered that whatever scheme of defence the Army detailed to hold the Suez Canal might adopt, certain of the existing bridge-head posts must develop into local bases from which water supply systems, roads and light railways, would lead eastward into the defences, and it was evident that the existing water supply system would be inadequate.

If, by sinking deep tube wells in the area, drinkable water in sufficient quantity could be obtained, this was obviously the simplest and most economical plan. Experimental borings were made at selected posts east of the canal. Although the wells were sunk to a depth of 300 ft., nothing but salt water was obtained. Later, similar borings, made in the Romani-Mohamdiya region, produced like results. The whole area appears to be saturated with salt to great depth.

When these borings were undertaken, it was realized that it was improbable that any satisfactory subsoil water-supplies would be met. It was therefore decided to proceed at once to develop the only existing known source of supply, the Sweet Water Canal. At Ferdan and Ballah, new branch canals were excavated to bring the sweet water to the west bank of the Maritime Canal.

The Cairo Waterworks Company undertook the design, construction and erection on site of mechanical filters, design of settling tanks, and the erection of engines necessary for installations for purifying the water. At the same time it asked for and got a quittance relieving it of all responsibility in case of infringement of patent rights, should parts be introduced in the design which were already protected by patent.

The Jewel Filter Company, whose patents were infringed, subsequently courteously waived their rights to any royalties they might have claimed.

Contracts were placed for the construction of ferro-concrete reservoirs at selected points on the east bank whence water, filtered on the west bank, could be pumped to the line of defence.

All pumps and engines available in Egypt, which were suitable, were brought up, and orders were cabled to England for further supplies.

The stock of piping available in the local market was small, as the extension of town supplies in Egypt for the Army had exhausted stocks.

On the 29th November, 1915, a final demand for 280 miles of piping 6 in. to 1 in. was cabled to England.

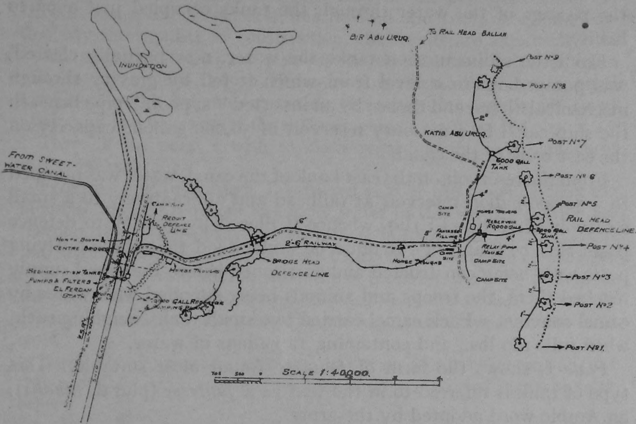
For the supply of the quarantine station beyond the southern end of the Suez Canal, a plant for condensing sea water was ordered locally of 10,000 g.p.d. capacity. A large order was also placed in England for tanks required for storage of water in the defence works, totalling 150,000 gallons in 30 units.

When this defence scheme, involving roads, light railways, and water supply, was being prepared, the Force in Egypt included only one company of Sappers and Miners which was employed on the Suez Canal defences, and a staff of six engineer officers who were fully employed at headquarters and on the work at Cairo and Alexandria. No organization existed to carry out the new works.

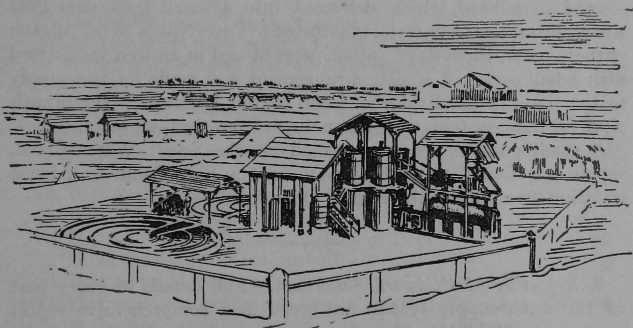
The army allotted to the defence of the canal had not materialized; on the other hand instructions were that work must start at once. The Public Works Department of Egypt was therefore called upon to provide a special staff to organize and carry out the work. Sir Murdoch Macdonald, K.C.M.G., then temporarily absent from Egypt, was appointed Deputy Director of Works, Suez Canal, and on the 4th December this staff, with the power and resources of the Egyptian Government behind it, took over the responsibility of the provision of landing stages and wharves on the canal banks, roads, installations of water-supply and engineer works at the canal bases of supply. Gradually as the work was completed and Army organization was established, this staff was eliminated, and in June, 1916, the appointment of Deputy Director of Works, Suez Canal, lapsed.

The water-supply system as completed up to July, 1916, is shown on *Map* No. II. The filter plants erected were capable of delivering about 1,000,000 gallons of water daily. Twenty-eight sets of power-driven pumps were installed; ferro-concrete reservoirs, with a total capacity of 1,272,000 gallons, had been constructed. One hundred and sixty-four miles of water piping had been laid, and almost innumerable iron, wood, and canvas storage tanks had been provided in the defence works.

7. *Details of Installation at Ferdan.*—The following brief description of the installation at Ferdan is typical (*see Sketches* 1 and 2).



1. Ferdan—Plan of Water-Supply Systems.



2. Ferdan—Filter Plant.

A branch canal was made connecting the Ismalia—Port Said Sweet Water Canal to the site of the filter-plant and pumping-station north of El Ferdan railway station. Water from this canal flowed under gravity into a sedimentation tank. On entering the sedimentation tank a solution of sulphate of alumina was added to the water, causing the suspended matter in the water to settle during the slow passage of the water through the tank. The capacity of the two sedimentation tanks was 64,000 gallons, and the rate of flow through these tanks to the filters was 6,000 gallons per hour, so that the passage of the water through the tanks occupied just over 10 hours.

From the sedimentation tanks the water, now partially cleared, was pumped up to a level from which it fell by gravity through mechanical filters, and thence by an inverted " syphon " pipe beneath the ship canal to a masonry reservoir of 50,000 gallons capacity on the east bank of the canal.

From the reservoir on the east bank of the canal, water was pumped to a 50,000-gallon reservoir at railhead and alternatively to a small reservoir at Katib-el-Uruq, whence it flowed by gravity to defence posts Nos. 7, 8 and 9. It must be understood that these outlying posts were being constructed and garrisoned before the piped supply reached them, the troops and animals being supplied with water by camel convoys. Each camel carried two small tanks weighing each, when full, 180 lbs., and containing 12 gallons of water.

Plate I. shows the form of *fantasse* found most suitable. This type of tank is referred to in the text as a *fantasse* (plural, *fanatis*), an Arabic word adopted by the army.

The pumps first installed at the canal bank were not capable of delivering water to the higher outposts, so a relay pumping plant was erected at railhead, which delivered into a small tank near Post No. 5. From this tank, water gravitated to Posts Nos. 1 to 6. At each of these posts, three days' rations were stored in an iron tank fitted with a ball cock. A similar arrangement was made for the supply to the posts in the Bridgehead and Reduit Defences. The branch pipes for these systems were taken direct from the 6-in. main.

A small pumping engine, erected on the Sweet Water Canal, supplied unfiltered water by pipe under the Ship Canal to a horse watering area outside the Reduit Defences.

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8. *Report by Mr. Edward Sandeman.*—Full details of every part of the water-supply system are given in a comprehensive report prepared by Mr. Edward Sandeman in December, 1916.

Mr. Sandeman arrived in Egypt from England in November, 1916, in response to a request from the Commander-in-Chief for a technical expert of " very high standard " to advise him as to whether the work which was being carried out on water-supply and pipe-lines, was being done in the best and most economical manner.

This report is too long to reproduce in its entirety. Mr. Sandeman's general summary and recommendations were as follows :—

General Summary.

"The work which has been done in the construction of the various works for the supply of water fit for human consumption along the line of the Eastern Defence is well carried out, and considering the circumstances under which it was devised and completed, and particularly the rapidity of construction, the results are admirable.

The pumping-station and pipe-line on the Kantara-El Arish route will, in my opinion, prove efficient—notwithstanding certain small hitches—for the purpose, assuming the suggestions made are acted upon, and the four sets of three-throw pumps are provided.

There is one point I wish to make regarding the maintenance of the 12-in. pipe-line.

From general indications I gathered that it was possible that the pipe-line may be required to supply water in this district not merely temporarily, but possibly for years. It is highly important that if this assumption is correct every care should be taken to preserve it from attack from the outside. It is probable the salts present in the sand will gradually destroy the steel, and tests should be made at various points to ascertain whether any destructive influence is at work.

It would be expensive, of course, to put on a protective coating, but it is probably necessary, and possibly more so in some places than in others.

Summary of Recommendations.

It is recommended that :—

(i.) On the Kantara-El Arish pipe-line :—
- (*a*). Air-outlets to be provided on high points.
- (*b*). Scour-pipes to be placed in depressions.
- (*c*). Pressure-gauges to be fixed along route.
- (*d*). Pipe-line shall be patrolled daily.
- (*e*). Repairing-stations to be established along route.
- (*f*). One set of three-throw pumps be erected at each pumping-station.

(ii.) That the Condensing-plant at Mohamdiya be dispensed with.

(iii.) That the intakes from the Sweet Water Canal be improved.

(iv.) That all the installations for the purification of water be placed under the control of one authority.

(v.) That no unchlorinated water be supplied to the troops.

(vi.) That an investigation be made to ascertain the effect produced on the steel pipes by the salts present in the desert sand."

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9. *Difficulties of Work.*—To arrive at some understanding of the work done, the extent of it has been indicated, and the staff employed on carrying it out has been briefly touched upon. It is, however, necessary to mention some of the difficulties which had to be contended with.

In the first place, although a general outline scheme was prepared, the detailed schemes for each section were, when the Army arrived to take up the line, constantly subjected to criticism by local commanders, and had to be constantly varied to meet temporary and changing requirements.

The ever-present difficulty of the provision of transport sufficient to meet all requirements, constantly delayed work. On the west bank of the canal there was a good railway service; an adequate service of canal boats and lighters working along the Suez Canal was also organized, but for some months the only means of transport in the desert was camels, and those were required for all services.

The desert is indeed a very desert, and produces nothing which was of any use in the work, except fine sand, not very suitable for engineer work. Even the gravel used for the construction of the reinforced concrete reservoirs and the sand for the filter plants had to be carried by rail from Cairo.

Most of the work was carried out by local labour, and although the officers in charge of the works received all possible assistance from the Divisional Engineer Units, difficulties necessarily arose as the Divisional C.R.E.'s and Corps C.E.'s were not responsible for these engineer services which were being carried out in their areas.

This may appear to point to bad organization, but the facts were :—

The work was initiated before the arrival of the troops as one great scheme under the D.D. of Works. Contracts for many of the works had been made by this central organization, specially qualified to deal with Egyptian contractors and labour. The whole composition of the Army, which commenced to arrive in the Suez Canal area in January, 1916, was in a state of flux. Divisions arriving in Egypt from Gallipoli, were in many cases sent on to Mesopotamia or to France after a short stay in Egypt. Working down to details, the Divisional Engineer Units put in charge of ferries, bridges, and water-supply systems, were liable at any moment to be withdrawn, and the whole maintenance staff was liable to be changed with dire results.

Later, as things settled down, it was found possible to place Army Troop Companies definitely in charge of the most important installations, but this could not be done at once.

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10. *Completion of Canal System.*—On the 5th February, 1916, the piping arrived from England and India in large consignments, and an attempt was made to discharge this at the various stations on the canal bank where it was required, but the ships had not been loaded to facilitate this distribution, so a large special Park for piping and water fittings had to be opened at Ismailia.

Not only were the consignments of pipes of various sizes, but also of various types, some with English screw-threads, some with American, with similarly varying special fittings. This meant that a special workshop to manufacture adaptors to connect English pipes to American pipes had to be opened. This was a difficulty that had not been foreseen, but the War Office in sending out supplies had also sent out a specialist who was of great assistance.

To lay an extensive piped water-supply system rapidly and efficiently without bad joints and possibilities of air locks, to guard against the expansion and contraction of the pipe-line in varying temperature before they are filled with water, and to turn out a workmanlike job, required much knowledge and experience which was not always available at the right place.

The Suez Canal Defence line with its elaborate water-supply system, ceased to serve any useful purpose after El Arish was occupied in December, 1916. During 1917, gangs of labourers were employed for many months on dismantling the works and in salving the machinery and water-piping.

The masonry and reinforced concrete engine houses and reservoirs in the desert and on the banks of the Canal alone remain.

Chapter III.

THE ADVANCE TO EL ARISH.

July, 1916 to January, 1917.

11. *Description of Sinai Peninsula.*—By the end of June, 1916, the Suez Canal Defence Scheme was practically completed. The advanced position on the north, Romani-Mohamdiya, was being strongly entrenched. The water-supply for this position was being developed, and the broad-gauge railway had been laid into the defence works. No preparations for further important work on water-supply were being made.

In front of the Army stretched the almost waterless country known as the Sinai Peninsula. To cross this, into the land of Palestine, there is only one practicable route. This starts at Kantara, traverses some 25 miles of arid and sandy desert where nothing grows except a few small bushes and some coarse grass, then, passing through the Katia oasis, runs along the northern edge of a belt of sand dunes, extending from the Sabkhet el Bardawil on the north, to the Gabel el Maghara on the south, and reaches the sea-coast near El Arish.

The Katia oasis is first entered at or about Romani and includes an area roughly about 20 miles from west to east and 10 miles from north to south. Here in the hollows of the rolling sand dunes there are numerous *hods* or plantations of date palms, and some shallow wells from which the nomad Bedouin population draws its water. There are also numerous *sabkhets* or flat marshes at about sea-level where water lies on the surface in winter. (*See* Map Romani 1/40,000 —*Map* III.).

The Sabkhet el Bardawil is an extensive salt marsh at sea-level. In winter, or after rain, this marsh is impassable, but in summer the water evaporates, leaving a thick crust of salt and gypsum on a thin clay surface. This *sabkhet* is separated from the sea by a bank of sand.

In the sand dunes, which extend almost without intermission along the Mediterranean coast from Mohamdiya to Caesarea, water can almost invariably be found by digging in the sand to, or nearly to, sea-level. This water from the sand dunes varies considerably. It is nearly always brackish, but some is quite drinkable. The sand dunes appear to collect the rainfall and retain water in their lower sand beds. Generally speaking, the dunes rest on the top of a salt-saturated bed covered with a thin layer of impervious clay. Between

Bir el Abd (the eastern limit of the Katia oasis) and El Arish, even these local supplies are scanty, but in the valley of the Wadi Arish (the River of Egypt) which drains a large portion of the Sinai Peninsula, unlimited supplies of water are available.

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12. *Note on Water-Supply Situation*, 15. 7. 16.—On the 2nd July, 1916, the Commander-in-Chief first noticed his intention to advance from Romani to El Arish with a force of one Mounted and two Infantry Divisions.

If circumstances allowed of it, this advance was to take place in October, but work on the railway line and the arrangements for the supply of water forward from Romani, were to be pushed on during the summer months.

The following note as to the water-supply situation was drawn up in the Engineer-in-Chief's office on the 15th July, for the information of the Commander-in-Chief :—

" It appears to be clear from all evidence we can collect that it is impossible to rely on finding any satisfactory supply of water fit for human consumption between Kantara and El Arish.

Deep well borings at Kantara, Bir Abu, El Aruk and Mohamdiya have failed to tap any drinkable water.

An additional deep well bore is being sunk east of Romani, but it is improbable that any satisfactory results will be obtained.

Generally speaking, the water available in the district is so bad that even horses will not drink it freely.

The present situation is, we have a filtration plant on the west bank of the Suez Canal, at Kantara, which draws its water from the Port Said branch of the Sweet Water Canal and can deliver up to 250,000 gallons of water daily to the east bank of the Suez Canal. Also a pump and syphon to deliver unfiltered water for the use of the railway and the animals in the camp at Kantara.

On the east bank of the Suez Canal we have storage capacity for filtered water of 100,000 gallons, and a pumping-station with duplicate engines and pumps to deliver water forward from Romani, Mohamdiya, and the intermediate posts through a 6-in. pipe-line.

The 6-in. pipe-line forward from Kantara supplies the posts at Hill 40, Hill 70, and Turk's Top, through 4-in. branch-pipes.

The water for Gilban and Dueidar is taken from the 6-in. main or sent out by rail from Kantara to Gilban railway station, and is taken thence by camels.

Under existing conditions, it is only possible to supply about 30,000 gallons daily to Romani and Mohamdiya along the 6-in. pipe.

To increase the supply to Romani a 5-in. pipe is being laid from Kantara to Hill 40, so that the 4-in. branch may be cut off the 6-in. main. When this is completed and a new pumping-station at Kantara is in working order, the daily supply by 6-in. pipe to Romani will be considerably increased, possibly to 60,000.

At Romani and Mohamdiya reservoirs for the storage of 100,000 gallons of water are under construction. A condenser to condense the sea water, capable of supplying about 20,000 gallons of water per diem, is being installed.

Pumps and engines for the local distribution of water in the Romani-Mohamdiya area and forward to Cohratina are being provided.

These arrangements deal with the immediate necessities where troops and natives, employed in the Romani-Mohamdiya area totals about 12,000.

These arrangements are, however, quite inadequate to deal with the concentration of one Mounted Division and two Infantry Divisions in the area, or to supply water necessary for the advance further east.

Estimating the requirements for such a force, we have :—

Mounted Division, say	8,000 men	at 2 gals.	16,000
	*10,000 horses	at 5 "	50,000
Two divisions,	40,000 men	at 2 gals.	80,000
	16,000 horses	at 5 "	80,000
For additional troops and native labour		.. .. ..	24,000
		Total, gallons	250,000
Add requirements of the Romani-Mohamdiya district		..	50,000
		Total daily requirements, gallons ..	300,000

To make the position safe, it is necessary to be prepared to provide two days' supply in any one day, and to have storage capacity for this quantity at Romani, and at each stage of the advance."

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13. *Scheme for Advance on El Arish.*—The forces detailed for the advance on El Arish were immediately available, the railway had reached Romani and could be extended, but nothing except the experience gained in the past six months was available for use on the new water-supply system required.

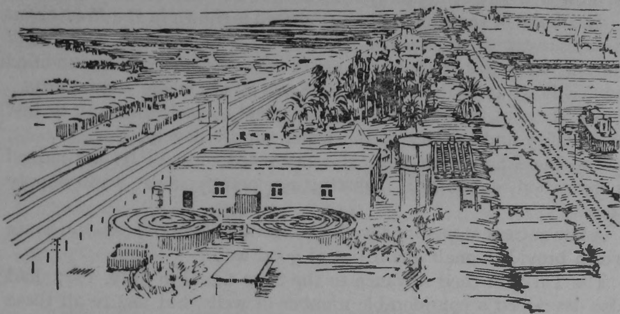
It was decided that the best way to carry the water forward from Kantara to within reach of El Arish, a distance of some 90 miles, was to work in four sections.

An entirely new installation was necessary, starting from the Sweet Water Canal on the west bank of the Suez Canal, including sedimentation tanks and filters capable of providing an additional 500,000 gallons (*see Sketch* 3), duplicate 60-H.P. engines with pumps; at Romani and at two other stations to be fixed later, similar reservoirs and pumping plant.

In coming to a decision as to the engine-power and what diameter of piping should be demanded, it was assumed that the pipe would

* It is presumed that half the horses will be able to be supplied from the local wells.

not have to be carried to any height much over 100 feet; that the safe working-pressure on the pipe should not exceed the equivalent of 250 feet total-head, and that a delivery of 600,000 gallons through 30 miles might be necessary in some section.



3. View of Filter Plant—Kantara West.

Working out the problem, a pipe between 10 in. and 12 in. was indicated, with engines capable of developing 55-H.P. The demand cabled home was therefore for 10-in. and 12-in. piping, and 60-H.P. engines.

The piping which was supplied proved on test to be capable of withstanding safely a working-pressure equivalent to 500 ft. head, so when in 1917 an increased supply of water through this pipe was required, the pumping-power was increased, and a delivery of 900,000 gallons per diem was obtained.

Arrangements for the provision of the new filters required were made with the Cairo Water Company on the 10th July.

Demands for 60 miles of 12-in. piping and 30 miles of 10-in. piping, and for the necessary engines, pumps and machinery, were cabled to the War Office on the 12th July.

The construction of the engine houses and reservoirs had been arranged for by the 14th July, and the provision of a timber pile wharf at Kantara to berth the ships bringing the material from England was put in hand.

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14. *Development of Local Desert Supplies.*—Arrangements had also to be made to develop and make the most of local water supplies during the march across the desert.

The R.E. field units, placed on a canal transport basis, as all other units and formations, had to organize and equip so that they should be able to meet the new conditions and specialize on water-supply.

Every Field Company, R.E., was organized to provide what was described as twelve "well units."

Each of these detachments or units carried lift and force-pumps, water-troughs, and a canvas tank to store water, also tools to dig shallow wells, and material with which to line them.

The detail of the equipment authorized is shown in the *Provisional Establishment of a Division with Camel Transport, E.E.F., 22nd August*, 1916 (*see Appendix* I.). It was to some extent modified by C.R.E.'s during the advance, but was on the whole satisfactory.

An officer of the R.A.M.C. was attached to each company to test the quality and salinity of the water supply developed.

The Field Squadron R.E. also discarded most of its authorized mobilization equipment, substituting pumps and water-supply stores.

A few ancient stone-lined wells were found along the caravan route which provided small quantities of good water.

The Turks in their advance to the Suez Canal in July, 1917, had also developed a considerable number of wells, but nearly all these had been lined with wattle revetment made from the roots of desert plants, or with split palm-tree logs, and the water had become so tainted with the rotting vegetable matter that they could not be used.

Digging new wells in the fine running sand of the dunes was no light task. To produce a well 12 ft. deep and 6 ft. square, it was necessary to start with the excavation of an area 40 ft. square and shift some 4,000 cubic ft. of sand. When this was completed, the well lining was placed in position and the sand filled in around it.

Well sinking parties in the desert gained considerable experience in the selection of suitable sites for wells.

The best water was generally found near the sea and where there was least vegetation. No drinkable water could be got near a palm grove, and where much scrub grew on the dunes very saline water might be expected.

An aneroid barometer was often found useful in coming to a decision as to whether it was possible to reach water-level by digging at any particular spot. In every case great care had to be taken not to sink the well into the salt beds lying under the fresh water.

Water with a salinity of 200 parts in 100,000 was considered good for men, while horses drank readily water with 500 parts, and camels with 700 parts of salt to 100,000 parts of water.

Tube wells of the pattern described in the *Manual of Military Engineering, Part V.*, 1914, were found very useful in searching for water, but were of no value as a source of supply.

The Field Squadron Anzac Mounted Division, provided itself with what were locally known as "Spear Points," a useful local variation of the Norton Tube Well, made of 2½-in. steel tubes cut into 5-ft. lengths.

The bottom or lowest length is fitted with a solid steel spear point to enable it to penetrate the sand, and is freely perforated to admit water ; the perforated portion being covered with fine gauze or wire cloth to exclude sand. The extension lengths are plain tubing with screwed collars, and a special coupling is provided to enable the suction length of the service lift and force pump to be connected to this tube well. Under favourable conditions this well can be driven in a few minutes, connected to the pump, and produce up to 600 gallons per hour. These " Spear Points " were also often found useful in improving the yield of old wells which had silted up or got choked with mud.

The use of "Spear Points" spread rapidly, and soon no Engineer Unit of the Egyptian Expeditionary Force was without some. *Sketch* No. 4 shows a "Spear Point" used in this way, and the usual arrangement adopted for storing water in canvas tanks, supported by a wall of sandbags.

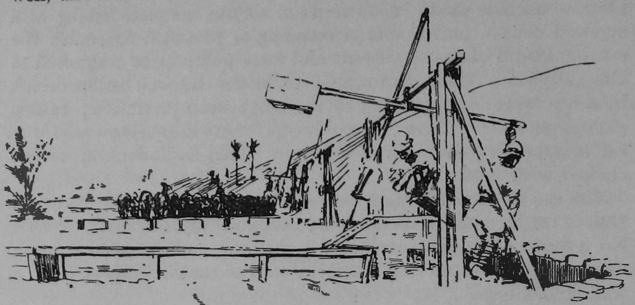
4. " SPEAR POINT " IN USE.

The service lift and force pump stood the test of this campaign well, but it was found necessary to organize a special workshop at the Base, to repair the working parts which wore out quickly owing to the all-pervading sand. It may be useful to note that it was found necessary to make a rule that spare pumps should be carried, but not spare parts of pumps, because the worn but repairable working parts, once replaced by spare parts, were nearly always lost, whereas, entire pumps were not easily mislaid, and it was impossible to keep up the supply of spare parts indefinitely.

Whenever it was possible to spare the necessary time, labour, and material, pumps on shallow wells were replaced by *shadoofs* The *shadoof* is an Egyptian device for raising water from wells or irrigation channels. It is very simple and effective. (*See Sketch* No. 5).

The horizontal spar of the *shadoof* is adjusted so that the weight of stone or clay at the shorter end readily lifts the bucket attached to the lower end when it is full of water.

The man working a *shadoof*, therefore, pulls the empty bucket down into the well, instead of pulling up a full bucket. The full bucket also is lifted straight up instead of banging on the sides of the well, and is held in a convenient position while being emptied.



5. WATERING BY SHADOOF.

The stiff mid-rib of a date palm leaf was found the most convenient means of suspending the bucket, as it could also be used to press the mouth of the bucket under the surface of the water.

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15. *Kantara-El Arish Pipe-line.*—The work connected with the installation of the piped water-supply system from Kantara to El Arish requires some further description. There is no great difficulty in drawing up a general rough scheme for even an extensive engineering project, in placing bulk orders, and allotting responsibility for working out details. The final success of any scheme depends on the skill and energy of those who work out the details, and to whom the execution of the work is allotted.

In the first place, the War Office staff cordially co-operated and provided everything ordered, sent a special expert to America to purchase the piping, and searched England for suitable engines, pumps and machinery to meet the extraordinary and special demands submitted.

The ships bringing the piping from America were specially escorted through the Mediterranean by the Navy.

The Cairo Waterworks Company designed the filter plant, introducing new fool-proof devices, kept its workshops going day and night on its manufacture, and finally installed the plant.

The Suez Canal Company carried out the work of laying syphons which entailed considerable dredging and diving operations.

The D.D.W., Suez Canal, arranged contracts for the provision of engine-houses and settling-tanks on the west bank of the Suez Canal, and supervised this work.

To the C.E., No. 3 Section (afterwards East Force), was allotted the responsibility of working out all other details and carrying out the necessary work.

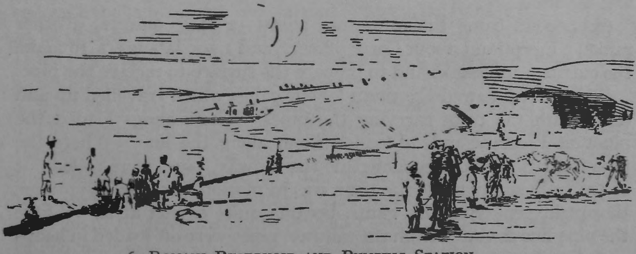
The total weight of pumping-machinery and stores transported from overseas was 10,000 tons.

Several small shipments totalling some 500 tons were landed at Alexandria and forwarded to their destination by rail, but the greater part, about 9,500 tons, was consigned direct to Kantara by steamer, where special arrangements were made for discharging and handling this material. For this purpose a special depôt was formed on the east bank of the canal at Kantara, comprising, in addition to sorting yards, workshops, and stores, a wharf of sufficient size to berth ocean-going steamers. (A key plan of Kantara is given on *Plate* II).

The additional filter plant installed (*see Photograph* (i.)) had a capacity of 500,000 gallons per day. It was situated on the west bank of the Suez Canal at Kantara, and from it the water was led by a triple syphon under the canal to the storage reservoirs on the east bank. These storage reservoirs had a total capacity of 500,000 gallons and were built of stone brought from quarries south of Ismailia. (A section of the canal and syphon is given on *Plate* III.)

The reservoirs in the desert at Romani, Abd, Mazar and El Arish were built of ferro-concrete, and 5,000 tons of materials, iron, cement, gravel and water required for their construction had to be transported from the Base by rail.

For work in the first section, Kantara to Romani, two railways were available to carry the piping, the broad gauge with its railhead east of Romani, and the metre gauge with its railhead at Dueidar: both these railways were extended into the sorting yards. Some special trucks were supplied by the railway, and other trucks were altered to transport pipes. Six Holt tractors were demanded from England to distribute the pipe in the desert. All these arrangements were complete, and other works well in hand, when the first ship reached Kantara with piping and machinery. (*Sketch* No. 6 shows the Romani reservoir and pumping station).



6. Romani Reservoir and Pumping Station.

16. *Handling and Screwing Pipes.*—As the R.E. companies were fully employed on other urgent work, Egyptian labour and local Europeans had to be used to lay the pipe-line. The necessary unskilled labour was easily recruited in Egypt. The difficulty of skilled labour to screw the large diameter pipe, however, had still to be faced. Artisans with experience in this work could not be found, as nothing larger than 6 in. screw-piping had been used in the country.

The first ship from America reached Kantara on the 24th September with 4,500 tons of machinery and pipes of 12 in. and 10 in. diameter, so, as it was necessary to start work at once, the section of the pipe-line from Kantara to Romani included pipes of two sizes. The ship was unloaded under R.E. supervision at the rate of 500 tons per day, and the screwing up of the pipe-line commenced 10 days after her arrival at the quay.

When the work of handling and screwing up the heavy pipe started, the progress was so slow and the work done so bad, that it appeared that it would never be completed. However, by dint of training the most prominent men and eliminating the inefficient, a satisfactory rate of progress was attained. The screwing gangs at the commencement with difficulty screwed up 15 lengths of pipe in the day ; later 25 pipes was the day's task, and paying the gangs on piece-work, as many as 40 12-in. pipes have been connected up in the day by one gang.

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17. *Organization of Pipe-Laying Parties.*—The work of laying the pipe-line involved six distinct organizations working under a central staff :—

(i.) First came a party of 1 officer, 6 other ranks, with 50 labourers to locate and mark the line the pipe should follow. As far as possible the pipe-line had to follow the railway to facilitate distribution, but as it could not be bent to take the same curves it had to deviate from it at times. Further, this heavy section pipe would not bend to sharp changes of grade, so in rough country heavy cutting and banking was required.

(ii.) Second came the formation party—2 R.E. officers, 9 other ranks, 3 Egyptian Labour Corps officers, and 1,500 labourers, to make the cuttings and banks and to prepare the surface to receive the pipe.

(iii.) Next followed Egyptian labour gangs which travelled up and down with the train carrying the pipes. These gangs loaded the pipes at Kantara and off-loaded them along the line. Where the pipe formation ran close alongside the railway, pipes were rolled out of the train singly while the train was in motion, and the Egyptians, thoroughly enjoying this game, became quite expert at it. Where the pipe-line deviated from the railway, pipes were off-loaded in heaps and distributed to the formation by tractors. From the rail side, the pipes were carried across the sand and laid out on the formation by Egyptian labourers, but only specially powerful men could be used, as a length of 12-in. piping weighs half a ton and is an awkward load to handle. The personnel employed on pipe distribution was, on an average, 2 officers, 34 other ranks (including mechanical transport) and 150 labourers.

(iv.) The screwing party, 3 European foremen and 250 Egyptian artificers and labourers divided into twelve gangs. Two gangs started screwing at one point and working away from each other met similar gangs which had started at other points 3 km. away, thus every 3 km. length was screwed up continuously from the centre, and the work of screwing-up was being carried out simultaneously at intervals over a length of 18 k.m. (*See Sketch* No. 7).

7. Screwing Gang at Work.

(v.) Working with, and immediately in rear of each screwing gang, followed parties aggregating 3 foremen and 500 labourers, to cover the pipe with sand and so protect it from sharp changes of temperature, which, by expanding and contracting the steel, would break the joints.

(vi.) The coupling up of the various 3 km. sections of the line with special expansion joints was carried out by a party of 3 N.C.O.'s and 25 Egyptians, provided with a tractor to carry their tools and fittings. It may be noted that these expansion joints practically ceased to act as such as soon as the pipe was covered and filled with water ; but, as a means of rapidly connecting sections, they were invaluable.

The supervision of these scattered and constantly moving parties, the arrangements for the supply of food and water to them, and for their transport, were extremely difficult in the desert where no motor cars or wheeled transport could be used, and the only means of moving from place to place through the heavy sand off the railway line was camels or horses.

Every available camel was required for the supply of the troops in front, and it was necessary to keep down establishments of transport animals on this work to the minimum.

While the pipe-line was being laid, the filter plant, reservoirs, and pumping stations were being built and erected, so that as soon as any section of the pipe was completed it would be taken into use.

The work of covering the pipe-line, to protect it from changes of temperature in a permanent manner, was not undertaken until the whole line had been completed into El Arish, when labour and transport from the other works became available.

By this time, a great deal of the original covering of sand had been blown away by the wind. In some high embankments part of the bank had literally moved away leaving the pipe-line suspended in mid-air, but as the pipe was carrying constantly flowing water it had not suffered from the changes in the temperature of the air. The situation was, however, unsafe.

This propensity of the sand to drift off the banks was finally defeated by reinforcing the banks with camel scrub collected from the desert. This scrub effectively retained the drifting sand, and banks grew larger instead of dwindling away. The work of final covering and reinforcing the banks occupied 2,500 labourers for two months.

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18. *Completion of Pipe-Line.*—The line was completed into El Arish, 155 km. from Kantara, on the 5th February, 1917, 125 days after the first pipe was screwed up, at an average pace of 1·25 km. per day. Since that time it worked without intermission, except once when, for a few hours, it was put out of action by an enemy aviator who descended on it and blew in a couple of lengths of pipe.

The engine houses and reservoirs were also subjected to attacks from the air, but as the reservoirs were in two separate parts and well protected, and the engines duplicated and in separated protected houses, no serious damage was done.

This pipe-line, laid to El Arish in 1916–17, was subsequently extended to beyond the Wadi Ghuzze in Palestine, where its branches supplied filtered Nile water, through a distance of over 150 miles, to the troops during the operations which drove the Turk from his position round Beersheba.

The important part in the advance which was played by this water-supply system, and how various sections when in service relieved the water situation of the Army in front, can best be judged by reading Sir Archibald Murray's dispatch, from which the following is extracted :—

> "But no organization could entirely overcome the chief difficulty which has faced us through the year, the adequate provision of water for the troops.

During the first half of November also the pipe-line was not yet delivering water at Romani, and the water for the advanced troops had therefore to be brought up by rail in tank trucks, and stored in improvised tanks at railway sidings made for that purpose. Since the railway had reached km. 109, considerable strain was thrown on its resources for this period owing to the necessity for maintaining the rate of construction, for forwarding materials for the construction of the pipe-line, for supplying the troops, and for undertaking the long haulage of great quantities of water in addition. By the 17th November, however, the water situation was somewhat relieved by the delivery of water through the pipe-line at Romani. Thereafter, the water difficulty again increased as the railway advanced, until the pipe-line delivered water at Bir el Abd, thereby again reducing the distance over which rail-borne water had to be carried, but as the month advanced the water question presented itself more insistently than ever. Every tactical preparation for the offensive had been made, Naval co-operation planned, and arrangements made for the landing of stores and construction of piers, as soon as El Arish was in my possession, but the difficulty of water-supply, even with my advanced railhead, was immense."

A very full report of the Kantara-El Arish pipe-line, with complete plans and drawings, was prepared by the officer in general charge of the work, but it is too long to reproduce here.

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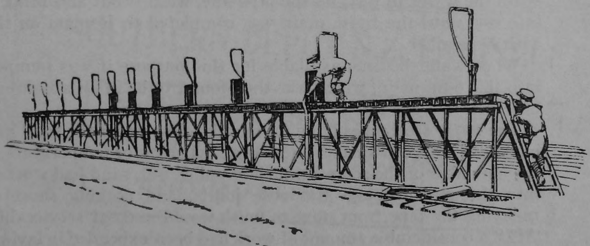
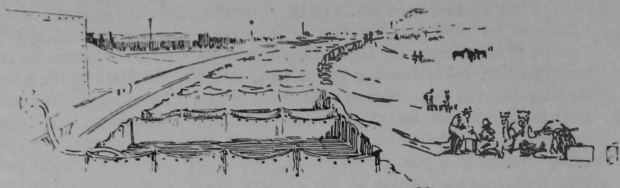
19. *Temporary Supplies During Advance to El Arish.*—During the deliberate advance from Romani to El Arish, the Army subsisted on scanty local supplies, and on filtered water brought up by rail from the nearest source of supply, first Kantara and then Romani and afterwards Bir el Abd. *Plate* IV. shows the method of distribution.

First at Kantara and subsequently at Romani and other watering stations as they came into service, special water sidings were laid by the railway, and here 20 or more standpipes were erected, so that a whole train of tank trucks could be filled without shunting. (*See Sketch* No. 8).



8. Battery of Stand-pipes—El Arish.

At railhead storage tanks were provided at a special water siding which could be filled quickly direct from the water train. (*See Sketch* No. 9).



9. Railhead Storage Tanks—Mazar.

The average load of a water train was twenty—2,000 gallon tank trucks, or 40,000 gallons.

The personnel necessary to work the filter plants at Kantara and the pumping engines along the pipe-line, to patrol and maintain the water-supply system from Kantara to El Arish was, in February, 1917, embodied into a special unit, the 360th Water Supply Company, R.E., with a strength of 5 officers, 1 warrant officer and 155 other ranks. (*See Appendix* II). The engine drivers, fitters, and artificers of this unit were to a large extent drawn from the skilled tradesmen who had enlisted in branches of the service other than the Royal Engineers.

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20. *Lessons from Failures.*—Two failures which at the time caused considerable inconvenience, must be placed on record :—

(i.) Between the beginning of August and the end of October the railway advance from Romani to Bir el Abd was followed by a party which laid a 6-in. and 4-in. main of salved piping.

The difficulty of maintaining the supply of water to Romani, and to the troops east of that place, produced a result which had not been foreseen. It never was possible, during this period, to spare the water to test, fill the pipe-line, wash it out and bring it into use, until the 12-in. main was completed to Romani on the 17th November.

When water became available for this purpose it was pumped into this 6-in. main, which was then found to be in an absolutely unserviceable condition.

The *empty* steel pipes lying for months close under the sand had expanded and contracted under great changes of temperature, a large number of the screw joints had pulled out, sand had worked into the pipe through the loose joints, and nothing short of re-laying the pipe from start to finish would make it serviceable. After a considerable amount of work had been expended in laying, and on attempting to repair this line, it was finally salved.

(ii.) As has already been mentioned a condensing plant was erected at Mohamdiya to supplement the water-supply in the Romani-Mohamdiya area. The condenser was erected on the sandy sea-shore, and arrangements were made for it to draw water to condense through a length of piping laid out some 200 ft. into the sea, which is very shallow here. The work of erection was completed under an officer specially detailed from the Base at Alexandria, before the reservoir to receive the condensed water was ready. One angle-plate of a sectional steel reservoir had been lost in transit from Alexandria and could not be replaced for some time.

The officer who erected the condenser was allowed to return to Alexandria, and the plant was taken over as complete without having been properly tested.

When, finally, everything was apparently ready the plant was set to work, and then it was found that the intake sucked in a considerable amount of sand which choked the tubes.

Experiments were made with filters to exclude sand, but these finally proved unsatisfactory.

After a great deal of time had been vainly expended on alterations of the intake-pipe from the sea, and on filters to exclude sand, it was found necessary to dig sump pits in the sand some 50 yards from the sea-beach, and to take the water which filtered into these for the condenser.

When finally the condenser was working properly in November, the need of it no longer existed.

The moral of both these tales is that the engineer must be prepared for many unforeseen conditions, and that no work is completed until it has been thoroughly tested throughout.

Chapter IV

EL ARISH TO BEERSHEBA AND GAZA.

December, 1916—November, 1917.

(*See Maps* IV. and V.).

21. *El Arish Area.*—When El Arish was reached there was, for a time, no great difficulty in supplying the Army with water. In the valley of the Wadi there were some wells of fairly good water, and the sand dunes right down to the edge of the sea, and especially on the sea beach, produced good supplies. The railway engineers, however, rejected the local supplies as altogether unfit for use in their locomotives. To meet railway requirements, and to provide additional supplies for the troops, the main piped water-supply was extended into El Arish, and a storage reservoir of 250,000 gallons capacity was built.

The geological conditions affecting the water-supplies in the El Arish area were discussed fully in a report by Dr. Hume, the Director of the Geological Survey of Egypt.

The plan prepared by Dr. Hume is embodied in this record for reference. (*Map* No. IV.). Dr. Hume subsequently prepared another full report on the Gaza-Wadi Ghuzze area. Both these reports are too extensive for reproduction in this volume.

The forward road, or caravan route, for there was no made or metalled road, followed the general line of the coast, and was separated from the sea by a belt of sand dunes from one to three miles wide. To the south west lay a plateau separating the valleys of the Wadi el Arish and the Wadi Ghuzze. This plateau was waterless except for a few scattered cisterns in which rain water is collected. It is, however, possible and probable that deep wells sunk in it might strike water at a little above sea-level. In the valley, between the plateau and the coastal belt of sand dunes, water was available from wells in the sand dunes and in the adjacent land. The essential difference between this country and that already traversed was that the sand dunes no longer rested on a salt-saturated bed, as on the northern side of the Sinai Peninsula.

The wells found in the small villages of El Burj, Sheikh Zowaid and Rafa were small, and their yield scanty, but could be supplemented by water in the dunes. It was not until Khan Yunis was reached that any local supply adequate to the needs of the Army was found. At Khan Yunis there were two principal wells about 100 ft. deep, and at Beni Sela, an adjoining village, on a higher site, a well 210 ft. deep. The yield developed from these three wells eventually reached 130,000 gallons per day. A few miles further on, at Deir el Belah, there were numerous wells from twenty to thirty feet deep, and the water-supply was practically unlimited.

In some parts of the valley of the Wadi Ghuzze and its tributary valleys water could be found by sinking shallow wells in the Wadi and also in pools and springs.

The wells of Beersheba have been famous since the days when Abraham watered his flocks there, and the town of Gaza has innumerable wells of good water.

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22. *Extension of Pipe-Line into Rafa.*—The railway was pushed forward to Rafa in March, 1917, and subsequently to Deir el Belah, Shellal and Gamli. This was followed by the extension of the Kantara pipe-line with what was available of 6-in. and 4-in. piping up to Rafa, chiefly to meet railway requirements.

The military had gradually become the chief consumer of the water pumped from Kantara, and, in July, 1917, the Director of Railways estimated that his requirements of water from this pipe-line might reach :—

At Romani	115,200	gals.
At El Abd	115,200	,,
At Mazar	115,200	,,
At El Arish	162,400	,,
At Rasum	192,000	,,
At Shellal E.	80,000	,,
Total	780,000	gals. per day.

Adding 120,000 gallons, the estimated requirements of the troops and hospitals on the Lines of Communication, and 300,000 gallons, to meet possible requirements forward, it was proposed to increase the capacity of the filter plant, pumps, and pipe-line from Kantara, to supply 1,200,000 gallons per day to Romani, and corresponding amounts to the stations further east.

After a careful consideration of the engineer problems involved, demands were submitted for new machinery and additional piping necessary, and orders were issued for the provision of the additional filter plant and reservoirs required.

This project for the increase of the piped supply of water from

Kantara was subsequently somewhat modified owing to the difficulty of getting the necessary plant, and because circumstances changed considerably before it could be collected, shipped, and installed.

The final arrangement of pumps, engines, reservoirs and pipes, with details of their capacities for delivery, are shown in *Plate* V.

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23. *Developments East of El Arish.*—It is hardly possible, and would be wearisome, to follow in detail the work carried out on the development of water-supply during the period between the first advance from El Arish and the operations against Beersheba and Gaza in October, 1917.

It may, however, be of interest to note that in April, 1917, for the first time, the work of laying pipes to supply water direct to troops in action was carried out.

The Turkish position at Gaza was to be attacked by the force assembled at Deir El Belah, and it was important that a forward supply of water should be available in the Wadi Ghuzze, where it could be distributed under cover to the troops during the operations.

Between the 4th and 6th April storage tanks to receive water brought by rail from El Arish were erected at Deir el Belah railhead. Pumping machinery, capable of delivering 4,000 gallons per hour against a 300 ft. head, was brought up and fixed on timber beds beside the storage reservoirs, and 4 km. of 4-in. screw piping was collected ready to lay out.

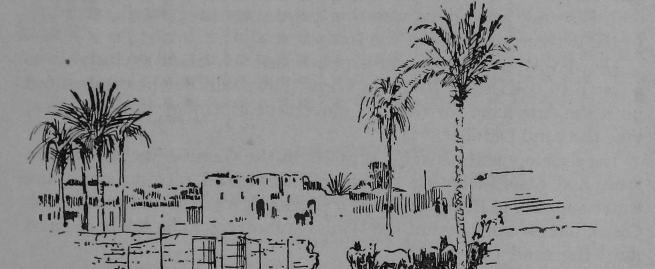
Between Deir el Belah railhead and the place selected for water distribution in the Wadi Ghuzze lay a ridge which rose some 200 ft. above the level of the railhead. The pipes had to be laid over this ridge, and, as its forward slope was in full view of the Turkish position, the distribution of the pipe had to be done at night.

Twelve separate parties of Egyptians were detailed for the work of screwing up the pipe-line and connecting up its sections. These parties started work at 16.00 (or 4 p.m.) on the 7th, and completed their work by 11.00 (11 a.m.) on the 8th. The pipe-line was tested and washed out, and by 15.30 (3.30 p.m.) on the 8th, it was supplying water into storage reservoirs in the Wadi Ghuzze. (*Sketch* No. 10 shows water-supply dump in Wadi).

Pipe-lines were also laid from Rafa through Abu Khatli to Shellal and Imara, and from Khan Yunis through Abu Sitta to Abu Khatli, with a branch from Abu Sitta to Abu Bakra, where several miles of piping were stored in view of possible operations in this direction.

Until September, when local water-supplies had been developed to the fullest extent by the installation of pumps and engines on existing wells, by local pipe-lines, and by sinking new wells, the Army continued to use water brought by rail from El Arish, where the supply from the Kantara pipe-line exceeded local requirements. (*Sketch* No. 11 shows the pumping-station at Khan Yunis).

10. Watering Area—Wadi Ghuzze.



11. Khan Yunis Pumping Station.

24. *Preparations for Advance on Beersheba and Gaza.*—It is not proposed here to describe military movements or to record the history of the War, but it is necessary to allude to them to explain what the Royal Engineers had to undertake in the way of provision of water.

Between March and October, 1917, the force in this area gradually grew to three Mounted Divisions, a Brigade of the Imperial Camel Corps, seven Infantry Divisions, and a composite Brigade of Allied and Indian Imperial Service Troops. G.H.Q. moved into the area in August, 1917, and preparations were put in hand for an enveloping attack on the Turkish position at Beersheba, combined with a frontal attack on Gaza.

In the *Map* No. V. an attempt has been made to indicate the water-supplies which were developed up to and during the operations which commenced on the 22nd October.

The supply of water which could be brought into the area by rail and delivered at Shellal or Gamli was some 100,000 gallons.

The El Arish-Rafa pipe-line, after meeting railway requirements at Rasum, could supply some 156,000 gallons per day to Rafa, whence 60,000 gallons per day could be delivered through Fukhari and Abu Khatli to Shellal or Abu Sitta.

The Khan Yunis well and pumping-station could supply some 100,000 gallons per day to Abu Sitta and thence by the cross line to Abu Khatli and Shellal, or direct to Abu Bakra.

These transferable supplies from the rear, amounting to 260,000 gallons, were controlled by G.H.Q. during the course of the operations, and deliveries at various watering points were regulated according to the daily movements of the troops.

The development of water-supplies east of Esani exclusive was allotted to the Desert Mounted Corps, but could not be commenced until the date fixed for the first movement of troops into the area, *viz.*, the 22nd October.

The development of water-supplies in the Gamli—Shellal—Hiseia area, and east, including the development and restoration of the water-supplies to Beersheba, when captured, was allotted to the 20th Corps, but no work east of the Wadi Ghuzze was to be taken in hand until the 22nd October.

The maintenance and development of the water-supply in the area Mendur to Sheikh Ajlin, on the sea, and back to Deir el Belah, was allotted to the 21st Corps.

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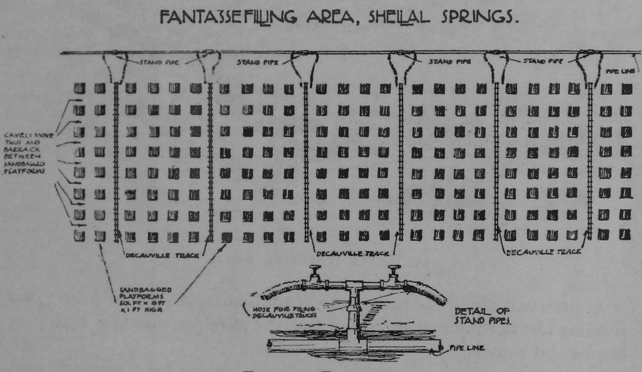
25. *Supplies for Concentration of Troops.*—The adequate development of the water-supply, and the arrangements for the distribution of water in the Gamli-Shellal-Hiseia area, from which three Mounted and four Infantry Divisions, accompanied by large convoys of camels for carrying water, were to be launched for the attack on the

Turkish position, was of first importance. There was a considerable amount of water in springs and in pools in the bed of the Wadi Ghuzze within the limits indicated, but to make it available for rapid distribution involved a great deal of preparatory organization and work.

At Shellal, springs, supplying about 14,000 gallons per hour of somewhat saline water, had been cleaned out and led through pipes into a water distribution area. A natural rock basin had been improved by a masonry dam, and provided storage for some 500,000 gallons of water. Here three sets of 25 H.P. engines and centrifugal pumps were erected for local distribution, and to pump forward water from the reservoir to Karm or beyond through a pipe-line which was to be laid about the 22nd October. The capacity of each pumping set was 4,800 gallons per hour against a 200-ft. head, and arrangements were made so that, if necessary, any two sets could work "in series" to pump against a 400-ft. head, keeping one set spare in reserve.

A *fantasse* filling area, in which 2,000 *fanatis* could be filled and loaded on camels every hour, was organized. (A detailed plan of the *fantasse*-filling area is given in *Sketch* No. 12).



12.—Fantasse-Filling Area.

The water-main supplied a line of six standpipes, each pipe being fitted with two hoses. From each standpipe a line of light rail ran out at right angles to the line of the water-main. Full *fanatis* were loaded on trucks on these lines of rails, and were carried from the trucks to sandbag platforms on either side.

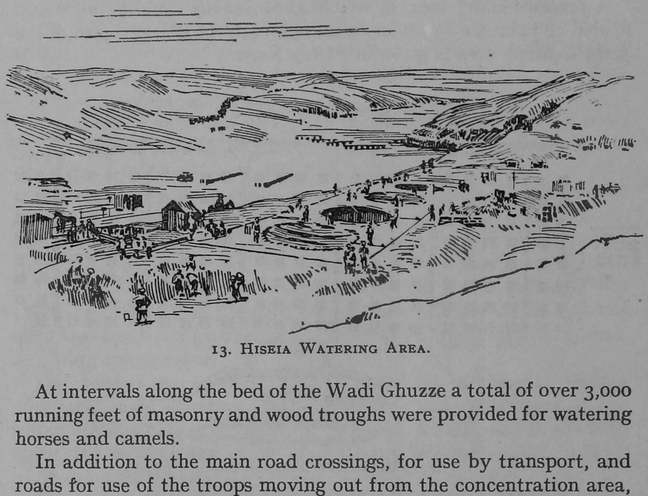
Camels marched up in eight "strings" of 24 camels, each string marching across the line of rails, and each camel was "barracked" between a line of platforms from which the *fanatis* were loaded on its back. In this way 192 camels were accommodated at one time, and there was an average carrying of only 15 ft. from the line of rails to the loading platform.

(*Photo* No. (ii.) shows loading area charged with full *fanatis* awaiting camel convoy).

(*Photo* No. (iii.) shows men of *fantasse* filling party loading *decauville* track with full *fanatis*).

The piping for the line to be laid, canvas tanks, watering-troughs, and everything which was likely to be required for water distribution forward was also collected here.

At both Hamli and Hiseia pumping engines were erected to fill high-level storage tanks supplying water by gravity to *fantasse*-filling areas, capable of filling 250 *fanatis* per hour. Details of a sunk brick reservoir at Hiseia are given in *Appendix* III, and a typical lay-out of a water area also at Hiseia is described in *Appendix* IV. (*Sketch* No. 13 illustrates Hiseia watering area).



13. Hiseia Watering Area.

At intervals along the bed of the Wadi Ghuzze a total of over 3,000 running feet of masonry and wood troughs were provided for watering horses and camels.

In addition to the main road crossings, for use by transport, and roads for use of the troops moving out from the concentration area, special tracks across the Wadi had been arranged for animals going to and returning from water, and others again for camel convoys carrying *fanatis* to and from the *fantasse*-filling areas.

All these roads were placarded with notice boards, showing what formations had to use them, and where they led to. (*Sketch* No. 14 shows the general arrangement in the Wadi).

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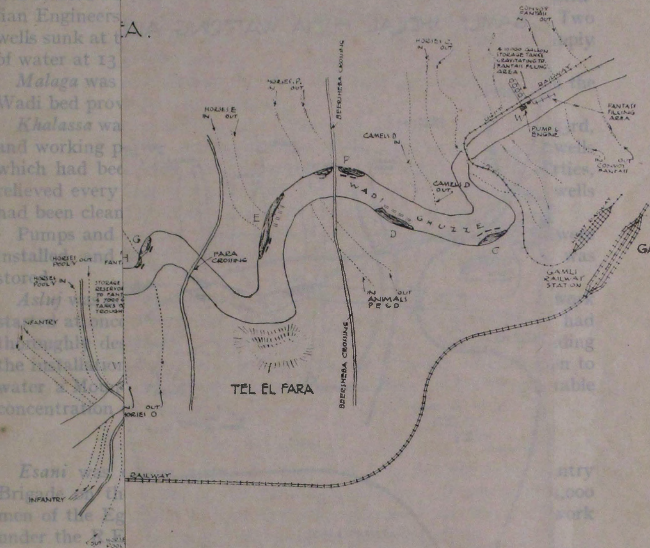
26. *Work of Corps during Advance.*—Until the 22nd October no troops or animals watered east of the Wadi Ghuzze. After this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GAMLI RAILWAY STATION
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BEERSHEBA CROSSING
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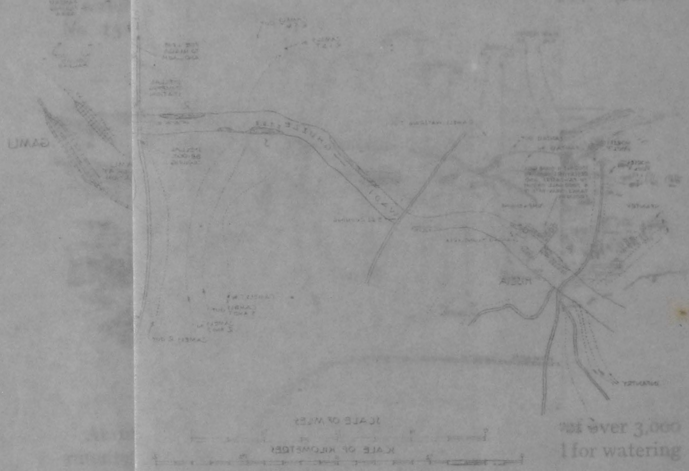

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date, troops began to move eastward to take up their position for the attack on Beersheba.

The following is a brief summary of the work done between the 22nd October and the 1st November :—

Desert Mounted Corps.

Abu Ghalyun was occupied at dawn on the 22nd October, and work on water development started at once. An old well was cleaned out, but failed to produce a satisfactory supply. Work on a second well was started but was abandoned. Meanwhile an officer of the Australian Engineers " divined " water in the Wadi bed not far away. Two wells sunk at the places indicated by him reached an abundant supply of water at 13 ft. depth.

Malaga was occupied on the same day, and here trenches dug in the Wadi bed provided a good supply.

Khalassa was occupied by the camel brigade on the night 22nd/23rd, and working parties started at dawn of the 23rd to restore two wells which had been effectively blown in by the enemy. These parties, relieved every two hours, worked continuously until finally the wells had been cleaned out to a depth of 42 and 36 ft. respectively.

Pumps and engines with a capacity of 4,500 gallons per hour were installed, and water sufficient for a Division of Mounted troops was stored.

Asluj was occupied on the night of the 25th/26th October, and work started at once on the restoration of the wells, which the enemy had thoroughly destroyed. After a great deal of heavy work, including the installation of machinery, Asluj on the 30th was in a position to water a Mounted Division, Corps Headquarters, and a considerable concentration of friendly Arabs.

20th Corps.

Esani was occupied by one Mounted Brigade and one Infantry Brigade on the night of the 22nd/23rd October. A party of 1,000 men of the Egyptian Labour Corps accompanied this force for work under the R.E., and work began on the morning of the 23rd.

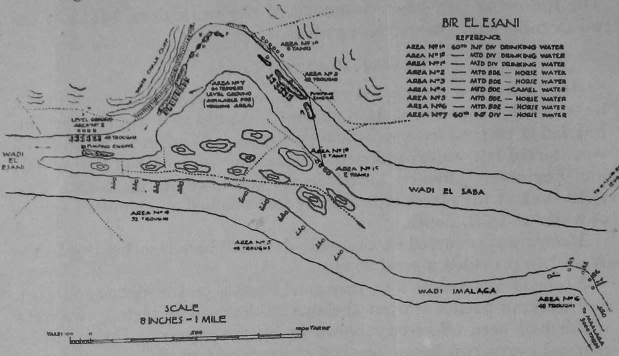
The source of water-supply was springs and pools in the Wadi bed (*see Sketch* No. 15).

Two portable power-driven pumping sets, with a combined capacity of 8,000 gallons per hour, canvas storage tanks with a capacity of 150,000 gallons, and water distribution gear, were installed. Two hundred wood horse-troughs filled by lift and force pumps were also provided in the Wadi bed.

Work was completed within three days, when a yield of 100,000 gallons per day had been attained.

Imara.—On the 25th October storage capacity for 60,000 gallons was erected at Imara, and the water was pumped forward to Imara from Shellal.

Karm.—Work on the pipe-line from Imara to Karm was started on the 23rd. On this day 5 km. of pipe were laid out and screwed up in ten sections. On the 24th these ten sections were connected through the pipe, tested, and washed out, and storage tanks and distribution arrangements were completed at Karm.



15. Springs and Pools in the Wadi Bed.

During the night of the 24th/25th the water was being pumped from Shellal through Imara to Karm, and was available on the morning of the 25th for the use of the troops.

(The organization of the pipe-laying detachments is illustrated in *Sketch* No. 16).

Later additional storage and second water distribution areas were provided at Karm for water brought by the rail from El Arish, when the railway extension had been completed. 80,000 gallons per day were delivered for some days.

Khasif.—At Khasif the cisterns were cleaned out and filled with 60,000 gallons of water, carried there by two camel convoys of 1,000 camels each on the 29th and 30th October. This provided an additional advanced reserve of water.

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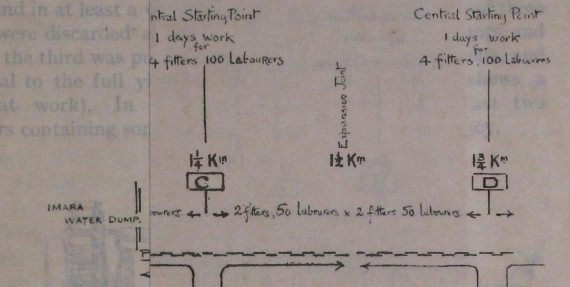
27. *Development of Beersheba Supplies.*—The problem of water development at Beersheba, after its capture, was not confined to the immediate provision of water sufficient for the minimum daily needs of the Cavalry Corps and two Infantry Divisions in itself a large order. More than this, it was necessary, with as little delay as possible, to reach a state of affairs which would allow the second phase of the operations to begin, that is to say, to allow the force to march out with a day's rations of water in hand for troops, and every animal to have drunk its fill before the march began.

The water question ahead of Beersheba was, at best, a doubtful one, and it was essential that, when the advance from Beersheba began, the force employed should be in a position to face a long waterless period.

Owing to the suddenness of the attack, the Turks left the town


ntral Starting Point
1 days work for 4 fitters 100 Labourers
Central Starting Point
1 days work for 4 fitters 100 Labourers
Expansion Joint
1¼ Km
1½ Km
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IMARA WATER DUMP.
ourers
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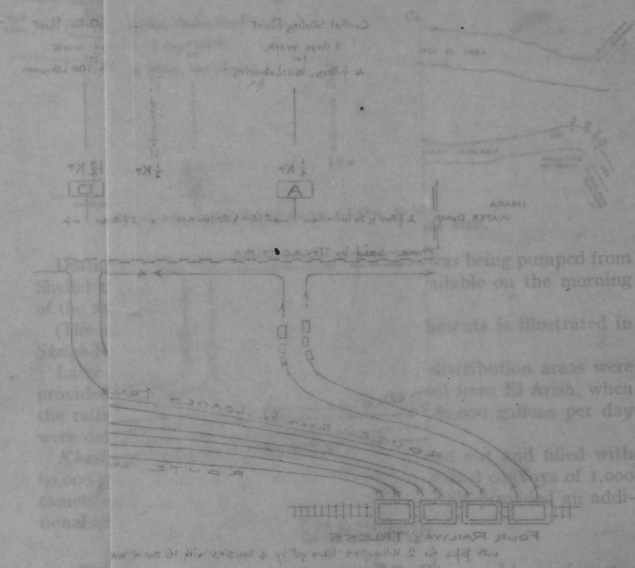
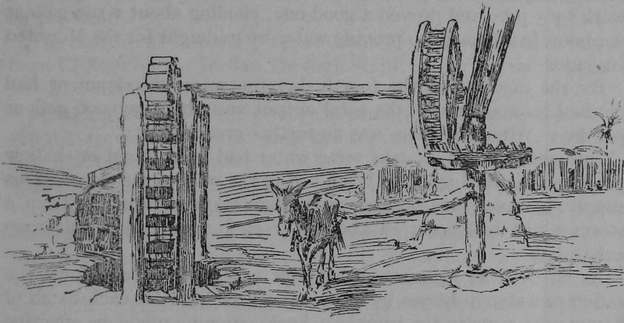
FOUR RAILW
with pipe f
n illustrating
method of
the PIPE LINE
A to KARM. October 1917



Central Starting Point
4 days work
4 fillers, 100 Labourers
A
D
Pipes laid by TRACTORS
ROUTE
FOUR RAILWAY TRUCKS

with only a few of the wells destroyed, though all the principal wells had been prepared for demolition, a state of affairs which reflects badly on the Turkish Engineers, for, however sudden the attack, it was only the work of a moment to light the fuses which were ready in position. Of the seventeen wells in Beersheba only two were thoroughly demolished and two partly damaged.

In three wells the pumps were in a workable condition, though the engines had been put out of action. In three other wells *saqqias* were found in at least a workable condition, and though two of these *saqqias* were discarded as unprofitable, and replaced by pumps and engines, the third was put in good working order in a few hours, and was equal to the full yield of the well. (*Sketch* No. 17 shows a *saqqia* at work). In addition the Turks had left intact two reservoirs containing some 90,000 gallons, a very useful legacy.



17. Saqqia at Work.

It was at once clear that the source of water in Beersheba was a large one, and likely to provide nearly the whole needs of that part of the force which was temporarily based on the town—a force requiring in all about 400,000 gallons per day as a full ration.

It was not to be expected that this volume of water would be available at once, but horses can subsist without water for 48 hours, and men can do with less than a gallon a day if the weather is at all favourable, as one might hope it would be in the beginning of November.

However, the three or four days after the capture of Beersheba were among the hottest of the year—a strong *khamseen* wind blew without intermission, and the whole district was enveloped in fine dust.

Of the plant carried by the tractor train, five engines and three pumps were erected, and parts of the sixth engine were used to replace similar parts in a duplicate engine left by the Turks. The three pumps left by the Turks were put in good working order. Four pumping sets brought in from Asluj were erected, one *saqqia* was put in order and used continually, and from two wells water was raised by bucket and rope.

Several of the wells were concealed in houses and gardens—two were not found until the third day, and one on the fourth.

On the third day, in the afternoon, the water situation was most acute, every available gallon of water stored during the previous night having been consumed.

The output was just equal to the demand, and it was expected that watering animals for the day would be finished by midnight.

At 4 p.m. a Mounted Brigade of some 2,000 men and horses with 48 hours' thirst arrived unexpectedly. A new well, with *saqqia*, had fortunately been found about noon on this day, the *saqqia* was being repaired and troughs were being erected, but there was no means of knowing what the yield of the well would be. This well was at work by 5 p.m. and proved a good one, yielding about 1,500 gallons per hour, just enough to provide water by midnight for the Mounted Brigade.

By the morning of the fourth day the water development had reached its maximum ; the total output was about 390,000 gallons per day. After this there was no further great anxiety.

During the first two days some water had been found in shallow pools and in pits dug in the Wadi bed to the west of the town. This supply, however, was nothing more than surface water left from a storm which had occurred about a week before, and it was soon exhausted.

As an extreme measure an attempt was made to cut down the ration of water to horses by imposing a time limit for each batch of horses as it came to the troughs. Such rationing might be effective where the control of the watering area was very perfect, and where animals had not been without water for an undue time.

In exceptional circumstances, as at Beersheba, the famished horses got out of control, and rushed the troughs as soon as they got near them, and, while some drank greedily, it was a difficult matter to get others to drink.

Limiting the ration of water for camels is always a simple matter from the habit of the camel of drinking in two "bouts" with an interval of about ten minutes.

The provision of a stout guard rail to every line of troughing was well worth the extra time and labour, as it prevented animals from breaking down the troughing in their eagerness to drink.

(Some further notes on the wells at Beersheba are given in *Appendix* V.)

For the operations against Beersheba, thirty-three pumps and engines were erected, having an aggregate of 290 horse-power.

The water storage capacity of tanks and reservoirs erected by the army amounted to 1,100,000 gallons.

Chapter V.

NOVEMBER, 1917, TO SEPTEMBER, 1918.

FROM THE BEERSHEBA-GAZA LINE TO THE WADI AUJA (JORDAN VALLEY)-TEL USUR-ARSUF LINE.

(*See Maps* VI. and VII.).

28. *Geological Conditions in Palestine.*—The country occupied between November, 1917, and September, 1918, stretched from the Dead Sea and the Jordan Valley on the east, to the Mediterranean on the west.

The northern boundary approximately followed a line drawn from El Auja on the Jordan, through Sinjil, on the Judean Hills, and Mejdel Yaba, in the foothills, to Arsuf on the sea.

Speaking generally, the geological conditions affecting the water-supply, are :—The Judean Hills are formed of irregularly stratified and much-fissured limestone rocks of various ages, resting on the Nubian sandstone beds. To the east, these hills fall steeply to the valley of the Dead Sea and the river Jordan ; to the west they extend some 20 to 25 miles into the plain, where they disappear. Between the Judean foothills and the sea there is an undulating plain of loam and sand, and along the edge of the sea a low ridge of sand dunes. A very definite geological fault is said to separate the limestone hill area from the plains which lie between it and the sea.

In the whole of this area there was very little water to be found above ground. In the hill country a few streams were found in deep gorges flowing into the Jordan and Dead Sea Valley, but these are very inaccessible except in the Jordan valley itself. On the western side of the hills water also ran for a short distance along the bed of a few deep valleys. Close to the sea-coast, water was found in the sand dune area in the bed of the Nahr Sukerier and the Nahr Rubin, while further north the river Auja rises from several strong springs at Ras el Ain about nine miles from the sea and flows into it over a shallow bar.

In the hill country springs were found at various altitudes, but the water from these was quickly absorbed into the fissured hill sides.

The population in this part of the country supplied itself with water from these springs, and also very largely from cisterns in which water was collected during the rainy season.

In the plains there were no springs, and the population drew its water from deep wells dug through some hundred feet of sand and loam, and sometimes calcareous sandstone of recent date, into water-bearing sands.

The fact appeared to be that a considerable quantity of the winter rain which fell in the Judean Hills was absorbed into the fissured mass of rock of which the hills are formed.

This water reappeared on the surface in springs wherever the irregular stratification and fissuring of the limestone afforded a favourable exit, and was then absorbed into the fissured hillsides lower down. Then it sank through deeper fissures, or a process of filtration into the lower levels. On the eastern side of the hills the water flowed out in streams into the Jordan valley and the Dead Sea. On the western side, at the edge of the foothills, it met water-bearing strata of sand, where it could be found by sinking wells into a regular and well-defined underground water table, which sloped gradually from the foothills to the level of the sea at the coast.

Along the coast-line there was also a repetition of the conditions, mentioned previously, of water-supplies in the sand dunes.

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29. *Orders for Pumping-Plant, etc.*—Preparations for operations in Palestine had been taken in hand many months before the Gaza-Beersheba position was taken, and the operations in front of the Gaza-Beersheba position were valuable training.

A great deal of information regarding water-supplies available in the area had been collected. This was eventually published in *Notes on Water in Southern Palestine*, first provisional edition, September, 1915-1917, with corrections up to 23. 9. 17.

It had been deduced from this information that we should reach a country where the Army would have, to a large extent, to rely on power-driven pumps designed for deep wells, and stocks of these had been demanded from England.

To receive, unpack, assemble, test and distribute these, also to repair and maintain them, a Machinery Park, with workshops, was erected at Rafa. Here also were collected a variety of pumps and engines partly salved from the Suez Canal area.

The pumps and engines stocked in this park were of many patterns and makes, but were roughly classified into :—

(*a*). Light engines with pumps for deep wells, capable of delivering up to 1,000 gallons per hour.

(*b*). Portable or semi-portable low-lift pumping-sets suitable for wells in which the level of the water was not more than 25 ft. below ground, capable of delivering 4,000 gallons to a height of 100 ft.

(*c*). Heavier deep-well pumps, many of which were manufactured in Cairo, with deliveries from 3,000 to 6,000 gallons per hour.

(*d*). Oil-engines of all sizes from 5 to 25 H.P.
(*e*). Low-lift pumps of the centrifugal pattern.
(*f*). High-lift pumps, capable of delivering water to 300 ft., some of which were afterwards altered in the shops to work up to 500 ft.

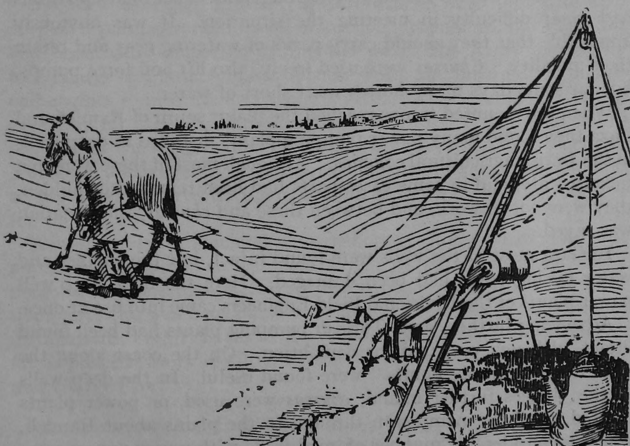
Plant for deep-well boring had been collected, and detachments were trained in this work under a specially selected officer.

Further details about the Machinery Park are given in *Appendix* VI.

The Army was no longer on the provisional establishment for desert warfare, and the Royal Engineer units had their normal equipment, except that no pontoons or bridging equipment were carried.

To the R.E. Headquarters of each Division was added a special park of engines, pumps and water gear, including two deep-well pumps carried on four trestle wagons, and the Divisional Field Companies trained special detachments in the erection of the deep-well pumping-plant.

Detachments of the Field units were also practised in the use of the ancient Indian device for raising water from wells in *chursas*, and a large number of these of various patterns were made and issued for the advance, and served their purpose well. One C.R.E. reported that for a time the life of his division depended mainly on the *chursa*. (*Sketch* No. 18 shows the *chursa* in use).



18. Chursa in Use.

An additional water-supply company, the 359th Company, R.E., was formed to follow the advance, and to establish and maintain water-supplies in rear of the Army on advanced Lines of Communication, and to take over installations left by Corps as they advanced. (For War Establishment *See Appendix* II, to *Chapter* III).

It is well to mention here that, when drawing up the establishment of this unit, the fatal mistake was made of not supplying sufficient transport, and that throughout the subsequent operations the work of this unit was badly hampered because of this mistake, and, through no fault of its own, it has often been unable to meet the requirements of the moment adequately.

The sphere of operation of this unit in maintaining pumping stations extended from Jerusalem to Jaffa and back to Beersheba and Gaza. Nearly every officer required a motor car, and a number of light cars to carry pumps and engines back to shops for repair, and to carry spare parts forward, would have been invaluable.

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30. *Supplies during Advance on Jerusalem.*—After the capture of the Beersheba-Gaza positions in the early days of November, 1917, the Army swept forward. Speaking very generally, the mounted troops advanced on the right through foothills where water was scarce, and the infantry along the coastal plains. The field squadrons had great difficulty in meeting the situation. It was obviously impossible that they should carry parks of watering gear and retain their mobility. *Chursas* were used freely, also lift and force pumps, but for some days many horses went short of water.

When the mounted troops reached the plains south of Ramleh and Gaza they found many power pumping plants installed in deep wells in the Jewish agricultural colonies. Although most of these were in a rickety state, and in some cases parts had been removed or hidden, they were got to work, and between these and *chursas*, the situation was saved.

In Gaza most of the wells were found intact, but the engines and water raising plant had been damaged. Here the light deep well power plants of the Divisional Field Engineers came into use at once.

Advancing further, some Turkish pumping plants had been found intact, although prepared for demolition. On the coast, along the sand dunes, "Spear Points" were found useful. In the deep wells in the villages further inland, *chursas* were used, or power plants erected, until the Army won through to the plains about Ramleh, where a considerable number of good wells with power pumps were found in orange groves and gardens. When the Army finally swung round to the right and moved into the hill country some rain had fallen, and the Army drew its supply from springs in the hill sides, and from cisterns found in the villages.

The new Water Supply Company in the meanwhile followed the advance, improving the water-supplies along the Lines of Communication.

It is unnecessary to enter into the details of all the work done between the first rapid advance to the Jaffa-Jerusalem line, and the more gradual advance which went on continuously until in September, 1918, the Turkish troops were finally swept away.

Work on the development and distribution of water-supplies continued without intermission; the railway extension, the hospitals, posts on Lines of Communication, Headquarter Camps, Reinforcement Camps, and the great Advanced Depôt at Ludd, required water-supply systems on a permanent basis.

Ludd was the centre from which four railway lines radiated north, east, south and west, and the railways required up to 200,000 gallons per day. Here also were established the R.A.S.C. Main Supply Depôt with its Bakeries, Ordnance Depôts, R.E. Parks, M.T. Depôts, Casualty Clearing Stations and the Headquarters of Technical Troops, all requiring water. (*See Plate* VI.).

The source of supply were some wells in the orange groves. Sets of pumping engines were installed here, and 9¼ miles of piping distributed the water.

As has already been mentioned, the best wells in the country were found in the orange groves. Most of these were provided with deep-well pumps worked by oil or suction gas engines, but the plant had been badly neglected during the war. The Army necessarily took charge of a large number of these wells, and repaired the pumps and engines to meet its own requirements. At the same time it was necessary for the sake of the country, and of its civil population, to provide for the irrigation of the orange groves; therefore, wherever a well was taken over by the Army, arrangements were made to pump all the water required for the irrigation, as well as the water required for the troops.

A well-equipped machinery workshop at Jaffa, where the civil population had been accustomed to get its pumps and machinery made and repaired, was taken over by the R.E. Advanced Park Company, and was kept busy in repair work for these local pumping installations, on all classes of Army work, and at the same time, as far as possible, work required by the civil population was dealt with and charged for.

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31. *Development of Existing Wells.*—A very large number of the wells in Palestine are more than 100 ft. deep. The village wells, although they provide sufficient water for the inhabitants, could not yield sufficient for large bodies of troops, and in many cases had only

been sunk for a very short distance into the water-bearing sands.* In nearly every case they were choked with many years' accumulation of mud, stones, and water vessels which had fallen into the well.

It was often difficult to decide whether to attempt to improve the yield of a well by cleaning it out or to leave it alone. Cleaning out deep wells cannot be undertaken lightheartedly. In the first place pumping-plant must be installed capable of keeping the well empty so that the men can work at the bottom of it.

Now heavy pumping-plant takes time to erect, and skilled men are necessary for the work. Lighter and more quickly erected plant may prove insufficient to keep the water-level down. Then pumps, sucking the mud stirred up in the well, get choked and the parts have to be continually disconnected and cleaned. In some cases the results of cleaning do not materially improve the yield. In every case the well is out of use while the cleaning is going on.

The following experience with wells is perhaps worth recording :—

At Beit Jirga, a village 10 miles from Gaza, the leading Field Company found a well with about 2 ft. 6in. of water at the bottom of it, installed one of its *chursas* and after half an hour's work had lowered the water so far that the *chursa* would not fill. The well was abandoned as incapable of yielding a useful supply. An Army Troops Company, following behind, after a closer inspection, installed a deep-well pumping set with the suction rose fixed at about 2 in. from the bottom of the well. When the engines set to work the pump delivered about 1,200 gallons per hour continuously for 52 hours, and for the next month this well proved a very useful source of supply.

The village well at El Tireh, 4½ miles north of Ludd, when first tested, yielded only a few hundred gallons per hour and was abandoned until taken seriously in hand by one of the Water Supply Company's detachments. After a month's work, during which three pumps of increasing capacity were installed, and the well had been deepened nearly 20 ft., a yield of over 2,000 gallons per hour was attained. For some months after, this well was supplying 30,000 to 40,000 gallons per day regularly.

Most of the agricultural colonies in Palestine have improved the yield of ordinary stone-lined wells very considerably by sinking perforated tubes, covered with wire gauze and screens, for 20 to 30 ft. below the original bottom of the wells, thus drawing water from greater depths of water-bearing sands. It is not uncommon to find wells of this kind yielding, with suitable pumping machinery, 6,000 gallons per hour.

The Royal Engineers, greedily seeking to increase the yield, have in some cases installed more powerful engines on such wells with the

* Exactly similar conditions were met with in the villages of Northern France.

result that these sand screens broke down and the well got choked with sand. The same breaking-down of sand filters or screens had also occurred in some of the tube-wells sunk by the Boring Detachments.

This caused a great deal of trouble. Difficulty in screening off the sand in the tube-wells was foreseen and precautions were taken, but no experience had been gained of various sand screening devices which are said to have proved satisfactory elsewhere.

In *Plate* VII. the borings made by the special Boring Detachments are indicated.

It is interesting to note that no tube-well sunk into the limestone hills, or which reached the limestone strata, yielded any satisfactory supply. "Water Diviners" stated that they had located good underground supplies in certain localities in the Judean Hills, and as a test, a Boring Detachment was detailed to sink a well at the most promising spot indicated. This boring was carried to a depth of 140·5 ft. without reaching water. At this stage the doubtful experiment was abandoned.

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32. *Jerusalem Water Supply.*—When the Allied Army entered Jerusalem in January, 1918, the town drew its water from the following sources :—

(*a*). Rain-water collected from the roofs and courtyards, stored in underground cisterns. The quality of this water was always open to suspicion, and the quantity was limited.

(*b*). Rain-water collected in the ancient reservoirs—the Birket Sultan and the Birket Mamilla. This is nothing but the surface drainage of the upper part of the town, and is quite unfit for human consumption.

(*c*). Water collected and pumped from springs near the Pools of Solomon, 8 miles S.S.E. of Jerusalem, which is brought into the town in an ancient, badly maintained aqueduct. The supply obtained from this source was estimated at 40,000 gallons per day.

(*d*). The springs of the Pool of Siloam which lie below the town and are polluted by its sewage.

In normal years these combined sources of supply barely meet the requirements of the population. In exceptional seasons water is very scarce and is carried in from long distances.

The troops billeted in, and camped near, Jerusalem, necessarily drew heavily on the water stored in the cisterns, and practically monopolised all the water flowing into the town through the aqueduct, so it soon became evident that Jerusalem would suffer from a water famine unless new sources of supply were developed without delay.

The problem to be solved was not a new one. It had been solved 2,000 years before, and in 1908 M. Franghia, a French engineer, had considered the problem and published his proposals for the water-supply of Jerusalem in a pamphlet. This pamphlet, with plans, was available for our use. In both solutions the springs in the Wadi Arrub, about 6 miles south of the Pools of Solomon, provided the additional supply.

Accepting the figures given by M. Franghia, who measured the springs on the 15th October, 1903, and continuously for two months afterwards, it appeared possible to collect from these springs a yield of 20 litres per second, which is roughly equivalent to 380,000 gallons per day.

There was no time for exhaustive investigation. Measurements taken in the winter would be no guide to the summer yields, so it was decided to do what was possible in the time, and with the plant available in Egypt and Palestine, to bring the water in the springs in the Wadi Arrub into Jerusalem.

The scheme put in hand provided for a maximum delivery of 300,000 gallons per day into Jerusalem. As much as was required up to that quantity was supplied, until in October the upper springs in the Wadi Arrub failed, and the yield of the lower springs was reduced to 150,000 gallons per day.

Storage capacity of 4,000,000 gallons was provided by repairing the Birket Arrub, and this part of the work was not completed early enough in the year to enable it to be utilized before the springs began to fail.

If this reservoir had been filled while the springs were running full this stored water could have been used to supplement the diminished yield of the springs, and a supply of 200,000 gallons might have been maintained in October and November. This quantity of water was, however, not then required by the Army or the civil population, as nearly all the troops had left Jerusalem, and the principal cisterns in the town had been cleaned out and refilled.

(The details of the scheme carried out by the Army and a plan of the ancient water-supply systems from the Pools of Solomon and the Wadi Arrub, so far as they can be traced, are shown on *Map* No. VI. and *Plate* X.).

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33. *Supplies during Final Advance.*—*Map* No. VII. shows the principal water-supplies developed during this stage of the campaign. It is unnecessary to enter into details, but some of the work must be touched upon.

The road from Jerusalem, 2,500 feet above the sea, to Jericho, some 800 ft. below the sea-level, is some 23 miles long, and during the long and steep descent it nowhere touches water.

When the Jordan valley was occupied and operations beyond the river were undertaken it was found necessary to establish a watering point on this road for the use of the troops and convoys. This installation pumped 40,000 gallons of water per day from the Wadi Kelt up to the road.

A duplicate set of engines and high-lift pumps, installed at the bottom of the Kelt Gorge, raised the water some 300 ft. to a similar relay pumping-station, whence it was pumped up another 300 ft. to the road.

Shortly afterwards it was found necessary to establish a camp near the "Good Samaritan's" Inn, a few miles nearer to Jerusalem and higher up the hill. To do this, two additional relay pumping-stations were installed.

In the hills north of Jerusalem during the summer, when the upper springs dried up and the village cistern supplies were exhausted, a number of pumping stations and pipe-lines had to be provided to bring the water from the deep valleys to within reach of the troops. In the plains, also, the development of water-supplies went on continuously to meet local requirements and in preparation for the concentration of troops before the final advance in September, 1918.

In preparation for this last stage of the campaign a third Special Waterworks Company, the 357th Company, R.E., was formed in March, 1918, and it took an important part in the work of developing and maintaining water-supplies in the forward area. (For War Establishment *see Appendix* VII).

During the advance in September, 1918, a somewhat remarkable record in laying pipes in quick time was attained.

Previous to the final advance on the 19th September, 1918, a pumping-station was erected on the river Auja, and 800 yards of pipe-line was laid reaching just beyond our first-line trenches. This work was done by night, and the work carefully camouflaged during the day. The necessary material for the extension of the line was all assembled, and all transport and labour arranged for.

On the day of the advance the line was extended to a pre-arranged point near the Ras el Ain-Tul Keram road, a distance of 5,000 yards, and a watering area of 60,000 gallons' storage erected there. The laying of this extension was commenced on the afternoon of the 19th September, as soon as the front was clear of troops, and the whole work completed by midnight.

After that advance nothing of special importance or interest was done. The R.E. Field and Army Troop Companies were able, without much difficulty, to cope with the requirements of the formations to which they belonged, and the leading Special Water Company sent forward detachments to restore and develop water for the railways.

CHAPTER VI.

CONCLUSION.

34. *Summary.*—The water-supply services carried out during this campaign in Egypt and Palestine were on a scale for which the pre-war Army was not prepared.

In Egypt and on the Suez Canal, without any exception, troops were provided with water pumped by machinery and distributed through pipes. Most of the water had also to be filtered.

During the advance across the desert, the troops found a little water, but its main supply was water filtered, pumped, and piped forward.

In the Judean Hills water had to be pumped from deep valleys, and in the plains of Palestine it was necessary to instal deep-well pumping machinery on nearly every well used by the troops.

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35. *Personnel.*—The R.E. units, as authorized in War Establishment, were not in any way equipped for this work.

The R.E. Companies of the old Army started with officers trained to some extent in general engineering work, but few had any practical training in the use of oil-engines, pumping-machinery, and pipe-fittings. Amongst the other ranks there was a small number of engine-drivers and fitters who could handle and erect machinery.

In Special Reserve and Territorial units some officers were professional engineers, but a proportion had no training or practical experience in engineering work. The units, however, generally had a proportion of other ranks who had handled engines and machinery.

The Companies of Sappers and Miners were officered by engineers, but it is no exaggeration to say that they hardly had any men who had ever touched machinery, or who could be trained to this work, because this class of tradesman is not enlisted in India.

All classes of professional engineers were commissioned during the war into R.E. A large number of skilled engine-drivers and fitters had enlisted in the new Army in branches other than R.E.

In Egypt a great deal has been done by the Water Works Companies of Cairo and Alexandria, and by the Suez Canal Company.

The water-supply system for the Suez Canal Defences was installed by the Public Works Department of the Egyptian Government, temporarily brought into the military organization.

To a very large extent it was necessary to rely on the temporary R.E. officers, or men drawn from other branches of the Service, and on Egyptian artificers and labourers, to carry out and maintain the water-supply systems in the field and in camps. It was imperative to form special companies of engine-drivers, fitters and skilled artificers, with specially selected mechanical engineer officers to deal with water-supply only. The A.T. Companies attached to the 20th and 21st Corps also, to a large extent, specialized on water-supply, and the Australian Engineers formed a special field troop of mechanics.

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36. *Stores and Equipment.*—The authorized equipment of the engineer units was found inadequate to meet the conditions. For the desert march the Field Companies, R.E., were reorganized and re-equipped. For work further in Palestine it was found necessary to add engines, special pumps and extra water-supply stores to normal equipment. The Sappers and Miners normally carry nothing for the development or distribution of water.

It is not possible to draw up any one equipment table for R.E. units which will meet the varied requirements of different lands. Engineer units will, in the future as in the past, have to equip to meet local requirements. Tools required for the artificers of the units will always be required, but it should be recognized that the rest of the equipment carried, and the transport required, depend upon a reasoned forecast of requirements for each particular operation.

(A short report by the Inspector of R.E. machinery, Palestine Forces, on engines, pumps and water-supply tools principally used is given in *Appendix* VIII).

The original report on the water-supply operations prepared by the Engineer-in-Chief, E.E.F., was supplemented by many Appendices, in which were given full details and working-plans of the principal systems, together with geological reports which had been prepared for each stage of the advance.

A copy of the complete report and appendices is filed in the office of the Director of Fortifications and Works.

APPENDIX I.

(To Chapter III).

Establishment of Field Company on Camel Transport.

	Personnel.			Transport.			
	Officers	Other Ranks.	Total	Riding Horses.	Camels.	Camel Drivers.	Fanatis Required.
Headquarters ...	3	9	12	*6	9	5	2
4 Sections: each	1	36	37	†2	15	5	4
	7	153	160	14	69	25	18

* 2 horses for O.C., 1 each for M.O. and Q.M. Serjt.
† Provides for 1 mounted O.R. per section.

Transport in Detail.

Headquarters.

Article	Amount to be carried.	Camels.	Drivers.	Fanatis.
Water Testing Equipment	... ...	1		
Technical Stores	Water-Supply, 3 loads	3		
	Explosives and Sandbags (1 load)	1	5	2
	Wire and sandbags (2 loads) ...	2		
Water	... 1 gal. per man, H.Q.	1		
Baggage	... Sun shelters, officers' kits, etc.	1		
	Total	9	5	2

For One Section.

Article.	Amount to be carried.	Camels.	Drivers.	Fanatis.
Stores, Tools, etc.	Pumps, troughs, corrugated iron and timber	9		
		2		
Water	37 men and 5 camel drivers at 1 gal.	2	5	4
Blankets	Blankets, picketing gear, camp kettles and off. kits ...	1		
		*1		
	Total	15	5	4

* To reduce loads of other 14 camels.

Stores Carried by Headquarters.

No. of Camels.	Stores Carried.	No in each load.	Weight of load. lbs. ozs.	Total Weight per load. lbs. ozs.
1 and 8	Norton tube well, complete with driving apparatus	1	248 0	248 0
	Pipe wrenches	2	9 14	19 12
	Bucket canvas		10	10
	Set of cleaning tubes		42 0	42 0
			Two camels, total weight each—	310 6
2	Fuse, safety, fathoms	32	$2\frac{3}{4}$	5 8
	Gun cotton, dry, primers with cylinders	80	$1\frac{2}{5}$	7 0
	Gun cotton, wet, slabs	42	15	54 0
	Detonators, tins of 25	3	15	2 13
	Boxes, gun cotton, dry primers	1	8 0	8 0
	,, ,, ,, wet ,,	3	10 0	30 0
	Sandbags, bundles of 25 ...	12	15 10	187 8
	Fuses, boxes	8	1	8
	Tape, india-rubber	1	1 0	1 0
	Shovels	2	5 0	10 0
	Spun yarn	5lbs.	5 0	5 0
	Wire, 16 w.g.	5	5 0	5 0
	Tallow in box, tin-lined ...	10lbs.	10 0	10 0
			One camel, total weight	326 5
4	Miscellaneous loads, wire, sandbags, ets.			344 12
			Six camels, total weight each—	344 12
5	Canvas tank, 30 ft. × 30 ft., with ropes and picket... ...	1	230 0	230 0
	Sandbags, bundles of 25 ...	6	15 10	93 12
	Water dippers and funnels ...	2	2 0	4 0
			One camel, total weight	327 12
6	Water, 8 at 1 gal., 5 native drivers (2 fanatis)	2	135 0	270 0
			One camel, total weight	270 0
7	Officers' kits		30 0	60 0
	Mess stores			30 0
	Blankets	8	4 8	36 0
	Sunshelter material			25 0
	Lantern	1	7 0	7 0
	Candles and matches	2	2 0	4 0
	Plane table and alidade ...	1	11 6	11 6
	Instruments, drawing	1	1 0	1 0
	Paper and linen			2 0
	Camp kettle	1	8 8	8 8
	Axes, felling	1	6 0	6 0
	Oil bottle, filled	1	8	8
	Sandbags, bundles of 25 ...	10	15 10	156 4
			One camel, total weight	347 10

Water testing equipment (Total 9 camels).

APPENDIX II.

(*To Chapter III*).

Water Supply Company, R.E.

WAR ESTABLISHMENT.

(i.) *Personnel and Horses.*

Detail.	Personnel.						Riding Horses.	Remarks.
	Officers.	Warrant Officers.	Staff-Serjts. and Serjts.	Artificers.	Rank & File.	Total.		
Captain	1					1	2	
Subalterns	4					4	4	(*a*) From Establishment for Engineer Services.
Co. Serjt. Majors ...		1				1		
Co. Q.M. Serjts. ...			1			1		
Staff Sjts. (Mechanists)			3 (*a*			3		
Serjeants			5			5	2	
Shoeing Smith				1		1		(*b*) Or riding mules for patrolling pipe-lines.
Corporals					9	9	2	
2nd Corporals					9	9		
Sappers					64	64		
Pioneers...					58	58	24(*b*)	
Batmen					5	5		
Total Company ...	5	1	9	1	145	161	34	

Notes.—1. The above establishment includes 8 Lance-Corporals.
2. No transport or technical equipment to be provided.

Distribution of Warrant Officer, Staff Serjeants and Serjeants, and Rank and File by Trades :—

Military Mechanists	3
Engine Drivers (Fortress)	24
Fitters	40
Turners	3
Plumbers (including Pipe Fitters)	20
Carpenters	5
Bricklayers	4
Blacksmiths	6
Shoeing Smiths	1
Tinsman	1
Draughtsmen	2
Clerks	3
Painter	1
Pioneers	38
Batmen	5
Total	156

APPENDIX III.

(*To Chapter IV*).

Sunk Brick Reservoir.

Plate VIII. shows a type of sunk reservoir having a capacity of 2,300 gallons per foot of depth. The particular example shown has a capacity of 12,600 gallons and is 5 ft. 6 in. deep. The depth was varied, and was in one case as much as 9 ft.

The floor was constructed of concrete 4 in. thick, and reinforced with rabbit-wire of 1-in. mesh as indicated. A small sump was made, giving access to draw-off pipe, and a 4-in. pipe steeped in the centre as support for the roof.

The walls were built of brickwork in cement mortar.

A light roof of timber framework supporting a rabbit wire and hessian canvas covering was provided.

The hessian was tarred to prevent dust from filtering through, and a manhole was fitted to allow access for cleaning.

It was possible to build a cistern of this type in seven days.

Quantities of material used.

Cement	$1\frac{1}{2}$ tons.
Bricks	2,000.
Rabbit wire	1,128 sq. ft.
Hessian canvas..	752 sq. ft.
Timber, 4 in. × 2 in.	220 ft. run.

APPENDIX IV

(*To Chapter IV*).

Hiseia Watering Area for Troops and Animals.

Plate IX. shows lay-out of typical water area designed for the supply of water to a Mounted Division.

The canvas storage was constructed in the usual way from 30 ft. × 30 ft. canvas sheets.

The brick tanks were of the design shown in *Plate* VIII.

The former were reserved for horse water storage, the latter for drinking water.

The storage was arranged on the Wadi bank, giving a head of 20 ft. over the standpipes and horse-troughs, which were built in its bed.

The standpipes were capable of filling 250 *fanatis* per hour, and the horses could be watered at the rate of 3,000 per hour for three hours.

A section of the masonry horse-troughs is shown on *Plate* IX.

These troughs were sometimes built of boulders and mud instead of lime mortar, the internal surfaces being rendered with cement mortar.

This form of construction was quite satisfactory, provided that the cement rendering was waterproof.

APPENDIX V

(*To Chapter IV*).

Development of Beersheba Wells.

1. The water-supply plant for Beersheba consisted of :—

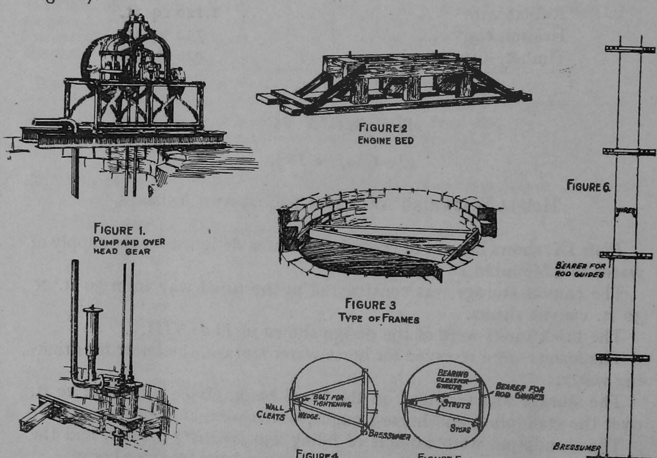
(*a*). Deep-well pumping-plant and well-sinking gear carried by a train of eight caterpillar tractors, which marched behind the Infantry along the Fara-Beersheba road, and—

(*b*). The pumping-plant from Asluj, which was dismantled from that place, and brought in by the Desert Mounted Corps.

Each tractor with its load formed an independent unit. Six of these units were pumping units, and comprised one deep-well engine and pump with such accessories as cement for repairs to well linings, timbering for support of the pumps and rod guides, derricks and tackle, a week's supply of oil, canvas storage tanks, pipes for distribution of water, and a party of 20 N.C.O.'s and men for erecting the plant and driving the engines.

Each engine was provided with a timber framed " bed " which was dug into the earth, and to which the engine was bolted. These frames proved to be as effective as concrete beds, and there was no necessity to allow time for concrete to set.

(*Sketch* No. 19 shows the method adopted for supporting the pump, rod guides, etc., in the well, and the type of timber bed used for the engines).



19. Details of Deep-Well Pumping Station.

(*See also page* 54).

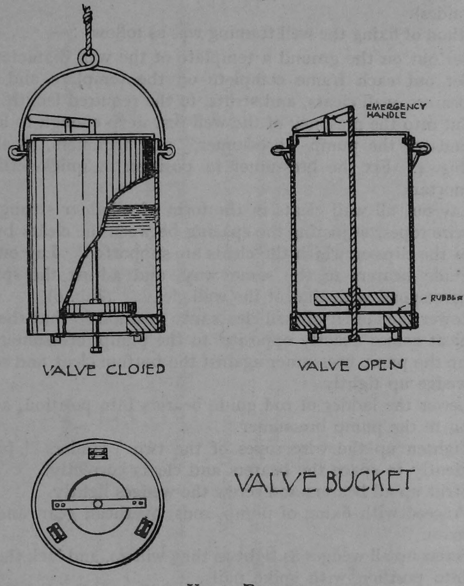
Three of the pumps were capable of delivering 2,700 gallons per hour each, and the other three 1,200 gallons per hour each.

The remaining two units were well-sinking units, and were to be employed in case the enemy had demolished the existing wells effectively.

Each of these wells comprised well-casing for a well 6 ft. in diameter by 50 ft. in depth, with necessary derricks and tackle for hoisting earth, and boring tools and explosives for use in hard ground.

The personnel for each of these units consisted of 6 N.C.O.'s and men of the R.E., with 8 miners who had been specially trained for the work.

In the event of its being unnecessary to sink new wells, these units were to be employed in raising water by means of buckets and joists. A special type of bucket (*see Sketch* No. 20) was provided for this purpose, fitted with an automatic valve at the bottom. The valve opened as soon as the bucket struck the water and closed again as soon as the bucket began to rise.



20. VALVE BUCKET.

The full bucket was lowered on to a staging fixed over the overflow, and this action caused the valve to lift and release the contents. With a heavy bucket holding 17 gallons of water the valve effected a saving of time, and from a well 90 ft. in depth water was raised at the rate of 1,600 gallons per hour.

Beersheba was captured by the Mounted Corps on the night of November 1st, 1917, and the Fara-Beersheba road was cleared by the infantry at 7.30 a.m. on November 2nd.

The train tractor entered Beersheba at 10.30 a.m., and the various units were on their allotted sites by noon.

The pumping-plant from Asluj was dismantled by the Desert Corps, R.E., and reached Beersheba on the afternoon of November 3rd.

2. The pumps available for the deep-well plant at Beersheba were not of a type most suitable for rapidity of erection, but they were the only pumps available at the time which met the requirements as regards output. It remained therefore to design reasonably quick methods of fixing these pumps (*see Sketch* No. 19).

(*Fig.* 1 shows a drawing of the pumps. The ordinary method of fixing the pumps and rod guides on joists let into the masonry was discarded, as too much time would be taken up in cutting into the stonework).

(*Figs.* 3, 4, 5 and 6 show the type of frame designed to carry the pump and rod guides).

The method of fixing the well framing was as follows :—

(i.) Set out on the ground a template of the well diameter.

(ii.) Set out each frame complete on the template and cut the bearers, wall cleats, and struts, to the required length.

(iii.) Cut into the masonry of the well just deep enough to let in the ends of the pump "bressumer" and trimmers, as shown in *Fig.* 4. Fix the bressumer in position in quick-setting lime mortar.

(iv.) Lay out all wall cleats in the form of a ladder strung on two wire ropes, adjusting the spacing between the cleats by means of the clips on which the cleats are supported. Lay out all rod guide bearers in the same way, and adjust the spacing to correspond with that of the wall cleats. (*Fig.* 6).

(v.) Lower the ladder of wall cleats into position so that the bottom cleat comes exactly opposite to the pump bressumer. Strut up the pump bressumer against the bottom cleat and screw the wedge up tightly.

(vi.) Lower the ladder of rod guide bearers into position, and hook on to the pump bressumer.

(vii.) Tighten up the wire ropes of the two "ladders"' just sufficiently to space the bearers and cleats correctly.

(viii.) Strut up all bearers and screw the wedges lightly.

(ix.) Proceed with fixing of pump, rods, overhead gear, and raising main.

(x.) Screw up all wedges as tight as they will go, and lock the wedges into position with spike nails.

(*Fig.* 2 shows the type of engine-bed which was employed).

The bed was dug into the ground and lined up with the pump ; the hole was then filled in and rammed down hard. The engine could be run as soon as it could be erected.

The time taken to erect one of these pump sets complete on a well 48 ft. deep was 47 hours from the time of arrival of the tractor on the site until the full delivery of 2,700 gallons per hour was obtained. From this time the pump was run for three days without a stop.

The time of 47 hours includes eight hours occupied in clearing the well of debris and of a broken pump left by the enemy.

The following table gives statistics of the various wells developed.

Well No.	Well.	Condition of Pump.	Engine.	Work done.	Yield galls. per hour.
1.	Water hole.	*Nil.*	*Nil.*	Bucket and hoist (temporary)	Negligible.
2.	Good.	Saqqia (workable)	—	1 pump and engine erected	1,000.
3.	Good.	,,	—	Valve and bucket hoist erected	1,600.
4.	Filled in.	—	—	— — —	—
5.	Good.	*Nil.*	*Nil.*	Pump and engine erected	1,000.
5*a*.	Destroyed.	—	—	— — —	—
6.	Good.	Centrifugal.	Parts missing.	Engine parts replaced and engine overhauled	2,000.
7.	Destroyed.	—	—	— — —	—
7*a*.	Partially destroyed.	—	—	— — —	—
8.	Good.	3-plunger Wagner.	Useless.	Pump repaired—new engine erected	2,000.
9.	Did not exist.	—	—	— — —	—
10.	Good.	3-plunger Wagner.	Useless.	Pump repaired—new engine erected	2,000.
11.	Damaged.	Damaged.	Broken.	2 pumps and engines erected	200.
12.	Good.	Broken.	*Nil.*	2 pumps and engines erected	3,700.
12*a*.	Good.	*Nil.*	*Nil.*	1 pump and engine erected	1,000.
13.	Good.	Good.	*Nil.*	Engine erected	1,000.
14.	Good.	*Nil.*	*Nil.*	Bucket and hoist	Negligible.
15.	Good.	Saqqia.	—	Saqqia repaired	1,500.
16.	Good.	*Nil.*	*Nil.*	*Nil.*	—

N.B.—The yield shown is the average.

Total = 17,000 g.p.h.
i.e., about 408,000 g.p.d.

APPENDIX VI.

(*To Chapter V.*).

Machinery Park.

When the Defences of the Suez Canal were taken in hand (*see Chapter II.*),a small Engineering Workshop was established to deal with the water-supply machinery and plant. This was installed at Ferry Post, the nucleus of the personnel being R.E. Sappers with the addition of native tradesmen.

As the advance progressed these shops had to be gradually increased in size, and in the summer of 1917 it was found necessary to move the shops forward to a new site.

The new Machinery Park was begun at Rafa in September, 1917, and was a running concern within one month of the commencement of building.

The new shops and stores enclosure covered roughly 6½ acres, of which more than 3,000 square yards were covered by offices, stores and shops.

The plant and work had increased to such an extent that practically a new engineering works organization had to be formed.

The Park was responsible for the issue and upkeep of R.E. Power Plants, the bulk of which consisted of engines and pumps for water supply. Thirty-two different makes of engine were handled, comprising sixty-eight different types and sizes varying from 3½ H.P. to 90 H.P. in addition to eighty-three various types and sizes of power pumps.

Approximately 300 engines and 350 power pumps were registered as being in use with the force.

Offices.—All machinery was given a R.E. number, and in the Drawing Office sketch records were taken of all parts likely to require replacement. Drawings for conversion of service pumps into deep-well pumps and *vice versa*, hand pumps into power pumps, medium-pressure pumps into high-pressure, constantly had to be made ; also in most cases foundation plans, as engines and pumps usually arrived without any working drawings. A register was compiled from the shop records giving the full history of each plant, every test, conversion, particulars of parts when specially fitted, all spares issued, also particulars of any deviation from the standard dimensions, such as cylinders when rebored, also crank shafts when skimmed up.

Pattern-Making Shop.—This shop worked under great difficulties, as it was never possible to obtain any of the woods that are regularly used for pattern-making, and shift had to be made with common deal or poor-quality pitch pine.

The stock of patterns and core boxes which were continually in use numbered roughly 1,000, not including those temporarily rigged up for special jobs.

Moulders' Shop.—Similar difficulties occurred here with the sand which was of very poor quality. The whole of the tools used in the shop and to be made locally, as were also the cupolas, blowers, and blast furnaces.

Certain articles were never procurable, including moulders' brads and blacking, ganister, core gum and limestone.

In spite of all difficulties an average output of 500 brass and iron castings per month was achieved.

During the last twelve months of the war practically all the brass or gun-metal used was material captured from the enemy.

Smiths' Shop.—It was found necessary to make locally the main tools for this shop, as the only available patterns were not large enough for the class of work undertaken. One of the greatest difficulties was to obtain mild steel suitable for welding, the English bar material supplied having a very high percentage of carbon, and being thus difficult to weld.

The enemy bar mild steel was much superior for general smiths' use, and the blacksmiths always searched for pieces of captured bar, if they had an important forging with a weld in it to make.

Machine Shop.—The tools included lathes, drilling machines, planing, milling, shaping, screwing machines, and grinders.

Work such as re-boring of cylinders up to 12½ in. diameter had to be undertaken on a 10-in. centre lathe, and all machine tools were kept working at high pressure throughout the whole period, an average of 1,000 jobs or articles being turned out per month.

Erecting and Testing Shop.—This department got through an exceptionally large amount of work. The special conditions under which engines and pumps had to be run, mainly out in the open desert, and so at times covered with sand, made it necessary to take every engine and pump completely to pieces when overhauling. All plants after overhauling were subjected to a specified test, the engine being fixed on special test beds (made on site), and run against a friction-brake load. The pumps were subjected to water-test load. The wear which took place owing to the presence of fine sand was astonishing, and a large number of engines had to be re-bored, or new cylinders fitted, after three to four months' running, the wear then being about 1/16th inch.

A great amount of very interesting work was done in assembling and testing incomplete captured engines, many of which were quickly put into regular commission.

Spare Parts Stores.—Orders on England took about nine months to arrive, and a large stock of spares and renewals had to be constantly kept on hand. Approximately 21,000 spares were held, these comprising 3,000 entirely different articles.

A large number of parts were actually made in the workshops, and a very careful system of card registration was maintained.

General.—As it was most important that all plants issued should be reliable, and carry a good factor of safety, many variations were made, which gave a working water-head pressure of double that which the maker had provided for.

When the problem of water-supply for the Judean Hills had to be met it was found that none of the pumps in the country were capable of pumping at the pressure necessary for providing water on the hill tops—for this service a heavy duty pump was designed, and several were turned out by the workshops. These were triple-ram pumps with a 14-in. stroke, and, as may be seen from *Photos*. (iv.) and (v.), were a very large undertaking for a field workshop. On test, when pumping at a water pressure of 320 lbs. per square in. the pump showed an efficiency of 84 per cent. From the commencement of the designing of this pump to the day of testing only six weeks elapsed—a time which it would be difficult for any engineering firm to beat.

During the twelve months following the removal of the park to Rafa, more than 200 power pumps and 300 engines passed through the shops for overhaul, examination, and test—in addition, approximately 500 salved hand lift and force pumps were overhauled, tested and made serviceable for issue.

These are striking figures when it is considered that the personnel employed contained a proportion of three natives to each British tradesman.

(A general view of the Park looking from the south is given in *Photo*. vi.).

APPENDIX VII

(*To Chapter V.*).

WATERWORKS COMPANY, R.E., EGYPT.

WAR ESTABLISHMENT.

(i.) *Personnel and Horses.*

Detail.	Personnel.							Horses.		
	Officers.	Warrant Officers.	Staff Serjts. and Serjts.	Artificers.	Rank & File.	Natives.	Total.	Riding.	Draught.	Total.
Major	1						1	1		1
Captain	1						1	1		1
Subalterns	6						6	6		6
Co. Serjt. Major		1					1	1		1
Co. Q.M. Serjt.			1				1	}		
Staff Serjts. (Machinists) ...			5				5	}		
Serjeants			9				9	}		
Shoeing Smith				1			1	} 5		5
Corporals					12		12	}		
2nd Corporals					13		13	}		
Sappers and Pioneers					183(*a*)		183	}		
Batmen						8	8			
Drivers { for vehicles						14	14		28	28
{ spare						4	4			
Total Co. (exluding attached) ...	8	1	15	1	208	26	259	14	28	42
Attached drivers (A.D.C. Mech. Transport)					10		10			
Total Co., including attached ...	8	1	15	1	218	26	269	—	—	—

(*a*) Includes 14 Lance Corporals.

(ii.) *Transport.*

Detail.	Vehicles.	Drivers.		Draught Horses.	Remarks.
		British.	Native.		
Wagons, trestle ...	1		2	4	
Carts, tool, R.E. ...	2		2	4	
Motor cycles with side-cars	5				(*b*) Captured vehicles.
Ford cars...	5	5(*c*)			(*c*) Provided by A.S.C.
Lorries, 3-ton	2	4(*c*)			
Lorries, 30-cwt.	1	1(*c*)			
Horse vehicles (*b*) ...	5		10	20	
Driver, spare			4		
Total	21	10	18	28	

APPENDIX VIII.

(*To Chapter VI.*).

NOTES ON ENGINES AND PUMPS IN USE FOR WATER-SUPPLIES, E.E.F.

Engines.—Engines of the following makes were in use :—Blackstone, Hornsby, Crossley, Bates, Ruston Proctor, Clayton & Shuttleworth, Keighley, Tangye, Lister, Winterthur, Olds (American), Robey, Petter and Deutz.

There was very little to choose between the various types ; most of them have done well.

The engine which has done most service with least trouble is the Blackstone ; all sizes of this engine from 4 to 20-H.P. have been excellent.

Among the petrol-engines the Lister 5-H.P. has done very well. This engine is really a 4-H.P., and under a brake test will rarely develop more.

Among the least satisfactory engines the Olds' 4-H.P., which is a cheap agricultural engine, and the Petter horizontal types, including the "Handyman," both types purchased locally, are of poor design. They gave trouble with lubrication and the parts wear too rapidly for continuous service.

The Petter vertical engines are, however, excellent, and have done well.

Pumps.—The Dando.—This has done very well and is the favourite with all users. The chief features are the ball valves which give least trouble with sandy or muddy water, and the balancing arrangement which can be adjusted to various depths and works well. The pump is of good substantial design, and is quickly and easily erected. The most suitable size for wells in this country is the larger one, giving 3,000 gallons per hour.

The Allesbrook.—This is similar to the Dando, but of poor and unsubstantial design. It was necessary to reconstruct these pumps on firmer bases before issuing them.

The Isler.—This is a good type of pump and has done well. The Isler 1,000-gallon pumps and Lister petrol-engines issued as a complete pumping-set gave excellent service. The only point of difference between this pump and the Dando is the ball valve of the Dando, which is preferred.

Portable Pumping-Sets.—Two types of combined engines and pumps mounted on wheels for transport were in use :—The Blackstone-Hayward Tyler and the Lee-Howll well pump.

In both pumps, and especially the latter, the wheel bases are not sufficiently rigid for the satisfactory working of the pump, and give trouble.

The Blackstone-Hayward Tyler Pump was very useful when a temporary set was required, and has done well.

The Lee-Howll Set consists of a portable well-head and deep-well pump. As supplied it will only lift water three or four feet above the ground. It has been tried in conjunction with a stuffing-box arranged to lift water to an elevated reservoir, but the working is not satisfactory owing to the vibration on its non-rigid wheel base. The pump might be used with a stuffing-box if taken off the wheels and mounted on a masonry foundation, but this would do away with its portability.

The bed-plate is not sufficiently rigid, and deflects under working loads, causing trouble with the engine-bearings. The so-called "war finish" results in the engine-shaft being 1/16th in. out of line and the gears not properly in mesh.

The engines have been supplied with air-admission regulators and the pump is unbalanced, causing the engine to race on the downward stroke. All these defects can be, and have been, remedied locally, and the first set worked successfully, but other types such as the Dando or Isler are preferred.

Compressed Air-Ejectors.—Six of these, of Hughes and Lancaster's manufacture, were received. As far as could be seen they would not be of much use. They were only suitable for masonry wells with a fair depth of water. The intention of the ejectors seemed to be a portable apparatus which could be rapidly placed in a well for immediate service, but for this purpose the apparatus was far too heavy. The ejector itself weighed 16 cwts. The crane provided would not lift it and bends under the load. It was not suitable for a permanent installation and was too heavy for a temporary one.

Chain Bucket Pumps.—These have not done well. They were too frail for rough usage and in practice were not successful.

Chain Helice Pumps.—These pumps, both for hand and power, have done well in positions suitable for them, *i.e.*, in open wells with a fair depth of water. When these conditions exist, however, a larger delivery is usually required than this type of pump is capable of, and so they have not been much used.

Water Belts.—The above remarks also apply to water belts. For a quick temporary service they would be preferable to the compressed air ejectors.

High-Lift Pumps.—Triple plunger pumps of Tangye, Pearne, and Evans make were in use and did good service. The most useful type was the Evans 4 in. × 6 in. × 300 ft. head. When higher lifts have been required these pumps were successfully converted by fitting them with plungers of smaller diameter to deliver half the quantity of water at 500 ft. head. Lifts of 800-900 ft. have been dealt with by using these pumps in two stages.

Centrifugal Pumps.—On the main Kantara-El Arish pipe-line, the Gilkes 5-in. pump did much better than the Rees-Roturbo. The latter type was apt to give trouble with the least amount of grit, and it is impossible to keep sand out of the water in this country.

The Gwynne 4-in. three-stage pumps have been worked continuously where from 6,000 to 7,000 gallons per hour by 200 ft. head is required. They have done well and given no trouble.

Deep-Well Pumps with Outside Rods.—Many pumps of this type were in use, principally of Hayward-Isler, Evans, and Wagner manufacture. The latter was made at Jaffa in a workshop owned by a German. Most of the wells in the occupied part of Palestine were fitted with these pumps of a capacity of about 6,000 gallons per hour, driven by Deutz engines. The first used with that at Khan Yunis was copied, and twelve similar pumps were made in Cairo to replace any which may have been damaged by the enemy. Wells had, however, usually been found with these pumps intact, and the new pump has been used in several instances to duplicate the machinery on large wells, for an increased supply.

The Jaffa workshop contained the patterns and parts of these pumps, and it maintained them for their upkeep.

Notes on Tools and Materials for Piping Work in the Field.

Pipe-Cutters.—The service pattern was good, but not the best. Tests might be made of other patterns.

Pipe-Threading Tools.—The service pattern was very old, slow in action and, owing to the absence of a " guide " for the dies, inaccurate. Trials should be made to find the best pattern which should be strong and simple in design. For trial for small sizes of pipes up to 2 in., the " Armstrong " stocks and dies and the " Little Giant " are suggested. There are many others. For the longer sizes of pipes it is considered stocks and dies of the " Receding Die " type would probably be most suitable—the following are two well-known makes—the " Toledo " and the " Beaver."

General.—It is suggested that the following tools and stores be added to the *Vocabulary of Stores* as being essential for piping work :—

(i.) A pipe-wrench of a " Stillson " type in say, four sizes, 10 in., 14 in., 18 in. and 24 in.

(ii.) One additional size to " Wrenches Adjustable," *viz.*, 14 in.

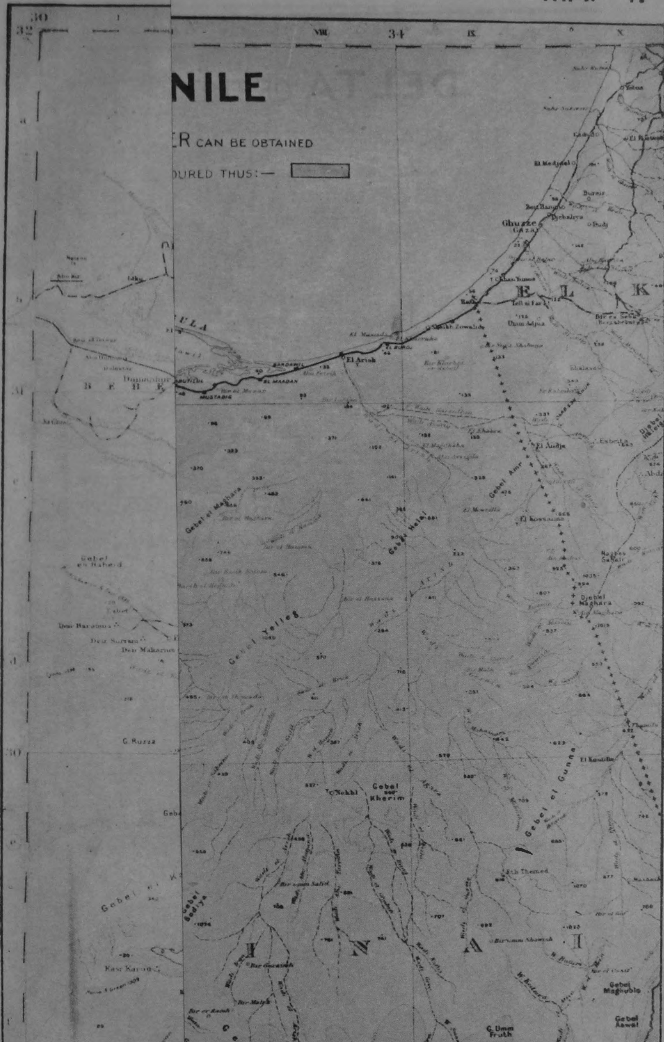
(iii.) Files, 3 square, 2nd cut, 10 in.

(iv.) Brushes, wire (for cleaning threads). These brushes are also used for cleaning ironwork before painting.

(v.) " Graphite " pipe-joint compound in, say, 1-lb. tins.

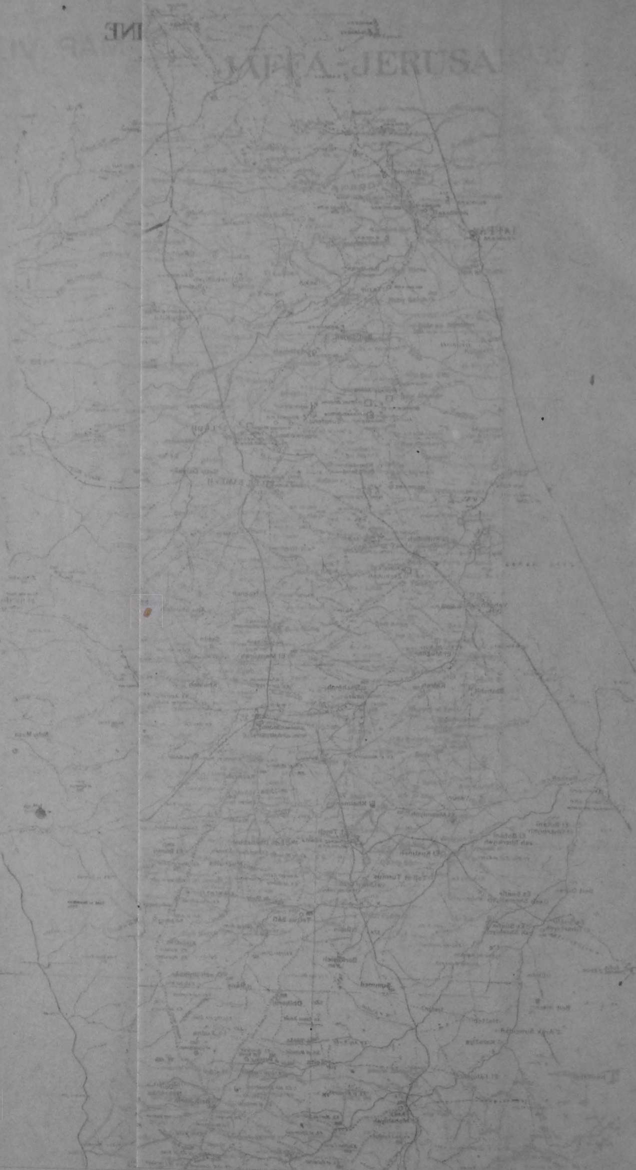
INDEX.

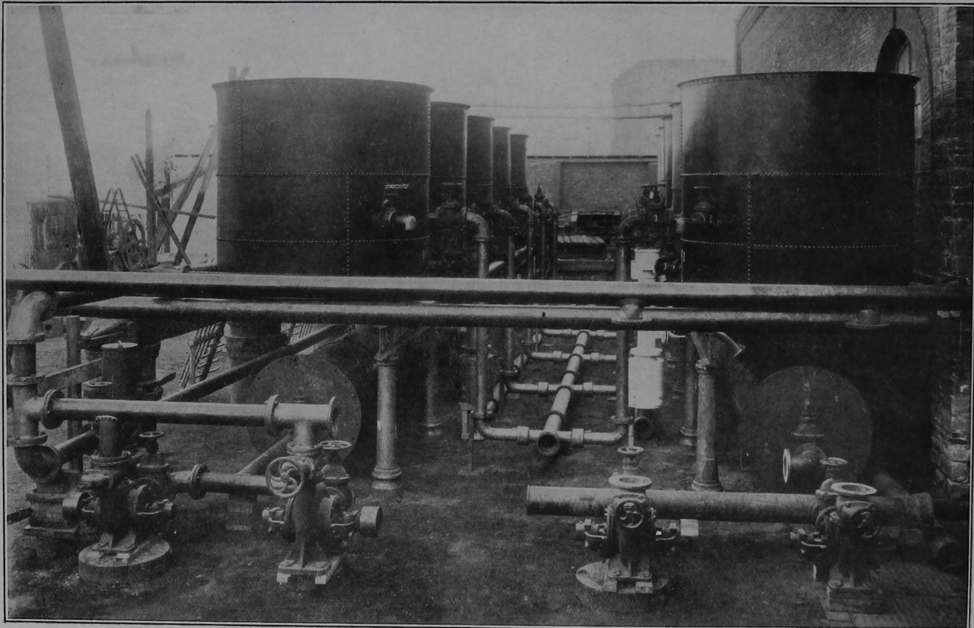
MAP I.



NILE
ER CAN BE OBTAINED
OURED THUS:—
El Arish
Ghuzze (GAZA)
Rafa
El Audja
Gebel Amr
Gebel Helal
Gebel Yelleg
Gebel el Maghara
Djebel Maghara
Gebel el Gunna
El Kuntilla
Nekhl
Gebel Kherim
Gebel Wuta
Gebel Edjma
G. Umm Fruth
Gebel Maghubla
Gebel Aawal
G. Rozza
G. Rayan
Gebel Bodiya
MUSTABIG
EL MAADAN

AP VII.

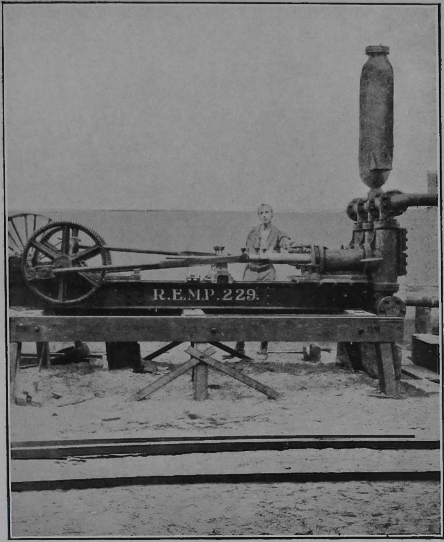


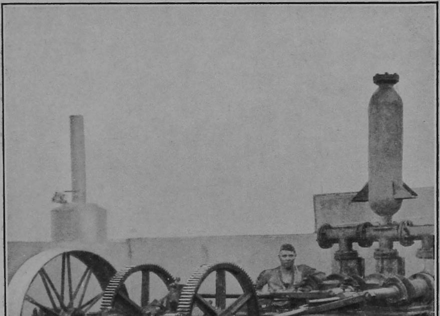


I.—Filtration Plant, Kantara.

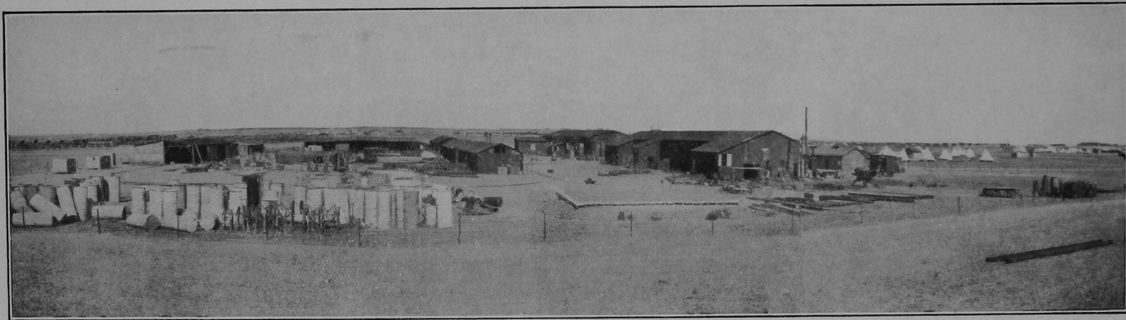
II.—Loading area charged with full Fanatis awaiting Camel Convoy.

III.—Men of Fantasse-Filling Party loading decauville truck with full fanatis.





IV and V.—Triple ram pump, local manufacture.

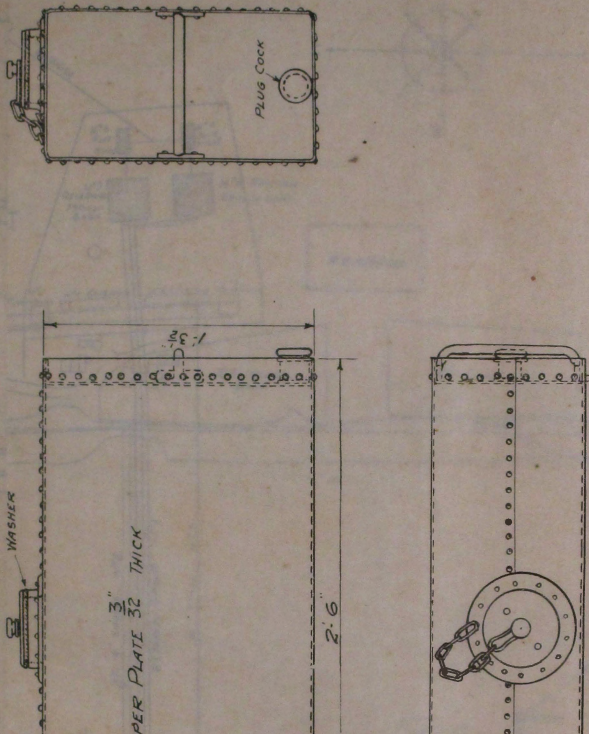


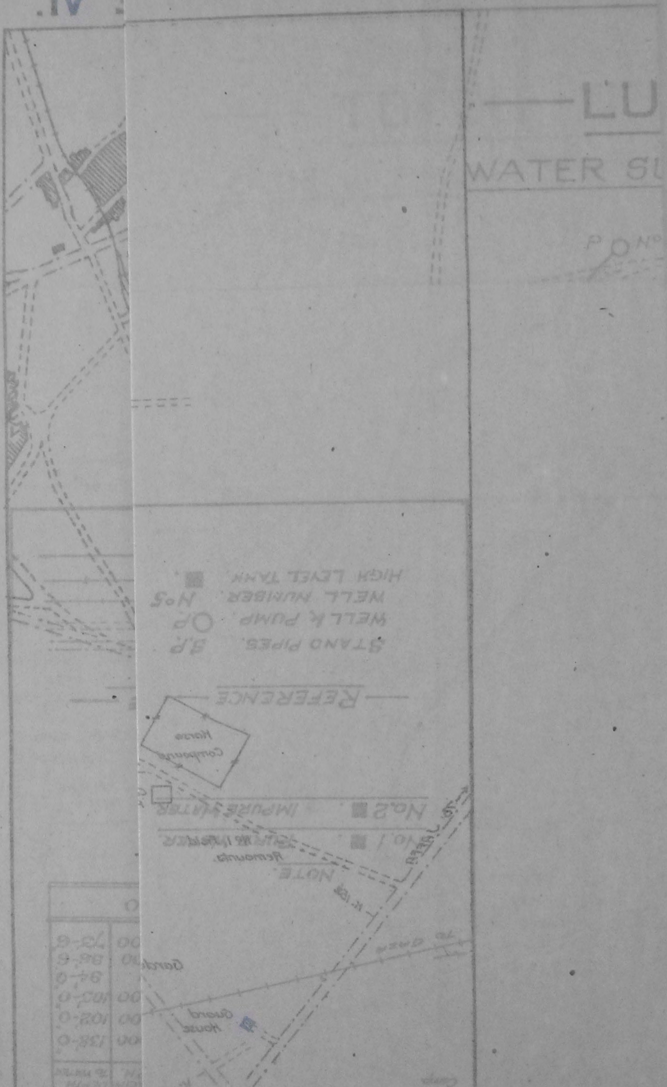
VI.—General view of Machinery Park.

PLATE I.

COPPER FANTASSE.

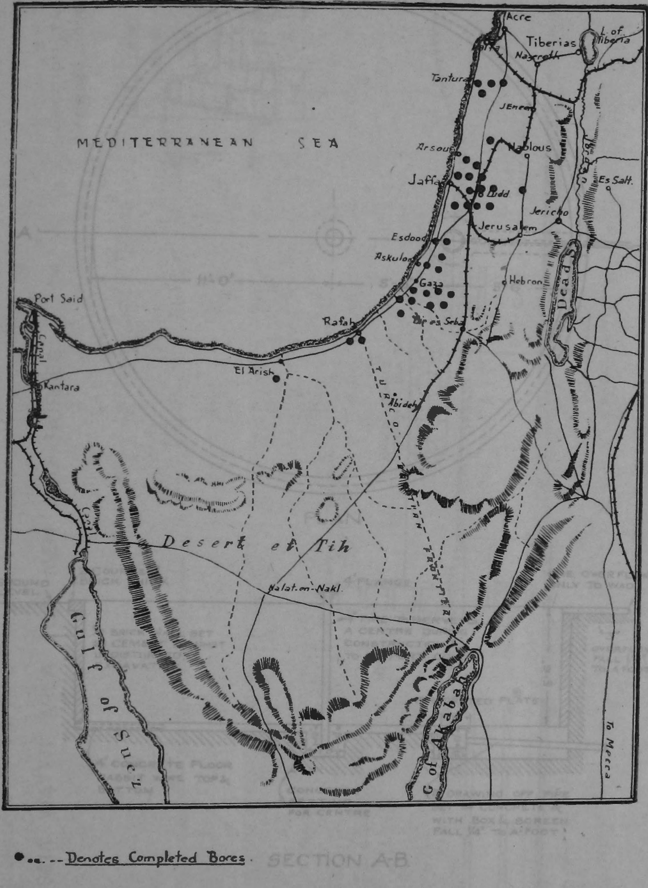
CAPACITY 12 GALLONS.




LU
WATER SU

EGYPT AND PALESTINE.

SHOWING LOCATION OF BORES.

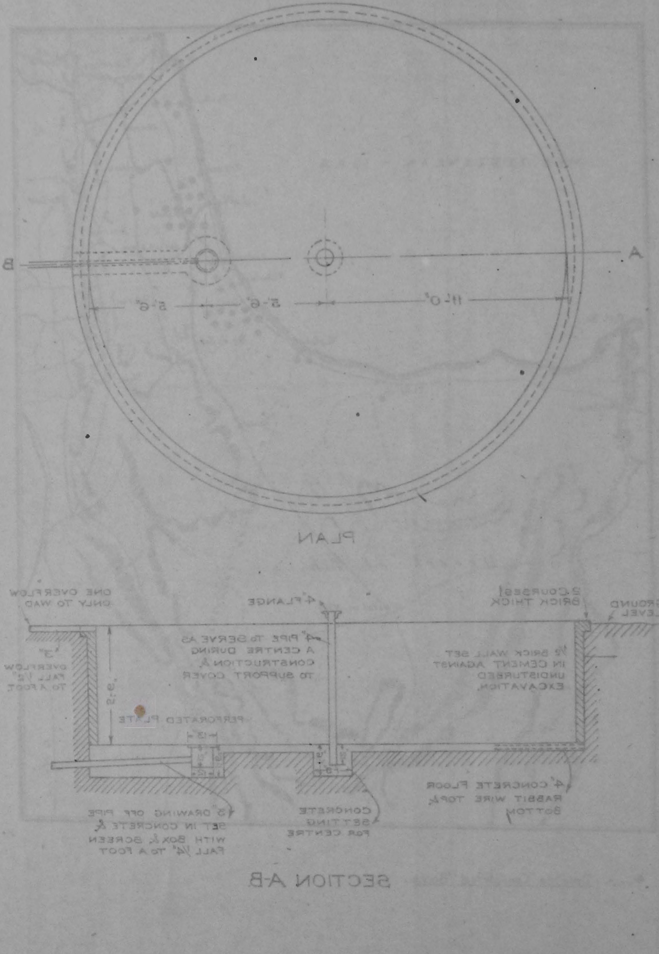


●.. --Denotes Completed Bores.

PLATE VIII

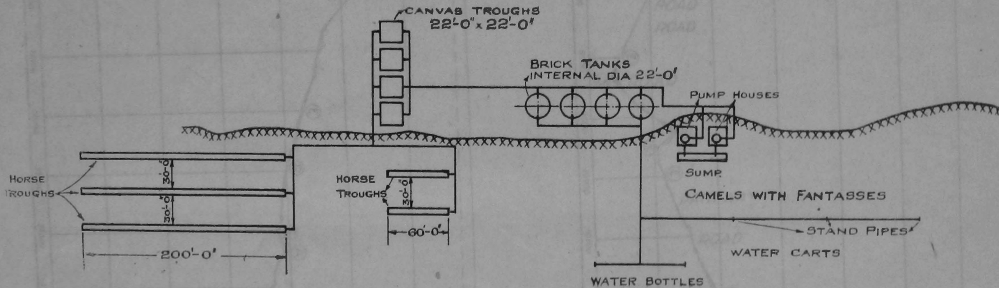
BRICK TANKS, HISEIA.

INTERNAL DIAMETER 22 FEET



SECTION A-B

HISEIA WATER AREA FOR MEN AND HORSES.



SECTION THROUGH HORSE TROUGH

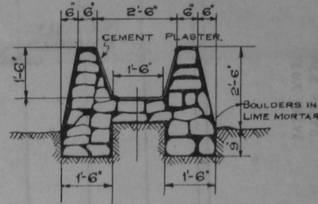
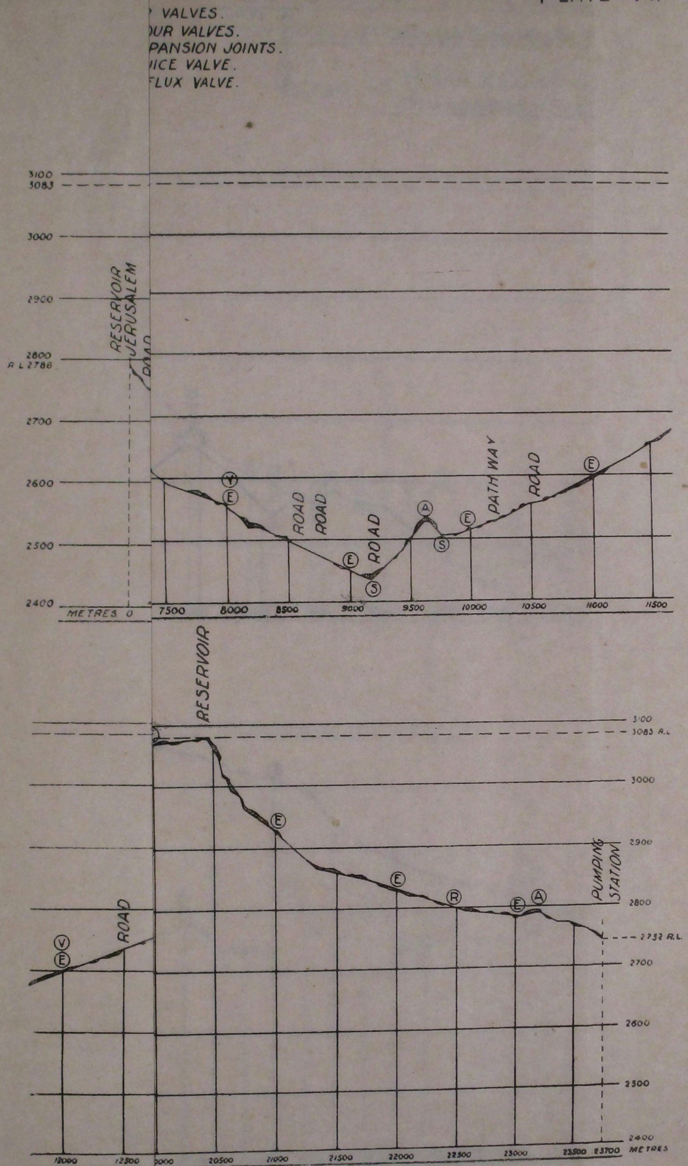


PLATE IX.



VALVES.
OUR VALVES.
PANSION JOINTS.
ICE VALVE.
FLUX VALVE.
3100
3083
3000
2900
2800
R.L 2788
2700
2600
2500
2400
RESERVOIR
JERUSALEM
ROAD
METRES 0
7500
8000
8500
9000
9500
10000
10500
11000
11500
ROAD
ROAD
ROAD
PATHWAY
ROAD
RESERVOIR
ROAD
PUMPING STATION
3083 R.L.
2732 R.L.
12000
12500
20500
21000
21500
22000
22500
23000
23500
23700
METRES

Date Due