

**Report on the measures taken against malaria in the Lahore (Mian Mir)
Cantonment, 1909 / by R. Nathan, H.B. Thornhill, L. Rogers.**

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India

REPORT

ON THE

Measures taken against Malaria in the Lahore (Mian Mir) Cantonment

BY

THE HON'BLE MR. R. NATHAN, C.I.E., I.C.S.,

LIEUTENANT-COLONEL H. B. THORNHILL, C.I.E., I.A.,

AND

MAJOR L. ROGERS, M.D., F.R.C.P., F.R.C.S., I.M.S.

1909.



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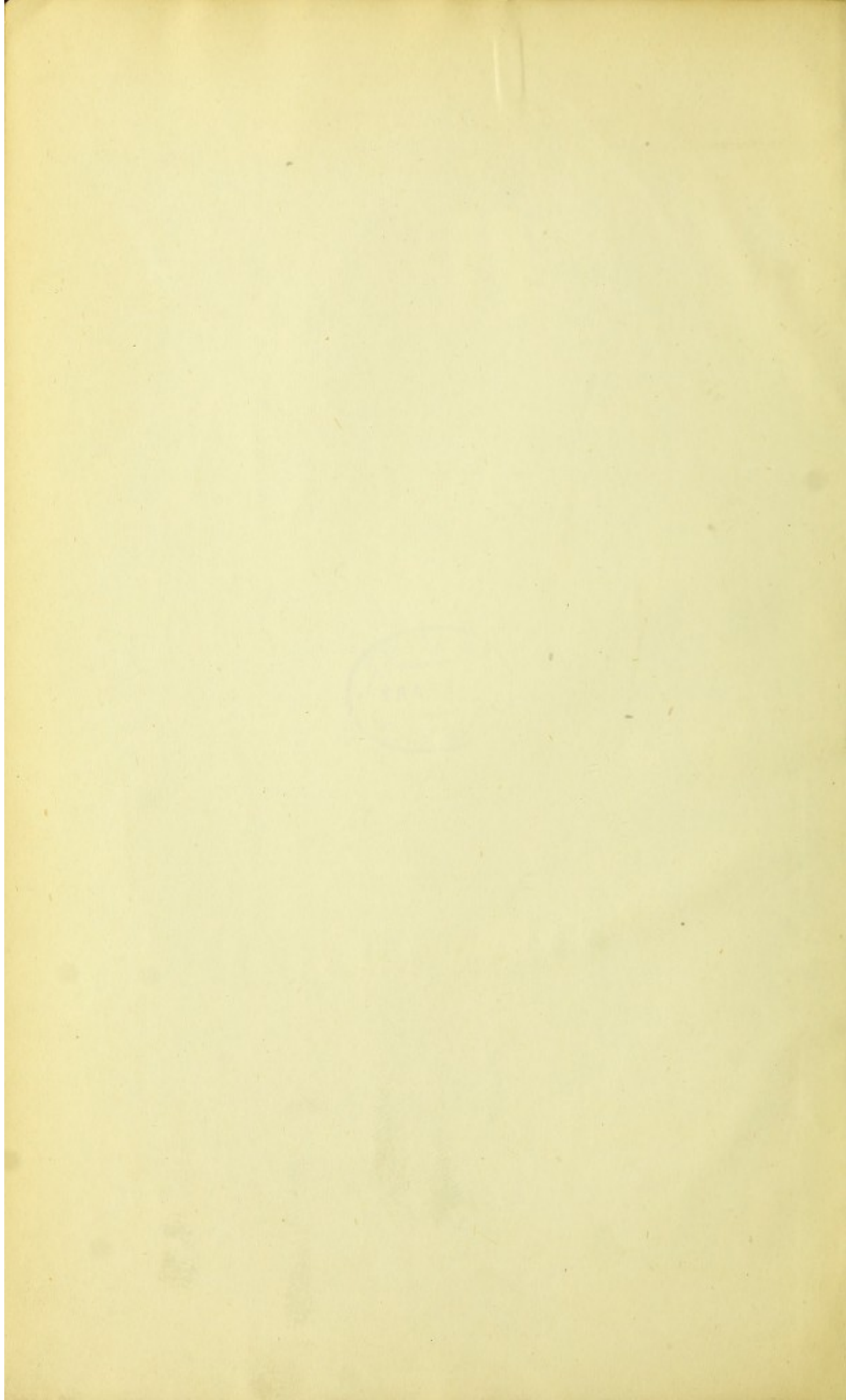
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THE HONORABLE MR. H. BATHAM, M.P.

MEMBER OF THE HOUSE OF COMMONS

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TABLE OF CONTENTS.

Subject.	Page.	Paragraphs.
PART I.—PRELIMINARY	1	1—4
PART II.—DESCRIPTION OF LAHORE CANTONMENT	3	5—9
PART III.—FIRST SERIES OF EXPERIMENTAL OPERATIONS IN LAHORE CANTONMENT.		
Preliminary investigations	6	10—13
Operations conducted by Major James	8	14—23
Operations conducted by Captain Christophers	9	24—31
Conclusions	11	32
PART IV.—GENERAL ANTI-MALARIAL OPERATIONS IN THE CANTONMENT.		
Inception of the operations	12	33—34
Organization	12	35
Sources of information	13	36—37
Closing and filling in of the irrigation canals	14	38
Filling in of depressions	14	39
Improvement of the drainage system	15	40—47
"Mosquito Brigade" operations	18	48—52
Measures in private compounds	20	53
Protection of wells	20	54—56
Miscellaneous measures	21	57—63
Quinine prophylaxis	22	64—67
Expenditure	24	68—71
PART V.—RESULT OF GENERAL ANTI-MALARIAL MEASURES.		
Arrangement of the subject	25	72
Breeding places of <i>anopheles</i> remaining in and around the cantonment.	25	73—78
Prevalence of malaria bearing mosquitoes	27	79—88
Incidence of malaria tested by spleen rates and endemic indices of Native children.	30	89—95
Influence of rainfall upon malaria in Lahore Cantonment	33	96—103
Incidence of malaria among the Native population	36	104—106
Incidence of malaria among British troops—		
Examination of causes affecting statistics from 1904 onwards	37	107—115
General examination of the statistics for British troops	41	116—119
Incidence of malaria among Native troops	43	120
Incidence of malaria among troops in October 1909	43	121—123
PART VI.—SUMMARY OF CONCLUSIONS	45	124—128
PART VII.—APPLICABILITY TO INDIA OF MEASURES ADOPTED IN OTHER PARTS OF THE WORLD.		
Summary of measures	47	129—137
General Indian conditions affecting anti-malarial operations	52	138—139
Anti-malarial experiments carried out in India	52	140—149
General conclusions	54	150—153

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REPORT

ON THE

Measures taken against Malaria in the Lahore (Mian Mir) Cantonment.

1909.

PART I.—PRELIMINARY.

ON the 19th of October we received, at Simla, the orders of the Government of India (letter no. 1701, dated 19th October 1909) to make an investigation into the anti-malarial operations which had been carried out in Lahore Cantonment. The letter forwarded a copy of the Secretary of State's despatch no. 103 (Revenue), dated the 27th August 1909, and directed us to enquire into and report on the following points:—

- (1) the manner in which the Mian Mir experiments, which had for their object the extermination of mosquitoes and the abolition of malaria by means of operations against mosquitoes, were carried out;
- (2) the results obtained from the operations at Mian Mir; and
- (3) whether operations similar to those employed at Ismailia, Panama and Lagos can be successfully applied to Indian centres of population.

2. We started from Simla on the 20th October, reached Lahore Cantonment on the morning of the 21st, stayed there until the evening of the 26th and then returned to Simla. On arriving at the cantonment we placed ourselves in communication with the military and medical authorities, and, with their assistance, we carried out the following programme:—

- (i) general survey of the cantonment during which we visited and examined all parts of the station;
- (ii) special examination of excavations and depressions likely to serve as breeding places;
- (iii) examination of the drainage system;
- (iv) search for adult malaria bearing mosquitoes; and
- (v) examination of the spleens and blood infection of children in the bazaars (spleen rate and endemic index).

We also collected statistics and other data and examined the witnesses numbered 1—14 in the list appended.

Captain Christophers, I.M.S., accompanied us to Lahore and rendered us invaluable aid.

3. After our return to Simla we examined witnesses numbered 15—21 in the list, collected further documentary and statistical evidence, and completed our examination of the data obtained. Colonel Thornhill paid a second visit to the cantonment from the 15th to 17th November in order to make a further examination of the extent and character of the pits and other depressions lying around the cantonment border.

4. We have now the honour to present the results of our investigation under the following main heads:—

- (a) description of the cantonment;
- (b) account of the operations carried out by Major James and Captain Christophers during the years 1901—1903 and of their result;
- (c) account of the general operations undertaken by the military authorities from 1904 onwards;
- (d) results of these measures; and
- (e) examination of anti-malarial campaigns in other countries with a view to test the applicability of similar measures to Indian conditions.

PART I.—PRELIMINARY.

On the 12th October 1904 we were joined at Simla by the Colonel of the Cantonment, Mr. J. H. Thornhill, and Mr. J. H. Thornhill, who had been in charge of the cantonment since the 1st October 1903. We were then joined by Mr. J. H. Thornhill, who had been in charge of the cantonment since the 1st October 1903. We were then joined by Mr. J. H. Thornhill, who had been in charge of the cantonment since the 1st October 1903.

- (1) The nature of the cantonment, which had been in existence since the 1st October 1903, and the nature of the operations carried out by the military authorities from 1904 onwards.
- (2) The results of the operations carried out by the military authorities from 1904 onwards.
- (3) The results of the operations carried out by the military authorities from 1904 onwards.

It was found that the cantonment had been in existence since the 1st October 1903, and that the operations carried out by the military authorities from 1904 onwards had been successful in reducing the number of cases of malaria.

- (4) General survey of the cantonment during which we visited all the pits and other depressions, and examined the water in them.
- (5) General survey of the cantonment during which we visited all the pits and other depressions, and examined the water in them.
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PART II.—DESCRIPTION OF LAHORE CANTONMENT.

5. The river Ravi, flowing in a south-westerly direction, divides the Lahore district into two sections. The northern portion of the cis-Ravi, or eastern, section forms a stretch of upland country comprising the central and principal portion of the celebrated *Manjha* tract, the home of the Jat Sikhs. In former times the Lahore *Manjha* was a wilderness presenting an almost uniformly level surface with hardly any variety of feature from end to end. The extension through this tract of the Bari Doab Canal converted it into a fertile and prosperous countryside. On the south the *Manjha* upland falls abruptly into the *Hithar* or low country formed by the old valley of the Bias and the present bed of the Sutlej. On the west it falls into the valley of the Ravi. The cantonment of Lahore is situated on the western edge of the *Manjha* upland and distant six miles south-east from the city of Lahore which stands on the Ravi river. The civil station lies between the city and cantonment and is about 3 miles from the latter. The cantonment is served by two railways, a branch of the North-Western Railway running from Lahore to Delhi and another branch running from Lahore to Mooltan.

6. Map no. 1 appended to this report shows the cantonment and the country surrounding it. The cantonment stands on a level plain about 700 feet above sea level, the great flatness of which is the most noticeable feature that strikes the eye. The ground slopes very gradually from north to south; the station is built on the highest portion and there is hardly a foot of difference in the level throughout its extent. The site was formerly arid like the rest of the *Manjha*. Irrigation was introduced about the year 1867 by a branch distributary from the Bari Doab Canal. Gardens were then cultivated and avenues of trees planted. The irrigation canals were abolished in the years 1904-1905 as a portion of the anti-malarial operations hereafter to be described. Some wells have been dug to irrigate gardens, but the station has lost much of its green fertility and many trees have already died. The irrigation system as it existed at the time of its abolition is shown in blue on map no. 1.

7. The average annual rainfall is about 20 inches. About 14 inches falls during the monsoon months, June to October, and about 10 inches of this during July and August. The hottest month of the year is June when the temperature in a carefully shut house varies from 96°-106° F., and unless rain falls the heat lasts into July.

"The hot weather indicates its approach in April, but indoors it is fairly comfortable until May. Then the air becomes very dry, and hot burning winds commence. The nights are warm but not troublesome during May, and both April and May are comparatively healthy months for Europeans. In June the heat increases considerably and hot winds are prevalent. Early in July there is a burst of the monsoon rain, but owing to its short duration its cooling effect only lasts for a few days, and unless more rain comes, the great heat begins again and is made more trying by the increased moisture of the air. Throughout July and August the nights are very hot, and in the latter month strong hot breezes sometimes spring up. In September the nights begin to be less hot and from September 15th the days also are distinctly cooler. Early in October it is quite cool out of doors, and by the middle of this month the weather becomes very pleasant. This, however, is the month when malarial fevers are most prevalent. November and December days are bright and clear and the nights cold. In January and February early morning frosts are noticeable. March is very variable but generally pleasant, and in April the hot weather begins to make itself felt again."*

"The surface layer of the soil consists for the most part of very dry finely powdered mud and sand, which, during the fierce winds of the hot weather, is blown about in clouds of dust. Beneath this superficial layer the soil

* Captain James's Report on anti-malarial operations, 1901-1903.

consists for the most part of clay and 'kankar,'* a soil which becomes hard and impervious on treatment with water.† This impervious soil will not allow rain water to sink in, and the collection of surface water which results from this cause is a potent factor (as in many other places in the Punjab) in the causation of malaria. Speaking of a period anterior to the recent improvement in the drainage, Major James described the condition of the cantonment after rain as follows:—"After one or two hours' rain the appearance of the cantonment is changed from that of a dry arid plain to that of a district in flood. Broad expanses of water, often a quarter of a mile in extent, cover the plain on every side, and the inhabitants of the followers' huts on some of the comparatively low-lying parts are literally flooded out. The majority of these large expanses of water dry up in the hot sun in three or four days, but numerous small deeper pools are left which, lasting for a week or ten days, form excellent breeding places of *anopheles* mosquitoes."

In spite of the unfavourable character of its sub-soil the tract of country in which the cantonment is situated is not highly malarious. Captain Christophers exhibited to the Malaria Conference at Simla a series of maps showing the distribution of malaria in the Punjab in epidemic years. An inspection of these maps shows that the area in which the cantonment is situated is subject only to comparatively slight epidemics which do not approach in virulence those which periodically occur in other portions of the province which lie lower or are subject to a heavier rainfall.

8. The cantonment dates from the years 1851-52 when the troops were removed to it from the neighbouring station of Lahore. It was formerly known as Mian Mir, and the name was changed in the year 1906 on account of the evil reputation the place had acquired for unhealthiness. Map no. 2 appended to this report shows the details of the station on a larger scale than map no. 1. The cantonment comprises two portions, first, the cantonment proper which extends in a long rectangle almost due north and south and, secondly, a large area of uninhabited and uncultivated land which projects eastwards from the station. The cantonment proper is about $4\frac{1}{2}$ miles long and $1\frac{3}{4}$ miles broad and has an area of a little less than 8 square miles. The area of the eastern projection is about 6 square miles. The flatness of the station has made it possible to lay it out with great regularity. There is a series of main roads running north and south and the principal subsidiary roads cross these at right angles. The cantonment is very large for the size of the garrison and the inhabited area is interspersed with open plots.

The ordinary garrison of the cantonment consists of—

- 2 batteries of Royal Field Artillery (4th and 38th Batteries at the time of our visit).
- 1 regiment of British Infantry (1st Battalion, South Lancashire Regiment).
- 1 regiment of Bengal Cavalry (25th Bengal Cavalry).
- 1 regiment of Punjab Pioneers (32nd Pioneers).
- 1 regiment of Native Infantry (38th Dogras).

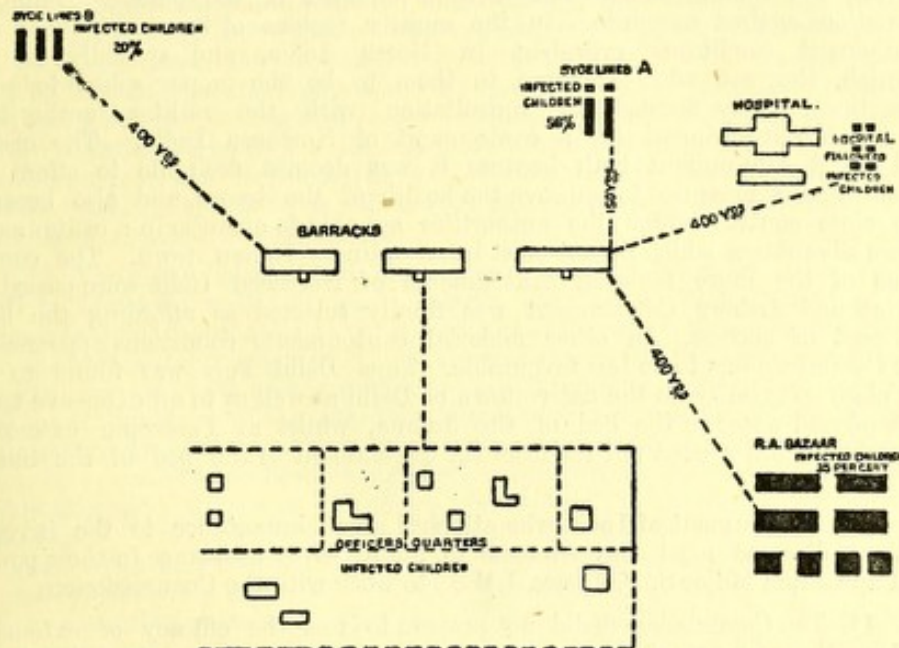
The total number of officers and men of these regiments averages about 3,900. The number of men actually in the cantonment varies greatly from time to time according as men are sent to the hills for the summer or rains or are away for manœuvres, etc., during the cold weather. At the time of our visit the number present amounted to about 2,200. In addition to the troops the station contains an ammunition column, mule, camel and bullock transport, a company of the Army Bearer Corps, and a company of the Army Hospital Corps. These represented a total of about 340 men at the time of our visit. On the same date the public followers belonging to all classes of troops, transport, etc., amounted to 465. The total population of the cantonment at the last census numbered 16,190, of which, exclusive of the troops, 8,804 were natives.

The British Infantry lines are in the north of the station, the Royal Artillery in the south-east, the Native Cavalry in the south-west and the two

* Nodules of lim-stone in course of formation.

† Captain James's Report on anti-malarial operations, 1901-1903.

Native Infantry Regiments in the centre. The bungalows of officers and subordinates lie mainly along the central main roads and the lines of the troops are situated outside them. The largest native quarter is the Sadar Bazaar lying to the north of the British Infantry lines. Its population is about 5,000. Each regiment (including as one regiment the two Artillery Batteries) also has its own bazaar, the position of which is indicated on the map. Apart from these 6 bazaars, native followers' lines, servants' quarters, etc., are scattered about throughout the cantonment. This general intermixture of bazaars and other places swarming with infected children with the barracks of the troops, and especially of the non-immune European troops, appears to us to represent a condition highly favourable to the spread of malaria. The following sketch reproduced from Major James's Report indicates the abundant sources of infection lying round the barracks of the Royal Artillery.



9. The European troops are housed in lofty one-storied buildings provided with a wide verandah and raised some feet above the ground. In the hot weather punkahs are provided by day and night. The condition of the native lines was unsatisfactory when the anti-malarial operations were undertaken, but much has been done to improve them during the past few years.

The station is provided with an elaborate system of surface drainage which is taken by a syphon under the Bari Doab Canal into the storm drain of the civil station. The main drains of the system are shown in red on map no. 1.

A piped water-supply was introduced into the station about the year 1879, and in 1897 filter beds were provided. The water is derived from the Bari Doab Canal. It is distributed by means of a high level reservoir and a system of pipes to the barracks for European troops and to the hospitals. To the remainder of the inhabitants the filtered water is distributed in cisterns on bullock carts and in buckets and tanks. The native population also obtains drinking water from wells, and, in spite of prohibitory orders, the numerous canals were used for the same purpose before they were filled in. The arrangements are discussed in the Sanitary Report of the station for the year 1904 in which they are described as highly unsatisfactory. An endeavour has since been made to furnish the whole of the station with piped water, the supply being derived from borings in the cantonment. The operation was undertaken at an estimated cost of R2,18,000. The work is nearly complete but the present position of affairs is unsatisfactory as the sanitary officers have now declared the water from the new supply to be brackish.

Night soil is dealt with by the trenching system. Recently some incinerators have been introduced and are now being tried.

The annual income of the cantonment is approximately R60,000, or about Rs. 3½ per head of the population.

PART III.—FIRST SERIES OF EXPERIMENTAL OPERATIONS IN LAHORE CANTONMENT.

Preliminary Investigations.

10. In the autumn of 1901 Dr. J. W. W. Stephens, M.D., and Mr. S. R. Christophers, M.B., were deputed by the Royal Society to prosecute enquiries respecting malaria in India. In the course of their researches in Africa, the Commissioners had become doubtful of the practical value of operations against mosquitoes in the moister regions of the world, but in the semi-desert conditions prevalent in North India, and specially in the Punjab, they saw what appeared to them to be the proper sphere for such operations. They decided, in consultation with the military authorities, to try the experiment in a cantonment of Northern India. The choice fell on a cantonment both because it was deemed desirable to afford an illustration of measures to improve the health of the troops, and also because the close control which the authorities are able to exercise in a cantonment offers advantages which do not exist in an ordinary Indian town. The conditions of the more malarial cantonments of Northern India were passed in review and Lahore Cantonment was finally selected as affording the best prospect of success. In other malarial cantonments conditions appeared to the Commissioners to be less favourable. Thus Delhi Fort was found to be in close proximity to the native town of Delhi as well as to an extensive tract of sand and water in the bed of the Jumna, whilst at Ferozepur extensive stretches of water exist not far from the cantonment in the bed of the Sutlej river.

The Government of India who attached great importance to the investigations directed local Governments to afford every assistance in their power and appointed Major S. P. James, I.M.S., to work with the Commissioners.

11. The Commissioners did not propose to test the efficacy of extensive and costly schemes of drainage or other engineering works; their object was to demonstrate the practicability of diminishing malaria by minor and inexpensive measures of mosquito destruction such as are described in the volume "Mosquito Brigades and how to organize them" published by Professor Ronald Ross in 1902, such as are outlined in his circular letter to the Indian press published in the autumn of 1901, and such as are foreshadowed in his inaugural lecture delivered at the Liverpool School of Tropical Medicine and published in the British Medical Journal of July 1st, 1899. The anticipated efficacy of such measures was based upon the then existing knowledge of the life habits of malaria bearing mosquitoes. It was believed that the breeding grounds of such mosquitoes are not common, that they lie close to the affected dwellings and that they may, therefore, be readily dealt with so as to destroy the dangerous larvæ. Thus in the lecture referred to above Professor Ross stated as follows:—"Finally, in order to extirpate malaria, it will not be necessary to declare war against all mosquitoes in general. We already know for a fact that only certain species can carry the disease. If it prove to be the case, as I think it may prove, that this particular species can breed only in a few isolated collections of water, then we may expect to find ourselves in possession of a cheap and effective means of extirpating malaria, at least from the more civilised and therefore from the more important areas." And again: "for a concrete example, suppose we were to discover by accurate investigation that all the malaria in a large town, say on the coast of Africa—arises from a few small puddles which can be obliterated at the expense of a pound or two, would not this discovery repay our exertions? And, further, if we could next extend our operations to other towns—to numerous towns—in the tropics, should we not be more than repaid for our exertions? At all events, the question can be decided only by experiment; and the experiment is well

"worth making." Similarly in the work on "Mosquito Brigades" Professor Ross summarised the then existing knowledge regarding malaria bearing mosquitoes as follows:—"It is now a matter of the general experience of many investigators that where mosquitoes abound in a house, their larvæ can easily be found at a short distance, say within a few hundred yards from the house. Occasionally, where the house is isolated, and no stagnant water is in its immediate vicinity, mosquitoes may attack it from a greater distance; but this is exceptional and in the great majority of cases, specially in towns, almost every house, breeds its own mosquitoes in its backyards, or in puddles or drains in the streets close by." Again in the letter to the Indian press Professor Ross remarked that: "even Rs 50 a month will suffice to maintain a gang of 5 or 6 men who would do much for any ordinary Indian cantonment," and again: "a warning must be recorded against commencing operations over too large an area; it is best to begin in the immediate vicinity of the houses of European and other subscribers. Experience shows that in the large majority of cases, where mosquitoes abound in a house, they are being bred close at hand." With considerations such as these in view the Commissioners hoped by means of simple and inexpensive operations directed against local breeding places to extirpate or greatly reduce malaria in a portion of the large Cantonment of Lahore. They selected for this purpose the Royal Artillery lines which are situated in the south-eastern corner and which, as will be seen from map no. 2, are somewhat isolated from the rest of the cantonment.

12. The Commissioners and Major James commenced work in September 1901 by a careful study of local malarial conditions. These investigations included (i) an examination of the prevalence of malaria both among the troops and among the native population, (ii) an examination of the various species of *anopheles* present with special reference to their malaria bearing capacity, and (iii) an examination of the breeding places of these species. These investigations furnish most valuable records for comparison with similar data collected after the operations had been completed and in future years. The two commonly prevalent species of *anopheles* were found to be the *Rossi* and the *culicifacies*. Previous observations in India had led to the conclusion that *A. Rossi* was a very inefficient carrier of malaria under natural conditions while *A. culicifacies* was a very good one. The Commissioners confirmed this conclusion by dissecting a large number of specimens caught in a bazaar in which both species were abundant. In the case of *A. culicifacies* 4.6 per cent were found infected with sporozoites, whilst none of the *A. Rossi* contained sporozoites in the glands. The species *A. culicifacies* was thus shown to be the main carrier of infection in Lahore Cantonment. The preliminary investigations of the Commissioners were made after the rains had dried up, and the conditions prevailing during the rainy season were thus imperfectly known to them. At the time of the investigations the irrigation canals were the principal breeding places, and it was found that the larvæ in these canals were almost entirely those of *A. culicifacies*. Such rain-formed pools as remained were also found to swarm with larvæ, but these were, with rare exceptions, those of *A. Rossi*. From these circumstances the Commissioners made the deduction that the irrigation canals formed the main source of infection and Dr. Stephens, in a letter dated the 25th December 1901, went so far as to say that if there were no irrigation canals in the cantonment the *A. culicifacies* could not breed and, therefore, as there would be no malaria carrier there could be no malaria. It was, however, decided to deal with pools and all other breeding places as well as with the canals, and subsequent experience showed that the breeding places of the *culicifacies* were by no means confined to the canals but included any collection of water in which the conditions were favourable for the development of the larvæ.

13. The investigations of the Commissioners extended to the end of December and were continued by Major James during March. In the meantime, first Dr. Stephens and later Mr. Christophers were obliged to leave India and the Government of India then directed, in consultation with the Royal Society, that the work should be carried out by Major James. He commenced operations in April 1902 and devoted himself to them until July 1903. His services were then required elsewhere, and the Government of India

appointed Mr. (now Captain) Christophers (who had in the interval joined the Indian Medical Service) to continue the operations through a second season. Captain Christophers took over charge from Major James in July 1903 and continued the work until nearly the end of the year. The experiment was then abandoned. The operations are described in volumes VI and IX of the "Scientific Memoirs by Officers of the Medical and Sanitary Departments of the Government of India" and are summarized below.

Operations conducted by Major James (April 1902 to July 1903).

14. The area covered by Major James's operations is coloured green in map no. 2. It extends for about one mile north and south and rather over three quarters of a mile east and west, giving an area of something under 2 square miles. It contains the Royal Artillery barracks and lines with the houses of the officers, the followers' lines, the Royal Artillery bazaar, the section hospital, the military prison, etc. Excepting on the west the line is drawn close round the residential quarters, no attempt being made to deal with the outlying uninhabited areas. A map showing the extent to which the barracks were surrounded by groups of infected children has been reproduced in paragraph 8.

15. Major James devoted the whole of his time to the superintendence of the operations. He was aided by a Hospital Assistant and an overseer of the Canal Department, and he was authorised to employ any amount of labour and to expend any funds that he needed. The work was partly done by hired coolies and partly by contract. Indent was made on the Canal Department for labour, and it was readily supplied free of charge as required. To ensure systematic working the breeding places were divided into six sections and one or more of these sections were carefully examined daily in regular order so that no part of the lines could be left unexamined and unoperated upon for more than a week at a time. A dry season facilitated the operations.

16. The breeding places dealt with may be roughly classified as follows:—

- (1) Canals.
- (2) Pools formed in connection with irrigation.
- (3) Rain-filled pits.
- (4) Surface drains.
- (5) Shallow standing water.
- (6) Miscellaneous.

17. *Canals.*—50 coolies were at first employed to clean the sides of the canals which were overgrown with vegetation. After this preliminary operation a smaller number of men was kept permanently at work removing fallen leaves and other *debris* and plastering the sides with mud. One sluggish canal which passed close to each of the three barracks and other residential buildings was converted into a bricked channel at a cost of Rs 5,365. During the height of the breeding season these measures proved insufficient to keep the canals clear of larvæ. It was necessary to keep a constant watch over them and breeding was checked by periodically shutting off the water and drying the water-courses, and also by oiling the canals and the pools left in them when the water was from time to time shut off. The operations were carefully controlled by searches for larvæ made at frequent intervals.

18. *Pools formed in connection with irrigation.*—These comprised, firstly, large more or less permanent pools formed from time to time by the overflow of the water-courses or the breaking down of their banks. The formation of such pools was as far as possible prevented and when they did form they were temporarily covered with a layer of oil and afterwards filled in with earth. Secondly, a number of small pools formed in the gardens because all the water given to an area in one day did not always sink in or dry up before the next day's supply reached it. In the weekly examination of the gardens pools of this nature containing *anopheles* larvæ were frequently found. The water was either drained away or emptied out and thrown over the land.

19. *Rain-filled pits.*—Scattered over the area were many excavations and pits of various sizes. Some idea of the number of these breeding places may be gathered from the fact that Major James recorded 167 pools or groups of pools and water-filled ditches as present within the area after a rainfall of a few hours' duration on July 27th. One large tank near the Royal Artillery Bazaar was filled in by the cantonment authorities, over 250 smaller tanks and pools were dealt with by contract labour. As soon as a pool was found to contain larvæ it was covered with a layer of kerosine oil or dried out and marked to be filled with earth and broken brick.

20. *Surface drains.*—The surface drains which existed throughout the lines were found to be dangerous breeding grounds. As they had little or no fall rain accumulated in them, and after a week or so they swarmed with *anopheles* larvæ. Owing to the large amount of water they contained they were difficult to treat. Some were dried out with buckets and on others oil was poured.

21. *Shallow standing water.*—Large shallow ponds of water formed almost throughout the lines on the level plain after every shower of rain. As a rule these superficial pools dried up in two or three days, but if before the end of that time more rain fell they were capable of remaining sufficiently long for larvæ to develop in them. By digging small channels in various directions it was found comparatively easy to drain these collections of water into the irrigation courses, and this was done every time rain fell.

22. *Miscellaneous.*—Numerous other breeding places were dealt with as they were discovered in the periodical examination. The small drains carrying off water from baths, standpipes, etc., in which larvæ were frequently found were swept out regularly. Tins and buckets kept full of water in the lines in case of fire were emptied weekly, as also horse troughs and cisterns. Drains and pools formed by the waste water of wells gave some difficulty. In one section this was met by collecting the water in deep pools which were kept constantly covered with a layer of oil.

23. It is clear from Major James's report that the above operations were carried out with thoroughness and care, and their course was checked by regular periodical search for larvæ in all kinds of breeding places. The results were not satisfactory. Major James considered that the operations had made but little impression on the number of *anopheles* mosquitoes present. As regards the prevalence of malaria the tests he applied tended to show that the advent of the malarial season was somewhat delayed and that there was a somewhat greater decrease in malaria in the area of operations than a healthy year had occasioned in other parts of the cantonment. These results, however, were so slight as to be doubtful, and Major James considered that unless a more marked reduction in the number of *anopheles* mosquitoes could be effected during a second year's operations it would be inadvisable to continue them further on the same lines.

Operations conducted by Captain Christophers (July to November 1903).

24. Captain Christophers continued operations on the lines of those already carried out. Owing to the amount of work already done it was possible to extend the area dealt with, and this was considered specially desirable in view of the negative results of the previous season. Captain Christophers accordingly included a large number of breeding places further to the east, west and south which had been left untouched by Major James. In especial he dealt with the large collection of pools lying along and to the immediate south of the cantonment boundary. The total area treated was about $1\frac{1}{2}$ miles east and west and rather more than two miles north and south. The coolies previously employed on the canals were retained since they had learned what was required of them. For other breeding places a large number was not needed but a fresh gang of about 30 was engaged for work during the rains.

25. The second season's operations may be classified as follows :—

- (1) Canal water-courses.
- (2) Rain-filled pits and drains.
- (3) Rain-formed surface pools.
- (4) Miscellaneous.

26. *Canal water-courses.*—During the breeding season the cleaning of the sides of the canals failed to stop the increase in the number of larvæ. The whole of their surface was therefore oiled at intervals of from a week to twelve days. After the institution of this regular oiling nymphæ were caught with the greatest rarity in the channels so treated. Whenever the water was shut off from the canals the residual pools were oiled.

27. *Rain-filled pits and drains.*—In the area undertaken by Captain Christophers there remained as many pits as had been filled up by Major James. As a rule they held, a few days after rain, three hundred to four hundred gallons of water, but some of the larger excavations contained several thousand gallons. The obliteration of these pits would have been a work of great magnitude, and it would have been very difficult to obtain earth for the purpose. Only pits in the central portion of the area were filled in by earth taken from old rifle butts and disused brick-kilns. Those remaining were dealt with mainly by bailing, and they were oiled where all could not be bailed in time to prevent the breeding of mosquitoes. In August when outlying pools distant half a mile or more from the residential portion of the area were found to be swarming with larvæ, operations were extended to these also, and they were regularly oiled and bailed. Directly after a downpour of rain all water lying in the brick and earth drains was removed by men with empty paraffin tins. As operations progressed the coolies became more expert and the work was done more easily and readily. The season of 1903 was favourable for these operations as the intervals between the downpours were considerable, amounting to 5, 6, 8, 15 and 15 days, respectively. Captain Christophers remarks that "had rain fallen at shorter intervals it would have been very difficult to effectively destroy breeding places over such a large area."

28. *Rain-formed surface pools.*—It was found possible with some care and thought to drain the surface water from almost the whole area. Thus in an area of about a square mile immediately around the bazaar and barracks over 50 sheets of water were permanently drained by earth-cut channels, and they required no further attention during the rest of the season. The most important of these operations were carried out to the south of the bazaar, where an extensive series of large sheets of water was drained into the canals by the construction of two drains, each nearly a quarter of a mile long, and a number of collateral drains.

29. *Miscellaneous.*—Larvæ were found in small cement tanks in connection with wells and with garden irrigation, also in waste water from large wells and other sources, as well as in kerosine tins, earthen vessels, etc., left filled with water. Breeding places of this nature were carefully sought for and destroyed, the whole area being examined at least once a week. Captain Christophers considers, however, that as sources of *anopheles* such breeding places in Lahore Cantonment were infinitely small as compared with the canals and with the innumerable pits which surrounded the area on all sides.

30. Captain Christophers records that although from August onwards the whole area of four square miles was thoroughly treated, and although the destruction of larvæ was enormous, yet they reappeared in undiminished numbers a few days after oiling, evidently being derived from adult insects within the area. Up to the middle of July no adult *anopheles* were found. During August *Rossi* became very abundant and *calicifacies* fairly abundant, the former showing no reduction and the latter a very doubtful one. Malaria was much less prevalent than usual among the men of the Royal Artillery, but the reduction was still more marked among the British Infantry living in an untreated area, the year being a healthy one with a low rainfall. During August and September the endemic indices among native children, and to a less extent the spleen rates, remained very much lower than in the control British

Infantry lines, but in October and November it was found impossible to prevent the bazaar rates rising in the treated area, and they were "apparently quite uninfluenced by the operations." An exactly parallel effect appeared to be produced upon malaria among the troops, the admissions being exceptionally low among the Artillery men during August and September, but becoming actually more frequent among them than among the British Infantry during the succeeding two months. In short all the "results pointed to the same conclusion (as in the previous season), namely, that by the operations the onset of the fever season was postponed, but that after the first two months no effect upon malaria was apparent." One of the most important points demonstrated by this year's work was that "where an abundant food-supply existed *anopheles* travelled long distances ($\frac{3}{4}$ of a mile or more) to reach it, and that they traversed an equal distance if necessary, to lay their eggs."

31. Major James attributed the failure of the first year's operations to the passage of adult *anopheles* into the area from without. Captain Christophers is also of opinion that the want of success during the second season was for the greater part due to the immigration of mosquitoes bred in pools lying beyond the margin of a half mile range from the inhabited centre of the operations. But as the difficulty of complete extirpation increased enormously with the increase of area, he considers that it is possible that a certain number of *anopheles* continued to be bred in a ring within the half mile radius. He explained to us that this is only his opinion, and that all he really knows is that though he appeared to have kept breeding places under very complete control adults still appeared in the bazaars in large numbers.

Conclusions.

32. The expectations with which the labours of the Royal Society's Commissioners commenced thus failed altogether to be realised, and the two years' work demonstrated that in the conditions which prevail in Lahore Cantonment it is not possible to destroy *anopheles* mosquitoes and to extirpate malaria by simple and inexpensive measures carried out in the immediate neighbourhood of the dwellings. Further, the result of the operations of 1903 would appear to indicate that malaria-bearing mosquitoes are able to travel in search of food to a distance from their breeding places considerably greater than had up to that time been held possible, a conclusion which would accord with that marvellous instinct which is so striking a feature of all insect life.

PART IV.—GENERAL ANTI-MALARIAL OPERATIONS IN THE CANTONMENT (1904-09).

Inception of the operations.

33. The malaria season of 1903 was somewhat severe, and the troops of the British Garrison (the South Wales Borderers and two batteries of Artillery) were seriously affected. Colonel Hamilton, the Principal Medical Officer of the Division, urged that wide and fundamental measures should be adopted to improve the health of the station. He presented to the General Officer Commanding the Division (Major-General F. W. Kitchener, C.B.) a note, dated the 24th April 1904, with two printed notes appended to it, in which his views were set out at length. He quoted a remark of the Sanitary Commissioner with the Government of India that the results of the experiments carried out by Major James and Captain Christophers were distinctly against the employment of anti-mosquito measures as a practical means of combating malaria in such a cantonment as Mian Mir. He remarked that such measures were extremely expensive especially as they required to be renewed from year to year. He enunciated the general theory that wherever in a tropical country drainage in its broader sense is interfered with or neglected malaria is increased, and that wherever such drainage is improved malaria is diminished. He stated his reasons for believing that canal irrigation and defective drainage were the main factors in determining the prevalence of malaria in the cantonment, and he described the water-logged and overgrown condition of considerable portions of the station. He finally recommended that canal irrigation should be stopped, that the drainage should be improved, that excavations should be filled in, and that undergrowth should be cut.

34. General Kitchener accepted this advice, and in a letter no. 6786, dated the 28th June 1904, he made a very strong recommendation that effect should be given to it. He dwelt upon the deplorable condition of the British troops. He expressed general concurrence with Colonel Hamilton's views, and although he was somewhat less sanguine than that officer, yet he considered that if the reforms indicated were carried out it would be reasonable to look for a very great improvement. General sanction to the scheme having been received, General Kitchener issued a special Divisional Order, no. 4, dated the 17th December 1904, in which he indicated the operations to be undertaken and called for the loyal support of officers commanding corps, of residents and of householders.

Organization.

35. Work had already begun before the issue of the Divisional Order quoted above. After its promulgation the whole organization and force of the cantonment and garrison were directed to the prompt and thorough execution of the prescribed measures. For medical and general purposes, the cantonment was divided into the six sections, lettered A to F in map no. 2. These comprised, starting from the south, (1) the Royal Artillery lines, (2) the Native Cavalry lines, (3) the Native Infantry lines East, (4) the Native Infantry lines West, (5) the British Infantry lines, and (6) the area containing the Sadar Bazaar and the Transport lines. The operations in each of the five regimental areas were placed in immediate charge of the commissioned medical officer attached to the regiment, whilst the Sadar Bazaar was entrusted to the cantonment magistrate and to the officer in charge of the Cantonment Hospital. These medical officers were under the immediate control of the Senior Medical Officer of the station, who was again under the Principal Medical Officer of the Division, the adviser in medical and sanitary matters of the General Officer Commanding. The medical officer of the section was aided by an Assistant Surgeon or Hospital Assistant, and in an

area occupied by British troops he had the further assistance of a British Sanitary Sergeant, and in an area occupied by Native troops of a Sanitary *Daffadar*. The appointment of such a considerable number of medical officers to comparatively small areas ensured frequent inspection and detailed control. For labour the officers had at their disposal sweepers and other menial servants of the area, a certain number of men of the Army Bearer Corps, specially employed coolies, and fatigue parties from the regiments. The Commanding Royal Engineer was responsible for the conduct of larger engineering works and he was assisted by the Garrison Engineer and the personnel of the Military Works Services. The engineering staff was specially concerned with the filling in of canals, the improvement and maintenance of drainage, and the filling up of large pits and excavations. The transport service lent its carts and animals. The regimental organization, under the officer commanding the station and the commanding officers of the regiments, provided the bulk of the large supply of labour which the operations involved, and the regiments also assisted in miscellaneous sanitary measures in the lines, such work being under the immediate charge of the regimental quartermasters. The cantonment organization under the Cantonment Committee and the Cantonment Magistrate dealt primarily with measures in private compounds. They enlisted the co-operation of residents and owners who themselves provided much of the labour required for filling up depressions and other work.

General Kitchener personally directed and closely supervised the conduct of the operations and utilized to the full the various agencies above indicated. The force concentrated on the operations was more powerful and better organized than would be possible anywhere in India outside a cantonment with an energetic officer at its head.

Sources of information.

36. No connected account has hitherto been prepared of the operations. Many different departments were concerned, the funds were derived from many different sources and frequent transfers of officers have taken place since the work began. We have compiled the present narrative with difficulty from the evidence of a number of witnesses and from scattered references in reports, orders and other documents. We examined numerous medical witnesses, including Principal Medical Officers, Senior Medical officers and Executive Medical officers in charge of sections. From the engineering point of view we examined the officer who was Commanding Royal Engineer when the operations began and the officer who was Garrison Engineer at the time of our visit. We also consulted the Sanitary Engineer to the Government of the Punjab. We further examined two Cantonment Magistrates, and several officers belonging to corps who took part in the operations.

37. The information which we thus procured we propose to discuss in the following order :

- (i) closing and filling in of the irrigation canals,
- (ii) improvement and maintenance of the drainage,
- (iii) filling up of depressions,
- (iv) "mosquito brigade" operations,
- (v) measures in private compounds,
- (vi) protection of wells,
- (vii) miscellaneous measures,
- (viii) quinine prophylaxis, and
- (ix) expenditure.

Closing and filling in of the irrigation canals.

38. In accordance with the first instruction contained in the special Divisional Order it was decided to close all irrigation and to fill up all canals and cuts within an area of eight hundred yards from the inhabited portion of the cantonment thus establishing a dry zone round it. Work began in August 1904 with the closing of the canal passing by the British officers' bungalows and the British Infantry lines and Hospital. Later in the cold weather all canal cuts running through the cantonments were gradually closed, and this work was completed by about the 1st April 1905. To avoid the payment of compensation water was as far as possible allowed to run through cultivated lands until the crops no longer required it, and the main channel was finally closed in August 1905 from the point marked with a blue A on map no. 1. The work of filling in the disused canals and cuts was started in the beginning of 1905 simultaneously with their closure and was practically completed by the end of the year. The operations, which were on a very large scale, were carried out mainly by the troops under the supervision of the Military Works officers. The special Divisional Order directed that the work should be carried out as a military fatigue duty, allotted the duties of the responsible officers, and directed the submission of daily reports. Colonel Barrow informed us that every man of the fatigue parties was required to fill in a cubic yard of earthwork as his daily task. The work was carried out by levelling the embankments on each side of the distributaries and cuts and by throwing the earth into the hollow. Earth was also obtained from the mud walls of dismantled buildings. Afterwards a number of distributaries were regraded and served as a portion of the drainage scheme; this again yielded earth for the filling in. The operations involved levelling the land lying along the canals. Colonel R. F. Chesney, R.E., who was Commanding Royal Engineer at this time, stated that the heaviest part of the work was the cut through the Artillery lines which was about 12 feet deep and 14 feet broad. This was mainly filled by the Pioneers. The military authorities have not been able to furnish us with any estimate of the amount of work that was done in this manner. In a letter no. 13997, dated the 16th December 1905, General Kitchener stated: "the whole of the troops constituting the Mian Mir garrison, British and Native, have laboured without remuneration for months in filling drains and depressions. The 20th Punjabis have specially distinguished themselves in willing pioneer work." Colonel Chesney estimated that about four or five hundred men were employed on the main portion of the work for a period of about four to five months. Some work lying outside the lines was done with coolie labour, but we have not been able to obtain any exact information as to the extent of this work or as to the amount spent upon it. For the purpose of irrigating the waste land lying to the east of the cantonment and of carrying water to villages supplied from the station main distributary, a fresh cut was made from the point A running southwards to the cemetery and thence westwards towards the village of Kaure (*vide* Map no. 1).

Filling in of depressions.

39. The Divisional order of the 17th December 1904 directed that the filling in of hollows made for building lines should be carried out as a military fatigue duty, and the work of levelling depressions has in fact been done regimentally. Each regiment has been responsible for its own section (A to E) of the cantonment, and the work has been supervised by the medical officers in charge of the sections. There were not many very large pits in or immediately adjoining the regimental lines, and no attempt was made to cope with the numerous excavations lying further afield, many of them outside the cantonment boundary. Some large borrow pits near the Native Cavalry lines were filled in by earth taken from a hillock on the parade ground. Another large pit in the East Native Infantry lines gave much trouble. It was partially filled by earth brought from a mound east of the Roman Catholic Chapel by means of a monorail lent by the railway and a part of the depression was cultivated. The 34th Pioneers laboured for over 2 years at this

excavation but the work was never finished, and when we visited the cantonment water containing numerous *anopheles* larvæ was lying in the portion of the pit still remaining. Mr. Aikman suggested that the experiment might be tried in such a case of embanking the pit, diverting storm water from it into neighbouring drains, and possibly sinking a well deep enough to penetrate through the impervious strata. In the West Native Infantry lines a depression or pond of this character was enclosed by an embankment and cultivated. Smaller depressions such as are described in the reports by Major James and Captain Christophers were numerous in many parts of the cantonment. Their number must have been reduced by the levelling operations conducted by the Military Works Services as a portion of the drainage reform scheme. The annual reports of the medical officers of the Native Infantry regiments show that much work was done by the troops to fill in the remainder. Major A. Cadell of the 38th Dogras also states that an immense amount of work was done by that regiment during the years 1906 and 1907 in the way of filling up canal cuts, pits and depressions, in clearing jungle, and generally in putting the West Native Infantry section into a sanitary condition. At certain periods General Kitchener suspended all military work, except station duties and musketry, and every available man was put on fatigue duty. From the 1st January 1906 to the middle of 1907 two to three hundred men were often on fatigue duty for periods varying from a week to three weeks. Extracts from the regimental order book show that the 34th Pioneers were occupied in filling in canal cuts and pits from December 1904 to August 1907, and that frequently several hundred men were working daily at these tasks. The officer responsible for the Native Cavalry lines reported in both 1905 and 1906 that useless drains and excavations had been abolished. The operations were apparently not complete, for in 1907 the medical officer stated that after the August rains he found a large borrow pit in the lines swarming with *anopheles* larvæ, and that he had it immediately pumped dry by the fire engine. Captain Fraser, who was at a later period in charge of the Native Cavalry section, comments on the unsatisfactory condition of this area. He states that there are several large ponds within it where water collects after rain, and that although an endeavour has been made to fill them in with horse litter, yet as they are of considerable size this work has only been partially carried out.

In the Sadar Bazaar section the work of filling in depressions was carried out by hired labour, and Colonel Faulknor informed us that about R3,000 was spent on this, the money being provided from the special grant for anti-malarial operations.

Improvement of the drainage system.

40. We have already commented on the extreme flatness of the cantonment. The centre of the station is absolutely level lying on the 705 foot contour, and from this the land slopes very gradually and to a very small extent. This flatness and the impervious character of the subsoil, render the surface drainage a matter of the first importance from the point of view of malaria prevention. We have not been able to ascertain when the existing drainage system was introduced. It dates from many years back, and is possibly co-eval with the cantonment itself. The system will be readily understood from an inspection of map no. 1 in which the main drains from origin to outfall are shown in red. It comprises four principal drains running from east to west and converging to the syphon under the Bari Doab Canal at point E, due west of the cantonment. After passing under the canal, the main drain joins the storm water channel on the south of the Lahore civil station and is thus led by the shortest and easiest way to the river Ravi. This convenience led to the drain being constructed on lines which do not follow the slope of the land which is from north to south. The main drains are fed by a large and intricate system of minor drains mostly lying along the sides of the roads. Before the commencement of the anti-malarial operations the drainage system was composed as follows:—

Brick-work drains	.	.	.	.	7 miles
Main earth channels	.	.	.	.	13 miles
Subsidiary earth drains	.	.	.	.	167 miles

The length of brick-work drains has since been increased and the reform of the drainage has involved some increase in the total length of earth drains. The system above described does not serve the east of the cantonment. The drainage of this portion is partially dealt with by the Shalimar drain which runs northward from opposite the East Native Infantry lines to a second syphon under the Bari Doab Canal.

41. In 1904 this drainage system was in a neglected and unsatisfactory condition, and it was decided to improve it. It was at first suggested that a fresh project should be prepared leading the drainage southward in accordance with the slope of the country. This idea was abandoned as it would have involved the making of a long and very expensive cut to the river. It was then settled that the existing system should be retained and brought into good order. The work was carried out mainly in 1905 under the supervision of Colonel H. F. Chesney, R.E., who has given us an account of the operations. In the first place the levels of the whole of the existing drains were taken. Operations were then started at the syphon at point E and the levelling was carried out along each main drain until at last a point was reached where the cutting came out flush with the ground at the minimum slope required to secure a flow. The principal side drains, which run north and south, were then sloped by accurate levelling into the main drains. By working in this way the existing main drain was lowered from about one to five feet. This resulted in a better flow in the side drains and made it possible to drain ground which had not hitherto been dealt with. Masonry cross sections were introduced at intervals in the earth drains to facilitate relevelling. The drainage of the Sadar Bazaar and the ground round it was treated in the same way as that of the lines. The drains of the Sadar Bazaar were originally very foul, many of them being earth drains carrying sullage, and even sewage. The more important of these were converted into masonry channels. The flat central portion of the cantonment comprising the British Infantry lines, the two Native Infantry lines, the Royal Artillery lines, etc., required specially careful drainage to prevent rain water standing on it. The method employed was to slope the ground gently down to the small shallow earth drains, which were again led into the large drains, and so on till the main drain was reached. In this way, Colonel Chesney states, no level ground was left on which water could stand. The closing of the irrigation channels facilitated the drainage improvements as the minor distributaries had interfered with the flow of water through the subsidiary drains.

42. The earthen Shalimar drain on the east of the cantonment was deepened in the same way as the other main drains and a proper flow secured. The drainage of this part of the station was led as far as possible into the Shalimar drain, but it was not found practicable to work beyond a point opposite the East Native Infantry lines as the fall was insufficient. The drainage of the Royal Artillery lines, Hospital and Bazaar could not, therefore, be conducted into the Shalimar drain, and endeavour was made to carry it towards the south-east. This was not very successful, and the drainage of this portion of the cantonment remained unsatisfactory. It has since been further obstructed by the new irrigation distributary which passes round the cemetery as shown in map no. 1.

43. The expenditure incurred on the above operations up to 1905-1906 amounted to Rs 24,563. In later years a further sum of Rs 14,974 has been spent in lining with masonry drains in the Sadar Bazaar, in the Native Infantry lines and along Amritsar Street, and also in relevelling the main drain in the neighbourhood of the Lunatic Asylum. The total amount spent on the general reform of the drainage thus amounts to about Rs 40,000. In addition to this work of the Military Works Services, many minor drainage improvements were carried out regimentally.

44. Mr. D. W. Aikman, Sanitary Engineer to the Government of the Punjab, kindly examined the present condition of the drainage system for us. He found that the distribution of the drains of the main system is good and well balanced, and that the existing drains are of ample capacity to remove the storm water of the greatest rainfall likely to occur in 24 hours. He was not able in the time at his disposal to examine all the waterways of the

culverts and the bridges, but those he did see were ample. On the other hand the syphon under the canal at point E was almost completely blocked. We visited this important point with Mr. Aikman and found the condition of the syphon to be such as to prevent its proper working. The syphon consists of a number of archways under the canal nearly all of which are silted up and blocked. The storm channel on the far side of the canal is also considerably obstructed by trees, shrubs and long grass. Mr. Aikman also found that the existing drains want regrading in some places. For example the bed level of the drain at point H is 692.15, while about a quarter of a mile lower down it is 693.25, a rise of 1.1 foot where there should be a fall of nearly one foot. Mr. Aikman commented upon the absence of drainage in the south-east of the cantonment and on the apparent block of the natural drainage in this direction. He considered that this area should be very carefully examined and proper drains constructed. Captain Fraser also informed us that the drainage in the south-west of the cantonment (Native Cavalry section) is inadequate and that the level of many of the drains is insufficient.

It is evident that the operations carried out from 1904-1905 onwards have very greatly improved the drainage of the cantonment, but the elaborate and delicate system then perfected requires minute watching and careful maintenance. The system would not appear to be at the present moment in such good order as Colonel Chesney left it in 1905.

45. The above remarks apply with special force to the condition of the surface earth drains. Apart from the question of the maintenance of their efficiency for drawing off rain water from the area they serve there is the further question of the danger arising from the accumulation of water in the drains themselves. This is a danger often met with and well recognised in India. It must be specially great in an area with 180 miles of earth drains with a very slight slope. Colonel Chesney and Mr. Aikman both recognised this defect and advised us that the drainage system needed constant watchfulness and care to guard against it.

Before the reform of the drainage both Major S. P. James and Captain S. R. Christophers found that the surface drains frequently held water, and the treatment of this source of breeding formed an important and regular portion of their operations. We examined a number of witnesses on the point and we received somewhat variable replies regarding the frequency and length of time during which the surface earth drains contain standing water during the monsoon months, a variation which is probably mainly due to the circumstance that several witnesses speak of their experience in years of different degrees of rainfall. Thus Colonel H. J. W. Barrow did not consider the earth drains to be of great importance. Some of them might contain water for as long as a week, but when water was found in them they were oiled. Lieutenant-Colonel O'Sullivan, whose experience in the cantonment extended over a dry season, was of a similar opinion. His successor, Lieutenant-Colonel H. D. Rowan, R.A.M.C., found but little water in the earth drains and thought that they absorbed it. Lieutenant-Colonel M. O'D. Braddell, R.A.M.C., told us that nothing was done to the drains during the rains except to oil them where water lodged in them. He thought it possible that this was not performed regularly owing to the extensive area to be covered. Captain Kempthorne, who was in charge of anti-malarial operations in the rainy season of 1909, found that water collected in the earth drains to a considerable extent and that they were so full of high grass that it was very difficult to see when they contained water. Lieutenant Lunn found that for the most part the earth drains ran dry very quickly but in places water stood for as long as a week and would thus allow of the breeding of mosquitoes: these places were all oiled. Captain W. J. Fraser found *anopheles* larvae on several occasions in the earth drains. He considered these drains to be very likely breeding places for *A. culicifacies*. Captain McEnery, R.E., Garrison Engineer, thought that the drains were kept in as good condition as can be expected in the case of earth drains, and did not apparently consider them a source of great danger. He informed us that buffaloes create pools by wallowing in the drains, and that this was specially the case in the Sadar Bazaar. Captain Christophers considered that with any

serious amount of rain the earth drains must become a very important source of *anopheles* breeding, especially of the species *culicifacies*, *fuliginosus* and *Rossi*. He had found larvae of *culicifacies* in drains in Lahore Cantonment, and in 1903 one such drain was a very important breeding place.

46. As regards the measures employed to keep the drains in order, Captain McEnery informed us that the earth drains were cleaned out and levelled twice a year, namely, before and after the rainy season. There was no regular staff employed to clear the drains of grass, etc., during the rains, but labour was occasionally used, as available, in that way. Attention was chiefly paid to drains in the lines and those not under immediate observation were less carefully treated. The work on the many miles of drains requires careful supervision and the subordinate staff was not adequate during the rains as the temporary establishment had been cut down. In reply to an enquiry as to the establishment he considered necessary for the purpose of keeping the earth drains in order, Colonel Chesney informed us that probably two gangs of about ten men each would be sufficient during the greater part of the year, but that during the rains four or five extra gangs should be employed. He added that intelligent men should be appointed to supervise the work during the rains, possibly two for the whole station. Lieutenant Sandes, R.E., made a higher estimate in 1904. He said that the establishment employed to look after the earth drains was altogether inadequate, and that it would take 10 gangs of 10 men each to keep them in proper order. It is interesting to note in this connection that in the Panama Canal zone the cost of maintaining surface earth drains was so enormous that it was found cheaper to make tile drains at a cost of about 1s. 4d. per foot.

47. The general conclusion to be derived from the evidence before us is that while most of the extensive earth drains rapidly run dry after even heavy rain, yet certain portions of them, especially those beyond the inhabited portion of the cantonment, sometimes hold water during the rainy season for sufficient periods to permit of the breeding of *anopheles*. This would be specially the case in years of heavy rain, and more particularly so when the rain falls on a large number of days with few dry periods of sufficient length to allow the complete disappearance of the water. Breeding conditions would also be favoured by the presence of grass in the drains which protects both the larvæ from being washed away and the water from rapid evaporation. We saw evidence of water having stood in the earth drains along the Ferozepur Road immediately to the south of the cantonment, for there were numerous depressions evidently made in the soft mud by the hoofs of cattle at the bottom of the drain. A good deal was done to meet this danger by oiling but it is doubtful whether this always was done systematically enough to prevent some degree of breeding.

"Mosquito Brigade" operations.

48. From 1905 onwards (and to some extent in 1904) regular "mosquito brigade" operations were undertaken to deal with any collections of water which remained in spite of the filling up of depressions and the improved drainage of the cantonment. The medical officer in charge of each section was responsible for the work within it under the general control of the Senior Medical Officer of the station. Operations were based on maps periodically prepared to show all collections of standing water. A "mosquito brigade" consisting of 12 men of the Army Bearer Corps was appointed for the cantonment. It visited one section a day and worked under the medical officer of the section aided by an Assistant Surgeon or Hospital Assistant belonging to the regiment of the area. The Army Bearer Corps men were eventually replaced by ordinary coolies and the number during the later years of the operations appears to have been diminished. Their work included filling in minor hollows not dealt with regimentally, sweeping, bailing or pumping out water, cutting undergrowth, and petrolage. The sectional medical officers supplemented the work of the regular "mosquito brigade" from other sources as they found necessary.

49. During Colonel O'Sullivan's time (i.e., 1905) the sectional organization appears to have been more important than the general "mosquito brigade," for this witness informed us that each medical officer made his own arrangements,

using as many coolies as he wished, supplying them with as much kerosine oil as was required and utilizing also the services of the sweepers of the section. Each place was oiled about twice a week. Colonel O'Sullivan considers that he was able to deal effectively with the whole area up to the railway line. Colonel Barrow, Principal Medical Officer, and Lieutenant-Colonel Rowan, who was Senior Medical Officer of the station from 1906 to 1908, except during periods of short leave, did not supply us with any details as to the manner in which operations were carried out, but they both considered that the "mosquito brigade" organization was inadequate. Colonel Barrow said that at least ten men would be required in each section, or 60 in all, under the supervision of an expert medical officer. Lieutenant-Colonel Rowan said that pools at some distance beyond the inhabited areas of the cantonment could not be dealt with by the staff employed, and that to obtain good results in such a large cantonment a larger force was needed. Lieutenant-Colonel Braddell, who was in charge of the operations during a part of 1909, informed us that after a sharp shower of rain in April a map was prepared to show where water lodged and that very shortly afterwards six coolies were employed to fill up small depressions and oil collections of water. They worked one day a week in each area. He also considered the number of men employed was inadequate for the work, and he expressed the opinion that effective measures would require an immense organization with a large and well-qualified staff. Captain Kempthorne, who was in charge of the operations during the rains of 1909, used four men for petrolage under a Hospital Assistant, and other men were employed from time to time for work such as filling up ditches, etc. He considered that this staff was not sufficient to make any great impression on so large an area.

50. We also examined three medical officers who were in actual charge of various sections of the cantonment. Lieutenant Lunn, R.A.M.C., was responsible for the Royal Artillery lines during the rainy season of 1909. After the first heavy fall of rain on July 20th a map was made of the places in which standing water remained, and with the aid of eight men a number of these were filled in during the following ten days. In addition, the oiling of collections of water was continued throughout the rainy season up to the date of our visit. This was carried out in the first instance by men from the "mosquito brigade." They could not cope with the work and Lieutenant Lunn supplemented their efforts by a man from the military police and a coolie. With this assistance he considered that the work was satisfactorily done except during one period of heavy rain which resulted in considerable flooding. He did not however pay much attention to places beyond 200 yards from the lines. Lieutenant Wells, R.A.M.C., was in charge of the British Infantry lines in which there were few collections of water. He filled in some small hollows including some bathroom drains, and he caused small collections of standing water to be swept out or oiled. He considered that mosquito breeding was efficiently controlled in his area. Captain Fraser, I.M.S., had very considerable practical experience of the operations, having been at different times in charge of both Native Infantry lines, of the Native Cavalry lines and of the Sadar Bazaar area. He considers that, as it is at present organized, the "mosquito brigade" is unable efficiently to carry out petrolage after heavy rains. After September, when the rainfall ceased, the remaining pools were satisfactorily oiled. In the Native Cavalry lines (section E on map no. 2) where the drainage is inefficient and large pools exist, Captain Fraser supplemented the work of the "mosquito brigade" by a Hospital Assistant from the regimental hospital and with a coolie and a supply of kerosine oil. With this assistance the pools, etc., were kerosined as frequently as possible, but after heavy rain the operation could not be carried out with complete efficiency. Oiling was extended to one-quarter of a mile beyond the lines. In the West Native Infantry lines (section B) where circumstances were more favourable the measures taken by the "mosquito brigade" were effective. In the East Native Infantry lines (section C, 32nd Pioneers) there was no difficulty in obtaining any number of men to supplement the work of the "mosquito brigade," and here also the work was satisfactory. Captain Fraser had charge for a short time of the operations in the Sadar Bazaar. He did not consider that they were carried out in this area as thoroughly as in the regimental sections.

51. It will be evident from the above account that the character and extent of the organization has varied considerably and that much has depended on the initiative of the various sectional officers responsible for the operations from time to time. Speaking generally it may be said that although much was done to prevent breeding in the diminished number of breeding places lying within and about the lines and the bazaars, yet the organization was not always sufficient to cope effectually with the difficult problem.

52. In the above discussion and comments we have not touched upon the exceptional flood year of 1908. An account of the condition of the station during that year belongs to a later section of this report. It will suffice to state here that water stood in such great abundance and for so long a period that it was not possible for the "mosquito brigade" organization to deal with it over a considerable portion of the cantonment, and that the breeding of *anopheles* was therefore uncontrolled.

Measures in private compounds.

53. In 1905 energetic measures were taken to ensure the abolition of breeding places in the compounds of private houses. For this purpose General Kitchener called a meeting of owners and occupiers, explained to them the necessity of the operations, and appealed to them for assistance. Measures were also taken under the Cantonment Regulations to ensure that the orders were obeyed. Owners and residents co-operated willingly and much work was done in the desired direction. It consisted mainly in filling up small irrigation channels leading from the larger distributaries and other minor depressions. This was in general done by gardeners and other private servants. Colonel Faulknor, the Cantonment Magistrate, said that the condition of the compounds was very greatly improved in this manner and that it left very little to be desired. Colonel O'Sullivan endorsed this view. Stringent orders were also issued against the making of fresh excavations in private compounds. Lieutenant-Colonel Rowan, speaking of a somewhat later date, stated that medical officers visited the compounds of their respective areas in order to ensure that trees were trimmed to the proper height, that the ground was free from jungle and refuse, and that the standing orders with reference to the disposal of bath water and sullage were carried out. In 1909 Lieutenant Lunn found a number of water-containing pools in the compounds of houses in the neighbourhood of the Royal Artillery lines. These excavations were apparently made to procure earth for roofs. He states that he reported the matter to the Cantonment Magistrate whose duty would be to compel the owners to fill them up. As a matter of fact they were not filled up. On the other hand Lieutenant Trafford, the officiating Cantonment Magistrate, stated that he experienced no difficulty in getting owners to fill up any depressions which had been brought. Apparently there was at this period some want of co-ordination between the different officers concerned in this part of the work.

Protection of wells.

54. After the closure of canal irrigation some new wells were constructed in the cantonment in order to allow of gardens being watered. Several wells were also constructed by the cantonment authorities for the purpose of watering roads, etc.

Great attention has throughout been paid to the protection of wells. In the first place all wells in bazaars or compounds were provided with wooden covers, while a number of unused wells were bricked over. In 1905 wells were all visited once in about ten days and covered with kerosine by an Assistant Surgeon. Lieutenant-Colonel Rowan informed us that in June 1906 he inspected all wells in the station and arranged that wells used for watering roads and gardening should be oiled twice weekly in the evening with two ounces of kerosine oil. This was done by ward servants of the Army Hospital Corps. Lieutenant-Colonel Braddell also paid special attention to wells and continued the oiling operations. At one time even wells used by natives for drinking purposes were oiled, but

complaints were made about this and the practice appears to have been gradually discontinued.

55. Colonel O'Sullivan is the only medical officer who stated that *anopheles* larvæ were found in wells in sufficient abundance to be dangerous. Major James found a few *anopheles* larvæ in the wells during his operations in 1902, but he stated that they were not sufficient to be dangerous or to require operations against them. Captain Fraser only found *culex* larvæ and hardly any *anopheles*. Colonel Hamilton did not consider that wells had any effect on local malarial conditions. Colonel Barrow knew of no case in which *anopheles* larvæ had been found in well water. Captain Christophers stated as follows :—“Two kinds of wells existed in Mian Mir in 1901-1903, (1) those used mainly for drinking purposes and having water at a considerable depth, practically negligible as a source of *anopheles*, and (2) those in connection with the irrigation channels which had water quite near the surface and which when not in constant use acted as very suitable breeding places of *anopheles*. The irrigation wells which were once very numerous have, I see, been closed along with the canals. The remaining deep wells are of an unsuitable character for the breeding of *anopheles*, being deep and narrow and for the most part in pretty constant use. The species of *anopheles* which is specially found breeding in wells (*A. Stephenosi*) is also a rare species in Mian Mir, a few specimens only being found in 1901 where a large number of *chattis* were kept filled with water for fire extinguishing purposes.” We examined a number of the wells and found the water to be over 20 feet down. This is probably the case all the year round as Lieutenant-Colonel Firth some years ago found that the ground water level in Lahore Cantonment varies only two and a half feet throughout the year. We found many *culex* larvæ in disused or little used wells but not in those in constant use, while no *anopheles* larvæ were discovered in any of them. On the whole we do not think that the wells in Lahore Cantonment are of importance as breeding places of malaria-bearing mosquitoes.

56. Standing water readily collects round deep wells used for irrigation purposes or otherwise used in a careless manner. *Anopheles* larvæ have been found in such water but accumulations of this character can be prevented or rendered harmless by simple precautions, and these appear to have in general been satisfactorily carried out in the cantonment.

Miscellaneous measures.

57. In addition to the main operations described above several miscellaneous measures have been carried out from time to time and may be noticed briefly at this place.

58. *Improvement of bazaars.*—The sanitation and reduction of extent of various bazaars was the last measure enumerated in the Special Divisional Order. Extensive improvements were made in the Native Infantry bazaars. In 1904 the medical officer of the 20th Punjabis reported that the West Native Infantry bazaar far exceeded the needs of the regiment and that it was ill-built and ill-kept. In the following year he stated that much of the bazaar had been pulled down and that it had been rebuilt of a size more suited to the requirements of the regiment. Major Cadell, 38th Dogras, informed us that in 1906 the bazaar of the Native Infantry East was a row of mud huts badly built, dilapidated, insanitary, and with little or no ventilation. These were pulled down and reconstructed of masonry, and the bazaar is now well built and well ventilated. Similar improvements were made in the Sadar Bazaar.

On the whole we found the bazaars to be better built and better kept than the houses of corresponding class in ordinary Indian towns. It was not, however, difficult to find uninhabited houses, cowsheds, etc., which were dark, ill-ventilated, and festooned with cobwebs, and which formed suitable places for *anopheles* mosquitoes to haunt during the day. No organized attempt has been made to deal with the general intermixture throughout the cantonment of barracks with bazaars and followers' lines containing infected children.

59. *Improvements in the barracks and lines.*—The reports of the medical officers of the Native Regiments show that a good deal has been done from time to time to improve the general sanitary condition of the barracks and lines. Thus in the reports for the 25th Cavalry for the years 1905 and 1906 it is stated that the floors of the barracks were raised and the roofs correspondingly heightened. Also that small closed in backyards which blocked out air and were hiding places for standing water and stale drainage had been swept away leaving clean clear alleys between the troop lines. The lines and officers' bungalows were also carefully inspected twice a week and a Sanitary *Daffadar* reported daily to the medical officer. In the 1905 report for the 34th Pioneers it is stated that the general sanitation of the lines "is very good as much trouble is taken and great interest shewn by the regimental staff in the maintenance of good sanitary conditions. On the arrival of the regiment the existing latrines were abolished and others were provided, places for washing were constructed in all compounds, a raised platform inside, discharging by a spout through the wall into a paraffin tin set upon the ground, being the pattern adopted." The medical officer for the West Native Infantry lines complained in 1904 that the barracks and lines and even the quarters of the Native officers were of a very inferior type and imperfectly lighted and ventilated. Major Cadell also stated that in 1906 the lines were in a bad state of repair. He added that they have now been thoroughly repaired, many of the buildings being re-roofed, and that their present condition is excellent.

60. *Removal of undergrowth.*—Lieutenant-Colonel Rowan informed us that the removal of undergrowth was carried out partly by the "mosquito brigade" gangs and partly by the Military Works Services, but that neither of these were able to cope with the excessive vegetation which springs up all over the cantonment after the rains. This was also removed on occasions by regimental agency under the orders of the General Officer Commanding. The removal of undergrowth is doubtless a desirable precaution, but the danger arising from it in Lahore Cantonment is far less than that which occurs in moister parts of India where the rank growth is far greater than in the comparatively dry climate of this portion of the Punjab.

61. *Fumigation.*—Lieutenant-Colonel Rowan states that attempts were made in 1908 to destroy mosquitoes in barrack rooms by fumigation, sulphur and Keating's powder being used for the purpose.

62. *Swimming baths.*—The swimming baths which were found to contain *anophles* larvæ are not now used and have been emptied out.

63. *Syphons.*—Mr. Aikman remarked that although the irrigation channels have been removed he saw a number of syphons under public roads and in private compounds. These were not mere culverts but syphons in which water remains for a long time after they have been in use from well irrigation, or after they have been filled by rainfall. Mr. Aikman considers that these should, as far as possible be abolished, and that where it is necessary to retain them for garden irrigation they should be treated with kerosine oil.

Quinine prophylaxis.

64. During the last few years quinine has been used very extensively in Lahore Cantonment as a prophylactic measure. It is therefore important to ascertain, if possible, whether the efficiency with which this anti-malarial measure has been used has varied in different years, and how far, if at all, its use may in itself account for any decrease of malaria which may have taken place. This subject must be separately considered as regards British troops, Native troops and the Native followers and bazaar population.

65. *Quinine prophylaxis among British troops.*—This measure has been in use to a greater or less extent for many years past in malarious stations such as Lahore Cantonment. The evidence we have collected regarding it is of two kinds. First, the facts recorded in the annual reports of Medical Transactions of the Station Hospital, and secondly, oral evidence. We have examined the medical reports since 1900 with the following results. In 1900 no mention is made of the measure. In 1901 it is recorded that "a prophylactic issue of quinine was administered daily during the season," no details being given. In

1902, 10 grains of quinine was administered to all troops on two consecutive days in each week, and to followers and children in proportionate amount. The period is not mentioned. In 1903 a similar method and dosage was employed from the 15th September to 15th November. In 1905, 15 grains were given on two successive days each week from 8th August to 15th November by an Assistant Surgeon at the hospital. In 1905 we have found nothing recorded on this point. In 1906, 10 grain doses were given in the same way as formerly, but in the presence of an officer, from 1st June to 31st October. A roll was prepared of the men not attending at the regular time, to whom the doses were subsequently administered. In 1907 the same procedure was adopted from June to November, and also in 1908 for the same period. The evidence obtained from the medical officers examined was as follows:—Colonel Barrow thought that quinine prophylaxis had been steadily improving during the last few years. Lieutenant-Colonel Rowan considers that quinine prophylaxis has had a considerable effect on malaria, and that it is becoming very popular. The men of the South Lancashire regiment go of their own free will to get quinine in addition to the regulation dose. It is given in solution. Lieutenant-Colonel Braddell considers that in this year (1909), with very few exceptions, British soldiers are anxious to take quinine, and that more has been taken this year than ever before. The improvement had been progressive year by year. Lieutenant Lunn reported that the men of the batteries took quinine regularly and were rather inclined to overdose themselves. They had suffered severely from malaria in 1908. In the 38th battery the plan was tried of giving 10 grains every day for a week, and then leaving it off for a week. At first this appeared to have a good effect, but during the week before his examination a considerable number of fever cases had occurred. Lieutenant Wells reported that in the British Infantry regiment the officers were all very keen on the quinine issue, and saw that it was taken regularly. It is clear from the foregoing that the prophylactic issue of quinine has steadily improved during the last few years, and that the period over which it is given has also been gradually extended. The severe outbreak in 1908 has educated the men to take it willingly, and all the medical officers agree that as now administered it must have a marked effect in reducing malaria among British troops.

66. *Quinine prophylaxis among Native troops.*—It appears from the medical reports of the Native regiments that in 1904-1905 the Native troops received a prophylactic dose of 15 grains twice a week and from 1906 onwards a dose of 10 grains twice a week. The period during which the issue was made varied considerably from year to year and from regiment to regiment. In 1904 the 11th Lancers received it from the 15th September to the 15th November; in 1905 the 25th Cavalry from the 12th August to the 31st October; in 1906 the 38th Dogras from the 15th May to the end of November and the 34th Pioneers from June to the end of October; in 1907 the 38th Dogras from the 9th June to the 17th November and the 25th Cavalry in August and September. In the last case the medical officer administered the quinine under standing orders but considered that it was not necessary for his men during a healthy season. In the abnormal malarial year of 1908 the same officer considered that general prophylactic measures were useless and that the use of quinine and protection by curtains were essential. He states that in this year quinine was given prophylactically to all inhabitants in the lines from July to December 15th. It is stated in various reports that quinine was administered under due supervision, and in one report (34th Pioneers 1906) that the administration was supervised by, and usually given in the presence of, the medical officer. On the whole it appears to us probable that although a fairly regular issue was made to the Native regiments the administration was not so perfect as among the British troops.

67. *Quinine prophylaxis among followers and in the Native bazaars.*—In the medical report for 1902 mention is first made of the prophylactic issue of quinine to the followers and to children in the bazaars. In 1905 similar mention is made in the medical report of the 34th Pioneers. In 1906 quinine was offered bi-weekly to the wives and children of native troops and followers, and also to children in the bazaars, who were bribed by sweets to take it. Similar measures were continued during the malarial season in 1908 and 1909.

According to Colonel O'Sullivan it was also offered in the Sadar Bazaar in 1906, but this does not appear to have been done since according to the evidence we have obtained. Lieutenant Lunn reports that the syces and followers of the batteries are paraded and given quinine twice a week, but that it is not given among them so regularly as among British troops, although a very fair proportion of them take it. In the neighbouring bazaar he thought most of the children took it on the inducement of receiving sweetmeats. Captain Fraser reported that a considerable proportion of the children in the regimental bazaars took the quinine. It was not given in the Sadar Bazaar. First Grade Hospital Assistant Fazl-din, who did duty at the station hospital on anti-malarial work, including the administration of prophylactic quinine, reported that a large proportion of the native followers took the quinine, while in the regimental bazaars about half, or sometimes more, of the children came for it when he visited the bazaars. It is evident from the above that most of the native followers take quinine, but not so regularly as the troops. Of the bazaar children, on the other hand, only a limited number take it, and probably not at all regularly. It is difficult to believe that so large a proportion would have had enlarged spleens at the time of our visit if they had regularly taken prophylactic quinine.

Expenditure.

68. No general account was kept of the expenditure, nor was any estimate made of the value of the supervision and labour devoted to anti-malarial operations in the cantonment from 1904 onwards. Funds were derived from a number of sources; in many cases expenditure does not appear to be clearly shown in any account; and the bulk of the supervision and labour was unpaid. We cannot, therefore, give even an approximate estimate of the total cost of the operations and must content ourselves with indicating a few details under various heads.

69. *Closing of irrigation and filling up of canals and main depressions.*—A special grant of R12,562 was made to the General Officer Commanding for filling in canals and depressions. Most of the labour for these purposes was supplied by the regiments and not paid for. Colonel Chesney has estimated that in the winter of 1904-1905 about 500 men were employed for four to five months. Much regimental labour was also supplied in 1906 and 1907, and fatigue parties were freely utilised up to the present time. Transport carts and animals were also lent when required.

The new (or Kaure) distributary referred to in paragraph 38 was constructed by the Canal Department, and about R12,000 had been spent upon it up to the end of October 1909.

An expenditure of R9,287 was incurred for wells for road watering, tree watering, etc., in consequence of the closing of the canals. The loss of income to the cantonment fund from the closure of the canal was estimated at a minimum of R6,000 a year. An estimate was made in June 1904, that the grass farm would incur an annual loss of R8,000.

70. *Reform of the drainage.*—A sum of R40,090 has been spent from 1905 onwards, and in addition minor reforms have been executed regimentally.

71. *Miscellaneous.*—From 1906-1907 onwards a total sum of R14,594 has been spent from cantonment funds on various anti-malarial operations. The value of the miscellaneous work carried out regimentally and by private persons cannot be reduced to figures.

PART V.—RESULT OF GENERAL ANTI-MALARIAL MEASURES, 1904-1909.

Arrangement of the subject.

72. Having described the measures carried out from 1904 to the present time, we have now to estimate their effect on the prevalence of malaria. We propose to deal with this aspect of the case under the following heads :—

- (i) breeding places,
- (ii) malaria bearing mosquitoes,
- (iii) spleen rates and endemic indices of native children,
- (iv) influence of rainfall upon malaria,
- (v) incidence of malaria among the native population,
- (vi) incidence of malaria among British troops, and
- (vii) incidence of malaria among Native troops.

Breeding places of *anopheles* remaining in and around the Cantonment.

73. At the time of our visit the rains had ceased for over a month, and very few collections of water suitable for breeding *anopheles* remained in or immediately adjacent to the inhabited portion of the cantonment. We found larvæ of *A. Rossi* in the deep depressions already referred to in the East Native Infantry lines and to the east of the British Infantry bazaar. We also found a few very young larvæ in some small pools around wells.

74. Although we were unable ourselves to test the degree to which the breeding of *anopheles* larvæ is still possible in the rains, there was sufficient evidence available to enable us to form a fair estimate on this point. In the first place Lieutenant-Colonel Rowan kindly furnished us with a set of the section maps showing the collections of water remaining within and adjacent to the station three days after a fall of rain which occurred in September last. These pools have been shown roughly in blue in map no. 2. A number of pools occur in the Supply and Transport lines and between those lines and the Sadar Bazaar. A few are also to be seen round the other sides of the same bazaar. The British Infantry and the two Native Infantry lines and bazaars show only a few depressions. The embanked depression west of the West Native Infantry lines, and the large depression close to the East Native Infantry lines which was partly filled in by the 34th Pioneers, both show standing water. The bungalow compounds of the three infantry lines also contain very few pools of water. The condition of the south of the cantonment is less satisfactory. In spite of all the work that has been done in the Royal Artillery area the map exhibits a considerable number of pools within and immediately around it. The Native Cavalry lines and bazaar are themselves free from standing pools but a large number of pools remain all round them and between them and the West Native Infantry section. These are situated about three-quarters of a mile or more from the inhabited centre.

It will thus be seen that in spite of the labour that has been devoted to the filling in of depressions, a considerable number still exist in and around the south of the station, a smaller number in the north, and a still smaller number in the centre. It must be remembered that the section maps were prepared for the purpose of treating these pools and that they were in fact regularly treated. We have stated elsewhere that we doubt whether this treatment has, especially in wet years, been always comprehensive and thorough enough completely to prevent breeding.

The map shows water standing in some of the earth drains and we have already expressed the opinion that although the condition of these has been greatly improved, they still afford in places opportunities for breeding. This is specially the case in drains lying outside the lines.

75. The military authorities dealt only with breeding places lying within the inhabited portion of the cantonment or situated fairly closely to it. They have not attempted to cope with excavations and other depressions lying outside the cantonment boundary nor with similar breeding places lying within the boundary but at a distance from habitations. These exist in enormous numbers. We have plotted roughly on map no. 2 the pits, depressions and brickfields lying around the cantonment boundary on the south, west and north, and the similar breeding places which occur away from the lines and bazaars within cantonment limits on the east. These depressions are shown in brown to distinguish them from the pools (shown in blue) reproduced from the maps furnished by Lieutenant-Colonel Rowan. The map does not pretend to accuracy either as to the position or as to the size and shape of the pits, etc. It is meant merely to indicate generally the character and abundance of breeding places. All along the railway line, which runs close to the western boundary, there are a series of borrow pits and smaller depressions with some larger pools. Outside them there are big pools close to the village of Gurumanjal and inside there is a Military Works Services brickfield in the north-west corner of section E. Beyond the north-west boundary of the cantonment the brickfields and pools are still more numerous. They are specially abundant between and adjacent to the two branches of the railway which divide off at Ambala Street, and along both sides of Lahore Street. Further to the north the land lying between the canal and the railway line and between the railway line and the cantonment border is filled with an innumerable number of pits of all descriptions. On the south of the cantonment there are borrow pits along the new canal cut, and the pits which Captain Christophers found to be prolific breeding places in 1903 still exist. To the east, the number of depressions is smaller. There are some along the Shalimar drain and along drains in the land lying between Cunningham Street and the rifle ranges. Along the ranges themselves are numerous rifle pits, etc., which must hold water in the rains, and to the north bigger pits have been dug for the earth required for the butts.

In the north excavations extend right up to the inhabited area, elsewhere they are for the most part distant from a half mile to a mile from dwelling places. It cannot, we think, be assumed that any of these breeding grounds are beyond infection distance from some portion or other of the station. To fill them all up would entail very great labour and cost.

76. We have already quoted a statement made by Major James in 1903 to illustrate how quickly and widely the station used to be flooded after rain. There is abundant similar evidence to show the water-logged condition of the cantonment during the rains before anti-malarial operations were undertaken. Since the improvement of the drainage matters have been better, and the rapidity with which a burst of rain flowed away in September 1905 affords good testimony to the thoroughness of Colonel Chesney's work. At the same time this danger has by no means been abolished as will appear from the evidence we collected regarding standing water during the past season (1909) which was one of fairly considerable rain. Captain Kempthorne, who was Senior Medical Officer during the monsoon months, said that after heavy rain water stood about in some places, such as the camping ground to the west of the British Infantry lines, although the latter remained dry on account of their good drainage. Water also stood for some time to the east of the Artillery lines, and actually in the lines themselves for about a week. Lieutenant Lunn, who is in charge of the Artillery lines, said that, during heavy rain, water stood practically all over the section, but that except in the places shown in the map (in blue) it dried up after three days. The cricket ground, however, was entirely under water for a week. Captain Fraser reported as follows regarding the Native Cavalry section:—"The impracticability of efficiently draining such a level station was forcibly impressed on me at the beginning of September 1909 after a week's steady and almost constant rain. The 25th Cavalry mess compound was largely under water and on examining it I found *anopheles* larvae swarming everywhere. The area under water was probably almost as great as that which remained dry. In many places the water was only two inches or three inches deep but contained numerous larvae. Samples were collected and on hatching them out we found them in all cases to be *M. Rossi*."

77. In the exceptional flood year of 1908 conditions were naturally worse. Colonel Barrow, who was in the cantonment during the monsoon of this year, said that the whole country was flooded for miles around and that water stood in the houses of the villagers. The cantonment was practically one sheet of water, only the roads standing out. There was a great sea extending to about 12 miles from the cantonment and the railway embankment was broken, about 9 feet of water standing at the breach. The water remained in the cantonment long enough for mosquitoes to breed, probably over two weeks, and it was quite impossible to deal with it. Surgeon-General Hamilton sent us the following description which was given by Captain A. H. Radice, of the Gloucestershire Regiment, who was also in the cantonment:—"Especially in August and September the whole country was water-logged and water lay about in sheets in the British Infantry lines. The ground generally dried up very quickly and I may say there was no water lying about shortly after it had finished raining, but the drains were always full. The barracks are exceptionally well drained. In other parts of cantonments things were not so good. In many places there were pools of water. On the Brigade Parade ground there are places that never got dry and some of the compounds of the bungalows were regular lakes which dried up very slowly."

78. Generally it may be said that, in spite of the improvement of the drainage, rain water still lies in some portions of the cantonment, especially in the south and that the drainage system is inadequate to cope with a year of exceptional flood such as 1908. Moreover, the elaborate system of minor drains does not extend beyond the inhabited portion of the cantonment, and water may therefore stand in the unevennesses of the level ground within breeding distance from the buildings. Thoroughly to drain the whole area around the cantonment up to a distance of from half a mile to a mile would be a very serious undertaking.

Prevalence of malaria bearing mosquitoes.

79. It is the habit of malaria bearing mosquitoes to lurk by day in the recesses of dark dwellings where they are not very easy to find; it requires special search and some knowledge to detect them. Captain Christophers recorded the following remarks on this point in his report on the operations of 1903:—"Of *anopheles* in general, it may be said that they are difficult of detection and require concentrated attention on the part of the searcher if they are not to be over-looked. *A. Rossi*, however, is a mosquito fairly easy of detection, and it is possible to employ comparative terms for their numbers, such as 'swarming,' 'abundant,' 'scanty,' 'found with difficulty' or 'not found at all'. In the case of *A. culicifacies* it is harder to arrive at any definite idea as to their numbers. This species is extremely careful to secrete itself, and if there are not any suitable collecting places, it may very easily be considered absent when in reality it is abundant. Should, however, a low roofed, rather dark shed be available, adults are usually caught readily. With regard to this species then we can only say that 'it was caught readily by looking in suitable places' or that 'a few specimens only were to be caught', or that 'they were not found'."

80. A series of observations has been made by different persons from time to time to test the abundance and seasonal prevalence of malaria bearing mosquitoes in Lahore Cantonment. The method employed has been to search for and catch the insects in likely resting places, and the observer has relied on his previous experience in detecting the insect under similar conditions in the cantonment to determine whether there has been an increase or decrease. The test is not an exact one and exception was taken to it by Professor Ronald Ross in the paper he read before the meeting of the British Medical Association at Oxford in July 1904. We know, however, of no better method of estimating the prevalence of mosquitoes lurking in native huts and sheds, and it appears to us that a competent observer should be able by this means to detect any considerable reduction or increase in the number of insects. The exact numbers found are indeed of less importance than the demonstration of the presence of considerable numbers of those varieties which are known commonly

to carry malaria, for given such a prevalence and a high endemic index (which we shall shortly show prevails), we have all the necessary factors for the production of a considerable degree of malarial infection, and any place presenting such conditions must be considered to be highly malarious.

81. We will now pass in review the results of the series of observations of this character that have been made from time to time in Lahore Cantonment. They comprise the following:—

- (i) Observations of the Commissioners of the Royal Society and Major James in 1901.
- (ii) Observations of Major James in 1902.
- (iii) Observations of Captain Christophers in 1903.
- (iv) Observations of Major James in October 1908.
- (v) Observations of Captain Christophers in the first week of October 1909.
- (vi) Our own observations, made with the assistance of Captain Christophers, in the fourth week of October 1909.

82. *Observations of the Commissioners of the Royal Society and Major James in 1901.*—In October and the first week of November 1901 all species were found, *A. Rossi* were exceedingly abundant. *A. culicifacies* were found in fair numbers though not so prevalent as *A. Rossi*. Other species were comparatively rare. During the second week of November the number of adults began to decrease rapidly and November the 28th was the last date on which specimens of *culicifacies* were caught in the bazaars: two *A. Rossi* also were found after an hour's search on December 5th.

83. *Observations of Major James in 1902.*—From the middle of May onwards, the number of adult *anopheles* increased steadily to a maximum in September and the beginning of October. In November the numbers began to diminish rapidly. *A. culicifacies* appeared earlier than *A. Rossi*, but once the *A. Rossi* were evident they increased rapidly and in a short time became much more abundant than the other species.

84. *Observations made by Captain Christophers in the Royal Artillery bazaar and lines in 1903.*—In July 1903 a search did not reveal a single adult. Early in September *A. Rossi* were abundant and *A. culicifacies* were readily caught. At the end of September *A. Rossi* were swarming, *A. culicifacies* were abundant and *A. fuliginosus* and *A. pulcherrimus* were not uncommon. The number of *A. culicifacies* reached its maximum in October when the number of *A. Rossi* was diminishing.

85. Major James has described the observations he made in October 1908 in the following terms:—"I searched for anopheline adults in the British Infantry bazaar, the Royal Artillery bazaar, the saddle rooms of the Royal Artillery, and the houses of the 34th Pioneers. In all these places they were exceedingly numerous. In the three places first mentioned, I attempted to form a rough estimate of their prevalence by ascertaining how many I could catch in test-tubes in a given time. The time was taken by the Hospital Assistant who accompanied me. After I had caught a mosquito and plugged the mouth of the tube with wool I handed the tube to him and he gave me another. In the British Infantry and Royal Artillery bazars, however, *Anopheles Rossi* were so common that I employed the test only for *Anopheles culicifacies*, a species which it is well known is difficult of detection. I found that from the ceiling rafters of one room in the British Infantry bazaar I caught 12 *culicifacies* in 20 minutes one morning and eight in the same time from another room the next morning. In the Royal Artillery bazaar I caught in one room four *culicifacies* in ten minutes, and in the saddle rooms, five *culicifacies* and 12 *Rossi* in the same time. An idea of the prevalence of *Rossi* in the British Infantry and Royal Artillery bazars may be formed from my observation that in the darker parts of the ceilings of every room they were so thickly set as to be separated from one another by spaces not more than one or two inches. In these bazars also *A. fuliginosus* and *A. pulcherrimus* were fairly common.

"On the whole I came to the conclusion that adult *A. culicifacies* and *A. Rossi* were somewhat more prevalent than in October 1901 and 1902."

It must be borne in mind that the season of 1908 was marked by a severe epidemic of malaria.

86. Captain Christophers has given us the following account of the observations he made in the first week of October 1909 :—"From experience of Mian Mir in 1901 and 1903, before the operations had been instituted, I was aware approximately of the number of *anopheles* which could be caught in the following situations: the British Infantry bazaar, the Royal Artillery bazaar, the Royal Artillery stables, and the Bengal Cavalry lines. Between October 1st and 6th, I visited each of these places and also the Sadar Bazaar with the following results.

"In the British Infantry bazaar, *P. Rossi*, *M. culicifacies*, *N. fuliginosus*, and *C. pulcherrima* were found. *P. Rossi* was found in every house examined. In houses suitable for *anopheles* these were very abundant. In a number of houses examined consecutively there were found :—

" In house 1	22 <i>anopheles</i> .
2	6 "
3	2 "
4	30 "
5	14 "
6	<i>Anopheles</i> were so abundant that 18 were counted in a square yard of the ceiling.

"I was accompanied on this occasion by Captain Forster, I.M.S., who could speak as to the very great abundance of *anopheles* in this bazaar.

"In the Sadar Bazaar want of time prevented anything but a cursory examination for adults being made but in the few houses entered *anopheles* were abundant, 13 being caught on a single cobweb and 24 on a coat hanging upon a peg.

"In the Royal Artillery Bazaar *anopheles* were also abundant. Three houses were entered in all of which *anopheles* were found. In the fourth house some counts of the number on different cobwebs were made.

" Cobweb 1	9 <i>anopheles</i> .
2	5 "
3	6 " (Including 1 <i>A. culicifacies</i> .)
4	7 " (" 1 <i>A. pulcherrimus</i> .)
5	1 " (Including 1 <i>A. pulcherrimus</i> .)
	(<i>A. culicifacies</i> .)

"In the saddle rooms of the Royal Artillery stables *anopheles* were extremely abundant. The numbers on saddles examined at random were :

" Saddle 1	25 <i>anopheles</i> (1 <i>A. culicifacies</i> .)
	(1 <i>A. fuliginosus</i> .)
2	1 "
3	12 " (1 <i>A. culicifacies</i> .)
4	15 " (1 <i>A. culicifacies</i> .)
5	1 "
6	6 "
7	34 " (2 <i>A. culicifacies</i> .)
8	32 " (2 <i>A. culicifacies</i> .)
	(2 <i>A. fuliginosus</i> .)

"In the Bengal Cavalry lines *anopheles* were abundant towards the western portions but less so to the east.

"The number of adult *anopheles* in these bazaars and the saddle rooms shows no perceptible diminution from the number in 1901 and 1903. Even *M. culicifacies* whose breeding places may be supposed to have been reduced by the filling in of the canal system was as abundant as I have ever known this species. I can speak with certainty on this point since for several

"hours daily extending over some weeks I had in 1901 along with Dr. Stephens and Captain James, I.M.S., searched for this species in the places I have mentioned."

87. The time at our disposal did not admit of an organised and thorough search for *anopheles* mosquitoes throughout the bazaars, and our visit was made late in October at a season when adult *anopheles* are already diminishing in numbers. Nevertheless we had no difficulty in detecting the presence of the dangerous *culicifacies* and *fuliginosus* varieties of *anopheles* in suitable places in several of the lines examined. *Anopheles Rossi* were considerably more numerous than other varieties but in one or two places their relative proportion was small enough to show that the reduction in their numbers must have already gone to some length. We found the dangerous varieties to be most prevalent in the British Infantry, Sadar and Royal Artillery bazaars. We made a short search in the first two of these localities in the course of our work on the morning of the 22nd, and similarly in the third on the morning of the 23rd. Specimens of the dangerous species were readily to be found in suitable places in all three localities and apart from *A. Rossi* we caught the following specimens in one or two houses in each bazaar :—

	<i>Culicifacies.</i>	<i>Fuliginosus.</i>	<i>Pulcherimus.</i>
British Infantry and Sadar Bazaar	19	8	10
Royal Artillery Bazaar	13	2	3

Adult *anopheles* were much less abundant in the Native Infantry and Cavalry bazaars. In the Royal Artillery saddle rooms a considerable number could still be detected under the flaps of the saddles but they had considerably diminished since Captain Christophers' visit three weeks before. The greater number were *A. Rossi*, but some specimens of *A. culicifacies* were also visible. In some cattle sheds in the Supply and Transport lines in the extreme north of the cantonment, some *anopheles*, including a few *A. culicifacies*, were also found.

88. On a review of the whole evidence it appears to us that the prevalence of adult malaria bearing mosquitoes has not diminished since the general operations throughout the cantonment were undertaken.

Incidence of malaria tested by spleen rates and endemic indices of native children.

89. The spleen rate and the endemic index among native children in the cantonment vary considerably according to the time of year, rising with the occurrence of new infections at the onset of the malaria season and falling again when infections cease at the close of the season. To illustrate this seasonal variation, Major James made a series of observations in the British Infantry bazaar, the result of which he tabulated as follows :—

Date.	Epidemic Index.	Spleen rate per cent.	Number examined.
October 5th, 1901	52	80	25
November 25th, 1901	20	38	25
June 17th, 1902	8.3	26	24
July 28th, 1902	8.5	37	35
August 25th, 1902	15	60	20
September 17th, 1902	32.2	65	31
October 22nd, 1902	42.3	69	29
November 19th, 1902	27	57	24

The rates began to rise at the end of July or the beginning of August, the number of new infections increased steadily until it reached a maximum in October and November exhibited a sudden fall.

90. An examination into the spleen rate and endemic index among native children in different bazaars of the cantonment has been made by several observers during the month of October (*i.e.*, at the time of maximum infection) in several years both before and after general anti-malarial operations were undertaken. The results are summarised in the two following tables :—

Spleen rate per cent. (Splenic Index.)

Locality.	October 1901.	October 1902.	October 1903.	October 1908.	October 1st week 1909.	October 4th week 1909.
1	2	3	4	5	6	7
British Infantry Bazaar .	80	69	77.5	64	76	71
Royal Artillery Bazaar .	75	64	64.5	...	55	65
Native Cavalry Bazaar .	36	...	...	55	50	48
Native Infantry West Bazaar	...	...	...	79	...	56
Native Infantry East Bazaar	...	...	...	74	...	62
Royal Artillery Followers (hospital and syce lines).	48 (syce lines) November.	...	60 (hospital) followers 67.5 syces.	85	...	...
Sadar Bazaar .	...	...	...	...	90.5	80

Percentage infected with malaria parasites (Endemic Index).

Locality.	October 1901.	October 1902.	October 1903.	October 1908.	October 1st week 1909.	October 4th week 1909.
1	2	3	4	5	6	7
British Infantry Bazaar .	52	41	...	68	48	42
Royal Artillery Bazaar .	35	20	...	78	43	60
Native Cavalry Bazaar .	25	...	...	85	9	...
Native Infantry West Bazaar	...	...	...	95	24	...
Native Infantry East Bazaar	...	...	...	83	...	...
Royal Artillery Followers (hospital and syce lines).	56	...	...	80	...	...
Sadar Bazaar .	...	...	...	...	45	...

The results shown in the different columns of the above tables were recorded by the following observers :—

Column 2, Commissioners of the Royal Society.

Column 3, Major James.

Column 4, Captain Christophers.

Column 5, Major James.

Column 6, Captain Christophers.

Column 7 represents the result of the investigations made for us by Major Rogers with the assistance of Captain Christophers.

91. In making our investigations as many of the children as could be collected by the inducement of a distribution of pice and sweetmeats were examined for enlargement of the spleen, and slides were also taken for working up the endemic index in the British Infantry and Royal Artillery bazaars, that is, the two which are in closest relationship with the lines occupied by British

troops. Only children between the ages of 2 and 10 years were examined. The history of each child was ascertained: the great majority had either been born in the bazaar in which we found them or had resided there for several years, and the few children who had not been in the cantonment during at least one malarial season were excluded. In the regimental bazaars we succeeded in procuring the attendance of a considerable proportion of the local children. The children who came belonged naturally to the poorest classes, that is, to the classes most likely to be infected and to disseminate infection. Among children of the better class, the results would doubtless have been less unfavourable. This point is illustrated by observations made by Captain Christophers earlier in the month. He examined a number of children, mostly of the sweeper caste, in the Sadar Bazaar and also a large number of children in the cantonment school which is situated in the same area. In the former case the spleen rate worked out to 90.5 per cent. and in the latter case to 64.5.

92. The following are the results of the spleen examination made by Major Rogers, classed according to the degree of enlargement:—

Bazaar.	Felt.	2 inches below ribs.	To navel.	Not felt.	Total enlarged.	Percentage enlarged.
British Infantry	5	4	8	7	17	70.8
Sadar	21	13	10	11	44	80
Royal Artillery	12	8	6	14	26	65
Native Infantry West . . .	7	1	1	7	9	56
Native Infantry East . . .	14	5	2	13	21	62
Native Cavalry	11	2	...	14	13	48
TOTAL	70	33	27	66	130	66

We thus found that no less than 66 per cent. out of 196 children examined had palpably enlarged spleens; in 26 per cent. of these cases the organ extended two inches below the ribs, and in no less than 20 per cent. it reached to or beyond the navel. The highest rates were in the northern end of the cantonment among the children of the British Infantry and Sadar Bazaars, while the lowest rates were in the bazaars attached to the Native Regiments. These spleen rates indicate a large amount of malaria among the native population of the cantonment.

93. The examination of the slides taken in the British Infantry and Royal Artillery bazaars yielded the following results:—

—	Total examined.	Malignant tertian.	Benign tertian.	Both forms.	Total.	Percentage.
British Infantry Bazaar . .	26	2	7	2	11	42.3
Royal Artillery Bazaar . .	25	3	12	...	15	60.0

Here again we have evidence of a large amount of malaria among the native population of the regimental bazaars quite sufficient to constitute a fertile source of infection for the neighbouring barracks.

94. In examining the two comparative tables given above it must be borne in mind that 1902 was a very healthy year, that 1909 was somewhat less so, that 1901-1903 were years of fairly high malarial incidence, and that 1908 was a year of severe epidemic. Taking this factor into account it cannot be said that on the whole columns 5 to 7 of the spleen rate table which relate to years after the general anti-malarial operations contrast specially favourably with columns 2 to 4 which relate to an anterior period. In the second table (endemic index) the first point to notice is the very high rate that prevailed during the epidemic year of 1908. Leaving that year aside, the figures for 1909 do not on the whole show an improvement over the earlier figures. The high

endemic index rate which we found in the Royal Artillery bazaar is worthy of notice, and it will be seen that there was also a considerable, though lesser, rise in the spleen rate of that bazaar. We have already noticed that *A. culicifacies* were found in abundance in the Royal Artillery bazaar and at the time of our visit a sharp outbreak of malaria had occurred among the men of the Royal Artillery. On the date of our visit to the barracks, 20 men were laid up with fever from this cause.

95. We were forced to the general conclusion that the spleen rate and endemic index indicated a very considerable prevalence of malaria at the time of our visit and that a comparison with earlier data does not reveal any improvement in malarial conditions among the native population.

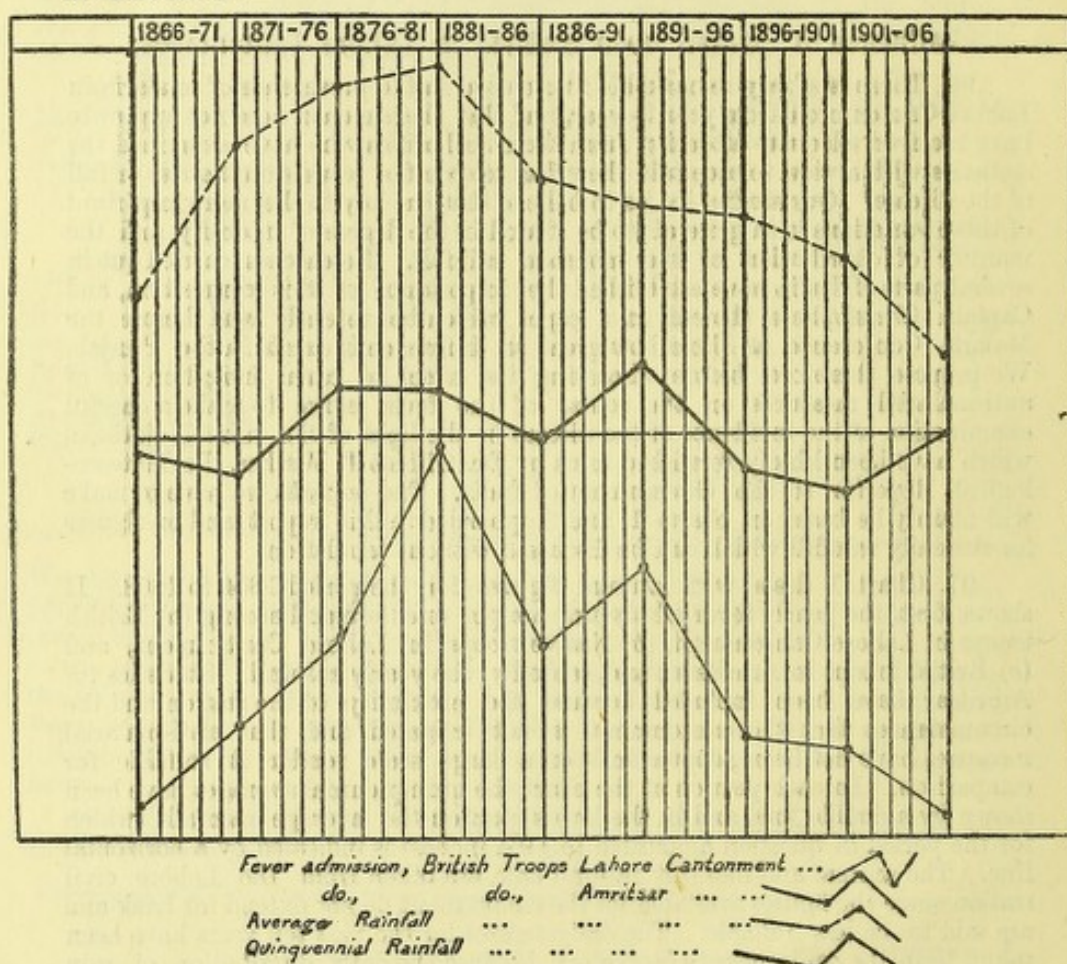
Influence of rainfall upon malaria in Lahore Cantonment.

96. There is a very remarkable fluctuation in the prevalence of malaria in Lahore Cantonment from year to year, and this phenomenon does not appear to have received adequate attention from those authorities who have examined the statistics with a view to ascertain the effect of specified causes on the rise or fall of the disease. Our studies led us to believe that the key to the more important of these variations is in general to be found in the degree of intensity and the manner of distribution of the monsoon rainfall. Researches carried out in several parts of India have established the importance of this connection, and Captain Christophers showed in a paper which he recently read before the Malaria Conference at Simla how great an influence it exerts in the Punjab. We propose, therefore, before discussing the effect of canal irrigation or of anti-malarial measures on the course of the fever curve to make a careful examination of the incidence of the disease in the light of the rainfall statistics which have been kindly furnished to us by Dr. Gilbert T. Walker, the Meteorological Reporter to the Government of India. The remarks we have to make will mainly be based on charts 1 and 2 appended to this report and on figures for the daily rainfall which can be discussed without tabulation.

97. Chart 1 deals with annual figures for the period 1864 to 1908. It shows, first, the yearly fever admission rate per one thousand among (a) British troops in Lahore Cantonment, (b) Native troops in Lahore Cantonment, and (c) British troops in Amritsar; and, secondly, the yearly rainfall. Statistics for Amritsar have been included because the proximity of the station and the circumstances that the cantonment is not irrigated and that anti-malarial measures have not been adopted in it on a large scale render it suitable for comparison. In each portion of the chart the quinquennial averages have been shown by a double line, and in the lowest portion the average rainfall (which for the period in question amounted to 19.4 inches) is indicated by a horizontal line. The annual and monthly rainfall data are taken from the Lahore civil station since the figures available for the cantonment do not extend far back and are said to be less reliable. The daily figures for the past ten years have been taken from the cantonment observatory because the daily distribution of rain is apt to vary considerably within short distances. The fever admission rates for the troops are taken from the published statistics. They do not furnish ideal data of the incidence of malaria since they are liable to be disturbed by a variety of causes (such as the transfer of troops) apart from the degree of prevalence of malaria in the locality. They form, however, the best data available over a long series of years and are good enough for the present purpose. The statistics for British troops afford better material than those for native troops, for the former are in general less immune to the disease whilst the latter are exposed to infection during their leave in places other than the station at which they are posted. Another point which tends somewhat to obscure the chart requires special notice. The incidence of malarial fever in the first part of any year tends to be in proportion to that of the previous malarial season in the autumn of the year before, except where the troops have been changed in the interval. The reason for this is the occurrence of relapses, which are very frequent among British troops. Consequently, in the second of two healthy years both the first and second six months will show low fever rates while the reverse will be the case in the second of two unhealthy years. In such cases the rise or fall of the curve is apt to be exaggerated. Similarly, in a comparatively dry year a high fever rate in the first six months due to a previous unhealthy year may to some extent neutralise the good effects of the

dry year. In this way irregularities are produced in the curve which would probably largely disappear if the admission rates could be calculated from June of one year to June of the next. Chart no. 2 compares the monthly rainfall with the monthly fever admissions for British troops, and, from September 1903 onwards, also with the monthly fever admission rates in the cantonment hospital, which is the principal hospital for natives in the cantonment. We will now deal in order with the quinquennial, annual, monthly and daily statistics.

98. *Quinquennial figures.*—Quinquennial figures may be readily studied from the following diagram which reproduces the quinquennial averages shown in chart no. 1:—



During the 15 years, 1871 to 1886, the Lahore Cantonment curve follows the rainfall curve fairly closely. This is a period of very high malaria and includes the two heavy rain periods 1874 to 1879 and 1881 to 1886. The Amritsar curve is similar in general character but shows a much higher rise in the 1876-1881 period. In the following decade (1886-1896) Lahore does not, but Amritsar does, show a rise corresponding with the period of heavy rainfall extending from 1889 to 1894. The annual figures in Lahore follow fairly closely the annual variations of rainfall, but the maximum points are not so high as might have been anticipated. Both Lahore and Amritsar follow closely the rainfall line in the quinquennium 1896-1901. In the last quinquennium (1901-06) both cantonments show a fall whilst the rain curve rises. This is explained in subsequent sections.

99. *Relationship of the total yearly rainfall to the fever incidence.*—If the minimum fever rate for British troops be compared with the corresponding rainfall in chart 1, a very close relationship will be observed, e.g., in the years 1868, 1871, 1874, 1880, 1883, 1885, 1888, 1891, 1896, 1899, 1902 and 1907. The effect on the statistics of two succeeding dry seasons is well shown by the years 1870-1871, 1895-1896 and 1901-1902. The most marked exception to the general rule is the fall in malaria among British troops in 1881 during a year of comparatively high rainfall. The same year, however, shows a rise in fever

rates both among native troops in Lahore and among British troops at Amritsar. The continuous fall in the fever rate for British troops during the years 1904, 1905, 1906 and 1907 is accompanied by a succession of years of deficient rainfall, the average being touched only once. The maximum points do not correspond quite so regularly as the minimum points and the cumulative effect of two years not infrequently makes the rise in the fever rate to be one year late, *e.g.*, in the years 1875-1876, 1885-1887, 1896-1898 and 1900-1901. There is, however, a marked degree of correspondence, as for instance in the years 1867, 1869, 1873, 1882, 1889, 1890, 1903 and 1908. A noticeable point, the explanation of which is not obvious, is the enormous rise both in Lahore and in Amritsar in the years 1878-1879 which were two years of approximately average rainfall following two years of heavy and one year of slightly excess rain. Making allowance for the causes which tend to obscure the chart it may be said in general that there is a close relationship between a high annual rainfall and a high fever rate and *vice versa*.

100. *Relationship of the monthly rainfall to the fever incidence.*—If the conclusion above stated is correct then there should be a still closer relationship between the monthly rainfall and the autumnal fever incidence. A scrutiny of chart 2 will show that the relationship is in fact most intimate. It will be convenient to notice briefly each year in succession.

1900.—A heavy rainfall which nearly all fell during the monsoon months and was accompanied by a high fever rate among the troops, the highest point shown on the chart being 250 in December.

1901.—The total rainfall was slightly below the average and although there was a heavy fall in July the rains practically ceased in August and only a moderate degree of malaria resulted; the highest fever point among the troops was 158 in November.

1902.—The rainfall was scarcely over half the average and the maximum in no month exceeded 4 inches. The fever rate was the lowest recorded up to that time, the maximum point being 55 in October.

1903.—The total rainfall was low, but it nearly all fell in the monsoon between July and September, and a short but sharp burst of malaria followed. The maximum point for the British troops was 324 in November and for the cantonment hospital 580 in October.

From 1904 onwards it will be best to rely mainly on the figures for the cantonment hospital. They are the more reliable since, as will shortly be explained, the figures for the troops for these years are somewhat confused and irregular.

1904.—A very light monsoon rain and a low fever rate. The highest point for the cantonment hospital was 73 in October.

1905.—A very irregularly distributed monsoon rain, none falling in August while September showed a very heavy fall of over 9 inches without any succeeding malarial rise. This appears to be an exception to the general rule, but the reason will become evident when the daily figures are discussed. The maximum point for the cantonment hospital was 75 in November.

1906.—The total rainfall was above the average and almost all fell from July to September. The malarial incidence rose considerably, the maximum point in the cantonment hospital being 282 in November.

1907.—The rainfall was below the average and the heaviest fall was in August. The admission rate at the cantonment hospital was higher than might have been expected, the maximum point being 386 in October, but among British troops the recorded fever admission rate was very small.

1908.—A very heavy monsoon with an abnormal rainfall in August. A severe epidemic ensued, the maximum point for the cantonment hospital being 1,035 in September. The rate for British troops was also comparatively high.

1909.—Heavy rain from June to September, the highest fall being in July. At the end of October the cantonment hospital figure had reached 268. The British troops rate was rising and had reached 132. The monthly rate for the first 20 days of November was 145.

It will be noticed that in both the malarial years, 1903 and 1908, the rise among the troops began at a later date than among the native population.

This is to be expected since it is mainly from infected children in the bazaars, etc., that the troops become infected.

101. *Relationship of the daily distribution of the monsoon rain to the incidence of malaria.*—The effect of a given quantity of rainfall in producing collections of surface water of sufficient duration to breed abundant *anopheles* will necessarily depend on its daily distribution. For example, a heavy fall on one day, if followed by a dry period, may not remain long enough on the ground for breeding purposes, although the same amount if distributed over a number of days at short intervals may keep pools filled long enough for the production of adult *anopheles*. On turning to the data for September 1905, we find that no less than 9.30 inches fell on the 11th and 12th of that month, and the remaining 0.25 two days later, after which the only remaining fall occurred on October 12th. We have the evidence of Lieutenant-Colonel Faulkner that the heavy September fall of over 8 inches in 36 hours ran off within two days, and did not form standing pools, such as occurred in the epidemic malarial year of 1908. The low malarial incidence of 1905, in spite of heavy September rain, is thus explained. On the other hand, in the highly malarious year of 1900 the 8.82 inches of rain in September were distributed over no less than 12 days, the longest dry period in the month having been six days, and the next longest four days. Again in 1908, rain fell on 14 days in July and on 13 days in August as well as on four out of the first five days of September, no break of more than five days occurring within the period mentioned. In 1909, July was a wet and August a very dry month in the cantonment. Between the 29th August and 11th September, when the rain finally ceased, about 7 inches fell with no dry interval exceeding three days. This late rain produced an outburst of malaria towards the end of October.

102. The general conclusion to be derived from the above examination is that a heavy monsoon rainfall, especially if it extends to late in the season and if the rain is distributed over a number of days with short intervals between them, always produces a high incidence of malaria in Lahore Cantonment, and that the reverse also holds good. No reliable deductions can be made from the fever statistics unless these considerations are carefully borne in mind.

103. In an article published in the *Journal of the Royal Army Medical Corps* (volume V, July-December 1905) Captain Sewell, R.A.M.C., attributed the prevalence of malaria in Lahore Cantonment in a wet year to the circumstance that irrigation water was cut off for long periods in such a year, and in consequence that pools replenished by rain formed in the canal beds. Such an argument would probably not be brought forward at the present time. It is opposed to the general experience of the Punjab and also to the experience gained at Lahore since the canals were closed.

Incidence of malaria among the Native population.

104. The prevalence of malaria among the native population of the cantonment, and the effect upon it of anti-malarial operations, may be gauged (1) by the fever admissions at the cantonment hospital in the Sadar Bazaar, and (2) by the mortality returns.

105. Captain Fraser kindly placed the registers of the cantonment hospital in the Sadar Bazaar at our disposal and we were able to work out the monthly attendance for fever among patients belonging to the Sadar Bazaar from September 1903 to October 1909. The figures have been plotted on chart no. 2, and we have already made use of them in the previous section for comparison with the rainfall. Lieutenant-Colonel Aldridge has pointed out that there has been some increase in the attendance at cantonment hospitals of recent years due to larger population and growing popularity, and that a comparison between later and earlier years may be affected by this cause. Between 1904 and 1907, the total attendance at the Lahore Cantonment Hospital increased from 8,538 to 10,200, and in 1908 to 14,160, but the latter rise was mainly due to the great prevalence of malaria, no less than 1,035 malaria attendances having been registered among the population of the Sadar Bazaar in the single month of September. The increase is certainly not sufficient to invalidate comparison. We have already noticed that the fluctuations in the chart closely follow the volume and distribution of the rainfall. There is nothing to indicate a falling incidence during the period under consideration; 1903 was an unfavourable year and the

chart shows a considerable prevalence of malaria. There is no distinction to be drawn between the two following healthy years, 1904 and 1905, the second of which immediately followed the closing of the canals. In 1906, malaria responded fairly readily to somewhat worse conditions. In 1907, the amount of malaria was very great for the seasonal conditions, in the epidemic year 1908 the rise was enormous, and in 1909 it was not smaller than might have been expected from the season. Marked malarial conditions thus continue to prevail, and they show no signs of abating.

106. Captain Christophers has demonstrated (*vide* paper read at the recent malaria conference) that malaria has so great an effect on the autumnal death-rate in the Punjab that the total mortality returns for different places and for different years give a very clear picture of the malarial incidence. In chart no. 3, we have plotted out the monthly death-rates for the past ten years in the canton-

* Areas in charge of subordinate police officers.

ment of Lahore together with the combined figures of the *thanas** of Munawan to the north, Kanakacha to the south-west and Barki to the east. We have also shown below the *thana* total mortality curve, the recorded fever death-rate for the same period. The two curves based on figures for all causes of deaths show large rises due to such diseases as cholera and plague. These are marked as such on the chart, and since as a rule they do not occur to a considerable extent in the autumn months they do not obscure the rises due to malaria at that season. A comparison of the two *thana* curves brings this out clearly, for it will be seen that the autumnal malarial rise in each year is exactly parallel and almost identical with the total mortality rise for the same season. It should be noted that the cantonment figures include the troops, but as a very large proportion of the deaths occur among the native population, the curve is sufficiently representative of its mortality. If the anti-malarial operations carried out in the cantonment have had the effect of greatly reducing malaria among its native population then the rises in the cantonment curve due to malaria since 1904 should, when compared with the corresponding rises in the *thana* curve, show a great and increasing diminution. As a matter of fact they do not. Both curves show great malarial rises in the unhealthy years of 1900 and 1908, little or no rise in the healthy years of 1902, 1904, 1905 and 1907, and intermediate moderate malarial prevalence in the years 1901, 1903 and 1906. The autumnal death-rates for the cantonment and the *thanas* are so closely parallel throughout the period that they indicate no decrease in the malarial death-rate in the cantonment.

Incidence of Malaria among British Troops.

Examination of causes affecting statistics from 1904 onwards.

107. It has been represented to us that various changes have been made, and that various causes have been at work, the cumulative result of which is to vitiate comparison between the statistics for British troops from 1904 with earlier periods. The subject is somewhat difficult and complicated and very diverse views have been placed before us. In the following paragraphs the various considerations bearing on this important point are discussed in order.

108. *Changes in diagnosis.*—It has been admitted by all the medical officers whom we have consulted that the diagnosis of malaria during recent years has been much stricter than was formerly the case. The aid of the microscope has been invoked and as a result many cases that would formerly have been registered as malaria have been classed as "simple continued fever" or more latterly as "pyrexia of uncertain origin." We were advised that it is necessary in order to allow for this change of system to combine the figures of malaria with those under the two other heads, and we have accordingly done this in all our figures and charts. Major James, the Statistical Officer in the Sanitary Department of the Government of India (and the officer who carried out the earlier operations in Lahore Cantonment) considers that even this is insufficient, and that cases formerly classed as malaria are now sometimes diagnosed as debility, inflammation and congestion of the liver or heat stroke. The information before us does not suffice to prove that any change of this nature has had a material effect on the statistics.

109. *The out-patient system (or treatment in barracks).*—Up to the end of November 1903 the regulations provided that men should only be recommended "light duty" for a period of 24 hours, after which they should be returned to duty or admitted to hospital. Also that men might be "detained"

in hospital for the day, but that at the evening visit if not fit for duty they were to be admitted to hospital. On the 30th November 1903, an order was issued that men not ill enough to be kept in hospital might be directed to attend hospital and to do such light duties as were recommended. The rule regarding men "detained" remained the same. From the 1st May 1904, a statistical form was introduced for recording particulars of the men treated "in barracks," but the numbers are not included in the tables of published returns. Up to that time no statistics had been kept of men treated without admission to hospital. These rules followed corresponding changes in the English regulations, since it has been the practice to keep the methods in both countries as far as possible the same.

110. Major James has represented to us that this change in the regulations has resulted at Lahore Cantonment in the treatment as out-patients of a number of malarial cases which would under former conditions have been admitted to hospital, and that the admission rate has thus been reduced vitiating comparison with the figures of earlier years. Lieutenant-Colonel Aldridge, the Sanitary Officer at Army Head-quarters, considers on the other hand that no such change has occurred. The arguments which have been placed before us in favour of this latter view may be summarised as follows: It is well known that before the change in the regulations was made it was the frequent practice to detain men and "to keep them attending" for some days although this was not authorised by the regulations. Lieutenant-Colonel Aldridge gave us some instances derived from his personal experience of the long standing prevalence of this practice and he quoted Lieutenant-Colonel Henderson, R.A.M.C., who has had large experience of station hospitals in India, in support of his statement. Colonel O'Sullivan and Lieutenant-Colonel Rowan, whom we examined on this point, both support Lieutenant-Colonel Aldridge and state that the change in the regulations did not as a matter of fact affect the admission rate for malaria in Lahore Cantonment. Lieutenant-Colonel Aldridge also obtained figures for us showing the number of men treated out of hospital in the Ferozepore Cantonment, both before and after the change in the regulations. These figures tend to show that in that cantonment the change has not resulted in an increase in the proportion of out-patients. We were further informed that in malarious stations it would be impossible in the malarial season to refrain from treating a considerable proportion of cases out of hospital since hospital accommodation would not be sufficient to allow of all being admitted. It was further argued that a considerable proportion of the cases shown in the barrack returns prepared under the new regulations relate to patients being treated with prophylactic quinine after their discharge from hospital and that if these cases were included in the statistics the same patient would be shown twice over for the same attack of disease.

111. The considerations which tend to show that there has been a change in Lahore Cantonment in the direction indicated by Major James are to the following effect. The out-patient system having now been regularised it can be more readily used, and it might easily be used, to reduce the number of hospital admissions. In chart no. 2, the number of fever out-patients from 1904 onwards has been superimposed above the hospital admissions and shown by a dotted line. An inspection of the autumnal rise in the malaria rate will show at once that the proportion of out-patients to hospital patients in the malaria season is very high in Lahore Cantonment. The following fractions show the proportion in each year: the numerator indicating the maximum height of the column of barrack admissions and the denominator the maximum height of the column of hospital admissions:—

November 1904	.	.	.	.	.	.	.	.	.	$\frac{2}{11\frac{1}{2}}$
" 1905	.	.	.	.	.	.	.	.	.	$\frac{1}{2}$
October 1906	.	.	.	.	.	.	.	.	.	$\frac{3\frac{1}{2}}{6}$
" 1907	.	.	.	.	.	.	.	.	.	$\frac{1}{3}$
September 1908	.	.	.	.	.	.	.	.	.	$\frac{16}{15}$
November 1909	.	.	.	.	.	.	.	.	.	$\frac{10}{4\frac{1}{2}}$

The proportion of out-patients in most years is very high and in seasons in which malaria is prevalent the height of the malaria column is vitally affected. The figures for 1908 and 1909 deserve special notice. Taking the past five years together, 36.1 per cent. of all patients with malaria or simple continued fever were treated in barracks. These figures are higher than those shown in any other cantonment, and they compare, for example, with 2.8 per cent. in Amritsar and 6.6 per cent. in Peshawar. Again a comparison of chart no. 2 with the figures given by Lieutenant-Colonel Aldridge for Ferozepore shows that the proportion of out-patients is higher in Lahore than in the other cantonment. The mere fact therefore that there has not been an increase in the out-patient system at Ferozepore does not affect the question whether there has been any such increase in Lahore. The suggestion that in a malaria year the number of out-patients must be large as there would be no room for all cases in hospital would not appear greatly to affect existing conditions at Lahore. The only year of the series since 1904 to which the argument might apply is the year 1908. During September, the worst month of the year, from 60 to 100 beds stood vacant. We have compared day by day the number of vacant beds with the number of out-patients, and we find that the great bulk of the out-patients could have been admitted. Moreover, the figures for the British troops in Lahore Cantonment given in chart no. 1, do not indicate that a maximum limit to the number of fever cases admitted to hospital has been fixed by insufficient accommodation. Take for instance the maximum year 1879, in which Lieutenant-Colonel Rowan estimates that on an average every man was admitted to hospital seven times. Extra accommodation must clearly have been provided and if out-patients had existed in the same proportion as in 1908, we should arrive at the impossible result that on an average every man had about 14 attacks of fever in six months. Nor does the contention that a large proportion of the barrack treatment cases consists of men discharged from hospital and undergoing quinine treatment appear to apply to Lahore Cantonment. In the first place, the chart shows that the rise in the number of out-patients and hospital patients is in general synchronous. Next the figures and returns for 1908, the most important year of the series, show that as a matter of fact the bulk of the out-patients were new cases. Thus, in September 283 admissions for malaria are shown in the barrack return, but during the previous three months there had been in all only 39 admissions to hospital from malaria. The great majority of the September cases must, therefore, have been new infections. Moreover, reports attached to the Lahore barrack returns show that cases treated after discharge from hospital were not included in the barrack return lists. Thus, in the return for October 1908, it is stated by Lieutenant-Colonel Rowan, the Senior Medical Officer, that 20 to 30 men of the Gloucestershire Regiment had been attending daily but that as they were mostly recent discharges from hospital only one admission and eight average daily patients were shown in the return. And again in the return for December 1908, it is stated that a large number of men who were attending daily after having been discharged from hospital were excluded from the figures.

112. Unfortunately statistics relating to out-patients of the Lahore Station Hospital prior to 1904 are not available and it is not possible, therefore, to form any accurate estimate of the result in this cantonment of the regulations introduced in 1903. Having regard, however, to the considerations examined in the preceding paragraph, it appears to us probable that there has been an increased use of the out-patient system and, therefore, that if the hospital admission figures alone are considered the comparison with earlier years would not be accurate.

113. *Alleged effect on the statistics of retaining troops in the hills beyond the close of the malaria season.*—We append a statement showing the average strength of the British garrison of the cantonment in each of the months, July to December, for the years 1889 to 1908. The rise in October and the further rise in November, which are characteristic of the figures in this table indicate that the troops sent to the hills returned generally between the middle and end of October. Only three years during the whole period fail to show a rise in October and these three years exhibit a more or less marked fall in that month. The years are 1904, 1905 and 1908, *i.e.*, the first two years of the anti-malarial operations and the year of the last malaria epidemic. In 1904, the autumn garrison was extraordinarily low and was reduced to 270 in October

against an ordinary average of 600 to 800. In 1905, also, the October figure was only 490. In 1908, the figures are larger, but there is a marked fall in October, from 704 to 653 and a rise in November to 875. The explanation of these figures is that men from the hills did not return until towards the end of November. In 1908, 900 odd men arrived between the 22nd and 24th of that month. It is contended that the retention of a considerable portion of the British garrison in the hills during the latter part of October, and first half of November materially affects the annual rate of admissions for malaria. The admission rate is calculated on the average strength of the year and a reduction in the garrison during a portion of the malarial season might, therefore, have a large effect on the number of malaria cases and a comparatively small effect on the average strength for the year on which the malaria rate is calculated. It is difficult to make a precise estimate of the effect thus produced, but we are of opinion that in 1908, the late return of the troops did have an appreciable effect in diminishing the rate of malarial admissions in that year.

114. *General examination of the statistics.*—A comparison of the curve for the troops and the curve for the native population in chart no. 2 also shows such great irregularities in the former as to indicate the operation of important disturbing causes. One such cause was doubtless the growing perfection of quinine prophylaxis, but this explanation would not suffice to account for all the irregular effects that were produced. In 1904 and 1905, there was a marked decline in the curve for the troops during the malaria months of September and October, whilst the bazaar curve rose in a normal manner during the same period. The year 1906 was fairly normal. In 1907, the figure for the troops remained steady and very low during October in spite of a heavy rise in the bazaar figures during both September and October. But the figure for 1908 is the least explicable. Taking together the figures for hospital admissions and out-patients there was a very sharp rise in September followed by an equally sharp fall in October. It would appear extremely difficult to account for this apparent fall of malaria among the British troops which occurred in a season of violent epidemic in which the breeding of *anopheles* was uncontrollable, and in a month in which adult malaria bearing mosquitoes were abundant, which showed abnormally high spleen rates and endemic indices, and in which malaria among the native population, as indicated both by admissions to hospital and by the vital statistics, still remained at an exceptionally high level. There would appear to be only three alternative explanations:—

- (i) that troops were moved from infection,
- (ii) that the figures do not represent the actual degree of malaria, or
- (iii) that quinine prophylactics acted so powerfully as to arrest the epidemic in mid course.

We have already observed that the October garrison declined from 704 to 653, and it is further to be remarked that 79 malaria and debility cases were sent away to the hills in October. These circumstances would not however, be sufficient to account for the phenomenon. An inspection of the monthly returns of in-patients and out-patients does not render the figures any more intelligible. It is stated in the hospital return for October 1908, that a very large number of the admissions from malaria during this month were relapses, a fact which merely accentuates the extraordinary fall in the curve. The following statements show hospital admissions and barrack treatments for the Royal Artillery and the Gloucestershire regiment for each of the months August to November. The figures are for all diseases, but the bulk of the admissions were fever cases, and the fever cases dominated the fluctuations. The figures include the Fort.

August.			September.			October.			November.		
<i>Royal Artillery.</i>											
H.*	B.*	T.*	H.	B.	T.	H.	B.	T.	H.	B.	T.
57	58	115	116	163	279	74	39	113	57	69	126

*H.=Hospital admissions.

B.=Cases treated in barracks.

T.=Total.

Gloucestershire Regiment.

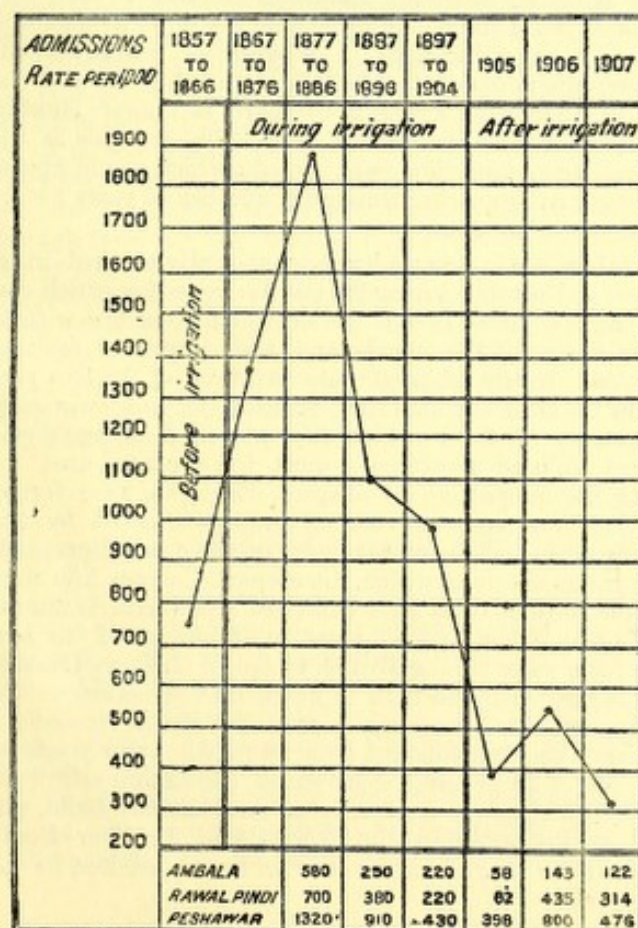
H.	B.	T.	H.	B.	T.	H.	B.	T.	H.	B.	T.
56	23	79	103	144	247	165	1	166	69	37	106

The Royal Artillery returns show a large fall in hospital cases and a very much larger one in barrack cases at the time when one would expect to see both figures on the increase. The Gloucestershire figures are even more remarkable. The hospital admissions rise during October from 103 to 165, whilst the barrack cases fall from 144 to 1. November shows 37 barrack cases but all but 3 of these are from the Fort. It is difficult to make deductions from figures which are so irregular.

115. It is clearly not possible to make any arithmetical calculation for changes in system or other causes affecting the validity of recent statistics but it appears to us that the cumulative effect of the evidence discussed in the present section indicates that considerable caution must be exercised in comparing figures for the years 1904 to 1909 with previous periods.

General examination of the statistics for British troops.

116. Some medical officers who have dealt with the question of malaria in Lahore Cantonment have found in the statistics of fever admissions among British troops reasons for attributing the prevalence of malaria in the cantonment to the canal irrigation which was introduced about the year 1867, and for holding that the abolition of such irrigation in 1904 and the other anti-larval operations subsequently carried out have converted the station from a highly malarious to a healthy place. Lieutenant-Colonel Rowan elaborates this view in an article published in the *Journal of the Royal Army Medical Corps* of September 1908, and he seeks to establish the position by means of the chart which is reproduced below:—



Colonel Hamilton in a note, dated March 1904, gives the admission rates for British troops for the years 1859-1879, and deduces from the fact that there were six years of low malarial incidence between 1859-1866, and only one such year in the period 1867-1879, the conclusion that the opening of canal irrigation resulted in a great increase of malaria. In a discussion before the Bombay Medical Congress the same officer compares the high figures for 1876-1879, with the greatly lower figures for 1904-1907, and argues that the abolition of the canals and other measures have greatly reduced the malarial incidence.

117. We must now examine these contentions and the general course of malarial prevalence among the British troops in the cantonment with the aid of charts 1 and 2 and table no. 2 appended to this report. This table gives the quinquennial fever admission rates per mille of Lahore Cantonment and of other malarious stations of the Punjab since 1864, as far as the data are available.

The canal was opened in 1867. 1868 was a year of low rainfall and showed a decline in the malarial incidence. In 1869 the rainfall was higher and the fever curve shows a corresponding rise. 1870 and 1871 were both years of low rainfall and the fever curve shows a very great drop falling to a point lower than was reached in any other year up to 1902. It would thus appear that the opening of the canal had no immediate effect in raising the malarial rate. It is true that the following decade shows a very heavy rise; it included the high rainfall period 1874-1879 with the year 1874 which shows the heaviest rain of any year in the chart. Malaria was extremely rife and the degree of its virulence suggests that general sanitary conditions must have been most unfavourable. The rise and the high incidence were not confined to Lahore Cantonment. They were much more marked in Amritsar, where there was no canal irrigation, and they are shared by other malarious stations of the Punjab. It cannot, therefore, be deduced that the high malarial rate in Lahore Cantonment was the result of opening the canal, although it appears to us to be quite possible that this may have been a contributing cause. The quinquennial figures show that after 1879, the fever incidence suffered a steady and marked fall, a fall which, subject to seasonal fluctuations, has extended through a long series of years up to the present time. This again was not confined to Lahore Cantonment but is common also to Amritsar and other malarious stations to the north of India. In Ferozepore and Delhi the period of decline began at a somewhat later date (*vide* Table 2). It coincides with a progressive improvement in general sanitary and hygienic measures to which it is probably in the main due. It, therefore, appears to us to be wrong to compare, as Colonel Hamilton does, years since 1904 with distant periods such as 1876-1879, for this is to attribute to operations extending a short time back a credit which would appear to be due to altogether different causes acting through a number of years not only at Lahore but also in other cantonments.

118. The fall in the fever rate has been specially marked in several of the stations included in the table during the last five years for which complete figures are available, namely, 1904-1908, a period which coincides with the quinquennium since the closing of the canals and the improved drainage of Lahore Cantonment. As already pointed out, in three of the five years the rainfall was much below the normal which was exceeded in one year only. The more thorough treatment of fever which has prevailed of recent years (involving more prolonged quinine treatment) must have contributed to the decline by diminishing the proportion of relapses. Relapses were formerly extremely frequent and their diminution of recent years is a marked feature in military hospital administration. The improvement in the general prophylactic administration of quinine to the men which, Lieutenant-Colonel Aldridge informs us, is common to these stations must have exercised a powerful influence in the same direction. We may examine the figures in table no. 2 to ascertain if the decline in the fever rates among British troops in Lahore Cantonment in the last five years is greater or less than in neighbouring malarious stations of the Punjab. It appears that an equal reduction has taken place at both Lahore Cantonment and Amritsar (distant some 25 miles), namely one of 48 per cent. whilst a reduction of 39 per cent. occurred at the station of Ferozepore (distant some 40 miles), one of 18 per cent. only at more distant Delhi, and an increase of 77 per cent. at Peshawar in the North-West Frontier Province. In the above comparison the bare admission rate for fevers is taken for Lahore Canton-

ment. For the reasons given in the preceding section we consider that this is unduly favourable to that station and that actually Lahore compares less favourably with the other cantonments than would appear from the figures. To take for instance one disturbing cause. If in the various stations we include both out and in-patients (the best criterion of the actual prevalence of malaria) then the reduction in Lahore Cantonment will amount to 21 per cent. as compared with 35 per cent. at Amritsar and 21 per cent. at Ferozepore. We find, therefore no proof that canal irrigation was the main cause of the high malarial incidence which prevailed in Lahore Cantonment in years gone by, nor that any improvement that may have taken place in malarial incidence among the British troops in recent years has been materially aided by closing the canals or by the anti-larval campaign in the cantonment.

119. One further point requires notice in this section. Detachments of troops from Lahore Cantonment are posted at Fort Lahore in the city. This place is unhealthy and the exposure of a small part of the garrison to infection in it during the malarial season must tend to raise the incidence of fever among the troops.

Incidence of malaria among Native Troops.

120. It has already been explained that the incidence of malaria among native troops is less variable than among British troops and that it is more likely to be affected by conditions outside the station. Again, the out-patient system prevails largely in the native army and the proportion of cases treated without admission to hospital varies widely according to the system of the medical officer in charge. It follows from these considerations that the malaria statistics for native troops do not afford a reliable guide to the actual prevalence of the disease. A brief examination of the figures for 1908 will make this point clear. The Native Infantry regiments of the garrison in this year were the 32nd Pioneers and the 38th Dogras. In the bad malarial month of September the 32nd Pioneers showed only 15 admissions for malaria. The disease was nevertheless prevalent among them and large numbers were treated out of hospital and not shown in the statistics. Infection became so rife that the men were moved into camp. Immediately afterwards the regiment was ordered to Simla. Eighty-eight sick men (the great majority malaria cases) had to be left behind, 75 men suffering from fever fell out during the march and were sent on by train, a few days after arrival 90 malaria patients were in hospital, and one quarter of the remaining 372 were found to have parasites in the blood. From the 8th to the 31st October the recorded admissions from malaria amounted to 174. Similarly although the 38th Dogras show only 28 malaria admissions in September and 34 in October the officer commanding the regiment informed us that his men did in fact suffer badly during these months. It is clear therefore that the published statistics afford so little indication of the facts that it is not possible to draw any deduction from the comparatively low figures shown by the curve during the period from 1900 onwards, nor useful to make any detailed comparison between the apparent decline in Lahore and that which has taken place in other Cantonments.

Incidence of malaria among troops in October 1909.

121. It is well known that the spleen rate in children is a far more important test of malaria than the frequency of enlargement of this organ in adults. When in addition the adults are in a position to be actively treated immediately they are attacked by fever the chances of enlargement of the spleen resulting from repeated attacks of malaria is still further reduced. It is clear, then, that even a very low spleen rate among troops under skilled medical care will not prove that they are practically free from malaria. On the other hand, an almost entire absence of enlarged spleens is evidence that there is no very severe prevalence of malaria of such a degree as to incapacitate large numbers of the men for lengthy periods. The following data of spleen examinations which we

made among the troops during our visit are of interest from this point of view :—

	Number of men examined.	Number with enlarged spleen.
British Infantry, 10 months in Mian Mir.	92	0
Royal Artillery, 2 years in Mian Mir .	57	2
38th Dogras, 4 years in Mian Mir .	102	1

Men who had been away during the malarial season were excluded.

As far, then, as this test goes, chronic malarial disease is not prevalent among the troops at Lahore Cantonment during the present season.

122. Towards the end of November 1901, Drs. Stephens and Christophers took the endemic index of a number of men of the Royal Artillery with the following result :—

	Number of men examined.	Percentage of infection.
54th Battery	52	17.3
51st „	34	29.4

In view of the extremely low spleen rate, and as the troops were all taking quinine prophylactically, we did not consider it desirable to devote any of the time at our disposal to working out endemic indices. We should not have expected to find so high a percentage of infection as that given in the table above.

123. The number of recorded fever cases among the British troops during October was not very high, but apart from the year 1908 it exceeded the figure in any year since 1901. The rate was rising at the time of our visit. A sharp outbreak had taken place among the men of the Royal Artillery, and other regiments were more or less affected.

PART VI.—SUMMARY OF CONCLUSIONS.

124. Anti-malarial operations in Lahore Cantonment were carried out under conditions which were in many respects favourable. The cantonment is situated in a comparatively high and not very malarious tract; the rainfall is light; there is no large native town in the immediate vicinity; the general sanitary arrangements are far better than ordinarily obtain in India; the thorough organization and the strict authority exercised over the inhabitants, the large number of medical officers available for purposes of supervision, and the unlimited supply of labour afforded by the troops and followers, could not be secured outside a cantonment. On the other hand, the station and surrounding country are extremely flat; the subsoil becomes impervious when wetted; the rainfall is concentrated into the autumn months, and its distribution in some years is favourable to the breeding of *anopheles* mosquitoes; the station is very large compared with the number of its inhabitants and its drainage system involves the maintenance of an enormous length of earth drains; a whole series of deep excavations and other depressions lie immediately around the cantonment; and native bazaars, lines, and servants' quarters with infected children are interspersed throughout the station with bodies of troops, including non-immune European troops.

125. The special facilities offered by the military organization and strength of the cantonment were utilised with great care and energy with the result that an immense amount has been done to abolish the breeding places of *anopheles* mosquitoes within the cantonment and to deal with those remaining. The closing of the irrigation channels, the reform of the drainage, and the filling in of depressions in the years 1904—1906 must alone have had the effect of enormously diminishing the opportunities for breeding. It would not be easy to find an example of equally thorough and painstaking operations.

Nevertheless even within the cantonment (and especially in its southern portion) breeding places have not been altogether abolished, nor have minor anti-larval operations in all parts of the cantonment and in all seasons been adequate completely to suppress breeding where the opportunities for it still exist.

126. The effect of the measures taken on the malarial conditions of the cantonment appears to us to be negative. Adult *anopheles* are as abundant as ever and malaria is no less prevalent than before among the native population. Making allowance for causes affecting statistics there would appear to be some, but not perhaps any great, diminution of malaria among the British troops. Having regard (i) to similar reductions in other cantonments, (ii) to the degree of perfection with which quinine prophylaxis is now carried out, and (iii) to the fact that any improvement that there may be would not appear to be shared by the native population, among whom quinine prophylaxis is imperfect or non-existent, we do not think that there is any proof that the anti-larval operations have contributed materially to the diminution. The figures for native troops are somewhat more favourable, but the statistics afford so little indication of the prevalence of the disease that it would be unsafe to draw any conclusion from them.

127. The failure of the elaborate measures carried out for a number of years in Lahore Cantonment illustrates the great difficulties of destroying mosquitoes in such a place, and emphasises the need for further research and experiment. In the present state of our knowledge it would be hazardous to conjecture what were the true reasons of the Lahore failure. We would merely draw attention to two points. The circumstance that a very great, but not altogether perfect, reduction of breeding places does not appear to have been accompanied by an improvement of malarial conditions may possibly indicate that, where other conditions favour the existence of malaria, partial abolition is of no avail until a point is reached nearer total abolition than has sometimes been anticipated. Or, secondly, the existence of an enormous collection of

breeding places situated all around the station, but at some distance from it, may enable mosquitoes breeding in those places to frequent the lines and the bazaars for their food in such numbers as to neutralise the effect of diminished breeding within the inhabited area. If this be the case, it must unfortunately follow that protective measures require to be extended to a distance considerably greater than has hitherto been considered necessary.

128. Finally it must be admitted that the amount of organization, supervision, labour and expenditure devoted to the task has been greater than would be possible in any ordinary Indian town or collection of hamlets of similar size and population. The operations cannot, therefore, be taken as typical of what might ordinarily be done in urban India, and still less in rural India.

PART VII.—APPLICABILITY TO INDIA OF MEASURES ADOPTED IN OTHER PARTS OF THE WORLD.

Summary of measures.

129. In carrying out the third instruction conveyed to us it will be convenient in the first place to note briefly the character and result of some of the main operations that have been carried out in other countries. We have selected for this purpose seven localities in which operations have been conducted on a considerable scale and with reference to which more or less definite information is available to us. The places selected are :—

- (i) Ismailia,
- (ii) Klang and Port Swettenham in the Federated Malay State of Selangor,
- (iii) Panama,
- (iv) Lagos, the capital of Southern Nigeria,
- (v) Bathurst, the principal town of Gambia,
- (vi) Hong Kong, and
- (vii) the Island of Mauritius.

The sources from which the information contained in the following sketch is derived are detailed in a list appended.

130. *Ismailia*, a town of the Suez Canal Company, stands in the desert on the shore of a brackish lake : a fresh water canal supplies it with water. The town has about 7,000 inhabitants, is well built, and is in a good sanitary condition. Malaria was formerly rife but examination showed that the breeding places of *anopheles* were confined to a few shallow and insignificant pools, and to the drains of some patches of cultivation. Operations were carried out in 1902-03 on the advice of Professor Ross. In the first place, as a temporary measure, petrolage and "mosquito brigade" operations were undertaken, and then, for permanent protection, swamps were filled up and drains improved and flushed. The task was so easy that before the permanent operations were undertaken a mosquito gang of 4 men was able to extirpate the mosquitoes. According to a report published by the Canal Company in 1906, the initial expenditure amounted to £2,000 and the estimated annual expenditure for maintenance and minor operations, including the destruction of *culex* mosquitoes, to £1,464. At the same time that anti-larval operations were carried out quinine prophylaxis was extensively used. Dr. Bentley stated at the Bombay Medical Congress that for several years expenditure on quinine alone amounted to two francs per head of the population. The published figures show strikingly good results.

131. *Klang and Port Swettenham* are both small places. Klang used to be the port of the district, and Port Swettenham was established five miles further down the river in 1901 and was connected with Klang by railway. Klang had a population of 3,576 in 1901, and in 1903 the population of the two places was about 4,000. The surrounding Klang district is 380 square miles in extent. It is a seat of rubber cultivation and contains some 14,000 scattered inhabitants. Klang and Port Swettenham are situated on low marshy land lying between the river and a semi-circle of low hills. The rainfall averages about 100 inches a year and the tract is marshy. In 1901 a severe epidemic, probably connected with the aggregation of labour for building Port Swettenham and making the new line, visited both places. Anti-larval operations began in the latter months of 1901. At Klang, undergrowth was cleared, swamps filled and a contour drain cut to intercept the inflow from the surrounding hills. The cost of these undertakings amounted up to the end of 1905 to £3,100. At Port Swettenham forests and mangrove swamps were filled, an elaborate system of drainage constructed, and the ground levelled. The total cost up to the end of 1905 was £7,000. For the two places with their 4,000 inhabitants the cost up to 1905

was thus £10,100. The total estimate for annual upkeep is £410. Professor Ross gives the cost per head of population at £1 4s. Owing to the heavy rainfall, to the large area of marsh, and to the luxuriance of the tropical vegetation it was recognized that "mosquito brigade" methods and petrolage were out of the question and that the problem was one of engineering. It was solved by the execution of engineering projects on a considerable scale. The epidemic declined at the usual season and before the next malarial months the works had been completed and the labour force dispersed. In 1902 the cases of malarial fever at both Klang and Port Swettenham showed a great decrease, an improvement which continued in later years and which was not shared by the surrounding district. Dr. Watson, the District Surgeon of Klang, remarked in 1905 that the improvement was no matter for wonder "for, I think, it is no exaggeration to say that 99 per cent. of the breeding places of *anopheles* of all species have been abolished and ground water has within the two towns been lowered considerably everywhere below the surface of the soil, and it is no new discovery that drainage abolishes malaria." Since these operations were carried out the port has grown and they no longer suffice to protect it. A malaria commission was appointed in August 1908 to devise further engineering projects.

In a report published in July 1906 it was stated that it would be almost impossible to protect the scattered population of the surrounding district from malaria by drainage and filling in swamps, and that regular administration of quinine and protection from mosquitoes was being effected on most of the estates. Similarly, it is stated in a medical report for Perak for the same year that with the heavy rainfall there existing the banishment of puddles and other suitable places for the breeding of mosquitoes is practically impossible and that the only way of keeping malaria in check is with quinine, mosquito nets and wire gauze.

132. *Panama* is a great example of anti-larval operations carried out on a heroic scale. The problem to be solved was a very special one. A large white and black labour force was collected, for an enormous engineering work in a malarial tract, and it had to be protected at all costs. The country through which the new canal runs is hilly and the breeding areas that gave the greatest trouble were small streams, swamps, low-lying marshy lands and seeps on the sides and at the bases of hills, resulting from water following small areas of impervious strata. It was found that the *anopheles* bred in clean water where grass and algae grow. Colonel Gorgas, the Chief Sanitary Officer of the canal zone, stated in 1907 that the *anopheles* is not much of a traveller and that in general it does not fly further than one or two hundred yards. Attention was, therefore, concentrated on breeding places within two hundred yards of the camps and villages of the labourers along the line of the canal. No attempt was made to deal with swamps, etc., which were at a greater distance than this from habitations. It is unfortunate that our later experience in India does not accord with these observations on the Panama *anopheles*. The total force of people to be protected numbered about 40,000, including about 6,000 Americans.

Operations began at the end of 1905 or the beginning of 1906. At first the general scheme included the cutting of all vegetation growing on soft or boggy places, the confinement of all water in small surface ditches, the copious use of crude oil, the screening of buildings and the cutting of all vegetation for a distance of six or seven hundred feet from the houses. The maintenance of the open drain system, however, was so expensive and unsatisfactory that the authorities found it necessary to use more permanent methods involving less annual expenditure on upkeep. They recognised that while there was water within reach of mosquitoes there would be larvæ, as experience had shown that with the greatest care in the use of larvicides and with the best inspection larvæ would escape destruction. An expensive and elaborate system of sub-soil drainage with tiles and pipes was then undertaken. The average cost of the tile drainage amounted to about 35 cents per foot, of which about 1s. 3d. was the first cost of the tile. The annual cost of maintenance of the previous open ditches amounted to 25 cents per foot. The following figures give some idea of the extraordinary scale of the operations. In 1906, at Colon

alone, 330,000 square feet of water surface were oiled; 200,000 lineal feet of new ditches were cut, of which 20,000 feet were stoned or cemented; 2,000,000 lineal feet of old ditches were cleared, graded, stoned or lined; and 21,000,000 square yards of bush and grass were cleared. Colonel Macpherson, C.M.G., R.A.M.C., informed Professor Ross after a visit to Panama that the total cost of sanitary and medical measures amounted to 2,000,000 dollars per annum, or about one-tenth of the total annual expenditure on the canal works. Quinine prophylaxis was carried out on a great scale along with the other operations, and it is recorded that in September 1905, 675,000 grains of quinine were dispensed. These vast operations are said to have had an excellent effect and the health of the labour force has been well maintained.

133. *Lagos* is situated on the southern portion of a small island surrounded by lagoons which also make deep indentations into its perimeter, and especially on its northern face. The island consists of a strip of low-lying porous sand, the highest portion of which is only 20 feet above the sea level, whence it quickly slopes down to the surrounding lagoons. Even the heaviest rain is rapidly absorbed in the central elevated portion on which the town is built, so that in a few days after continuous rain all surface pools disappear. Around the several lagoons there lies a low strip, rising to five feet above sea level, which abounds in pools and these form the principal breeding places of *anopheles* mosquitoes. The total population of the settlement is about 35,000. The European quarter of the town lies on the south of the island and the native quarter is mainly to the north. A small swamp on the southern edge was formerly the main breeding ground for *anopheles* near the European quarter. It is much smaller than the large lagoons on the north and the marshy tract on the east of the island. Doctors Stephens and Christophers reported to the Royal Society in 1900 that the only means likely to reduce malaria would be to raise the low-lying strips and areas with sand up to the five foot level. They doubted whether even this costly measure would be successful. Operations were, however, undertaken, and much has been done to improve the condition of the southern portion of the island, i.e., the European quarter. The low swamp referred to above has been filled in and since 1900 a sum of £43,163 has been spent in swamp reclamation. The work has been mainly carried out by convict labour. In 1907 a pontoon pump dredger was purchased for £3,300. In a report, dated 12th June 1907, His Excellency the Governor estimated that at least another £40,000 would be required to complete the work of reclamation. This would seem to be a very low estimate as the most difficult parts have still to be treated. The execution of the measure must have been greatly facilitated by the abundance of sand readily available for reclamation work. In addition to the above, considerable sums have been spent on drainage and general sanitation. The total public works expenditure on anti-malarial and sanitary measures from 1900 to 1906 amounted to £81,702. Petrolage and other minor measures have simultaneously been utilised. Quinine prophylaxis was strongly recommended and the medicine was supplied free to all Government servants: over a million grains were distributed in 1906. Medical expenditure from 1901 to 1906 amounted to £1,418, of which £1,322 was for quinine and the bulk of the remainder for kerosine, creosote and larvicide. The Principal Medical Officer says that there has been a great change for the better in the health of Europeans. No data are given with regard to the native population. It is noticeable that black-water fever is at least as common among Europeans as before the operations were undertaken. In India the prevalence of black-water fever has been found to denote the existence of hyper-endemic malaria among the surrounding native population. The results up to date do not appear to be conclusive, and it is noteworthy that the Principal Medical Officer states that "mosquito proof houses are perhaps the most potent aid against malaria in this colony in view of the great difficulty, if not impossibility, of entirely exterminating mosquitoes and the danger from the malaria poison existing in the native population. * * * * If malaria infection is to be avoided it is imperative that at least the rooms used in the evening hours should be mosquito proof."

134. *Bathurst* affords an interesting example of the use of "mosquito brigade" measures. These were initiated by the late Dr. Dutton who was sent

out by the Liverpool School of Tropical Medicine. In accordance with his advice measures have been carried out from 1901 onwards on the following lines :—

- (i) Ten labourers were employed to fill up stagnant hollows, clean water courses, etc.
- (ii) The Inspector of Nuisances was directed to make a daily inspection of water receptacles, etc., in private premises.
- (iii) Useless articles likely to serve as breeding places were collected and buried.
- (iv) Wells were covered in.
- (v) Petrolage was utilised during the rainy season.
- (vi) Pamphlets were published to instruct the residents (the instructions included references to mosquito netting and quinine prophylaxis).
- (vii) Measures were taken to prevent stagnation of water in boats lying on the shore.

Tables are appended to a report forwarded in 1906 relating (1) to the total population, and (2) to the European residents. The figures extend from 1900 to 1905 both inclusive. The table for Europeans shows a marked improvement in their health, that relating to the general population appears to us to be inconclusive.

The following quotation is of special interest :—“ The town of Bathurst, “ partially surrounded and skirted by creeks and swamps as it is, is most unfortunately situated, so far as the total annihilation of mosquitoes is concerned, “ otherwise, with its long dry season, it would have been possible to reduce the “ mosquito pest to almost zero, but as it is, almost every wind that blows “ towards the town brings its swarms of that troublesome insect, and all we can “ hope for the present is the abolition of their artificial breeding grounds in and “ around our dwellings by the constant application of the few simple sanitary “ precautions which are now in full operation, and in which we are endeavouring “ to enlist the energy and intelligence of the public in general.” It is not in accord with Indian experience that minor measures carried out in such unfavourable circumstances would have a very marked effect on the incidence of malaria.

135. *Hong Kong* city extends for nearly 5 miles along the north coast of a small island. The town is built on a hill sloping down to the water, some of the terraces and houses being situated 500 feet above the sea level. The population was 378,000 in 1905. The rainfall is 70 to 80 inches. Anti-larval operations have been carried out from 1901 onwards, and especially the training of water courses (nullahs) within and near the city. A list of measures is given in the medical report for 1906 as follows :—fumigation of the basements of European houses, training of nullahs, filling in of pools, sub-soil drainage of swampy ground, and resumption here and there of paddy fields which approached too close to European habitations. The estimated cost of these operations up to the end of 1906 amounted only to £6,500. Statistics given by Professor Ross for 1896-1905 show a considerable reduction of malaria. It is to be noted that the death rate from this disease during the earlier years amounted only to from 2 to 3 per mille. In Hong Kong favourable results appear to have been obtained at a comparatively small cost. The facility for drainage in a town built on a slope to the sea appears to have been the main cause determining this satisfactory issue.

136. *The Island of Mauritius* has a surface of 705 square miles ; its population in 1901 was 378,000 ; and its revenue in 1906-07, R1,03,30,000. In a report, dated 29th November 1906, it is stated that anti-malarial operations were carried out by a committee as far as funds would permit according to a scheme drawn up by it in 1903. The three principal measures adopted were :—

- (i) gauze wire netting in houses,
- (ii) prophylactic administration of quinine, and
- (iii) execution or general works of sanitation.

Under the third head were included draining of marshes, canalization of gutters, clearing of rivers and suppression of stagnant pools. The third measure is described as by far the most important, and it is said that not an inconsiderable amount of work has been done in some districts. It is further stated that appreciable results were obtained in some parts as far as the health of the riparian population is concerned. These results have not since been fully maintained owing to want of funds. The question of imposing local financial responsibility for anti-malarial operations has been considered. In 1907-08 Professor Ross visited the island, made a thorough study of its conditions, and submitted the following main proposals for its improvement:—

- (i) A periodical spleen census of children in schools and on estates.
- (ii) Treatment of children with enlarged spleens in schools and on estates and a certain amount of quinine distribution.
- (iii) Occasional house protection.
- (iv) Mosquito reduction where advisable (a) by minor works, and (b) by major works.
- (v) A suitable organization and an annual malaria report.

Under the heading of minor mosquito destruction works the following details were included:—

- (a) Keeping clear of weeds and other obstructions street gutters and surface drains.
- (b) Clearing of weeds, levelling, and discharging road side ditches and channels.
- (c) Keeping main water channels clear of weeds and pools.
- (d) Removing grass, weeds, and pools from the margin of ponds and streams, and rough canalisation of the latter.
- (e) Discharging, filling, or deepening surface pools where practicable.
- (f) Discharging leakage from standpipes.
- (g) Filling or oiling certain pits.
- (h) Concreting hollows in rocks and holes in trees.
- (i) Cutting undergrowth.
- (j) Dealing with house waters and other useful work in spare time, especially in the cooler and drier non-malarious season.

To carry out these measures it was estimated that 109 gangs of 3 men each, and costing R50 each, would be required as well as 10 *moustiquiers* to seek out breeding places and keep a surveillance over the gangs. Professor Ross recommended that minor works should be undertaken before major works, and that the latter should not be carried out until it became apparent that the former were inadequate. A scheme of major works for the whole island was drawn out comprising mainly the drainage of marshes and the clearing of streams. The estimated initial cost for the whole island was R6,30,000 and that for recurring expenditure for maintenance, R42,300. We have no information as to whether operations have been commenced on this large scale. Judging from the financial difficulties previously experienced it would seem difficult for the island to afford so heavy an expenditure.

137. Some general deductions may be made from the above brief analysis:—

- (i) Where conditions are favourable "mosquito brigade" operations alone (Ismailia) or combined with drainage (Hong Kong) can be carried out so as to extirpate or greatly reduce the prevalence of mosquitoes at a small cost.
- (ii) Where conditions are unfavourable "mosquito brigade" and other minor operations are futile and nothing avails short of a thorough system of sub-soil drainage (Klang and Panama) or the reclamation of swamps (Lagos).
- (iii) These latter operations are a reversion to older methods and are apt to be laborious and costly.

General Indian Conditions Affecting Anti-Malarial Operations.

138. The following table shows the ratio of deaths from fevers in each thousand of the population in the several major provinces of India:—

United Provinces	27.6
Bengal	22.4
Eastern Bengal and Assam	21.6
Punjab	20.3
Central Provinces	18.9
Bombay	14.9
Lower Burma	9.8
Madras	8.4

In the provinces in which malaria is most rife it is essentially a disease of the plains, and neither natural nor social conditions in the river-valleys, deltas and sub-montane tracts in which the disease chiefly persists are such as to favour measures for mosquito destruction. There is a heavy rainfall, much low-lying and marshy land, and luxuriant vegetation. In the north-west conditions are somewhat different, the rainfall is not so heavy and the vegetation is less rank, but even in the Punjab plains and riverine tracts a heavy monsoon rainfall quickly produces a water-logged condition which results in severe epidemic outbreaks of malaria. Apart from such natural causes the drainage of towns and countryside is defective; the dwellings of the poorer classes are generally insanitary and ill-ventilated; other sanitary conditions are defective; the ignorant mass of the people are often indifferent or hostile to sanitary improvement; and, especially, where large bodies of labour congregate, physiological conditions favour the spread of the disease. An additional difficulty of great importance is the enormous number of pits and excavations which abound in every town and village site. The country is too flat for earth to be obtained except by digging holes; such digging is carried out without reference to health conditions, and the stagnant pools which result favour the convenience and meet with the approval of townsfolk and villagers.

139. The financial resources available to carry out anti-malarial operations in these difficult conditions are strictly limited. The superior inspecting staff of the Sanitary Department in the Indian provinces is maintained by the local Government, but the cost of local sanitary measures is primarily a charge on the municipalities and district boards who are entrusted with the conduct of local self-Government in India. There are 750 municipalities with an aggregate population of 16 millions which includes only 7 per cent. of the total population of British India. Only 176 of these towns have a population exceeding 20,000. Excluding the four great ports of Calcutta, Bombay, Madras and Rangoon, the average income of a municipality amounts to Rs. 45,000. Excluding the same four cities, the average income per head of municipal population varies in the principal provinces from Rs. 1.2 in Madras to Rs. 1.9 in Bombay. Outside municipal limits 194 district boards exercise jurisdiction over nearly 205 million people. The total income of these boards amounted in 1906-07 to 450 lakhs (over half of which is hypothecated for communications and education), the income per head thus averaging three and a half annas. These figures make it clear that the funds available for new sanitary expenditure are not very considerable, and although local resources may from time to time be supplemented for special purposes by subventions from imperial or provincial revenues, the amount that can be spent in this way is not susceptible of expansion on a great scale.

Anti-Malarial Experiments carried out in India.

140. The measures carried out in *Lahore Cantonment* which have been described in this report are wider and more thorough than any others hitherto attempted in India. As we have seen their result is not very promising. An exceptionally strong organization and a very considerable expenditure of labour and money appear to have failed to reduce malaria in a place with an area of 8 square miles and a population of 16,000 inhabitants.

141. Outside Lahore Cantonment the experiments in *Bengal* are the most important. In that province test operations have been carried out in several

places during the past five years under the advice of the Sanitary Commissioner and under the control of Deputy Sanitary Commissioners and Civil Surgeons.

At Berhampur (headquarters of the Murshidabad district, and situated about one hundred miles to the north of Calcutta) which was selected as a fair, but not easy, place to deal with, anti-larval operations were carried on in 1905 and 1906. In the former year the southern part of the town, including the old cantonment, was dealt with, the only unfavourable ground included being a waterlogged and jungly area to the south-east. The usual "mosquito brigade" methods were adopted. Difficulties arose from rice fields in some parts and during the rains even hoof marks on the cantonment maidan were swarming with *anopheles*. *Anopheles* are reported to have been considerably reduced, but no effect on the prevalence of malaria in the treated as opposed to the untreated areas could be ascertained. In the following year the area was extended, but difficulties were encountered due to a heavier rainfall, while the river by the side of the town changed its bed, leaving several miles of flooded land some hundred yards in width which it was impossible to control. At the end of this year's operations the Deputy Sanitary Commissioner reported that the task was hopeless as the natural conditions were too unfavourable.

142. Jagdispur, in the Shahabad district, was selected as a fairly severe test of the efficiency of anti-malarial measures. There were few tanks or ditches, but a considerable length of village channels leading from irrigation canals. The municipality was compact, and the energetic European chairman threw himself into the work with ardour. In addition to the usual measures of filling hollows and kerosining pools the irrigation channels were cleaned and their sides plastered with mud, and tarred, but this plan failed as the lining was rapidly washed away. At the end of the first season the fever cases treated in the dispensary had considerably increased, and there was no evidence of any benefit from the measures. The sanitary officer thought that the rice fields with fresh water and little current were the principal breeding ground of *anopheles*. The operations were continued on the same lines for a second year, when it was recorded that comparatively few areas of water, tanks, and ditches remained, and that these were easily cleaned and regularly oiled. Cleaning and levelling of the drains was left to the municipality, but could not be thoroughly done for want of funds, as the place is a poor one. The year was healthy both in the town and in the surrounding district, but this was not considered to be "in any way associated with the operations carried out" but to be due to favourable climatic conditions, the neighbouring rural area showing a greater decrease than the theatre of the operations. The sanitary officer was now convinced that rice fields were the main source of *anopheles* in Jagdispur, and that it was useless to continue the operations until wet cultivation could be abolished in the vicinity of the town. As this was not found to be feasible the anti-malarial measures were abandoned.

143. At Ranaghat, in the Nadia district on the Eastern Bengal Railway, anti-malarial operations were carried out continuously from 1906 to early in 1909. It is a compact town of 8,000 inhabitants with fair drainage, not many hollows, and presenting no insuperable difficulty, such as a silted up river. During the three years many hollows were filled up at a cost of Rs. 12,466, but Rs. 41,906 more was required to complete this part of the operations. Petrolage was also carried out, and some improvements were made in the drains. At the end of three years' work no improvement in health could be detected, and operations were stayed for the consideration of a more extensive drainage scheme.

144. North Barrackpur municipality was selected for further anti-malarial experiments in 1907 because it is near Calcutta and the operations might thus serve as an object lesson to Bengali gentlemen. The operations are still being continued on the same lines as elsewhere in the province, but on account of the scattered population and dense vegetation in portions of the area no good results have as yet been recorded.

145. These operations serve only to show that it is difficult to effect a reduction in malaria by anti-larval operations in a low-lying tract of country with a high rainfall and rank vegetation.

146. In *Eastern Bengal* experiments are being tried at Jalpaiguri and Dinajpur, two malarious towns situated in the north-west of the province. In Jalpaiguri the experiment is confined to the *Naya Basti*, a small native quarter adjoining the civil station, and inhabited largely by servants of the European residents. Operations began systematically in the spring of 1909. They comprise mainly (i) quinine distribution, and (ii) filling in of depressions, improvement of drains and other "mosquito brigade" operations. Quinine is distributed by a Hospital Assistant but the distribution and its acceptance have been by no means perfect. The conditions for anti-larval operations are not easy. There is much low-lying land and many pools and depressions. In the rains water collects in all these places and the drains become choked with vegetation. Some of these depressions have been filled with sand brought from the Teesta river. Petrolage has also been undertaken. The expenditure for 1909-10 was estimated at Rs.5,000. The officiating Sanitary Commissioner of the province visited the locality in August last, and it is clear from his report that the operations have not been conducted on a scale and with a thoroughness likely to command success. In the town of Dinajpur work has been carried out on similar lines, and with similar imperfections.

147. An interesting report on anti-malarial measures in the *Madras Presidency* up to September 1905 and in *Burma* up to date was submitted to the Simla Conference by Colonel W. G. King, I.M.S., for many years Sanitary Commissioner in the former province, and now Inspector-General of Civil Hospitals in the latter. Under his instructions "mosquito brigade" operations have been carried out in a number of places in both provinces. He considers that results in Burma show that at Akyab, Kyaukpau, Amherst and Mogoke diminution of the mosquito population resulted while operations were actively and intelligently conducted, but that no approach to extirpation was secured. Quinine prophylaxis was of great service, especially among the military police and in jails. At Kurnool in Madras, as long ago as 1881, the municipality was induced to prohibit wet cultivation up to a one mile radius from the walls of the fortifications which more or less surrounded the town, with beneficial results. At Cuddapah a more limited prohibition failed to be effective.

148. Some experiments have been made in other provinces but not on a scale or with a thoroughness to afford data which would repay detailed examination.

149. In India generally the encouragement of the use of quinine has hitherto held the first place in anti-malarial measures. Although the total amount sold or distributed by Government is large, yet compared with the population it is insignificant. In some parts of India quinine treatment appears to be gaining ground, but the general use of quinine as a prophylactic measure in malarious tracts has not hitherto come within the range of practical politics.

General Conclusions.

150. A consideration of the facts summarised in this part of our report does not lead us to the conclusion that anti-malarial operations, such as have been carried out in other countries, can be readily adopted in India with the assurance of speedy and certain success.

151. In the first place it is to be remarked that in several of the operations which we have noticed the main point in view has been the protection of the European residents. This is not the problem presented to us in India, where, for reasons that have been ably explained by Professor Ross, Europeans do not (certain special localities and conditions being excepted) suffer very greatly from malaria, as they do, for instance, in West Africa. The main problem with which we have to deal is a much wider one, namely, the extirpation of malaria from among the vast native population.

152. Secondly, a consideration of general conditions, and the experience gained by actual experiment, alike tend to show that in the malarial tracts of India we cannot expect great results from cheap and easy measures such as were achieved at Ismailia and Hong Kong. The indications point rather to

the need for wide measures executed with considerable perfection of detail. Such operations are in general possible only where the population is concentrated in towns, and we have not as yet before us an Indian example of their success even in such conditions. As soon, also, as it is admitted that operations may be required on a major scale, the question of cost assumes immense importance. The lavish liberality of Panama would be out of the question except to protect the labour force of a vast commercial undertaking which provided the funds. The heavy expenditure of Lagos could not ordinarily be incurred for the sake of a body of people of equal size; even the outlay of Klang and Port Swettenham would far exceed the means of a small Indian town. The general prosecution of such schemes is beyond our present resources and public opinion is not ready to incur fresh local burdens for the purpose of fighting malaria.

153. The problem is thus one of immense complexity and difficulty and no satisfactory solution is as yet in sight. Nevertheless the operations carried out in various parts of the world suffice to show that anti-larval measures combined with quinine prophylaxis offer great possibilities and we do not think that Government should be deterred because of the magnitude of the task or the uncertainty of the issue. But if ultimate success is to be obtained we must not act as though a cheap and easy tool were ready to hand and only waiting to be applied. The work for the immediate future lies in patient and searching investigation and in careful and continued experiment. The recent Conference at Simla outlined a scheme of this nature involving regular scientific study, the improvement and thorough scrutiny of available data, the selection of test localities, and the prosecution of experimental operations on well considered lines and under careful supervision. Time will show, as this scheme is perfected and as the lessons it affords are studied, how far it may be possible in the difficult conditions of India to combat the scourge of malaria by destroying mosquitoes and by encouraging the population in the use of quinine. It is essential for the wide success of any such measures that they should secure the active co-operation of the people whose interests they are intended to serve, and that they should go hand in hand with the general amelioration of the insanitary conditions of life which are so potent a factor in augmenting disease in this country. Such amelioration must come in the main from the people themselves, and their education thus lies at the root of the problem.

R. NATHAN.

H. B. THORNHILL.

LEONARD ROGERS.

Dated the 25th November 1909.



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E. E. Austen,
and Major G. M. Giles, M.B., I.M.S.
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- (iii) "A Discussion on Malaria and its prevention."
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- V.—*The Island of Mauritius* . "Report on the Prevention of Malaria in Mauritius."
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- (ii) "The Practice of Malaria Prevention."
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Egypt, and parts of America."
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- (v) "Note on the Habits of Europeans in India and Africa
in relation to Malaria."
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- (vi) "The Possibility of Extirpating Malaria from certain
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LIST OF WITNESSES EXAMINED.

1. Lieutenant-Colonel H. D. Rowan, R.A.M.C. . . . 24th October 1909.
2. Captain S. R. Christophers, I.M.S. . . . Ditto.
3. Mr. D. W. Aikman, Sanitary Engineer to the . . . Ditto.
Government of the Punjab.
4. Lieutenant-Colonel M. O'D. Braddell, R.A.M.C., 25th October 1909.
Senior Medical Officer.
5. Captain G. A. Kempthorne, R.A.M.C. . . . Ditto.
6. Lieutenant W. E. C. Lunn, R.A.M.C. . . . Ditto.
7. Lieutenant A. G. Wells, R.A.M.C. . . . Ditto.
8. Colonel H. J. W. Barrow, Principal Medical Officer . 26th October 1909.
9. Captain W. J. Fraser, I.M.S. . . . Ditto.
10. Lieutenant E. A. Trafford, 52nd Sikhs, Officiating . Ditto.
Cantonment Magistrate.
11. Captain J. A. McEnery, R.E., Garrison Engineer . Ditto.
12. Fazl-din, No. 892, Hospital Assistant, First Class, . Ditto.
Station Hospital, Lahore Cantonment.
13. Captain S. R. Christophers, I.M.S. . . . Ditto.
14. Surgeon-General H. Hamilton, C.B., M.D., I.M.S. . 30th October 1909.
15. Colonel D. O'Sullivan, R.A.M.C. . . . Ditto.
16. Lieutenant-Colonel A. A. M. M. Faulknor . . . Ditto.
17. Colonel H. F. Chesney, R.E. . . . 3rd November 1909.
18. Major S. P. James, I.M.S. . . . 4th November 1909.
19. Lieutenant-Colonel A. R. Aldridge, R.A.M.C. . . . Ditto.
20. Captain G. S. Clarke, 34th Pioneers . . . 6th November 1909.
21. Captain T. N. Howard, The Prince of Wales's Own 14th November 1909.
[West Yorkshire Regiment].
22. Major A. Cadell, 38th Dogras . . . 16th November 1909.



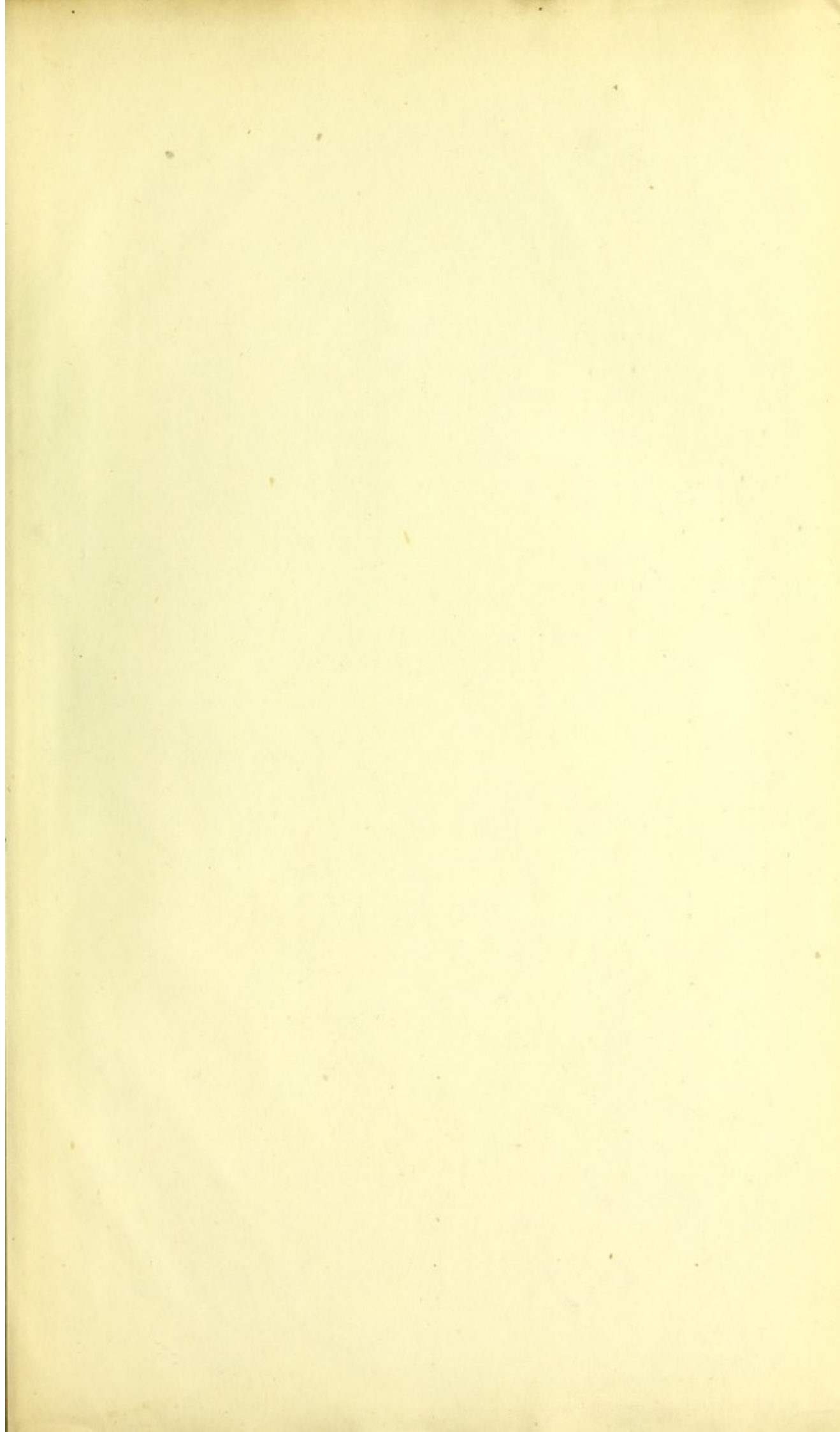


CHART No. II., Monthly Fever Admissions and Rainfall.

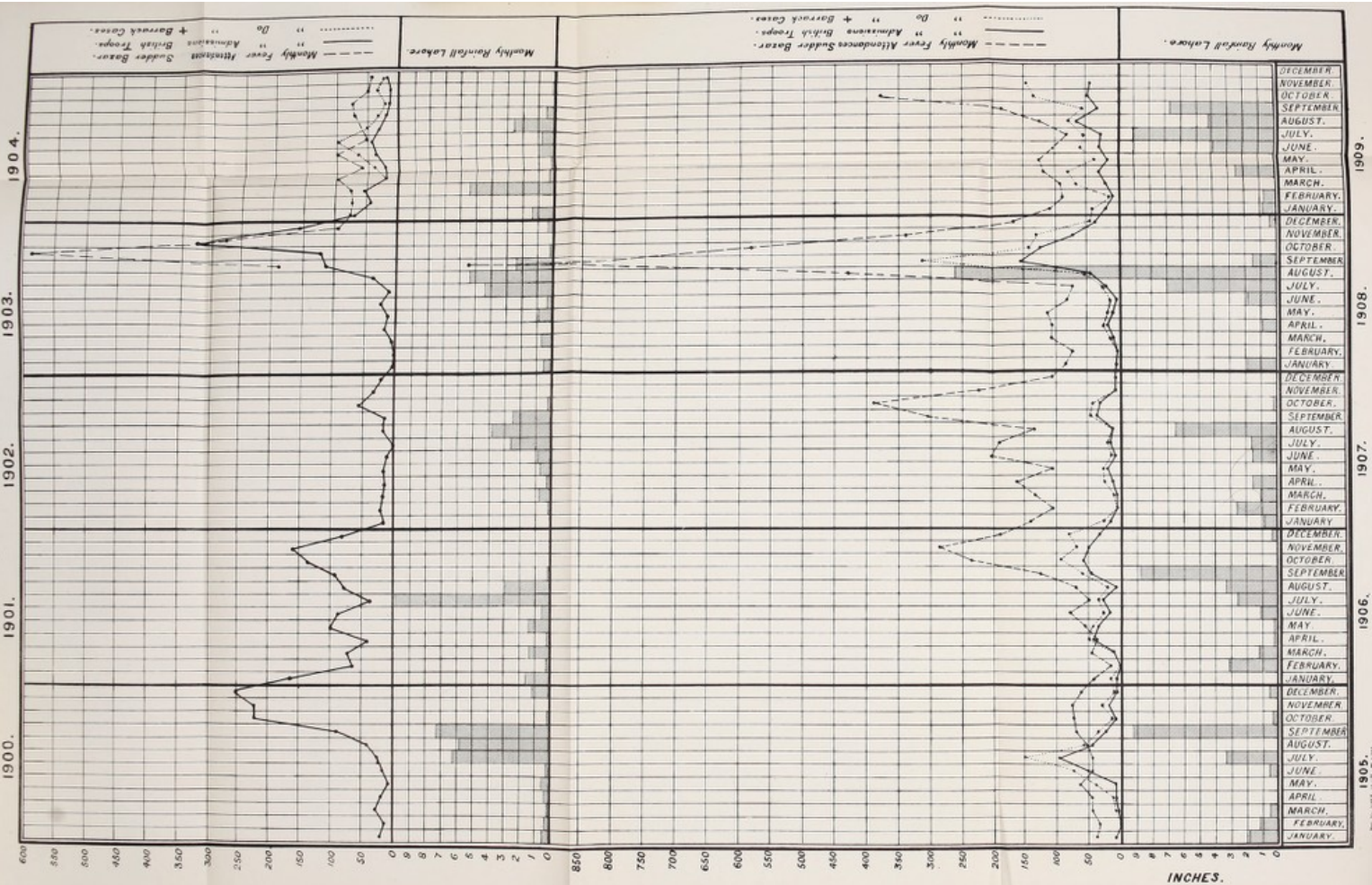
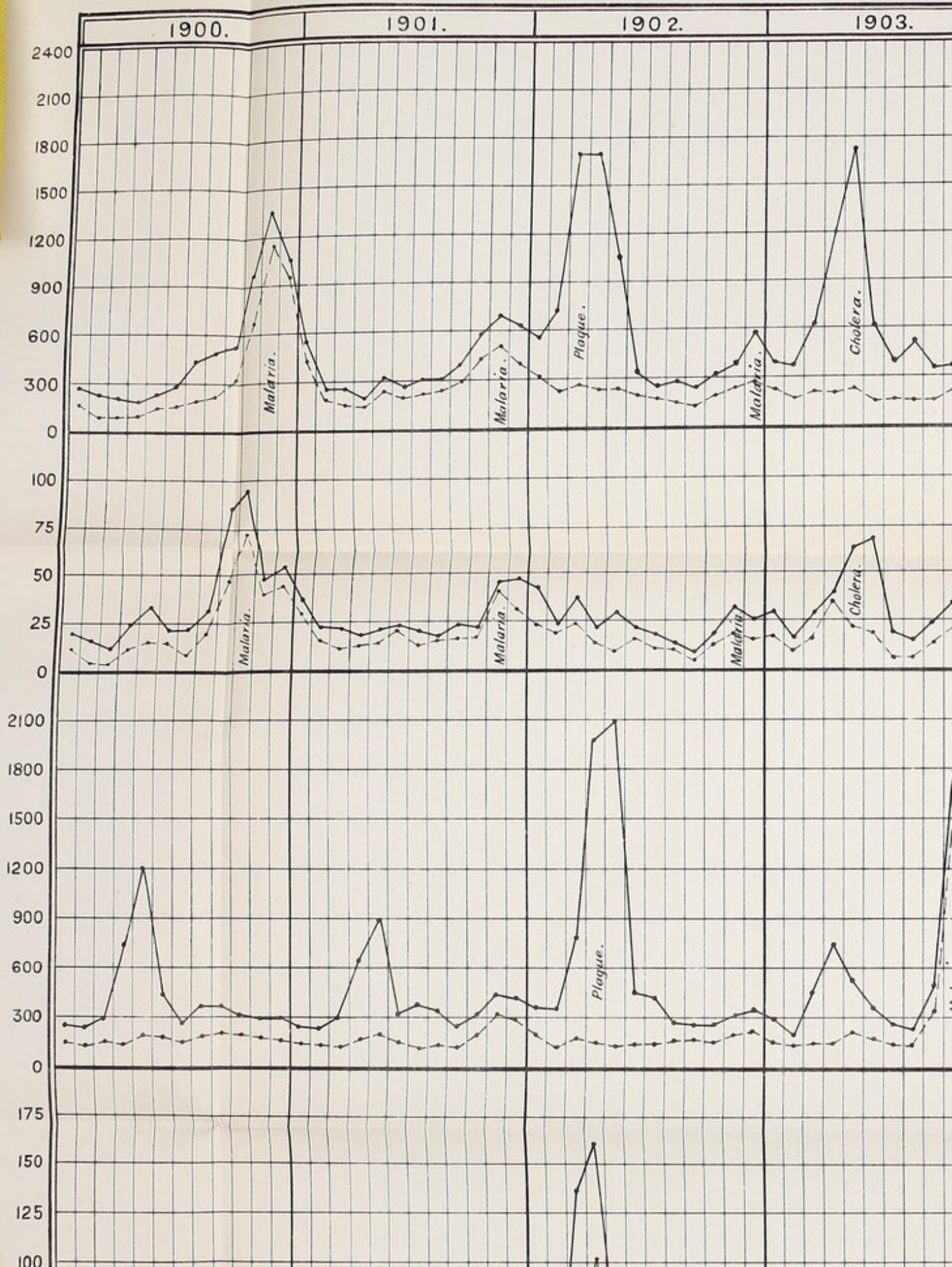
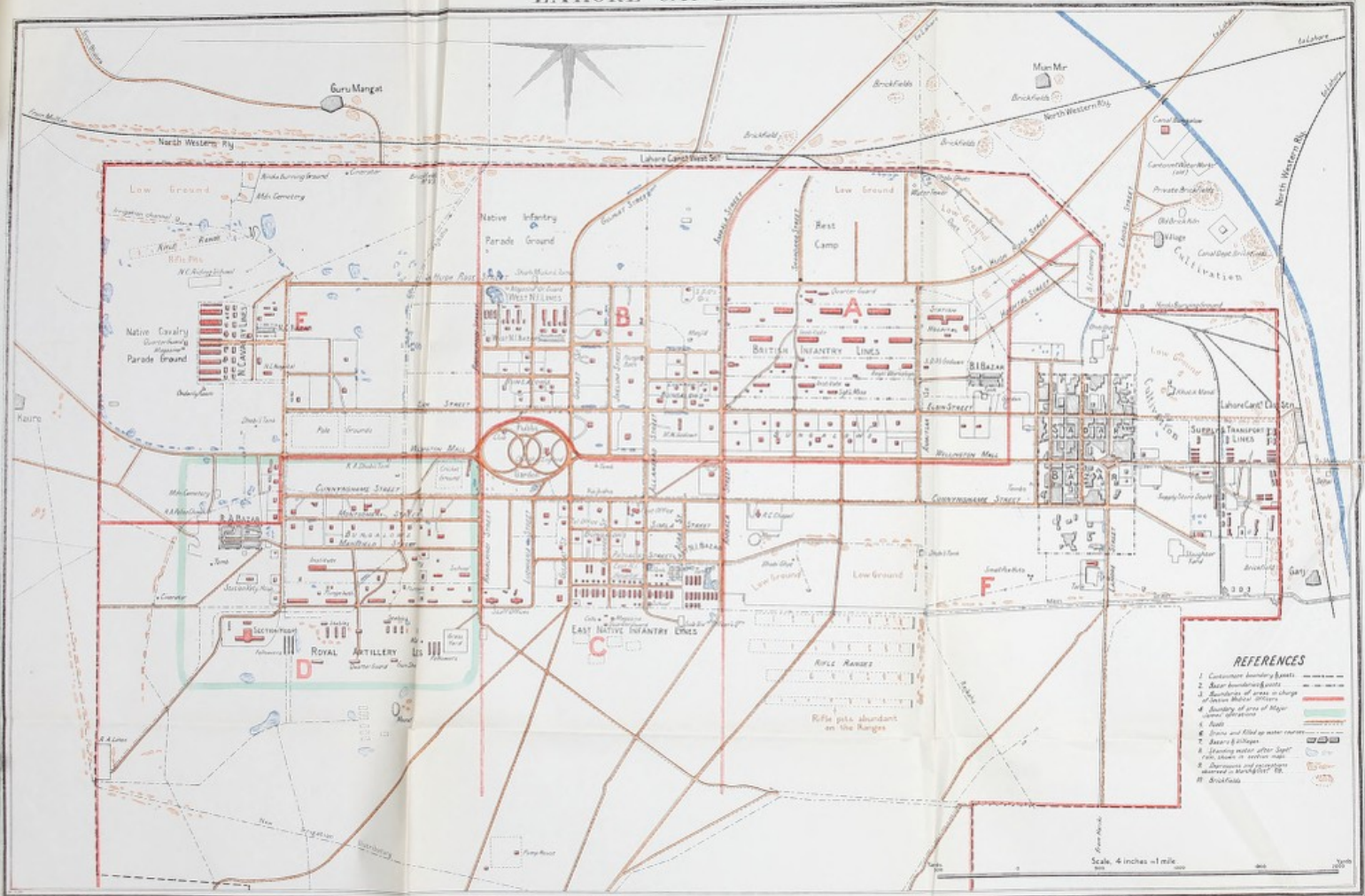


CHART N^o III., Monthly Death Rates (Total and Fever) in Lahore Cantonment and Surrounding Thana

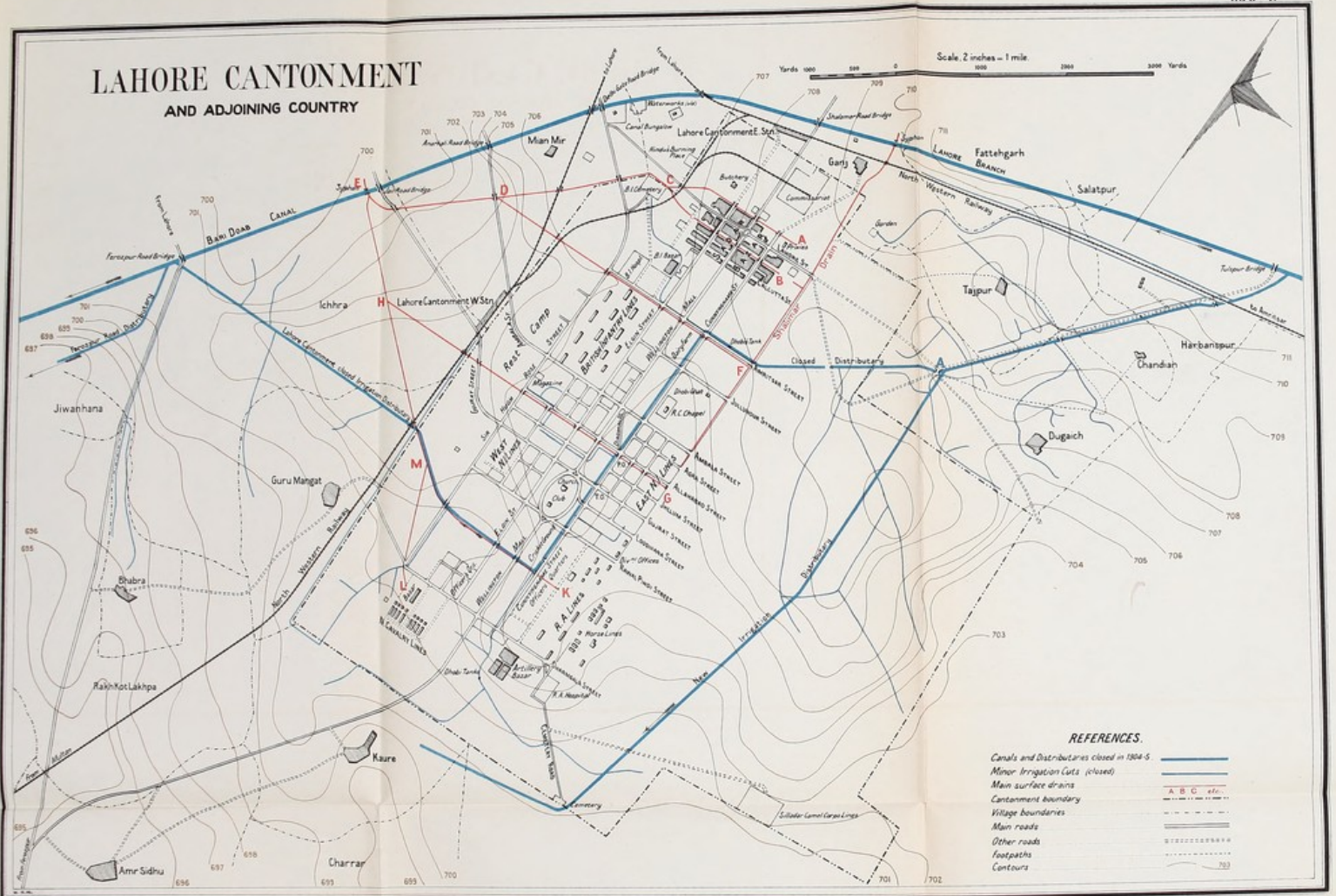


LAHORE CANTONMENT.

MAP 2.

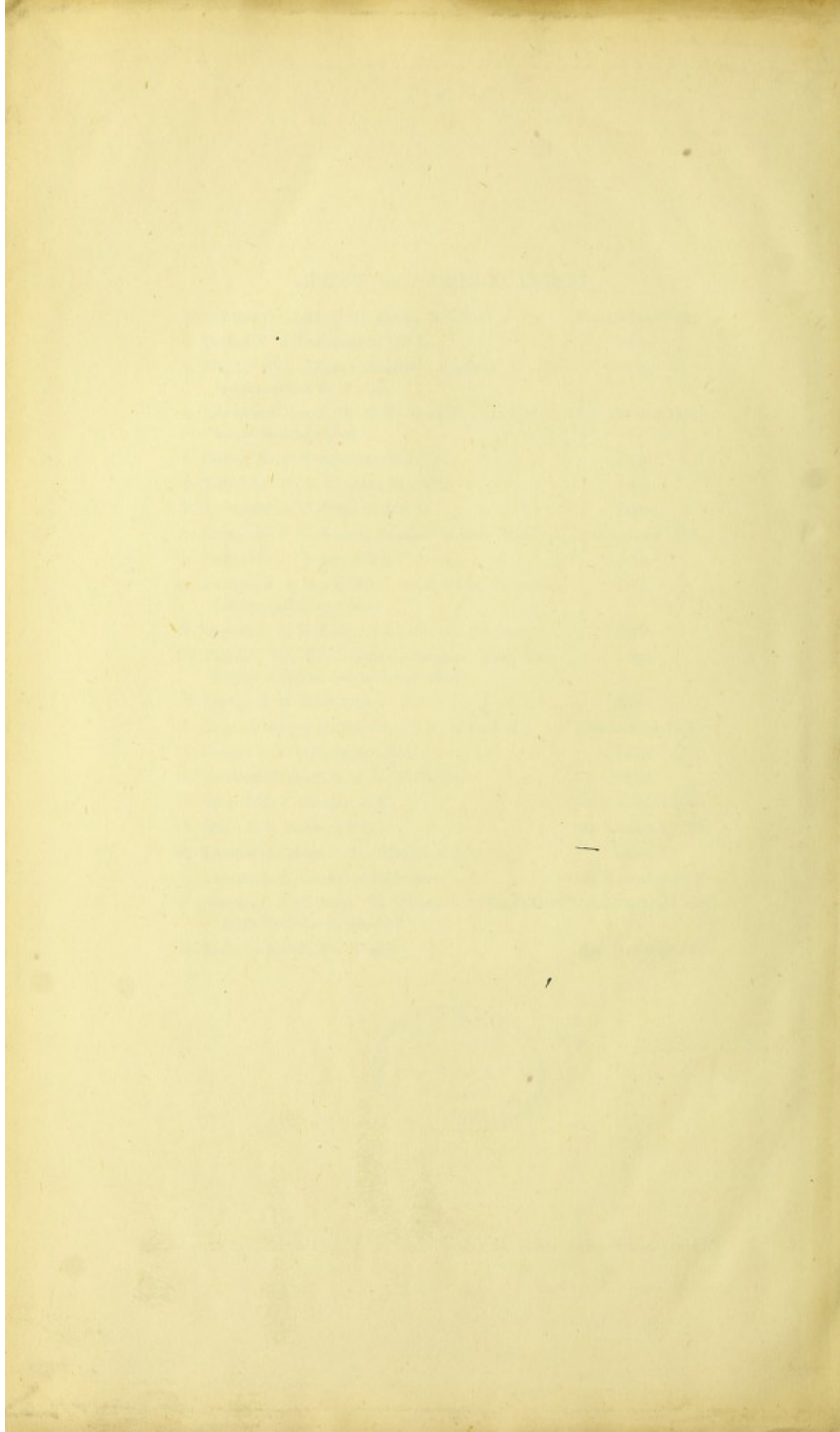


LAHORE CANTONMENT AND ADJOINING COUNTRY



REFERENCES.

- Canals and Distributaries closed in 1904-5.
- Minor Irrigation Cuts (closed).
- Main surface drains.
- Cantonment boundary.
- Village boundaries.
- Main roads.
- Other roads.
- Footpaths.
- Contours.



6-12-22
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