

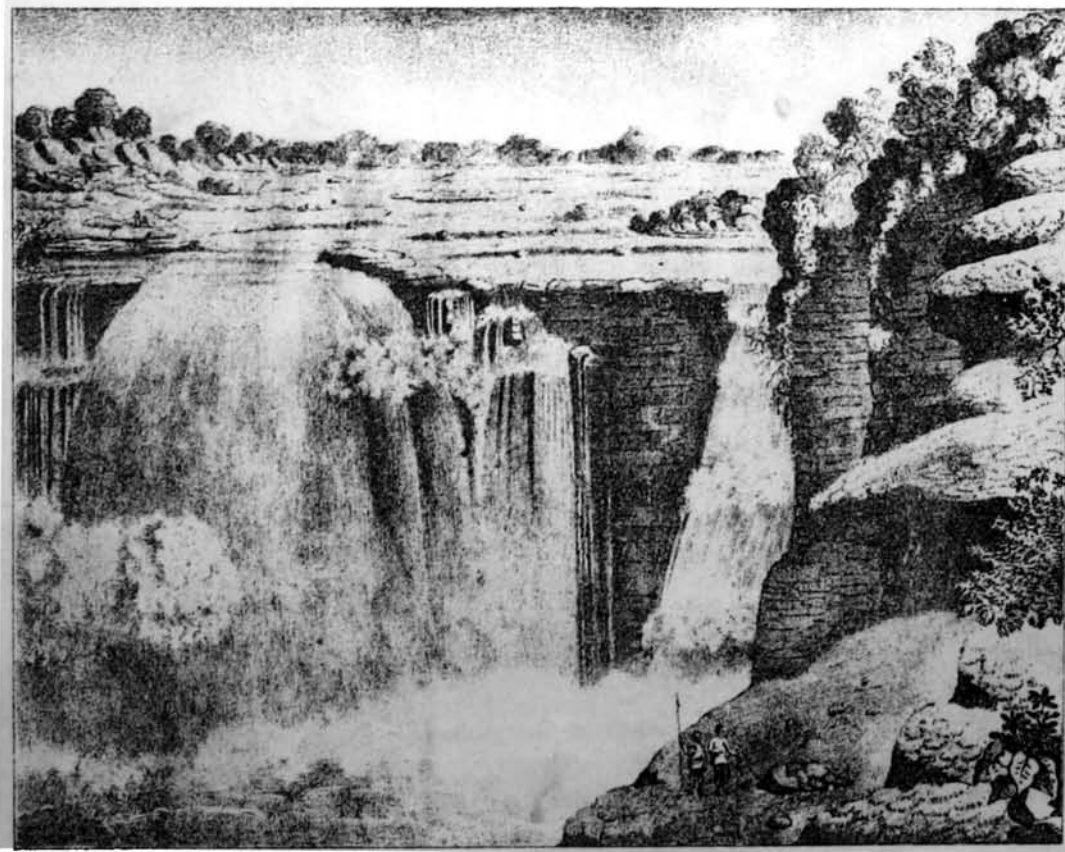
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A FALL OF THE RIVER TONSE IN REMWAN.
Drawn on Stone by J. Bennett from an Original Drawing by Capt. Mason 10th Regt. L.C.

HYDRO-ELECTRIC SURVEY OF INDIA.

VOLUME II.

Second Report on the Water Power Resources of India.

Ascertained during the Season
1919-1920

By F. E. BULL,

Chief Engineer, Hydro-Electric Survey of India,

AND

J. W. MEARES, M.Inst.C.E., M.I.E.E., M.Am. I.E.E.,

Electrical Adviser, Government of India.



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INTRODUCTION.

The Preliminary Report on the Water Power Resources of India was issued in the early autumn of 1919, some 3,000 copies being distributed. In this Second Report it is not proposed again to traverse the ground already covered by the Preliminary Report, of which copies may be obtained through the Agents for the sale of books published by the Superintendent of Government Printing, India.

The first report was fully reviewed both in the lay and technical Press of India and the United Kingdom, considerable portions of it being reprinted, in some of the weekly Engineering Supplements. Widespread interest has been aroused in the investigation as it has gradually been realized how vast is the ground to be covered, and how great are the possibilities of the future.

A few errors, though none of capital importance, have been brought to light by reviewers and correspondents; a certain amount of supplementary information (though by no means so much as was expected) as to sites and other data has been sent in by officials and private persons interested.

Criticism in the reviews was mainly concentrated on the sufficiency or insufficiency of the organization for dealing with so large a problem in so immense an area. As regards the central direction, which is obviously on very delicate ground when decentralization is rightly proceeding in every direction, some writers have urged the formation of an Imperial Water Board, such as has been constituted in some of the Dominions, on the plea that one or two officers cannot efficiently direct the operations. Provincial Water Boards have also been recommended.

Nationalization of Indian water powers, as opposed to development by private enterprise, has also had its advocates. There are cases where the interests of Government as a consumer are paramount, so that the construction of works to be run by or for Government may be advisable; but if so some method, as proposed elsewhere in this Report, must be found of keeping accounts on a commercial basis.

Many writers have apparently overlooked the abnormal shortage of available engineers, due to absence on military duty or to absence on leave after an unavoidably long spell of work during the war. Staff, both superior and subordinate, has only with difficulty been found for the work of reconnaissance which is the first essential stage in the investigation.

From the time that Mr. Barlow died the direction of the Survey was in the hands of Mr. Meares, who prepared the Preliminary Report and made the arrangements for the work of the cold weather of 1919-20. In December 1919, Mr. F. E. Bull took over the direction as Chief Engineer, and proceeded on tour accompanied by Mr. Meares, who

reverted to his original post. The following is a diary of the places visited during the cold weather :—

December	11th to 14th	. Delhi.
"	16th	. Allahabad.
"	19th to 20th	. Lonavla and Andhra Valley.
"	25th to January 2nd	. Shillong.
January	5th and 6th	. Ranchi (Mr. Bull) and Calcutta (Mr. Meares).
"	9th	. Nagpore.
"	12th to 16th	. Indore.
"	18th and 19th	. Bhusaval.
"	21st and 22nd	. Bhopal.
"	23rd	. Budni.
"	26th and 27th	. Sehore and Rajgarn.
"	31st to February 3rd	. Poona and Bhatgarh.
February	6th to 10th	. Baroda and Sankheda.
"	13th to 14th	. Madras (Mr. Meares to Colombo).
"	15th to 27th	. Mr. Bull in Mysore and Ootaca- mund.
		. Mr. Meares on deputation to Ceylon.
"	28th to March 6th	. Mr. Bull in Alwar and Delhi. Mr. Meares in Palni Hills, Madras.
March	11th, 12th	. Calcutta.
"	13th to 19th	. Mr. Bull to Rangoon.
"	19th	. Mr. Bull to Delhi. Mr. Meares to Delhi and Simla.

It was decided by the Government of India that any officers detailed on special duty with the Survey should work under the direction of their own Chief Engineers but in close touch with the Chief Engineer, Hydro-electric Survey. The actual arrangements which were made differed to some extent in various parts of India, according to the wishes of the Local Government. The following is a list of officers detailed for the Survey with the dates on which they took up the work:

Assam.—Mr. B. A. Blenkinsop, Executive Engineer. (October 1919.)

Bihar and Orissa.—Mr. H. H. Stevens, Executive Engineer. (October 1919.)

Bombay.—Mr. (formerly Col.) P. L. Bowers, C.I.E., M.C., Executive Engineer. (November 1919.)

Burma.—Mr. B. Raikes, Electrical Engineer. (October 1919.)

Central Provinces.—Mr. Powys Davies, Executive Engineer. (December 1919.)

Madras.—Mr. (formerly Capt.) R. T. S. Sneyd, M.C., Executive Engineer. (October 1919.)

United Provinces.—Mr. T. M. Lyle, Executive Engineer. (October 1919.)

The Government of Bengal were unable to spare an officer, being abnormally short-handed. In the Punjab Mr. H. W. Nicholson was about to take over when his services were again requisitioned for the Bhakra Dam project. Various other officers have also been employed on specific work, publicly or privately, as noted in the body of the Report.

Of the officers placed on special duty Messrs. Blenkinsop, Lyle, Raikes, Sneyd and Stevens came to Simla from the 22nd to the 25th November 1919 to formulate the programme of work; to visit the local hydro-electric works; and generally to discuss with the Chief Engineer questions of funds, staff, equipment and methods of carrying on. At a slightly later date Mr. Bowers also followed suit, but Mr. Davies was not placed on special duty until January 1920, by which time the remainder had all settled down to work and the Chief Engineer was on tour also. Owing to difficulties in the matter of personnel and equipment it was realized from the outset that the cold weather of 1919-20 could not be expected to produce very large results; thus none of the Zeiss-Watts levels or tacheometric plane tables ordered by Mr. Barlow in September 1918 have yet been received.

The Chief Engineer, accompanied by the Electrical Adviser, spent the season in touring, and arranged to meet all the above officers. A good many sites were also visited in Native States and elsewhere and various reports were prepared on their possibilities and were delivered to the officers immediately concerned.

To sum up, the first season was spent in making enquiries and preparing the ground, ordering instruments, and obtaining promises of selected engineers in the Provinces. The result were given in the Preliminary Report. The second season has been spent in visiting the officers on special duty, checking their reconnaissances and making other reconnaissances both in British India and in Native States. Meantime the selected officers have been collecting and training their staff and following the lines pursued by the Chief Engineer in the first season. The results are recorded in this Second Report, which also adds some further technical data contributed by Mr. Meares and repeats those from the "Addendum to the Elementary Note" on pages 60, 61 of the Preliminary Report. The results of the reconnaissances, as was to be expected, are not very extensive; the next season's work should result in a real advance. Nevertheless a good deal of additional power has been located and assessed.

An Index to both the Preliminary and Second Reports will be found at the end of this Volume.

SECOND REPORT.

PART I.—TECHNICAL MATTERS.

1. General Principles of development and storage of water for electrical purposes.—The Preliminary Report on the Water Power resources of India prepared by Mr. Meares contained chapters on "Water Power in general"; on "Weather and water"; on "Localities and surveys"; on "Power and its uses"; all of which were of the nature of brief technical treatises to bring the subject home to the lay reader and the engineer unused to water power. Not long after the issue of the Report the Institution of Electrical Engineers (London) published (Vol. 57, No. 233, June 1919) a paper by the same writer on the "General Principles of the development and Storage of Water for Electrical Purposes"; of which reprints were circulated to all those likely to require them; and the further reprinting of this paper *in extenso* in various British and Indian technical journals will have helped to disseminate sound ideas on the subject. The following extracts will be found useful to those investigating hydro-electric projects.

Figures i to xiii have now been prepared to show diagrammatically the varieties of "layout" ordinarily met with in hydro-electric work, on the lines of the diagrams in the original of the above mentioned technical paper. The figures are accompanied by their own explanations, if any are needed. It is very necessary to realize that there may be more than one way of dealing with most possible sites, though as a rule one way will be the best way and the remainder will be unsatisfactory.

Extract from a paper on "The general Principles of the development and storage of water for electrical purposes" from the Journal of the Institution of Electrical Engineers, Vol. 57, No. 233, June 1919.

THE CONDITIONS REQUISITE FOR WATER POWER; CLASSIFICATION ACCORDING TO HEAD.

"A country may have vast rivers and yet very little water power capable of economic development. For, unless a natural fall is ready to hand, an artificial one must be created. If a river bed has a slope of only a few inches to the mile, as is the case with many large rivers in flat countries, the power that exists in the sluggish flow is incapable of utilization except possibly by very small under-shot water wheels. The difference of level at different seasons would alone put any such proposals out of court, as would also the cost.

“As the power obtainable in any case is proportional to the product of the weight of water multiplied by the height of fall, it follows that either a large volume of water flowing under a small head or a small volume flowing under a high head will serve; the majority of installations actually utilize a medium volume flowing under a moderate head. The problems of low, medium, and high heads differ considerably, however, and each may be dealt with in various ways. There is no exact line of demarcation between the three stages, but generally speaking, low heads may be taken to be those involving the use of pressure or reaction turbines, often submerged, with suction or draft tubes connecting the outlet with the tail race, from about 3 feet as a practical limit up to 80 or 100 feet. High heads are such as are dealt with by the jet impulse type of turbine wheel exemplified by the Pelton wheel, from a possible 5,000 feet or so down to 300 or 400 feet. Between these two extremes lie the medium falls, using impulse turbines of various types according to the head. In America this type of wheel is little favoured and jet impulse wheels are mostly used. The gross head in high and medium falls is the vertical difference in height between the point of application to the wheel and the water-level at the pipe intake; while for low heads the difference between the level of the head and tail waters must be taken. The net head is the gross head diminished by the loss in the connecting system.

FLOW AND STORAGE.

“The above classification according to head may be further subdivided in considering possible sources of water power, for just as the head may be natural or artificial so may the flow of water. With rivers and canals the natural flow is the prime feature, and even with mountain streams it is of great importance; but in every case, given suitable conditions, storage may be an almost equally important factor. In a project recently described natural flow into the reservoirs only operates for a few weeks during the monsoon, and for the greater part of the year the maintenance of supply is dependent solely on storage; more frequently flow and storage are combined, and the conditions resulting from each category are dealt with in this paper.

EFFICIENCY OF HYDRO-ELECTRIC PLANT.

“At the most economical load the efficiency of various types of hydraulic turbine or wheel varies from 85 to 90 per cent. in large sizes, while the corresponding overall efficiency of alternators, including excitation losses, will be from 95 to 97 per cent. Thus the overall efficiency under the most favourable conditions will vary from 81 per cent. to 87 per cent. In practical working, however, the most favourable conditions are not maintained; the plant will not all be running at full load and there will be some appreciable additional loss in all systems having any length of pipe—a loss increasing with time and incrustation. In low-head plants eddies also affect the efficiency. For practical industrial purposes it will be sufficient to assume the overall commercial efficiency, E , of the plant to be as in Table 2.

TABLE 2.

For 500 kw.	.	.	.	.	.	74 per cent.
" 1,000 "	.	.	.	.	.	76 "
" 1,500 "	.	.	.	.	.	78 "
" 2,000 "	.	.	.	.	.	80 "
" 3,000 "	and over	.	.	.	.	82 "

"Using the convenient irrigation unit of a "cusec" for a flow of a cubic foot of water per second (termed a foot-second in America), we then have :

$$\text{E.H.P. output} = \frac{\text{cusecs} \times 62.4 \times \text{gross head in feet}}{550} \times \frac{\text{E.}}{100}$$

As, however, we are more concerned with kilowatts than with electrical horse-power it will be convenient to use a direct conversion factor and to avoid decimals of no real significance, as follows :—

TABLE 3.

For 500 kw.	=	cusecs	×	gross head	×	0.062	
" 1,000 "	=	"	"	"	"	×	0.064
" 1,500 "	=	"	"	"	"	×	0.066
" 2,000 "	=	"	"	"	"	×	0.068
" 3,000 "	or over	=	"	"	"	×	0.070

"For rough purposes indeed it is quite sufficient to take kilowatts = cusecs × feet/15, or B.H.P. of turbine = cusecs × feet/11 for mechanical power as reliable mean figures, except for small installations where the divisor will be higher. Thus

6,500 cusecs on	3.5 ft. head will give 1,500 kw.
650 "	35 " " "
65 "	350 " " "
6.5 "	3,500 " " "

LAY-OUT OF HYDRO-ELECTRIC SCHEMES.

"With a steam generating station the main considerations in fixing a site are facilities for condensing water and for fuel delivery and ash removal ; none of these operate in the case of hydro-electric plant, which must be placed where the ground admits, and designed to suit it. Thus it may happen that a high fall cannot be developed conveniently as a single station) but can be utilized in the form of two-stations in series, the tail water of the one discharging into the head-works of the next. This has been done at the two Santa Ana Creek stations at Redlands, California; and in the small development at Darjeeling, India, which the author carried out in 1896, the method has been used for subsequent extensions.

HIGH-HEAD LAY-OUT.

"High-head schemes are necessarily located in mountainous country and are generally fed from torrents of small volume, liable to heavy

flood and consequently bringing down much mud as well as gravel and large stones. Even if the headworks have a dam it is generally necessary to have settling tanks and a forebay, in order to prevent damage to the wheels from foreign matter travelling at high velocity. In order to get the most suitable fall with as short a length of pressure pipe as possible, it is almost always necessary to carry the water along the hillside for a considerable distance in an open channel, generally of artificial construction, though occasionally merely a cutting in earth. This will be dealt with subsequently, so far as the design of the canal, channel or flume is concerned. The channel offers a weak link in the chain, and duplication is impossible, though occasionally two or more separate sources of supply may be tapped by different routes. To allow for fluctuations of load (apart entirely from the question of settling tanks) a forebay at the head of the pressure pipes is essential, unless water is so plentiful that an excess is always running to waste at that point. The forebay must be of such capacity that it will supply the excess water, over and above what the supply channel brings, at the time of peak load, or in the case of sudden heavy loads (*e.g.*, short-circuits) thrown on the station. If the forebay is too small, and runs off even momentarily, air will get into the pipes and water hammer will probably follow when they refill.

“Thus if the channel can deal with a steady load of 2,000 kw., and the peak load averages 2,500 kw. for 2 hours, there must be at least 1,000 kw.-hours stored in the forebay. On 1,000 ft. head this amounts to about 56,000 cubic feet. This amount, however, is of no practical use as a reserve against a temporary breakdown in the channel or at the headworks, and wherever possible a scheme of this nature should have enough storage at the pipe head to tide over at least a few hours stoppage from such causes. For this much greater capacity is necessary and it may not always be possible to provide it. If the ground will allow no more than a regulating forebay, a reservoir must be constructed elsewhere, and the nearer to the pipe head the better. If, however, large-scale storage by means of a dam is possible it will almost always necessarily be either upstream of the headworks or at them, and the chances of a break in the flume must be risked. Large reservoirs, constructed by means of dams, can obviously only be located where the ground offers natural facilities, *i.e.*, at a comparatively narrow neck in a valley, which opens out above and does not rise steeply. Where comparatively small storage is required more latitude is found. In some cases of steep ground it is possible to locate the power house so near to the headworks, even with high heads, that the water can be carried in pipes the whole way, without an open channel. Here the risk of breakdown is a minimum. An intermediate case between these two extremes is where the distance from reservoir or headworks to power house is considerable, but a channel cannot be constructed, owing to the slope of the ground. Generally the steep fall will be at the lower end of the pipe line, and the upper reaches will fall very little. In America the usual method of dealing with such problems is to use wood stave pipes for the upper part of the pipe line, with a surge tank

at the junction of these with the steel pressure pipes, where the steep fall begins. The surge tank consists of a reservoir, elevated to the level of the water where it enters the stave pipes, connected by a large pipe (or separate pipes) to the junction. It not only serves as a regulating forebay, giving the water in the comparatively level upper section time to alter its velocity, but also it takes up and relieves all jars that might damage the weaker sections above it.

MEDIUM-HEAD LAY-OUTS.

“Medium heads will generally be developed either from actual waterfalls or rapids in rivers, or from rivers near the base of mountains where the volume is great and the slope comparatively small. Higher upstream it is generally possible to utilize a high head at less cost, even though a large volume may be available. Where many rapids occur in a short length of bed it may be possible to pipe the water direct from the stream to the power house with a forebay interposed to prevent detritus getting into the pipes. In several American schemes either the whole power house is located at the bottom of a shaft, cut down vertically in the rock behind the fall, or the turbines are placed in such a shaft and operate generators on the surface. Where there is an actual waterfall, as in many of the largest undertakings, it is seldom necessary to carry the water far to the forebay. Sometimes the pressure pipes can be led directly into the reservoir or into a forebay constructed immediately above the fall; a short canal at most is required, and as it must be of large carrying capacity there is a great saving in such a natural fall.

“Where the river has a considerable bed slope, or rapids, it may be necessary to carry the water for miles in a canal in order to accumulate a few hundred feet of fall; and if an earthwork canal is impracticable an artificial flume is required, which adds both to the capital cost and to the liability to breakdown.

“As the head decreases, and the volume of water increases, not only the flume but also the pipes increase in size, so that carriage to site often becomes a difficult and expensive problem where the installation is some distance from the railway. Occasionally a medium-head plant may be worked directly from a reservoir behind a high dam but in such cases there will obviously be very large variations of head to contend with, sometimes from full head to none at all; sometimes—in fact generally—such a reservoir will have been built primarily for irrigation purposes, so that beyond a certain minimum the flow is strictly regulated according to season. This detracts from the commercial value of any such scheme.

LOW-HEAD LAY-OUTS.

“Slow-running rivers and canals, with a small bed slope and no falls, cannot ordinarily be used for power purposes, as it is not possible to develop even a low fall without the risk of flooding the surrounding country above the dam; while the rise and fall of both head and tail waters, not necessarily to the same extent, further complicate the

problem. Even where a small fall exists or can be made, these factors complicate the design.

"In the case of irrigation canals, falls of from 3 to 10 feet are not uncommon, and can be developed by taking a feeder channel as a by-pass to the power house, continuing as the tail race back to the canal below the fall. Sometimes a subsidiary canal (generally in the form of a tail race) will enable two neighbouring falls to be combined so far as the turbines are concerned. Larger heads, but still of the low type, may occasionally be developed, where irrigation requirements permit, by discharging part of a high-level canal through turbines to a low-level canal. All irrigation canal projects suffer from the disadvantage that an occasional closure is necessary—whether for purposes of repair, or because the water is not required, or because it is more urgently required elsewhere.

"In the case of rivers, low falls may be developed on the lines already described for medium falls—always bearing in mind the ever-increasing size of channels and pipes as the fall decreases. In addition there are various schemes in which a dam is placed across a river not so much with a view to storing water as for the purpose of obtaining head. Here the water is fed directly from the dam to the turbines which in some cases are placed inside a hollow dam.

"Great variations in the level of the head and tail waters are often a feature of low-head river developments, and floods are a serious menace. In some cases, *e.g.*, at the station of the Portland Railway Light and Power Company, Oregon, and at Bhatgar Dam plant in Bombay Presidency, double turbines are installed, one for the maximum head and the second for the reduced fall. Flood gates, as used in irrigation canal headworks, are required to deal with abnormal rises.

HEADWORKS AND CLEAR WATER.

"There is always present the liability of bringing down mud and debris from the source of supply to the turbine wheels, though in the case of canals this is not of great importance from the point of view of power development. This liability increases with the head, as torrents take the place of larger rivers, and its effect on the wheel buckets also increases with the head and the spouting velocity of the jet or nozzle. Even the finest grit under a head of 1,500 or 2,000 feet is most destructive, and loss of efficiency soon results from worn nozzles.

"Where the headworks have a considerable dam there is no danger from stones or heavy matter except that their deposition will reduce the capacity of the lake; but in hill torrents this in itself is so serious a matter that high dams would seldom be justified. Such a lake could only be cleaned out at great expense, though undersluices may enable the debris to clear itself if there is enough water to spare and if the lake is only of moderate size. If, however, such a dam is necessary it will sometimes pay to put another and smaller one further upstream, simply as a means of arresting the silt for a few years. The capital charges would generally be less than the cost of periodical cleaning.

out. With lower velocity in the stream such dams are often practicable, though not necessarily at the point where the water is tapped off.

“On high and medium heads.”—Generally speaking, in the case of high and medium-head plants, a low diversion dam is all that is necessary, sufficient to ensure the possibility of getting the water into the channel or pipe under normal conditions, and also to protect the stream at this point from scouring out the channel and endangering the supply in times of flood. Cases have occurred within the author's experience where a few days' abnormal rainfall have lowered the level of a stream bed 30 or 40 feet. For protecting the banks above and below the headworks boulder crates, made up of large boulders enclosed in a framework of heavy-gauge galvanized wire, have been found invaluable in every sort of river training works. Cases will sometimes be found where a permanent dam is not necessary, the natural lie of the ground alone ensuring the supply. Timber dams are sometimes used in America for levelling the bed.

“In the absence of a dam, whether the water is taken direct into pipes or into a channel—but more especially in the former case—arrangements must be made at the headworks for catching all debris. Generally there will be a succession of screens or trash-racks through which the water passes to a small tank, in which any heavy matter coming through will deposit. This will need constant cleaning out, and should (in the absence of other reserves) be in duplicate. Nothing but fairly fine silt should pass beyond it. If there is no open channel this tank should be large enough to remove even such silt as will deposit readily, or there should be an adjoining settling tank for this purpose. Where there is an open channel there will always be the liability of further debris being collected along it, and a forebay is necessary at the point where the pipes take off; sometimes the lie of the ground makes it convenient to put intermediate silt tanks along the route. All these should be designed for rapid clearance at several exits, controlled by gates of substantial size. By sloping the floor from all points towards the exits the flow may to a great extent be utilized to carry off the deposited mud. The size of these settling tanks should be such as to reduce the normal velocity of flow to a few inches per second. Where there is a reservoir at the pipe head it is still necessary as far as possible to prevent the accumulation of mud in it, as a large volume will become so solid that its clearance is a matter of difficulty, and a silt trap immediately before it will assist in this direction. Where water is considerably in excess of actual requirements it is possible to allow a proportion to run off continuously at the headworks chamber, through partly open sluices which will pass out all solid matter rolling along the bottom.

“On low heads.”—In the case of low heads the water is generally clear, as low velocity postulates a small bed slope and deposition will occur in the river itself. In any case the quantity to be dealt with is so great that artificial settling cannot be arranged for. Strainers (known in America as trash-racks) are necessary to prevent floating matter entering the pipes, and a forebay may be required to catch anything that may pass through, as well as for regulation. A long

canal is seldom necessary, and the forebay will either be at the side of the fall, parallel with the river, or across it on or in a low dam. It depends on the ground whether a diverting dam or anicut is required or whether a forebay can be opened directly into the bed of the river. In the majority of cases of very low heads the power station is built across the river, and the water flows directly through the strainers into the turbines.

CANALS AND OPEN CHANNELS.

"In the case where a very large canal is required in connection with a hydro-electric development, the design is carried out on lines of irrigation canals, to which no further reference is necessary. On medium and high heads the channels, if required, are of a smaller order. They may vary in length from a few hundred yards up to many miles, and may be single, duplicate, or multiple. The De Sabla plant of the Valley Counties Power Company in California collects water from a number of streams by means of ditches aggregating about 100 miles in length, like an inverted irrigation system, smaller channels feeding larger ones up to the forebay.

"In the case of long channels a break might only be discovered after many hours; and even if due only to an earth fall, diverting the supply without breaking down the channel, it would take time to get this cleared and the water at the forebay again. In the absence of a substantial reserve at the forebay end this would involve complete breakdown. Water-level indicators, electrically controlled, are therefore often used in these cases. In the 10-mile flume of the Columbia Improvement Company at Tacoma, U.S.A., the indicator shows every inch of rise or fall; and the large capacity of the flume itself forms no inconsiderable reserve. As a motor runs on rails above the flume little time is wasted in reaching the source of trouble.

"*On high heads.*—For very high heads a comparatively small discharge is required, and this will sometimes be collected from more than one source and by more than one route. Earthwork channels can seldom be constructed in these cases, and the choice generally lies between galvanized iron (for very small discharges), masonry or concrete and timber. The first and last have the advantage that they can be carried on a structure without cutting away the ground, at least in the majority of cases. As landslips are always liable to follow the cutting of a roadway on a mountain side this is a great consideration, and an inspection path can be carried alongside or over the channel. If masonry or concrete is used, water running down the hillside behind is stopped at the channel, and either flows into it with mud and stones or sinks in and causes slips. Catch-water drains of substantial size, leading to the nearest culvert, are in such cases essential. Smaller torrents may have to be crossed on bridges, and each of these should be used to afford a discharge outlet for the water in case of accidents and for scouring. Sometimes where water is not over plentiful it will pay to divert these small torrents into the channel through a small settling tank; for, though their discharge may be negligible ordinarily,

it may be sufficient in times of heavy rainfall to tide over a breakdown in the channel higher up. Furthermore, when the main stream is in flood, the intake may have to be temporarily closed owing to floating debris, etc.; whereas the flood water of small supplementary streams will probably be clear and much collection of mud in the forebay may thus be avoided. This is not always true, but, is borne out generally by the author's experience.

"Fairly low velocities, not exceeding $3\frac{1}{2}$ feet per second in unpitched earth channels and 6 feet per second in other kinds, are generally necessary for the preservation of the channel.* The cross-section may be square, semicircular or trapezoidal, the latter being generally the best as giving the larger hydraulic mean depth. In order to lose as little head as possible (although a few feet on very high heads do not really count much) the slope should be kept small. The interrelation between slope, velocity, dimensions and the construction and condition of the channel are stated in a number of rival formulæ, none of which are universally applicable; the most useful of these have been discussed by the author elsewhere† and need not be referred to in detail here. In practice the slope is generally decided on first—from 1 in 500 for small channels, to 1 in 1,500 or so for large ones—and the dimensions are calculated to suit. It is very necessary, however, to remember that any data found by a formula dealing with a straight length of channel will need alteration where there are bends or irregularities. An opening out of the width by an extra 5 or 10 per cent., carried back to the limit of the possible afflux, may be required to prevent overflow, or a corresponding raising of the height or increase in the slope. Uncontrolled overflow would be almost certain to produce landslides and breakdowns. As, apart from faults in design, a small fall of earth may easily cause such an overflow, it is sound practice so to regulate the height of the side wall that overflow will take place most easily at places where it can do no harm, *i.e.*, over solid rock, or into streams passed by the way, or, in the absence of these, down artificial spillways.

"In order to prevent the channel being overfilled at the headworks a method often used is to place a diverting place in the fairway at a point near the headworks, such that any flow beyond the capacity of the channel is skimmed off and discharged back to the stream.

"Where masonry or concrete channels are used most of the above considerations apply with equal force. Here it is necessary first to cut a roadway for the foundation, so that the liability to landslips and rock falls is greatly increased. Where the ground is at all doubtful cut-and-cover is necessary, and it is better to spend money on revetments to begin with, than to take the chance of bad ground holding up. It is essential to make culverts under, or preferably over, the channel for the very smallest lines of natural drainage, both for safety and to prevent the access of stones to the channel. Often it will be advisable to lay small drains down such places, with cross-collecting drains to prevent a wash-out.

* For details see Captain Garrett's "Hydraulic Tables and Diagrams" (Longmans).

† "Electrical Engineering Practice," 3rd edition (Spon), para. 349 to 351.

"In extreme cases tunnelling may have to be resorted to, for the avoidance of bad ground. It may also pay at times to tunnel through a bluff rather than go round it. Tunnelling on a large scale is also sometimes required either to join up two sources of supply in different watersheds or to lead water collected in one area to a different watershed, where a more convenient or higher fall can be obtained. There are many examples of this class of work in America and elsewhere.

"*On medium heads.*—While small works on medium heads may be served by the same methods as apply to high heads, canals in earth are generally unnecessary. The cost of an artificial channel would generally be prohibitive over a certain size. The largest timber flume the author has seen was at Tacoma, U.S.A., and was 8 feet square and about 10 miles long, with a fall of 7 feet per mile. No other material could then be used for a channel of this size, and timber has its drawbacks. Unless the water is running full all the time, warping is certain to occur, while boring insects and rot have to be faced. The large flume of the Jhelum hydro-electric works has suffered severely in this way.

FOREBAY RESERVOIRS.

"Whether the forebay is mainly for regulation, or whether it also holds a considerable reserve supply, it is an important link in the chain. It must be so designed that, while acting as an efficient surge tank, and as a regulator to deal with loads temporarily exceeding the capacity of the channel, it does not allow any foreign matter to get into the supply pipes. Coarse and fine strainers should be provided, and they should be of such breadth that the full flow required by the wheels can pass through them if the water accidentally falls low. This is often overlooked in designing. In some small installations the actual reservoir is at a little distance from the forebay or pentrough, and the two are connected by a closed pipe large enough to deal with the peak load. In such cases the reservoir performs these latter functions, while the forebay proper becomes only a surge tank.

"The forebay, or forebay reservoir where these are combined, should if possible be sectionalized or duplicated to admit of cleaning out; and the design should be such as to facilitate this, as suggested above for silt traps. Where the channel discharges into it, which should be at a point as far as possible from the pipe entry, there should first be a small chamber to take eddies and induce still water; this will also catch some of the residual silt, and as its walls will stop a foot or two below normal water-level only the clean overflow will pass into the reservoir proper, and not the bottom layers, except at cleaning-out times. (This of course assumes that the width of the sill is greatly in excess of the width of the channel.) The spill-way and scour valves of the reservoir should be near this point, where most of the mud will collect.

"The strainer that finally ensures no foreign matter getting into the pipe requires careful thought. The obvious plan is to put it immediately behind the bell mouths of the pipe, and to close it in at the top. But there is a chance then that some part of it may eventually

rust away and get into a nozzle. Repairs would be difficult without emptying the forebay and shutting down the plant, and it has been found in practice that the arrangement is not satisfactory. The alternative design, which should be adopted, is to put the strainers in the main forebay, at the entrance to a separate walled-off chamber feeding the pipe, and this chamber should be covered over. Rolling screens, operated by a winch, are useful because of the facilities they offer for cleaning. A point of importance is that the screens must be capable of passing the full flow when the forebay is nearly empty.

"An emergency by-pass from the channel, also provided with a screen, should be made to discharge direct into the bell-mouth chamber. If repairs are required to the reservoir this will prove invaluable, and when the water is running clear it can be used while cleaning out proceeds. These small points of design may spell the difference between success and partial failure, though of course a good deal depends on whether clear or dirty water is generally brought in. For reasons already explained high heads need the most careful treatment. Medium heads may or may not need complicated forebays, and with low heads a plain tank is generally sufficient.

PRESSURE PIPES.

"There is considerable diversity of opinion as to the best arrangement of pipes for feeding a number of turbines. Apart from the question of cost there can be no doubt that the ideal arrangement is self-contained units of pipe, turbine, generator and step-up transformer, just as in modern steam practice. Where very large units are involved no other arrangement is likely to be used, and on low heads no other arrangement is generally possible. Intermediate cases must, however, be discussed. Structural design is beyond the scope of this paper, but it may be stated that the diameter of a short pipe on a moderate head may be such as to give a velocity as high as $0.1\sqrt{2gH}$ or 10 per cent. of the spouting velocity. The loss of head with such velocities would soon become too great, and about 3 to 4 feet per second is a good average. On high heads 9 to 12 feet per second in the smallest section is about the limit used.

"*On high heads.*—With very high heads comparatively small pipes of great strength are required; the locality is likely to be far from rail-head, so that carriage to site is an expensive matter. It therefore pays as a rule to keep down the weight of individual loads, and to use a single pipe for each turbine. It is, however, often advisable to interconnect the various pipes at the forebay. Each pipe should be capable of being instantly closed at the forebay in the event of a bad blow-out, either by an automatic valve or by electrical control from the power house. Each pipe must also have an isolating valve at the forebay or a gate in the forebay. Air pipes and filling valve may also be required.

"Where conditions are favourable a single pipe is often used to serve two or more units by means of a receiver at the power house, especially in the case of small plants, but this is not ordinarily recommended.

"In order to reduce the thickness of the lower sections of pipe it is customary to use two or more diameters, the smaller at the bottom, and this also economizes in freight where they can be nested.

"Where individual pipes serve each wheel it is advisable to interconnect them at the power house, so that in the event of a joint blowing on one pipe while another generating unit is out of service they can be cross served. This involves extra expense in isolating valves, but is generally worth it. It is not an identical proposition with the receiver.

"Long lines of pipe, such as are required on high heads, require very substantial anchoring not only at the top and bottom but at several intermediate points. These also provide safe positions for expansion joints, which can be dispensed with only where the temperature variations are small or the line has many angles in it—and not always then.

"Air valves are not often required, but will be where there is an unavoidable rise in the pipe line. Occasionally air cushions are provided in very long lines, to take up shocks; at the Mill Creek plant in California the pipe is 8,700 feet long for a head of 1,950 feet, and both air valves and cushions are installed. The latter consist of duplicate cylinders for recharging at the necessary high pressure.

"The reduction of effective diameter due either to ordinary furring from lime, etc., or more particularly to fine mud deposited when the water is standing, may seriously increase the loss of head. Although cleaners of the revolving turbine type can remove a good deal of this deposit, the initial diameter should be always greater than is indicated by the velocity decided on.

"*On medium heads.*—There are no special points in which the pipe system on medium heads differs from that already dealt with. The pipes are of larger size, and their carriage becomes more serious unless they are built up at site, but on the other hand the locality is generally more accessible. Air valves and cushions are seldom required.

"*On low heads.*—With very low heads and submerged turbines the draft tube is the only pipe required, while with somewhat higher heads there will be both pressure pipe and draft tube. With large units of plant the size of the pipes becomes very great and the internal hydraulic pressure becomes a secondary consideration. Cases are on record where an automatic gate, serving a very large pipe, was closed at the forebay and air pressure caused a complete collapse. No interconnection is usually practicable or necessary with low heads."

2. **Reconnaissance, Survey and Report Form.**—In order to be able to compare reports on sites it is desirable that data shall be collected in a more or less standard form; and the following form was therefore prepared and printed on one side of the paper only, leaving the blank pages for the answers to the questions. It has proved most useful and copies are obtainable from the Chief Engineer.

Hydro-Electric Survey Reconnaissance and Survey of Sites.

CONTENTS.

PART A.—RECONNAISSANCE OF SITES.

Para. I.—Site. II.—Type of project possible. III.—Head or fall. IV.—Flow and storage. V.—Flow of rivers. VI.—Rainfall; catchment; run-off. VII.—Regulating storage. VIII.—Main storage. IX.—Head-works. X.—Open channels or canals. XI.—Forebay. XII.—Pipe line. XIII.—Power house. XIV.—Irrigation considerations. XV.—Facilities and materials. XVI.—Local Rates. XVII.—Additional information.

PART B.—SURVEY OF SITES.

Para. I.—Longitudinal section. II.—Cross sections and contoured plan. III.—Site of power house and forebay and location of pipe line. IV.—Survey of open channel. V.—Headworks. VI.—Storage. VII.—Project estimates.

PART C.—GENERAL REPORT ON SITE.

Note by the Chief Engineer for Officers engaged on the work.

The following notes have been prepared to show generally what is required in the reconnaissance (Part A) or the Survey (Part B) of a water power site. Some of the information will not be easily obtained during the reconnaissance stage and, if so, the fact should be stated. Any other information bearing on the site, although not specifically asked for, will be useful and may be added in the space at the end of each part.

The following abbreviations are used below:—

“Report” refers to the “Preliminary Report on Water Power resources in India.”

“Practical Conditions” is brochure on “Practical Conditions in determining the value of Water Power” by the Electrical Adviser to the Government of India.

“Elementary Note” is that by the late Mr. Barlow on the preliminary investigation of water power sites, reprinted as Appendix 1 to “Report.”

"I. E. E. paper" is the paper on "Development and Storage of Water for Electrical Purposes" in the Journal of the Institution of Electrical Engineers, Vol. 57, No. 283.

Where alternatives are given in the forms below those not applicable should be struck out.

PART A.—RECONNAISSANCE OF SITES.

I. *Site*.—*Map square* according to Atlas sheet.* Sheet Number
Letter , Square , Square of 1 inch map

River , tributary of

Reached from *vid* (route,
rest houses, etc.)

by motor, other vehicle, or on foot?

Transport available

* See method explained on the key map in pocket of "Report." The 1-inch map squares generally have 9 squares, but old ones have more. The same system may be used for these, *viz*: 1 to 9, etc. For exact location of a particular spot give bearing and distance from nearest village shown on 1-inch map.

II. *Type of project possible*.—Mark off which division or subdivision appears most likely from inspection of site. For classification according to head see I. E. E. paper, page 426, where general descriptions of layouts on high, medium and low heads are also given on page 433 *et seq.* [*The illustrations referred to below are those in the present Report see para. 1.*]

High or medium heads with artificial fall.

(1) Headworks (or diverting dam) with pipe line direct to power station, and no open channel, either

(a) with pipe line on a steep grade throughout, not involving a surge tower; (Figs. ii and v)

(b) with upper portion of pipe line on a gentle slope, probably involving a surge tower at junction with more vertical part of pipe line. (Figs. iii and vi)

(2) Headworks (or diverting dam) with open channel (which includes tunnels) to forebay from which pipe line will take off to power station, either

(a) as in 1 (a) above, without surge pipe; (Fig. i)

(b) as in 1 (b) above, with surge pipe; (Figs. i and iii combined)

(c) variation where the open channel will pass through a watershed in a tunnel, giving a better fall on the other side. (Fig. v)

Note.—Purely storage schemes, such as those depicted in Figs. v and vi, should be reported as such.

Medium heads—

- (3) Natural waterfall or series of cascades capable of development by direct pipe line from forebay at head of fall to the foot of the fall; with no open channel, as in case 1 (a); (Figs. vii, ix, x)
- (4) Natural waterfall or series of cascades where bed slope of river enables extra head to be got by development on the lines of 2 (a). A surge pipe is seldom necessary on medium heads. (Fig. viii)

Medium or low heads—

- (5) Rapids, developed
 - (a) by means of a headworks dam, to give extra head only (not for storage except regulation), with pipe line to power house below rapids; (Fig. iv)
 - (b) by a low diversion dam only, where the natural head cannot be increased conveniently, with a short pipe leading to the power house below the rapids, but no open channel; (Fig. iv)
 - (c) as in case (a) or (b) but with an open channel (which may include tunnels) leading to a forebay, from which a shorter pipe line will suffice. (Fig. i)

Low heads—

- (6) Single canal fall. (Fig. xi)
- (7) Combination of two or more canal falls,
 - (a) by reconstruction of the length of the canal;
 - (b) by means of a subsidiary channel leading either to a power house near the lower fall or from the tail race of a power house near the upper fall, as may suit best. (Figs. xii, xiii)
- (8) Special case of utilizing a fall from a high level canal to a low level canal, or from river to a canal. This might be a medium head proposition, but would generally be a low head.

III. *Head or fall.*—Approximate gross height of natural waterfall feet.

Approximate gross height of artificial fall (Preliminary Report para. 3) or of natural fall increased by extra head obtainable above or below same, by means of an open channel, feet.

State method of determination, by level, aneroid or map contours. The gross head should be estimated from the power house site to the forebay site in the case of high and medium heads. For falls classified as "low," take the vertical height between head waters and tail waters.

(*Vide* notes on aneroid survey in Preliminary Report, para. 13 and in para. 4 of this Report. State if aneroid readings have been corrected for diurnal variation and air temperature or not.)

IV. *Flow and Storage*.—State whether it appears probable that the project in the first instance will mature :

- (a) on natural flow alone, with (without) regulating storage only. Nearly all low falls will be of this nature as cost of storage is usually prohibitive.
- (b) on natural flow supplemented by storage in dry months. Applicable to medium or high falls.
- (c) on storage alone. High falls only, as a rule.

(See flow and storage curves in "Practical Conditions" and I. E. E. paper, and also page 60 of Preliminary Report.)

V. *Flow of rivers*.—If known give the maximum recorded flood discharge,

If known give the minimum recorded discharge
cusecs.

Recorded at (location).

Where records are kept give the rough average discharge that is found during the dry months in good and bad years : cusecs at (location).

Where no regular records exist give results of any special gaugings available in form :

Year , date , previous
rainfall of month inch, discharge observed
cusecs. When is the discharge likely
to be at its lowest?

In the case of low head *river* developments of type para. II (5) above, state whether it is likely that in flood times the tail waters below will back up more than the head waters, and thus diminish the available head. In a gorge, or where there is a gorge near by down stream, this is likely to be the case. With a river narrow at the headworks and wide, with a fair bed slope, below the station site the head will probably be increased.

Is the river liable to sudden spates of great intensity?

Is it snow fed from permanent or from winter snow?

(See "Elementary Notes" on gauging and Preliminary Report, para. 10 and Appendix I, II.)

VI. *Rainfall ; catchment ; run off*—

Catchment area above dam or headworks

Raingauge stations within or near same

(a) Average total rainfall in dry months from
to

inclusive, inches.

(b) Minimum rainfall in dry months from
to

inclusive, inches.

(c) Average for rest of year

(d) Minimum for rest of year

Maximum rainfall in one day, if known; (small catchments only)

Probable annual run-off (known or estimated) in million cubic feet in average year

Probable annual run-off (known or estimated) in minimum year

VII. *Regulating Storage.*—In the case of high or medium head schemes there should be at least a few hours supply stored, preferably in or close to the forebay, but if no site exists then further back. State if such a site exists and in what position relative to the probable layout; its capacity very roughly if an intelligent guess will give it; whether it will be formed by a dam in the main or a subsidiary stream or by an artificial tank; and any further information as to probable cost of construction, nature of ground, etc., so far as inspection only makes this possible.

Site for regulating storage at

Distance from forebay site

Capacity roughly _____ cubic feet.

Whether formed by dam in main stream.

Ditto _____ dam in subsidiary valley.

Ditto _____ artificial tank.

Further details from inspection.

VIII. *Main Storage.*—In the case of medium or high fall projects dependent partly or entirely on storage give (as near as may be) location of dam and nature of ground, very roughly the length and height, with corresponding capacity, so far as inspection or 1-inch maps will give any information.

Location of dam (on 1-inch map)

Approximate length

Nature of ground

Height likely to be adopted (so far as can be seen without survey)

Probable method of surplussing flood waters

Probable capacity in million cubic feet (or approximate length and breadth of lake surface)

(See Preliminary Report, para. 4, and addendum to "Elementary Notes.")

If data under para. VI are scanty, state if there is a reasonable probability of filling the reservoir proposed and whether the conditions render a large carry-over necessary for probable bad years (two fairly bad years are generally more dangerous than one exceptionally bad one between good years).

State nature of ground which will be submerged, whether forest, jungle, waste land, good or bad agricultural land.

Does it contain any villages, temples, etc.

IX. *Headworks*.—(See I. E. E. paper, page 435.) Give particulars so far as inspection discloses them as to how the supply from the river (in cases of river development) will be regulated at the headworks, and brought into the open channel or forebay, as the case may be.

Probable location of headworks

State if the water is fairly free from, or particularly charged with, silt and detritus in the rains.

State if river is used for timber flotation, and if this is likely to interfere with its development for power.

X. *Open Channels or Canals*.—Where the site involves these the ground should be examined. In the case of low heads a canal in earth or rock alone will serve. With medium (or even high) heads where the power will be large, the same remark applies. In smaller high or medium head projects an artificial duct will generally be indicated: timber seldom lasts well, so masonry or concrete is generally used. Masonry requires special care where crabs are found, as they rapidly cause heavy leakage. For small schemes on high heads even galvanized iron troughing has been used, with a comparatively high slope.

State type of channel probable,

State if the ground is favourable or whether special difficulties will be involved

State if any tunnelling, bridging or syphoning will apparently be necessary, with such brief particulars as inspection discloses

Approximate length of channel from headworks to forebay

In most cases it is unnecessary

at this stage to go into details as to capacity, slope, etc.

Which bank does examination show to be most favourable for the open channel or canal?

(See "Canals and open channels" in I. E. E. paper, page 436.)

XI. *Forebay*.—State position of forebay and whether the site is good. (This may be, but is not necessarily, the means for regulating storage; but it must be large enough to take charge of ordinary fluctuations of load if the regulating storage is at a distance.) There must be the possibility of surplussing water not required for the power house and in some cases of dissipating considerable energy in the process. In other cases this is necessary at the main or a subsidiary reservoir.

(See I. E. E. paper, page 437.)

XII. *Pipe line*.—Give approximate length of pipe line from forebay to power station site (alternatives may be suggested, with head in each case). Pipe details need not be gone into, but the line should be as short as practicable.

(See I. E. E. paper, page 437 bottom.)

XIII. *Power house.*—Give information as to area of site available; approximate height above river bed and above flood level if ascertainable.

As noted in para. III, the gross head should usually be estimated from this site.

Probable location

Area of site approximately

Height above bed level

Ditto flood level

Nature of ground for building

Note that in low head installations the power house can be placed (if necessary) up to 24 feet above low water level, by the use of draft tubes. Where the height is greater the turbines can be placed in a pit and connected to the generators by a long vertical shaft.

Will any difficulty occur over the tail race discharge?

XIV. *Irrigation Considerations.*—Will development of the site in any way interfere with the functions of existing irrigation works?

Are there any vested rights such as privately owned water courses for irrigation, or to feed mill wheels, between the proposed headworks and power station site?

In the *district* one in which irrigation exists or is needed?

If this is so, would the fall it is proposed to utilize or develop have to be curtailed in order to utilize the tail waters? This will generally not be so if the power station site is at considerable altitude above the neighbouring plains, so that the tail waters would in any case continue their course in the natural channel: on the other hand, there are cases where the tail waters could conveniently be led hereafter directly into a canal, where some power head might have to be sacrificed to give command.

XV. *Facilities and materials.*—Will existing roads (rivers) carry the machinery, etc., required?

If so by what means?

If not, what length of road approximately will be required to complete connection?

Will there be exceptional difficulties in making this road?

Are bridges involved?

Are stone, bricks, lime, suitable sand, kankar, etc., known to be available in the neighbourhood of the works?

Is labour available or would it have to be obtained from elsewhere?

XVI. *Local rates.*—State rates, if known, or probable rates, for:

Masonry in lime per cent.

Masonry in cement per cent.

Concrete in lime per cent.

Concrete in cement per cent.

Excavation in earth per thousand.

Excavation in hard ground per thousand.

Blasting rock per thousand.

Contour roads, 4 feet, per 1,000 r. feet.

XVII. Additional information acquired during reconnaissance.

(NOTE.—Photographs of headworks site, power station site or any other feature may be of value. A sketch of the plan and longitudinal section should invariably accompany the report.)

Signature.

Designation.

PART B.—SURVEY OF SITES.

When reconnaissance shows that a site is probably worth developing the data require to be checked by actual survey, on the lines laid down in Part I, but sufficiently accurately to enable estimates to be framed for the civil engineering works. The various parts that make up the scheme are all dealt with in the I. E. E. paper. In the case of canal falls the survey will already exist, and what is required is a detailed report as to the best method of utilizing the fall or falls with rough estimates of the works required. In most other cases there will exist at the best a 4-inch contoured forest map and at the worst an uncountoured (and practically useless) old-style 1-inch map, so that very little exact knowledge can be obtained.

I. *Longitudinal section.*—In the first place a longitudinal section should be made of the bed of the river, between the limits that may prove useful.

II. *Cross sections and contoured plan.*—The next point is to determine on which bank the works may best be placed, and for this purpose, unless the maps give a clear answer, it is necessary to take cross-sections across the valley at intervals, extending up to the highest point where there may be works. This will enable a large scale contoured plan (8 or 16 inches to the mile) to be made, on which the lay-out can be sketched out roughly. The best site for the headworks, the alignment of the canal (if any), the position of the forebay and of the regulating reservoir (if any), the best alignment for the pipes and the position of the power station can be approximately determined on this plan. There will often be many alternatives to choose from, so that it will be a case of balancing probable extra cost against extra power obtainable on a higher head. It may be noted that if the best site for the headworks is considerably above the highest level of which an open channel appears feasible the extra head can be sacrificed. Until the survey is complete it is obviously impossible to say exactly what the best lay-out will be.

III. *Site of power house and forebay and location of pipe line.*—A plan and sections on a large scale should next be prepared of the forebay site; of the regulating reservoir if near to or combined with the forebay-

(none may be needed); of the pipe line route; of the power house site and tail race. From this the best locations can be definitely determined, and the capacity and rough dimensions of the forebay and regulating reservoir worked out. Pipe design need not be entered upon, and the power house can be left over so long as the plan shows the area available for it. The tail race back to the nearest stream should be dealt with and also the overflow from the reservoir. (See paras. on "reservoirs," "storage," "forebay," "pipes," "tail races" in I. E. E. paper.)

IV. *Survey of open channel.*—The route already determined on for the open channel (when one is involved)-from the forebay up to the neighbourhood of the headworks will next be surveyed, and its nature, dimensions and slope determined according to the flow to be allowed for. If the regulating reservoir has to be placed somewhere along this channel, instead of close to (or combined with) the forebay, this will involve a break of levels; i.e. it will be fed at top level and will discharge at bottom level. Silt traps may have to be provided for in the run of the channel, unless clear water can be counted on and landslips are improbable. Various points to note are dealt with in the paragraphs "Headworks and clear water" and "canals and open channels" in the I. E. E. paper. Tunnelling may be required, as well as means of crossing nals or the route and of allowing overflow at safe points if the channel gets blocked.

V. *Headworks.*—Similarly the headworks site will be surveyed (it is assumed to have been definitely located before the channel is surveyed) and examined with a view to such a design as will secure the supply in times of low water and both the supply and security in times of flood. Protective works may be necessary to ensure this, probably in the form of boulder crates, and this matter should be examined.

VI. *Storage.*—If storage on a large scale is involved the dam site and submerged area will be surveyed so as to determine the dimensions and consequent capacity at draw off level, and the practicability of the site for construction. The problem of surplussing extra water must also be dealt with in the design, by whichever method appears to suit the conditions best.

(See also enquiries in Part A.—VII.)

VII. *Project estimates.*—Rough project estimates should then be framed of the quantities involved and approximate cost, care being taken to indicate very clearly what is included and excluded. It is not intended that the estimates should do more than indicate whether the scheme will prove cheap, moderately cheap, moderately expensive or very expensive in terms of rupees per horse power capable of development. Beyond this point the matter can be left over until it is decided to proceed with the works.

Signature.

Date

Designation.

PART C.—GENERAL REPORT ON SITE.

Such information as is available should be summarized in this form, which is drawn up to be progressive from the worst to the best sites.

I. The site is certainly (very probably) useless as shown by the particulars in Part A-B para. above; or because the cost of works especially (the) would be prohibitive; or

II. It is useless to investigate the site further until gaugings have shown what the minimum flow and/or the yield of the catchment will be; but if these prove favourable development under a head of about feet may be feasible.

III. The site appears to be worth further investigation but its value for power is very indefinite owing to lack of knowledge of the minimum flow and/or yield of the catchment and for storage possibilities or

It is however probable that the power capable of development under a head of about feet is of the order of :

e.h.p. for the 3-4-5 driest months :

e.h.p. for the rest of the year.

(For power from flow and storage see I-E. E. paper.)

IV. The site is worth a preliminary survey as it appears favourable and can be developed under a head of about feet.

It is likely to yield power of the order of :

e.h.p. for the 3-4-5 driest months :

e.h.p. for the rest of the year.

V. The site is certainly worth detailed survey. Under an available head of about feet it will, if the results of the survey are satisfactory, yield not less than :

e.h.p. for the 3-4-5 dry months :

e.h.p. for the rest of the year.

Signature.

Designation.

Date

Remarks by higher authority.

3. Pipe data and diagrams.—From time to time enquiries have been made as to pipe layouts, although the time has not yet arrived to go into details in such matters. Nevertheless the following memorandum with its two accompanying logarithmic diagrams (Figs. xiv and xv) will be found useful for rough estimating purposes. The general form of the curves follows that given in Garrett's "Hydraulic Tables and Diagrams" for cast iron pipes, and acknowledgment is due to that Author; it has the advantage that complete data for any size and thickness of pipe can be contained in one diagram. To avoid crowding however separate curves are given for A. Welded pipes and B. Rivetted pipes.

Working head; basis of diagram.

In calculating the working head the ultimate strength of the steel is taken as 25 tons. A factor of safety of 4 is assumed and, in the case of rivetted pipes, an in-efficiency of 0.8. The formula then becomes

$$\text{Working head, } H = \frac{t}{r} \times k$$

$$\text{or } t = \frac{H \times r}{k}$$

where k is 32,000 for welded pipes and 26,000 for rivetted pipes; being the internal diameter and t the thickness, both in inches.

Weight of pipes; basis of diagram.

The weights given are only approximations, as for any particular complete pipe the addition due to the weight of flanges of varying thickness may be spread over a length of 10 to 30 feet. Garrett in the book quoted above gives curves for the plain tube only, with a note as to the way to add for the flanges. The present curves are based on the weight of the tube at 41 lbs. per sq. foot 1 inch thick, so that:

$$\text{Weight per foot run in pounds is } 3.14 d (41 \times t) 12.$$

For welded pipes 25% has been added for flanges in the thinner pipes and 20% in the thicker ones. Rivetted pipes have been taken as 16% to 20% heavier than plain tubes, with an addition as before for flanges. Reference to the weight list of pipes in catalogues (where flanges are included) show that the results are near enough for rough estimating purposes.

Working head; example.

The diagonals sloping downwards from left to right are used to find the working head for a given pipe, or the thickness of a pipe of given size to work on any head. Thus, finding the working head on the abscissae and the diameter of the pipe on the ordinates, the diagonal at which they intersect gives the required thickness.

So, from diagram B, a rivetted pipe of 50 inches internal diameter to work on a head of 260 feet must be $\frac{1}{2}$ inch thick.

Remembering that the scales are logarithmic, interpolation can be effected by eye nearly enough. If however a slide rule is laid across

any of the scales (vertical, horizontal or diagonal) in such a way that any two numbers correspond on the paper and the rule, then exact interpolation is obtained. Care must be exercised not to use the wrong set of diagonals.

In the above example, as 1 foot head = 0.433 lbs. per square inch, the static pressure will be 112 lbs.

Weight of pipes ; example.

The diagonals sloping *upwards* from left to right are used to find the weight of the pipe, after determining its thickness. Taking the internal diameter on the ordinates, and running up until the diagonal for the required thickness is met, the abscissa opposite will give the weight per foot run approximately. Interpolation as before will give intermediate points.

The scales have been made so comprehensive that they include pipes which would ordinarily be impracticable, as for instance a 250 inch pipe of unmechanical thinness. This however will cause no confusion, and a very thin pipe of large diameter may be used as a core in a concrete pipe.

From diagram A, a welded pipe of 50 inches internal diameter and $\frac{1}{4}$ inch thick will weigh (with flanges) about 161 lbs. per foot run; while a rivetted pipe of the same size will (from diagram B) weigh about 193 lbs.

Carrying capacity and loss of head in pipes.

For convenience the following table is added to show, for a pipe of any given diameter, the flow in cusecs Q with the corresponding velocity in feet per second and loss of head L per 100 feet of pipe. As however pipes invariably become encrusted to some extent, and sometimes to a very serious extent, it is always advisable to use a somewhat larger pipe than would serve at the first.

Diameter inches.	Velocity in feet per second.							
		3.0	3.5	4.0	4.5	5.0	5.5	6.0
6	Q	.58	.68	.78	.88	.98	1.07	1.17
	L	.82	1.13	1.50	1.80	2.30	2.80	3.20
8	Q	1.05	1.21	1.40	1.57	1.73	1.92	2.08
	L	.56	.77	1.00	1.30	1.60	1.90	2.20
10	Q	1.62	1.92	2.18	2.45	2.72	3.00	3.26
	L	.42	.57	.75	.95	1.20	1.40	1.58

Diameter inches.		Velocity in feet per second						
		3·0	3·5	4·0	4·5	5·0	5·5	6·0
12	Q	2·36	2·58	3·14	3·54	3·92	4·30	4·72
	L	·33	·45	·59	·75	·90	1·12	1·33
14	Q	3·20	3·74	4·28	4·80	5·34	5·88	6·40
	L	·28	·39	·49	·61	·76	·92	1·10
16	Q	4·16	4·87	5·58	6·27	6·96	7·67	8·37
	L	·23	·31	·41	·52	·64	·77	·92
18	Q	5·28	6·20	7·10	7·92	8·84	9·67	10·60
	L	·20	·27	·35	·44	·55	·67	·79
21	Q	7·18	8·41	9·60	10·80	12·00	13·20	14·40
	L	·16	·22	·29	·37	·45	·55	·67
24	Q	9·42	9·90	12·60	14·10	15·70	17·20	18·90
	L	·14	·19	·25	·31	·38	·46	·55
27	Q	11·90	13·90	15·90	17·80	19·80	21·80	23·80
	L	·12	·16	·21	·27	·33	·40	·48
30	Q	14·70	17·20	19·70	22·00	24·50	26·80	29·40
	L	·11	·14	·19	·24	·29	·34	·42
33	Q	17·80	20·80	23·70	26·70	29·70	32·60	35·60
	L	·09	·13	·17	·21	·26	·31	·37
36	Q	21·20	24·70	28·30	31·70	35·40	38·80	42·30
	L	·08	·12	·15	·19	·23	·28	·34
42	Q	28·80	33·70	38·40	43·20	48·00	52·00	57·50
	L	·07	·09	·12	·16	·19	·23	·28

4. Aneroid levelling notebook.—In many cases information has been sent in as to falls of so many feet "as found by aneroid", with no statement as to whether the readings have been "reduced" or not. A handy notebook for recording and reducing such readings was circulated to the officers on special duty and is reproduced here so far as the explanatory matter is concerned; the form of sheet for readings is also given.

Notes on Levelling with Aneroid and forms for recording Levels.

Notwithstanding claims made on behalf of the Aneroid for accurate levelling it is certainly true of most instruments by the best makers that, after the necessary corrections have been made, there remain serious discrepancies; this is especially the case in extremes of climate, whether in the hot weather in India or in the polar regions. In the latter case Dr. G. C. Simpson, F.R.S., found this method of determining altitudes unreliable and the present writer's experience confirms the opinion in warmer climes.

The majority of levels based on aneroid reading that the writer has received have however not been corrected at all, so that they may be wrong to an unnecessary degree unless the corrections happen to balance out. In the first place it must be remembered that the aneroid, even though calibrated in feet, shows the pressure of the atmosphere and *not* the altitude. Owing to a depression or to anticyclonic conditions variations of an inch or more are common enough at different times of the year, and may occur in a day during disturbed conditions; this represents from about 900 feet variation at sea level to 1,100 at hill station altitudes. The actual "reduced level" or height above sea level can therefore only be found (approximately) when a known altitude or contour line is included in the readings; and then not easily in disturbed weather conditions. Nevertheless the method is most useful in hydro-electric reconnaissance, where *differences* of altitude are required.

Clearly the best results can be obtained when one instrument is left at the starting point and read at intervals, so as to give the actual atmospheric variations during the time the readings are being taken elsewhere. From the fixed instrument a curve can be constructed which will give the reading at that station at the time other readings are being taken, thus balancing out diurnal and climatic variations by simultaneous readings. This method however is seldom practicable in the field. Even when two instruments are available it is generally necessary, and always more convenient, to take both over the ground and average their reduced results. For one thing the discrepancies between them give an idea of the probable error.

Diurnal variation.—This reduction offers no difficulty when it is understood, but cases are on record where a correction has been applied in the wrong manner for the diurnal variation. Molesworth's "Pocket Book" gives two curves (see "Aneroid levelling") showing the mean annual correction for diurnal variation for Calcutta and Simla respect-

ively, with factors for correction for latitude and altitude. The difference in these two curves, and the fact that they are only *mean results* and that the mean results elsewhere will differ from either, shows at once that unless the *actual* diurnal variation for the period in question is known there may easily be considerable uncertainty. In fact the actual variation will sometimes be half that of the curve or may be masked by other changes. Taking these curves as the basis however it will be found that the diurnal variation crosses the zero line at about 1 hour, 6 to 7 hours, 13 to 14 hours, and 20 hours. Where 2 aneroids are employed their readings should be kept separate and independently reduced. To each reading should be added or subtracted the diurnal correction in feet from the curve to give the reduced apparent altitude of the station. Thus if two readings are taken at different places at 11 hours and 16 hours some 40 to 50 feet will be added to the apparent altitude at the former and the same amount will be subtracted from the latter, so as to reduce both readings to the zero or datum line of the curve. This may convert an apparent rise into an actual fall or *vice versa*, as shown in Table XVI.

The following pages give the actual mean correction in feet at a number of stations in India, alphabetically arranged, for every month in the year, and have been furnished by the Meteorological Department. In any case the nearest station should be taken, or the mean between adjacent stations, the plus correction being added to the observed height and the minus subtracted. This will give closer accuracy than the use of Molesworth's curves. The tables give local, *not* standard time (82½° East or 5½ hours East of Greenwich). Thus Belgaum is 74½° longitude or 8° West of the Indian standard meridian. As each degree is equal to 4 minutes of time Belgaum local time is 32 minutes different, local noon in the table being 12.32 Standard time. Burma Standard time is based on 6 hours East of Greenwich or 97½° longitude so is practically Rangoon local time.

[Tables.

Table I.—ALLAHABAD.

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	- 1	0	+ 3	- 1	+ 4	+ 7	+ 14	+ 12	+ 9	+ 1	- 4	- 2
1	- 5	- 7	- 5	- 13	- 9	+ 1	+ 4	+ 2	+ 1	- 8	- 9	- 6
2	- 13	- 15	- 14	- 20	- 17	- 7	- 8	- 9	- 8	- 15	- 16	- 13
3	- 20	- 22	- 20	- 25	- 17	- 12	- 15	- 15	- 15	- 20	- 19	- 18
4	- 24	- 26	- 22	- 21	- 11	- 9	- 15	- 18	- 14	- 21	- 22	- 21
5	- 19	- 18	- 10	- 6	+ 2	+ 2	- 8	- 8	- 5	- 11	- 14	- 14
6	- 4	- 1	+ 7	+ 17	+ 21	+ 19	+ 6	+ 8	+ 13	+ 8	+ 5	- 2
7	+ 16	+ 21	+ 32	+ 36	+ 43	+ 38	+ 21	+ 21	+ 31	+ 29	+ 27	+ 21
8	+ 40	+ 45	+ 57	+ 60	+ 57	+ 48	+ 35	+ 35	+ 48	+ 49	+ 48	+ 43
9	+ 64	+ 65	+ 73	+ 72	+ 65	+ 55	+ 41	+ 47	+ 55	+ 63	+ 66	+ 64
10	+ 73	+ 71	+ 74	+ 72	+ 62	+ 54	+ 44	+ 51	+ 56	+ 63	+ 65	+ 70
11	+ 55	+ 62	+ 63	+ 59	+ 52	+ 44	+ 37	+ 44	+ 43	+ 49	+ 52	+ 53
12	+ 28	+ 38	+ 39	+ 41	+ 34	+ 29	+ 26	+ 29	+ 27	+ 25	+ 24	+ 24
13	- 4	+ 6	+ 7	+ 13	+ 10	+ 7	+ 7	+ 8	- 1	- 5	- 9	- 9
14	- 27	- 21	- 23	- 17	- 15	+ 14	- 17	- 16	- 27	- 28	- 31	- 31
15	- 42	- 41	- 47	- 41	- 39	- 41	- 39	- 39	- 49	- 43	- 43	- 43
16	- 45	- 48	- 57	- 58	- 61	- 58	- 53	- 54	- 61	- 48	- 44	- 46
17	- 40	- 48	- 58	- 62	- 65	- 64	- 55	- 56	- 59	- 43	- 38	- 42
18	- 33	- 39	- 51	- 54	- 57	- 54	- 48	- 48	- 49	- 37	- 29	- 31
19	- 19	- 26	- 38	- 41	- 47	- 37	- 29	- 31	- 30	- 23	- 16	- 20
20	- 5	- 9	- 20	- 21	- 27	- 19	- 9	- 11	- 6	- 3	- 2	- 6
21	+ 5	+ 3	- 3	- 4	- 9	- 3	+ 7	+ 9	+ 10	+ 5	+ 5	+ 5
22	+ 9	+ 5	+ 8	+ 6	+ 11	+ 11	+ 23	+ 21	+ 16	+ 9	+ 8	+ 8
23	+ 5	+ 5	+ 7	+ 5	+ 10	+ 12	+ 21	+ 18	+ 13	+ 7	+ 4	+ 6

ANEROID NOTEBOOK.

Para. 4.

Table II.—BELGAUM.

Para. 4.]

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+ 8	+ 8	+ 9	+ 7	+ 7	+14	+12	+13	+10	+ 7	+ 7	+10
1	- 8	- 5	- 7	- 9	- 7	+ 2	+ 5	- 4	- 2	- 7	- 7	- 4
2	-16	-20	-19	-18	-17	-10	-19	-17	-16	-19	-20	-20
3	-27	-31	-28	-25	-22	-18	-26	-26	-24	-25	-27	-28
4	-25	-32	-28	-23	-17	-19	-27	-26	-23	-23	-24	-27
5	-13	-19	-15	- 8	- 4	-11	-21	-21	-13	-11	-10	-16
6	+ 4	- 1	+ 5	+ 9	+13	0	- 7	- 8	0	+ 7	+ 8	- 1
7	+26	+25	+29	+33	+33	+13	+ 8	+10	+18	+29	+29	+23
8	+50	+48	+55	+54	+49	+26	+23	+26	+35	+45	+48	+45
9	+67	+64	+68	+62	+57	+33	+38	+37	+45	+57	+60	+58
10	+67	+72	+71	+61	+54	+38	+34	+40	+50	+59	+60	+60
11	+45	+51	+53	+45	+37	+20	+20	+31	+34	+37	+34	+39
12	+16	+22	+21	+22	+13	+ 6	+11	+15	+10	+ 8	0	+ 9
13	-18	- 9	- 7	-10	-12	-10	- 2	- 4	-17	-22	-24	-20
14	-44	-37	-39	-38	-35	-21	-18	-21	-38	-47	-45	-42
15	-59	-55	-60	-59	-53	-37	-28	-35	-52	-60	-57	-55
16	-59	-61	-67	-68	-61	-41	-35	-42	-50	-59	-54	-55
17	-49	-51	-54	-59	-54	-37	-29	-36	-34	-43	-42	-44
18	-30	-36	-40	-43	-37	-25	-19	-24	-25	-27	-24	-37
19	-12	-15	-20	-14	-19	- 7	- 4	- 6	- 6	- 6	- 5	- 3
20	+10	+ 8	+ 4	+ 9	- 3	+ 8	+ 8	+10	+12	+16	+15	+16
21	+24	+23	+22	+22	+17	+ 8	+21	+30	+27	+27	+25	+28
22	+25	+28	+29	+26	+30	+27	+28	+35	+32	+27	+30	+28
23	+15	+18	+20	+17	+21	+25	+22	+27	+24	+18	+21	+19

ANEROID NOTEBOOK.

Table III.—BELLARY.

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETRE. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+ 9	+ 8	+ 9	+10	+10	+22	+22	+22	+22	+14	+12	+13
1	+ 1	0	- 1	0	+ 1	+10	+10	+10	+ 9	+ 1	0	+ 2
2	-12	-12	-12	-12	- 8	0	- 2	+ 1	- 3	-10	-12	-10
3	-20	-22	-19	-19	-13	- 8	-12	-11	-13	-19	-22	-19
4	-22	-24	-22	-19	+11	- 9	-13	-11	-13	-18	-22	-21
5	-10	- 8	- 7	- 4	+ 5	0	- 6	- 1	0	- 6	- 8	- 8
6	+ 9	+ 9	+13	+17	+22	+12	+ 5	+ 9	+14	+14	+11	+ 7
7	+30	+32	+37	+38	+43	+25	+18	+27	+30	+36	+32	+28
8	+54	+54	+66	+60	+62	+39	+32	+44	+50	+55	+52	+52
9	+72	+74	+73	+71	+70	+45	+40	+51	+59	+66	+68	+65
10	+75	+82	+74	+73	+70	+46	+ 4	+50	+58	+67	+68	+70
11	+60	+70	+61	+58	+58	+34	+30	+36	+43	+47	+49	+56
12	+27	+38	+34	+34	+33	+16	+13	+20	+17	+14	+25	+18
13	- 9	+ 5	- 2	+ 5	+ 3	- 6	- 7	- 6	-16	-17	-19	-18
14	-42	-33	-34	-28	-27	-27	-30	-33	-47	-48	-42	-46
15	-63	-53	-58	-57	-52	-49	-43	-55	-69	-67	-64	-63
16	-68	-72	-70	-72	-71	-63	-57	-68	-76	-71	-68	-68
17	-62	-67	-67	-71	-73	-61	-55	-64	-69	-60	-57	-58
18	-43	-54	-59	-60	-63	-51	-41	-51	-53	-45	-41	-43
19	-28	-37	-40	-43	-44	-31	-21	-31	-29	-22	-17	-21
20	- 7	-15	-18	-22	-25	- 4	- 1	- 5	- 3	+ 4	+ 5	+ 3
21	+10	0	0	- 1	- 7	+11	+16	+16	+16	+18	+19	+19
22	+18	+14	+15	+16	+11	+27	+23	-31	+31	+26	+24	+26
23	+16	+16	+17	+17	+16	+29	+30	+30	+30	+23	+20	+22

ANEROID NOTEBOOK.

[Para. 4.]

Table IV.—CHITTAGONG.

Para. 4.]

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.

Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+14	+14	+7	+4	+13	+15	+25	+21	+21	+7	+12	+14
1	+5	+3	-4	-13	-2	+3	+5	+9	+10	-1	+3	+8
2	-5	-8	-17	-25	-16	-9	-8	-7	-5	-8	-5	-1
3	-16	-17	-27	-33	-23	-17	-12	-10	-14	-17	-14	-13
4	-21	-26	-29	-33	-21	-19	-13	-14	-13	-16	-19	-15
5	-19	-20	-19	-18	-6	-17	-13	-10	-9	-7	-10	-8
6	-4	-3	-1	0	+5	+1	0	+2	+1	+11	+6	+1
7	+12	+19	+21	+24	+23	+20	+14	+16	+20	+27	+25	+17
8	+33	+37	+46	+47	+39	+31	+27	+30	+39	+46	+43	+38
9	+55	+58	+63	+61	+52	+36	+36	+40	+50	+60	+59	+53
10	+68	+70	+68	+66	+56	+38	+38	+45	+51	+60	+58	+57
11	+49	+57	+58	+58	+44	+38	+30	+37	+38	+43	+37	+36
12	+20	+31	+37	+43	+31	+18	+16	+22	+18	+17	+11	+8
13	-9	+4	+10	+17	+14	+5	-1	+2	-9	-12	-21	-23
14	-31	-24	-14	-12	-10	-13	-23	-23	-35	-37	-40	-42
15	-47	-51	-38	-31	-34	-31	-35	-43	-55	-51	-52	-51
16	-61	-53	-52	-45	-55	-44	-50	-55	-55	-49	-56	-56
17	-42	-50	-52	-55	-56	-48	-50	-55	-55	-40	-51	-46
18	-31	-41	-47	-47	-45	-40	-39	-44	-41	-24	-15	-17
19	-18	-32	-32	-31	-36	-25	-21	-27	-24	-4	+3	+1
20	-2	-11	-18	-11	-18	-6	-1	-9	0	+9	+17	+16
21	+11	+7	+5	+6	+2	+13	+18	+13	+17	+20	+22	+25
22	+17	+20	+20	+20	+15	+27	+31	+29	+29	+15	+19	+22
23	+18	+17	+13	+16	+21	+24	+34	+29	+26			

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Table V.—CUTTACK.

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+11	+21	+16	+12	+16	+23	+22	+18	+15	+11	+1	+12
1	+4	+5	+5	+2	+9	+8	+10	+5	+6	-1	+21	+3
2	-5	-5	-5	-7	0	-2	+1	-7	-7	-10	-8	+7
3	-13	-15	-14	-15	-6	-10	-8	-14	-16	-16	-16	-14
4	-17	-14	-16	-11	-9	-14	+8	-16	-17	-15	-16	-13
5	-7	-8	-6	0	+2	-7	-4	-10	-8	-9	-6	-2
6	+7	+6	+15	+18	+21	-9	+7	-2	+4	+11	+11	+11
7	+26	+27	+36	+39	+36	+23	+21	+16	+20	+30	+30	+30
8	+49	+49	+55	+58	+48	+33	+29	+31	+37	+45	+45	+51
9	+66	+68	+71	+67	+56	+41	+35	+41	+47	+57	+62	+68
10	+68	+71	+71	+63	+51	+37	+35	+43	+46	+53	+60	+62
11	+49	+53	+51	+47	+36	+26	+29	+31	+34	+34	+37	+42
12	+19	+23	+22	+23	+16	+11	+13	+15	+15	+9	+10	+11
13	-12	-11	-10	-8	-10	-10	-10	-2	-12	-18	+22	-23
14	-44	-41	-44	-40	-37	-30	-28	-25	-33	-39	-42	-46
15	-62	-65	-69	-61	-59	-48	-44	-41	-49	-53	-55	-60
16	-68	-73	-81	-77	-76	-61	-57	-53	-57	-58	-61	-61
17	-58	-66	-73	-73	-69	-55	-48	-48	-51	-46	-50	-51
18	-43	-51	-60	-58	-53	-38	-40	-33	-35	-32	-34	-38
19	-23	-28	-33	-29	-31	-18	-21	-16	-18	-17	-14	-21
20	-1	-3	-6	-6	-11	+1	+1	+3	+5	+3	+3	+1
21	+17	+16	+14	+15	+10	+16	+15	+20	+19	+22	+12	+13
22	+26	+26	+27	+23	+26	+31	+23	+28	+26	+24	+18	+20
23	+20	+24	+22	+22	+23	+29	+27	+23	+25	+18	+16	+17

ANEROID NOTEBOOK.

[Para. 4.]

Table VI.—DEESA.

Para. 4.]

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	- 1	+ 3	- 2	- 5	- 4	+ 5	+ 5	+ 1	+ 5	- 2	+ 3	+ 1
1	-10	- 7	- 8	-12	-10	- 2	- 4	- 4	- 3	-10	- 6	- 7
2	-17	-16	-15	-19	-14	- 6	-11	-14	-12	-16	-14	-12
3	-24	-23	-20	-22	-15	- 9	-17	-20	-19	-20	-21	-22
4	-29	-28	-19	-19	-13	- 7	-24	-22	-18	-22	-21	-22
5	-16	-17	- 4	- 1	+ 9	+ 7	-11	-11	- 2	- 7	- 9	-11
6	+ 2	- 1	+12	+19	+29	+26	+ 6	+ 7	+14	+14	+ 8	+ 8
7	+20	+18	+31	+40	+48	+43	+25	+24	+32	+37	+30	+20
8	+40	+41	+56	+57	+62	+54	+39	+40	+50	+53	+49	+44
9	+65	+60	+69	+70	+68	+58	+47	+50	+58	+66	+63	+62
10	+72	+67	+73	+68	+66	+55	+48	+54	+61	+66	+59	+66
11	+53	+51	+57	+52	+48	+43	+41	+40	+47	+45	+38	+46
12	+23	+29	+31	+29	+28	- 22	+25	+22	+23	+14	+10	+15
13	- 9	- 1	0	- 1	+ 3	- 1	+ 7	+ 3	- 6	-16	-18	-12
14	-35	-29	-27	-27	-22	-23	-13	-15	-32	-37	-39	-35
15	-47	-48	-52	-49	-45	-45	-31	-35	-47	-50	-51	-49
16	-48	-56	-61	-63	-63	-64	-47	-49	-54	-53	-55	-54
17	-43	-50	-54	-58	-62	-66	-50	-49	-52	-46	-46	-45
18	-30	-37	-44	-46	-53	-57	-41	-38	-41	-32	-27	-32
19	-10	-18	-27	-29	-40	-40	-28	-23	-24	-18	-13	-14
20	+ 6	+ 1	-11	-12	-18	-16	- 9	- 7	-10	+ 1	+ 4	+ 1
21	+15	+13	+ 4	+ 2	- 2	+ 2	+ 6	+ 7	+ 8	+12	+17	+13
22	+22	+22	+11	+10	+ 6	+13	+16	+16	+16	+20	+26	+21
23	+10	+14	+ 6	+ 6	+ 2	+11	+14	+12	+13	+11	+18	+13

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Table VII.—GOALPARA.

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+11	+14	+10	+ 3	0	+14	+13	+19	+19	+ 8	+ 9	+11
1	+ 6	+ 8	+ 2	- 6	-11	+ 4	+ 6	+10	+10	+ 1	+ 5	+ 6
2	- 1	- 7	-11	-19	-16	- 9	- 2	0	+ 1	- 8	- 1	+ 1
3	-11	-16	-18	-21	-22	-16	- 9	- 8	- 9	-13	-11	- 7
4	-21	-21	-21	-21	-14	-15	-12	-12	-10	-17	-17	-14
5	-17	-15	-11	- 4	- 4	- 7	- 7	- 5	- 5	-10	-13	-13
6	- 3	+ 4	+12	+19	+18	+12	+ 7	+ 8	+ 9	+ 8	+ 2	+ 2
7	+19	+ 80	+38	+48	+44	+29	+22	+26	+29	+31	+27	+25
8	+46	+53	+66	+68	+63	+42	+37	+42	+47	+54	+52	+50
9	+70	+71	+79	+78	+73	+49	+44	+54	+59	+70	+72	+76
10	+78	+76	+77	+78	+73	+49	+46	+55	+59	+70	+74	+79
11	+55	+60	+64	+66	+62	+45	+37	+45	+50	+56	+55	+60
12	+21	+29	+36	+43	+40	+31	+21	+25	+26	+26	+25	+25
13	-15	- 9	- 1	+11	+17	+ 8	+ 3	+ 1	- 5	- 7	-11	-16
14	-42	-40	-34	-24	-12	-15	-19	-28	-35	-34	-41	-44
15	-58	-61	-57	-50	-39	-39	-42	-49	-56	-53	-57	-62
16	-64	-71	-73	-66	-60	-59	-56	-64	-68	-59	-62	-66
17	-58	-64	-72	-74	-69	-63	-58	-66	-69	-57	-57	-60
18	-42	-51	-62	-64	-67	-55	-50	-57	-58	-50	-47	-47
19	-21	-31	-42	-43	-51	-34	-29	-39	-39	-31	-27	-27
20	- 2	- 8	-15	-26	-30	-16	- 8	-13	-13	- 9	- 9	-11
21	+11	+10	+ 4	- 8	- 8	+ 5	+14	+12	+10	+ 8	+ 6	+ 5
22	+16	+18	+15	0	+ 7	+20	+26	+23	+21	+13	+12	+15
23	+16	+18	+12	+ 6	+ 8	+21	+23	+23	+25	+14	+15	+16

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[Para. 4.]

Table VIII.—HAZARIBAGH.

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETRE. FEET.

Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hs.												
0	+ 4	+ 8	+ 8	+ 5	+ 4	+ 11	+ 14	+ 14	+ 14	+ 5	+ 2	+ 8
1	0	+ 2	- 3	- 5	- 6	+ 3	+ 4	+ 3	+ 3	- 3	- 5	+ 1
2	- 7	- 9	- 12	- 5	- 14	- 5	- 6	- 5	- 3	- 11	- 12	- 7
3	- 15	- 18	- 22	- 22	- 19	- 12	- 15	- 14	- 18	- 17	- 9	- 15
4	- 22	- 26	- 26	- 22	- 18	- 15	- 18	- 16	- 16	- 22	- 22	- 20
5	- 22	- 25	- 19	- 14	- 11	- 9	- 14	- 14	- 11	- 17	- 19	- 20
6	- 12	- 14	- 5	+ 3	+ 6	+ 5	- 3	- 2	+ 1	- 3	- 9	- 11
7	+ 6	+ 9	+ 17	+ 24	+ 24	+ 19	+ 12	+ 13	+ 20	+ 17	+ 11	+ 6
8	+ 28	+ 30	+ 39	+ 41	+ 39	+ 31	+ 23	+ 27	+ 36	+ 33	+ 31	+ 27
9	+ 51	+ 48	+ 55	+ 54	+ 48	+ 37	+ 31	+ 39	+ 47	+ 52	+ 50	+ 50
10	+ 59	+ 60	+ 59	+ 57	+ 52	+ 39	+ 35	+ 44	+ 49	+ 58	+ 58	+ 53
11	+ 48	+ 54	+ 53	+ 51	+ 44	+ 33	+ 32	+ 37	+ 43	+ 45	+ 46	+ 48
12	+ 26	+ 35	+ 37	+ 36	+ 33	+ 22	+ 22	+ 25	+ 28	+ 26	+ 27	+ 26
13	0	- 9	+ 12	+ 14	+ 11	+ 4	+ 7	+ 5	+ 2	+ 1	0	- 3
14	- 22	- 17	- 15	- 11	- 10	- 15	- 11	- 17	- 25	- 20	- 21	- 23
15	- 36	- 35	- 37	- 34	- 29	- 33	- 30	- 35	- 44	- 35	- 36	- 36
16	- 41	- 43	- 46	- 50	- 46	- 45	- 40	- 49	- 53	- 41	- 42	- 40
17	- 37	- 41	- 54	- 54	- 56	- 46	- 44	- 50	- 50	- 37	- 38	- 36
18	- 28	- 33	- 42	- 49	- 48	- 39	- 38	- 42	- 40	- 32	- 30	- 28
19	- 15	- 23	- 28	- 37	- 33	- 26	- 25	- 28	- 25	- 19	- 16	- 15
20	0	- 6	- 10	- 17	- 13	- 9	- 2	- 5	- 5	- 2	- 1	- 2
21	+ 9	+ 6	+ 5	0	+ 6	+ 6	+ 11	+ 14	+ 14	+ 9	+ 8	+ 8
22	+ 13	+ 14	+ 14	+ 13	+ 16	+ 19	+ 23	+ 24	+ 22	+ 14	+ 12	+ 16
23	+ 12	+ 13	+ 13	+ 12	+ 14	+ 18	+ 22	+ 22	+ 19	+ 11	+ 10	+ 14

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Table IX.—PACHMARHI.

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+ 5	+ 4	+ 5	0	+ 2	+ 9	+ 7	+ 4	+10	+ 2	+ 1	+ 2
1	- 5	- 7	- 9	-11	- 8	- 2	- 1	- 6	- 3	- 8	- 9	- 6
2	-14	-19	-20	-21	-16	-11	-11	-15	-14	-19	-20	-15
3	-25	-29	-28	-28	-18	-17	-19	-23	-22	-26	-27	-24
4	-29	-33	-29	-26	-15	-17	-19	-22	-25	-29	-28	-30
5	-24	-26	-20	-14	- 5	- 9	-13	-14	-16	-18	-22	-22
6	-12	-12	- 6	- 1	+ 7	+ 4	- 3	- 3	- 5	- 4	- 8	-10
7	+ 3	+ 8	+11	+18	+23	+17	+10	+10	+11	+14	+10	+ 5
8	+22	+26	+33	+35	+35	+27	+21	+24	+26	+29	+28	+24
9	+43	+44	+50	+49	+46	+36	+30	+34	+33	+43	+45	+44
10	+57	+59	+57	+55	+50	+40	+38	+41	+45	+51	+53	+53
11	+44	+52	+50	+48	+44	+35	+33	+38	+39	+38	+41	+39
12	+24	+30	+32	+34	+32	+24	+23	+26	+28	+18	+21	+18
13	- 3	+ 5	7	+13	+13	+ 6	+ 9	+ 9	+ 3	3	5	6
14	-24	-17	-16	-10	- 9	-13	- 8	- 9	-18	-22	-25	-25
15	-34	-32	-33	-29	-28	-29	-22	-25	-35	-32	-34	-36
16	-38	-38	-43	-43	-45	-43	-37	-37	-43	-36	-37	-37
17	-30	-34	-40	-42	-43	-44	-37	-35	-38	-31	-31	-28
18	-18	-21	-29	-32	-37	-36	-29	-25	-27	-19	-20	-15
19	- 4	- 9	-17	-19	-23	-22	-16	-13	- 9	- 7	- 2	- 2
20	+10	+ 4	- 1	6	-10	- 6	- 3	- 1	+ 6	+ 9	+13	+12
21	+20	+15	+13	+ 6	+ 1	+ 7	+ 9	+15	+19	+17	+20	+19
22	+22	+20	+18	+16	+10	+15	+21	+21	+25	+19	+19	+19
23	+15	+14	+13	+10	+ 9	+16	+15	+14	+13	+10	+12	+13

Table X.—POONA.

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+ 10	+ 14	+ 15	+ 7	+ 12	+ 18	+ 12	+ 9	+ 12	+ 10	+ 5	+ 12
1	— 1	+ 2	— 1	— 3	+ 2	+ 5	— 3	— 0	— 2	— 1	— 7	+ 1
2	— 13	— 12	— 13	— 15	— 8	— 10	— 18	— 16	— 15	— 13	— 13	— 13
3	— 21	— 19	— 22	— 18	— 15	— 14	— 27	— 21	— 21	— 17	— 16	— 22
4	— 17	— 19	— 18	— 14	— 10	— 15	— 30	— 24	— 21	— 14	— 10	— 17
5	— 7	— 14	— 5	— 1	— 2	— 10	— 22	— 12	— 12	— 4	+ 1	— 7
6	+ 11	+ 8	+ 16	+ 18	+ 17	+ 5	— 10	— 13	+ 1	+ 16	+ 21	+ 9
7	+ 32	+ 33	+ 40	+ 40	+ 34	+ 21	+ 7	+ 11	+ 21	+ 35	+ 45	+ 32
8	+ 58	+ 57	+ 63	+ 58	+ 49	+ 30	+ 20	+ 28	+ 40	+ 53	+ 62	+ 57
9	+ 75	+ 72	+ 73	+ 67	+ 53	+ 35	+ 30	+ 35	+ 46	+ 63	+ 74	+ 69
10	+ 71	+ 74	+ 71	+ 59	+ 48	+ 32	+ 33	+ 38	+ 47	+ 57	+ 66	+ 63
11	+ 47	+ 53	— 51	+ 38	+ 31	+ 22	+ 28	+ 27	+ 32	+ 33	+ 41	+ 41
12	+ 11	+ 19	+ 22	+ 14	+ 10	+ 8	+ 16	+ 15	+ 8	+ 3	+ 7	+ 9
13	— 24	— 13	— 15	— 17	— 18	— 10	+ 2	— 1	— 21	— 24	— 25	— 27
14	— 52	— 46	— 47	— 44	— 41	— 28	— 13	— 19	— 43	— 53	— 51	— 51
15	— 66	— 68	— 68	— 67	— 56	— 42	— 24	— 33	— 55	— 67	— 68	— 64
16	— 67	— 73	— 76	— 70	— 64	— 49	— 32	— 41	— 54	— 63	— 67	— 63
17	— 57	— 66	— 71	— 62	— 57	— 46	— 32	— 38	— 44	— 50	— 57	— 53
18	— 39	— 52	— 53	— 44	— 39	— 28	— 23	— 25	— 26	— 33	— 41	— 39
19	— 15	— 28	— 27	— 20	— 21	— 12	— 6	— 8	— 1	— 9	— 18	— 16
20	+ 4	0	— 1	0	0	+ 7	+ 9	+ 11	+ 16	+ 11	+ 5	+ 6
21	+ 20	+ 20	+ 18	+ 16	+ 17	+ 21	+ 21	+ 20	+ 29	+ 26	+ 18	+ 21
22	+ 25	+ 29	+ 27	+ 26	+ 24	+ 32	+ 30	+ 30	+ 29	+ 25	+ 19	+ 24
23	+ 16	+ 23	+ 24	+ 20	+ 24	+ 31	+ 24	+ 22	+ 22	+ 18	+ 14	+ 17

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Table XI.—RANGOON.

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+13	+11	+15	+12	+12	+17	+15	+20	+18	+18	+15	+16
1	+9	0	5	+4	1	+3	+5	+7	+6	+4	+3	+5
2	6	12	18	0	15	8	7	3	7	5	5	6
3	19	20	16	7	20	14	14	15	17	14	13	16
4	18	23	13	5	20	20	17	18	20	13	14	16
5	9	11	6	4	10	19	13	18	12	6	9	11
6	+5	+6	+15	+21	+6	5	3	5	+3	+14	+4	+5
7	+24	+33	+39	+44	+29	+16	+15	+13	+19	+33	+22	+27
8	+51	+50	+65	+66	+47	+32	+32	+29	+40	+51	+42	+53
9	+66	+72	+73	+73	+53	+40	+42	+40	+54	+61	+57	+67
10	+66	+77	+74	+73	+55	+37	+41	+42	+55	+62	+59	+69
11	+45	+55	+57	+58	+43	+29	+31	+35	+41	+43	+36	+45
12	+17	+24	+29	+31	+21	+14	+16	+18	+22	+14	+9	+9
13	19	6	3	8	3	2	1	4	6	18	23	27
14	42	35	35	39	24	19	18	22	30	45	47	49
15	63	58	65	63	48	36	36	39	48	65	61	63
16	54	67	76	76	61	49	53	49	60	66	60	62
17	52	60	70	81	62	45	49	48	57	59	49	51
18	36	47	52	66	49	36	41	39	45	41	29	36
19	20	28	37	45	23	19	20	22	22	23	11	13
20	3	7	17	18	+1	+7	3	1	1	2	+8	+5
21	+18	+6	+8	+3	+17	+24	+16	+19	+21	+15	+16	+18
22	+18	+17	+17	+17	+25	+30	+30	+29	+29	+22	+21	+21
23	+16	+18	+19	+19	+23	+30	+26	+26	+27	+20	+21	+22

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[Para. 4.

Table XII.—SIMLA.

Para. 4.]

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+ 3	+ 5	+ 5	+ 5	+ 1	- 3	+ 5	+ 9	+ 4	0	+ 1	- 1
1	- 3	- 1	- 3	- 7	- 11	- 7	+ 2	- 1	- 8	- 9	- 5	- 7
2	- 7	- 9	- 13	- 17	- 19	- 15	- 6	- 9	- 15	- 16	- 13	- 13
3	- 15	- 19	- 24	- 26	- 25	- 20	- 13	- 15	- 20	- 23	- 19	- 19
4	- 22	- 25	- 31	- 29	- 25	- 20	- 16	- 17	- 21	- 25	- 23	- 25
5	- 23	- 27	- 29	- 27	- 19	- 15	- 13	- 15	- 17	- 22	- 22	- 27
6	- 20	- 21	- 23	- 18	- 9	- 7	- 6	- 9	- 8	- 15	- 14	- 19
7	- 11	- 10	- 11	- 5	+ 5	+ 3	+ 3	+ 1	+ 3	- 3	+ 1	- 7
8	+ 6	+ 5	+ 4	+ 10	+ 17	+ 14	+ 13	+ 11	+ 17	+ 13	+ 17	+ 10
9	+ 24	+ 21	+ 19	+ 23	+ 26	+ 23	+ 19	+ 19	+ 27	+ 26	+ 29	+ 28
10	+ 34	+ 32	+ 28	+ 31	+ 32	+ 27	+ 24	+ 25	+ 33	+ 32	+ 35	+ 38
11	+ 33	+ 35	+ 31	+ 33	+ 33	+ 29	+ 25	+ 25	+ 33	+ 29	+ 31	+ 35
12	+ 21	+ 27	+ 26	+ 27	+ 30	+ 25	+ 20	+ 21	+ 27	+ 19	+ 17	+ 22
13	+ 5	+ 13	+ 14	+ 19	+ 22	+ 18	+ 13	+ 11	+ 17	+ 6	+ 3	+ 3
14	- 6	+ 1	+ 1	+ 5	+ 11	+ 9	+ 2	0	+ 3	- 5	- 7	- 7
15	- 12	- 11	- 9	- 7	- 3	- 2	- 9	- 11	- 9	- 13	- 13	- 13
16	- 15	- 15	- 15	- 15	- 13	- 13	- 20	- 20	- 15	- 15	- 16	- 14
17	- 14	- 15	- 15	- 17	- 19	- 19	- 27	- 23	- 16	- 13	- 15	- 15
18	- 9	- 11	- 11	- 15	- 18	- 17	- 25	- 21	- 14	- 8	- 10	- 9
19	- 3	- 5	- 3	- 7	- 12	- 13	- 16	- 13	- 7	- 1	- 3	- 1
20	+ 3	+ 3	+ 7	+ 4	- 4	- 6	- 7	- 1	+ 1	+ 7	+ 3	+ 6
21	+ 9	+ 9	+ 13	+ 11	+ 3	+ 1	+ 3	+ 8	+ 7	+ 11	+ 7	+ 11
22	+ 11	+ 11	+ 16	+ 13	+ 5	+ 6	+ 11	+ 13	+ 9	+ 11	+ 9	+ 13
23	+ 9	+ 9	+ 13	+ 10	+ 1	+ 6	+ 13	+ 14	+ 7	+ 7	+ 5	+ 9

ANEROID NOTEBOOK

Table XIII.—TRICHINOPOLY.

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+18	+25	+24	+24	+23	+26	+25	+27	+26	+22	+18	+17
1	+4	+3	+9	+10	+9	+12	+11	+16	+13	+5	+1	+2
2	-10	-10	-5	-2	-4	0	-2	+1	0	0	-13	+1
3	-22	-20	-14	-10	-13	-10	-11	-8	-10	-19	-23	-25
4	-29	-26	-20	-18	-21	-17	-20	-15	-17	-25	-31	-34
5	-14	-12	-5	-2	-6	-2	-4	+1	-1	-12	-16	-20
6	+2	+6	+13	+11	+9	+11	+9	+12	+13	+7	-2	-3
7	+21	+29	+37	+30	+30	+28	+27	+31	+31	+31	+22	+15
8	+48	+50	+56	+52	+47	+40	+37	+45	+49	+49	+43	+38
9	+61	+67	+70	+64	+55	+47	+45	+52	+57	+60	+54	+53
10	+67	+73	+74	+67	+58	+50	+49	+56	+60	+65	+58	+59
11	+45	+53	+52	+44	+37	+27	+28	+36	+38	+38	+35	+39
12	+18	+23	+24	+21	+12	+5	+7	+9	+7	+7	+7	+14
13	-12	-9	-12	-12	-19	-18	-15	-21	-27	-24	-21	-14
14	-43	-43	-45	-42	-44	-42	-39	-48	-55	-54	-46	-38
15	-62	-70	-72	-69	-67	-60	-59	-70	-74	-70	-62	-53
16	-73	-81	-85	-84	-82	-74	-72	-84	-85	-76	-67	-60
17	-57	-72	-76	-74	-71	-62	-62	-71	-72	-59	-51	-47
18	-42	-58	-62	-59	-54	-45	-45	-52	-51	-39	-33	-32
19	-19	-33	-39	-32	-25	-24	-21	-26	-23	-13	-8	-10
20	+6	+3	-9	+3	+5	+4	+5	+2	+2	+15	+17	+14
21	+27	+22	+20	+23	+29	+23	+25	+26	+31	+33	+34	+32
22	+40	+41	+42	+44	+45	+40	+40	+48	+50	+45	+44	+42
23	+29	+36	+33	+28	+35	+31	+31	+36	+38	+33	+32	+30

Table XIV.—TRIVANDRUM.

Para. 4.]

CORRECTION TO BE APPLIED TO DETERMINATION OF HEIGHT BY BAROMETER. FEET.												
Local time.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Hrs.												
0	+ 19	+ 21	+ 19	+ 23	+ 19	+ 19	+ 22	+ 21	+ 21	+ 15	+ 13	+ 16
1	+ 1	0	0	0	0	0	+ 4	+ 4	+ 3	- 7	- 8	- 1
2	- 18	- 18	- 18	- 16	- 16	- 14	- 11	- 12	- 14	- 22	- 24	- 18
3	- 29	- 28	- 27	- 23	- 25	- 23	- 20	- 20	- 19	- 28	- 33	- 27
4	- 28	- 28	- 25	- 20	- 24	- 24	- 21	- 19	- 17	- 26	- 29	- 24
5	- 19	- 17	- 16	- 10	- 15	- 15	- 14	- 11	- 8	- 15	- 16	- 12
6	- 3	+ 1	+ 4	+ 5	- 1	- 3	- 3	- 1	+ 3	+ 3	+ 3	+ 6
7	+ 21	+ 25	+ 27	+ 23	+ 19	+ 14	+ 13	+ 15	+ 33	+ 25	+ 26	+ 26
8	+ 43	+ 50	+ 49	+ 47	+ 38	+ 28	+ 27	+ 32	+ 42	+ 44	+ 49	+ 49
9	+ 53	+ 65	+ 60	+ 56	+ 47	+ 39	+ 35	+ 39	+ 50	+ 53	+ 55	+ 56
10	+ 52	+ 60	+ 56	+ 51	+ 42	+ 37	+ 31	+ 36	+ 43	+ 47	+ 49	+ 49
11	+ 35	+ 38	+ 36	+ 35	+ 28	+ 25	+ 20	+ 24	+ 25	+ 25	+ 28	+ 23
12	+ 8	+ 7	+ 7	+ 9	+ 8	+ 8	+ 4	+ 4	- 1	- 3	- 1	0
13	- 22	- 23	- 24	- 22	- 15	- 12	- 15	- 22	- 27	- 29	- 29	- 31
14	- 50	- 51	- 49	- 47	- 37	- 30	- 32	- 41	- 50	- 52	- 53	- 54
15	- 63	- 65	- 64	- 63	- 54	- 48	- 48	- 55	- 63	- 63	- 62	- 64
16	- 61	- 64	- 66	- 69	- 55	- 50	- 53	- 59	- 65	- 57	- 55	- 59
17	- 48	- 52	- 55	- 57	- 45	- 42	- 43	- 46	- 51	- 41	- 39	- 44
18	- 27	- 34	- 34	- 33	- 27	- 24	- 23	- 24	- 28	- 19	- 16	- 21
19	- 5	- 11	- 10	- 8	- 6	- 2	- 3	- 2	- 4	+ 5	+ 7	+ 1
20	+ 20	+ 14	+ 16	+ 12	+ 14	+ 16	+ 18	+ 19	+ 19	+ 28	+ 29	+ 24
21	+ 38	+ 34	+ 33	+ 31	+ 32	+ 31	+ 33	+ 36	+ 36	+ 42	+ 41	+ 36
22	+ 41	+ 41	+ 42	+ 40	+ 39	+ 37	+ 39	+ 44	+ 45	+ 43	+ 38	+ 37
23	+ 34	+ 35	+ 37	+ 34	+ 33	+ 34	+ 38	+ 39	+ 38	+ 33	+ 27	+ 28

ANEROID NOTEBOOK.

Air temperature correction.—After applying these corrections the apparent differences of level must be multiplied by a factor *K* depending on the temperatures of the air at the two stations. A table of values of *K* for various values of *T + t* in Fahrenheit degrees is also given in Molesworth's "Pocket Book," and reprinted here.

Table XV.

TABLE SHOWING VALUES OF *K*.*T + t in Fahrenheit.*

<i>T+t</i>	<i>K.</i>	<i>T+t.</i>	<i>K.</i>	<i>T+t.</i>	<i>K.</i>	<i>T+t.</i>	<i>K.</i>	<i>T+t.</i>	<i>K.</i>
0		0		0		0		0	
40	.973	70	1.007	100	1.040	130	1.073	160	1.106
42	.976	72	1.009	102	1.042	132	1.076	162	1.108
44	.978	74	1.011	104	1.044	134	1.078	164	1.111
46	.980	76	1.013	106	1.047	136	1.080	166	1.113
48	.982	78	1.016	108	1.049	138	1.082	168	1.115
50	.984	80	1.018	110	1.051	140	1.084	170	1.117
52	.987	82	1.020	112	1.053	142	1.087	172	1.120
54	.989	84	1.022	114	1.056	144	1.089	174	1.122
56	.991	86	1.024	116	1.058	146	1.091	176	1.124
58	.993	88	1.027	118	1.060	148	1.093	178	1.126
60	.996	90	1.029	120	1.062	150	1.096	180	1.129
62	.998	92	1.031	122	1.064	152	1.098	182	1.131
64	1.000	94	1.033	124	1.067	154	1.100	184	1.133
66	1.002	96	1.036	126	1.069	156	1.102	186	1.135
68	1.004	98	1.038	128	1.071	158	1.104	188	1.137

In the absence of a thermometer (which however is very necessary) *K* may be taken as from 1.10 in the cold weather in the plains up to 1.14 in the hot weather; while in the hills it will generally vary between 1.08 and 1.10.

Method of recording.—Two examples will illustrate the method and serve as a peg for further advice; also to show the form of note book which may advantageously be used for this work. The following table illustrates a not uncommon case in difficult country where it is required

from a good forebay site to determine approximately where the head-works of the feeding channel would be. It may in such cases be necessary to make a long detour to traverse the route, and ordinary levelling would take much longer than determination by aneroid.

Table XVI.

Date.	Hour.	Station.	Locality.	Temp.	Bar.	Diurnal cor- rection to Zero.	Corrected height.	Difference Rise or Fall.	K.	Final result. Ft.	
<i>Aneroid 89.</i>											
17th October	6	I	Forebay . .	63	6240	-25	6215	} R. 15	1'073	6	
"	9	II	Head-works .	68	6190	+40	6230		} F. 13	1'091	14
"	16	I	Forebay . .	77	6267	-50	6217				
										Mean.	15
<i>Aneroid 92.</i>											
17th October	6	I	Forebay . .	62	6365	-25	6340	} R. 23	1'073	24	
"	9	II	Head-works .	68	6323	+40	6363		} F. 14	1'091	15
"	16	I	Forebay . .	78	6398	-50	6348				
										Mean	19½

It will be observed that the site which in the reduced readings is the lower one appears in all the original readings to be at the higher elevation, the diurnal correction (from Molesworth) being greater than the difference of height. Giving less weight to the abnormal 2½ feet the actual difference of height may be taken as fairly close to 17 feet provided the actual diurnal variation followed the curve. But this may easily have had a less amplitude by 10 or 15 feet, so the final results are far less certain than they appear. At the same time the general indication will suffice in reconnaissance. The anomaly shows the necessity, where small differences of level are involved, of allowing as short an interval as possible to elapse between the readings and of taking them (if possible) at the times when the variation is least. Thus, in the case of a small fall, a series of readings up and down between 15:30 and 16:30 or between 9 and 10 hours would generally give really accurate results on reduction.

The final table relates to points on a considerable fall, and here the percentage error due to the curve being incorrect is minimized; on the other hand, there is a greater chance of errors due to jars on the road. The corrections for diurnal are taken here from Molesworth, and are considerably too great.

Table XVII.

Date.	Hour.	Station.	Locality.	Temp.	Reading ft.	Diurnal correction to zero.	Corrected height.	Rise or Fall.	K.	Final result. Ft.	Probable reduce level.
<i>Aneroid 18.</i>											
19th October	8:30	I	Bahli	60	8,550	+30	8,580	} 2,365	1'078	2,540	*8,100
"	10:45	II	Tacklech	70	6,160	+55	6,215		} 1,720	1'108	1,906	5,560
"	15:30	III	Kakrola	82	4,620	-25	4,495	} 275		1'135	312	3,654
"	17:0	IV	Bridge	84	4,260	-30	4,220				
Total drop										4,758	

*Datum.

If in this case no intermediate readings had been taken it will be found that between stations I and IV the corrected difference comes to 4,800 instead of 4,758. The use of a single instrument, and the fact that the difference was measured only once (downhill) gives room for much greater doubt than anything in the diurnal correction. In this case the starting elevation was known to be 8,100 feet and the finish about 3,300 feet, so the actual drop of 4,800 feet agrees fairly well with the readings and the intermediate readings will be moderately accurate.

One correction, however, has still to be dealt with. The temperature correction shown above is for the varying density of the air, but there is generally also differential expansion, not fully compensated for, in the metal work of each instrument. In all the above 3 surveying aneroids half an hour in the sun caused a definite rise (after allowing for the diurnal variation and air temperature by means of a shaded control instrument) of about 60 feet, after which further heating caused the rising curve to turn over and descend again. It follows that unless the instruments are carried in well lagged cases, or left to settle down in the shade for a considerable time before each reading, errors will creep in which are peculiar to the particular instrument and can only be corrected for when its individuality is known. These errors will be greatest in intermediate readings and will hardly effect terminal results when there is time for the case to settle down before beginning and after finishing the day's work.

In the case given in Table XVII work was begun in the cool of the morning and the journey was made in the sun. Therefore, while actually dropping down all the time, the readings of the instrument in feet tended to rise from the heaving up. The drops shown are therefore less than they should have been. It is probable that some 10 feet extra drop should be allowed to Station II, 30 feet to Station III, and 60 feet to Station 4 where the instrument had no time to cool down. Making this allowance it is probable that the computed elevations are

within 30 feet or so of the actual reduced levels. The computed values are as follows:—

Station I datum 8,100.

Station II Drop 2,540. Extra for heating 10 feet. Elevation 5,550 feet.

Station III Drop 1,906. Extra for heating $30-10=20$ feet. Elevation 3,624 feet.

Station IV Drop 312. Extra for heating $60-30=30$ feet. Elevation 3,282 feet.

Where the readings are taken without an appreciable change in the temperature of the instruments no such correction is required. If the instrument is warmed up as the reader rises in altitude the estimated correction must obviously be deducted instead of added, assuming that the heating error is of the same nature as in the instruments here used.

[Form for recording readings; P. T. O.]

Reference was made in the Preliminary Report (page 12) to the lack of correct compensation in aneroids. Further trials confirmed the fact that errors of 60 and 70 feet are common from this cause. Correspondence with the makers through the Mathematical Instrument Office in Calcutta elicited no information of any value, and the Director of the National Physical Laboratory has now been addressed. It has been ascertained that in certifying certain aneroids now in use the National Physical Laboratory did not test the compensation, the fact being stated on the certificate.

Corrected reading.	Rise or fall.	K for temperature.	Corrected rise or fall.	Correction for instrument.	Final rise or fall.	Probable reduced level.

5. Instruments.—Although comparatively few of the sites enumerated in the Preliminary Report have been “proved” sufficiently to warrant survey, yet, had this been so, lack of instruments would have prevented it. The late Mr. Barlow wished to have a particular type of level, embodying certain recent improvements, and he accordingly ordered levels of that type through the usual channel. These levels have not as yet arrived, and it has been ascertained that exception was taken to the order of instruments from a particular maker with the result that the order was placed elsewhere. Whether the improvements will be incorporated in these instruments remains to be seen.

As regards the tacheometric plane tables ordered in 1918, delay was experienced owing to the fact that priority was withheld, without the cognizance of the Chief Engineer. The instruments were to have been shipped in February 1920, so are too late in any case for this season’s work. One or two were however obtained in India.

Nine aneroids, ordered in 1918, were received early in the season and distributed. Those subsequently ordered have not arrived at the time of writing this Report. It has been found however that a number of suitable aneroids, certified by the National Physical Laboratory, could be obtained by local purchase and several were so obtained. The machinery for ascertaining how urgent requirements can be met in India itself appears to be in need of overhaul.

Twelve self-recording gauges, giving a six months’ graph of water level without attention, have been received and distributed. British manufacturers, whose similar instruments in all cases require frequent winding up of the clock work, have been addressed on the subject. A long running period is essential for rivers which are practically inaccessible for months on end. A useful feature of the gauges obtained is that if the needle should reach the limit of its travel it automatically retraces its steps; and this cannot be mistaken for a sudden fall in level.

A self-recording rain gauge (as distinct from a tank gauge giving merely the total rain fall) is greatly needed for many places where no reader can be found. A record over at least four and preferably six months is desirable; and there should be no great difficulty in designing such an instrument. Automatic instruments to show the changing intensity of a fall are also required.

6. Fuel consumption in power houses.—In paras. 16 to 18 of the Preliminary Report the question of fuel consumption in relation to the cost of power was discussed. Enquiries have since been received on the subject and two curves are now reproduced from the report of the Hydro-electric Power Commission of Ontario to illustrate the matter. Fig. xvi shows, according to the capacity of the station, the average number of pounds of coal used per horse-power hour, in America; the horse-power hours obtained per 100,000 British Thermal Units; and the load factors of the particular plants from which these curves were derived. Fig. xvii shows the number of pounds of coal consumed per unit (kilowatt hour) according to size of the plant and the load factor, based also on American data.

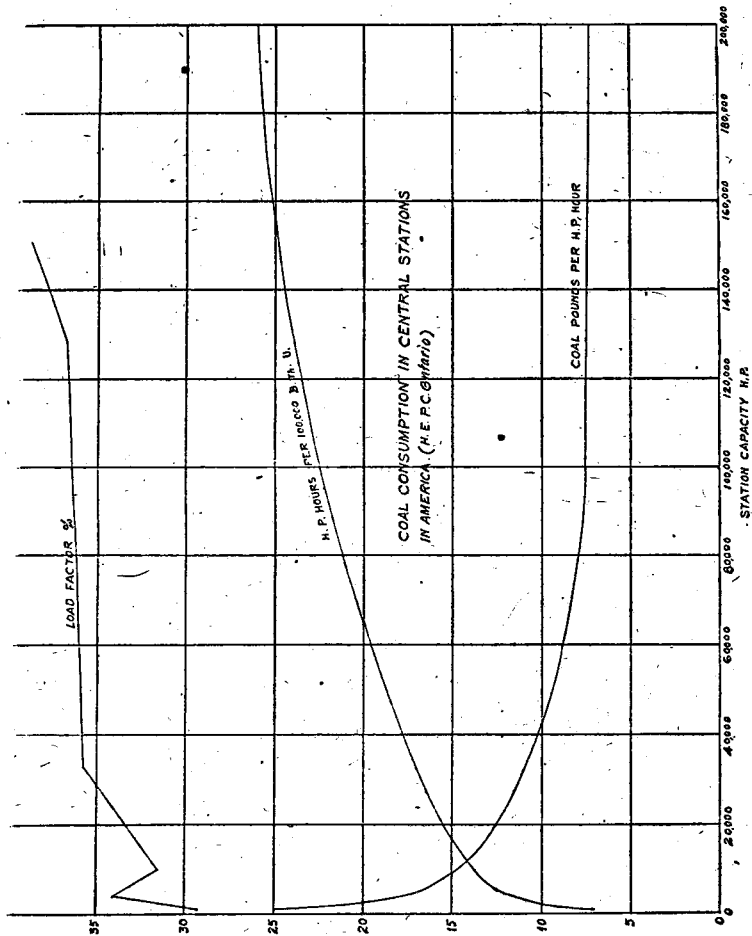
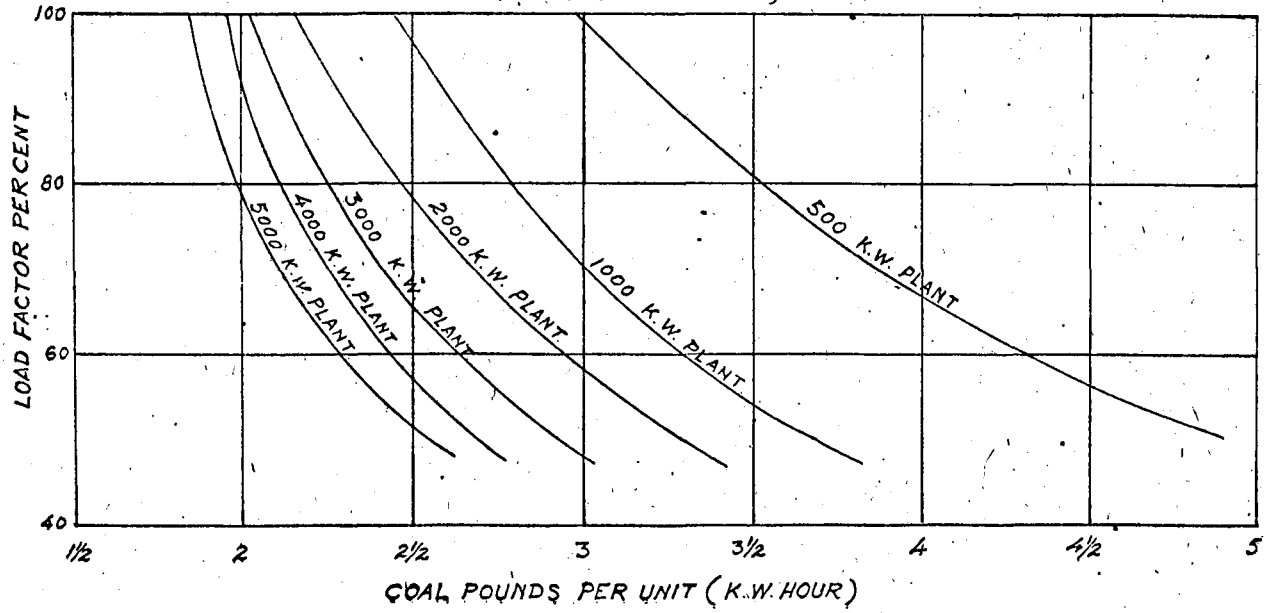


Fig. xvi. Coal consumption in Central Stations in America.

COAL CONSUMPTION PER UNIT ACCORDING TO PLANT SIZE &
LOAD FACTOR.
(H. E. P. C. Ontario —)



FUEL CONSUMPTION

Para. 6.

PART II.—ADMINISTRATIVE MATTERS.

7. Recommendations in Preliminary Report.—Attention may again be drawn to the following matters which require detailed investigation ; the few officers employed on the Survey cannot undertake these duties without neglecting their immediate work of reconnaissance.

(a) *Census of Power.*—(Preliminary Report, para. 31.) A memorandum was sent to all Chief Engineers and all Directors of Industry in December 1919, explaining what is needed and how it may be obtained. Results are awaited.

(b) *Rainfall records.*—(Preliminary Report, para. 32.) So far as is known no action has been taken on this very important recommendation ; nor is it clear by what agency it can best be undertaken. Technical knowledge is required, but the Meteorological Department has no spare staff for such work.

(c) *Discharges and run-off.*—(Preliminary Report, para. 33.) In the United States the Geological Department has long been engaged on examining the discharges and run-offs of rivers and technical works state that the conditions are known for practically every river in the country. In India the Irrigation Branch has data regarding the rivers which are used, or likely to be used, for irrigation canals ; but no information whatever exists as regards the greater part of the immense number of rivers and streams, even in accessible places.

(d) *Training in hydro-electric work.*—(Preliminary Report, para. 36.) The question of special classes or special lectures on the subject of hydro-electric work was taken up by the Government of India and proposals for meeting the suggestion made have been circulated by them to certain local Governments and Administrations. The employment of special lecturers to third year students at Engineering Colleges has been recommended, and a grant made for the purpose.

8. Form of Lease or Concession.—Reference was made in Chapter V of the Preliminary Report to the general question of the control of water power, and in para. 21 the need of a definite policy in the matter of leases was urged. A considerable number of applications have been received, and in several cases concessions have been given by the Local Governments concerned ; but in more than one case attention having been called to an obvious site, generally in the neighbourhood of some hill station, which might or might not in the end prove capable of economic development, before full investigation has been made either by any competent authority or by the would be concessionaire an application is put in for the exclusive use of the water power : the intention (generally apparent and often admitted) is to sell the concession so obtained to the highest bidder, so that if the work is ultimately taken in hand the consumer will for all time be handicapped by the watered capital due to the bonus paid to the original discoverer of the site. A glaring instance of this was encountered during the reconnaissances made this cold weather. This is obviously altogether contrary to the public interest ; where the site is remote and

inaccessible and money has been actually spent in investigating its possibilities it is a different matter.

The questions referred to in Chapter V are now being considered by the Government of India who will consult Local Governments and Administrations at an early date.

The following paragraphs deal with one difficult aspect of the question in relation to works owned or worked by Government, and to some extent the remarks may also apply to company run concerns.

9. State control of water power.—In the Preliminary Report (para. 19, *et seq.*), the question of the control of water power was tentatively examined, but no definite opinion was expressed as to the method which would prove of the greatest advantage to India. The investigation has not yet reached the stage where a definite policy can be proposed; at various times however during the past season enquiries have been made as to the possibility of combining State and Company ownership. Hitherto as is well known there has been a tendency for local bodies to wait until companies applied for electrical licenses before themselves applying and opposing the applicant; being afraid on the one hand of incurring a loss and apprehensive on the other hand of the licensee making a profit. A Bill proposing to give the local authority, the prior right to a license where the project has been investigated by an outside promoter has lately been before the Imperial Legislative Council. Here a constructive suggestion may be put forward from German practice. "In Germany, before the war, not a few of the great municipalities entrusted the management of undertakings of public utility, gas, water, electric light, tramways and so forth, to a Company in which the municipality held shares sufficient to make it an important if not a predominant shareholder. The system is understood to have worked satisfactorily. The public authority protects the public and gives the company the benefit of its superior credit, while at the same time the benefits of private enterprise are preserved."* The article here drawn on is on the subject of railway nationalization, but the proposal appears to contain the germ of a principle of very wide application. The writer goes on to point out that (as in Canada) the business could be managed by a Board of business directors, but, in the case of undertakings so combining State or municipal with Company ownership, the Board would, consist partly of official nominees and partly of representatives of shareholders. The private shareholders would then receive some agreed proportion of the net profits above their guaranteed net income, as already suggested in the Preliminary Report.

10. Accounts of undertakings belonging to Government.—There is a general consensus of opinion, both lay and technical, that it is both impolitic and impracticable to attempt to run a Government hydro-electric project on the accounts systems of the Civil Accounts Code. There are no doubt many excellent reasons why the various Codes are necessary for the ordinary run of Government work, including such quasi-commercial undertakings as irrigation works. An electrical undertaking however is on a very different footing and it is submitted that its accounts (at any rate after construction is completed) should be kept on

* Quarterly Review No. 460, July 1919, p. 174.

strictly business lines, by commercial accountants, and subject to commercial audit by a Chartered Accountant. At that stage it will doubtless be possible for the Accountant-General to take the audited accounts and pass them into the Provincial accounts in any form he thinks fit. It has been suggested by the Director of Industries, United Provinces, that the best way to compass this end would be to place the management of such a concern in the hands of a responsible firm of Managing Agents, who would deal with the concern precisely as though it were a limited liability company under their charge, subject to the decisions of a Board of Directors in which Government would have the deciding voice. No doubt grave objections will be raised to any such procedure, but it seems essential if such undertakings are to be run on sound lines; and new departures require new methods. To take only one instance, a scheme of this nature *must* be written down for depreciation and *must* carry a reserve fund for emergencies; otherwise its real financial position will never be known. A canal does not depreciate beyond the extent to which periodical repairs will bring it back to its original condition; whereas plant not only wears out but may become obsolete while still in full working order, by which time it will have been already written down to scrap value so that there will be no disturbance in the accounts. No Accounts Code takes account of "obsolescence," if the use of this Americanism is permissible; hence examples can be found of plant working in Government factories that has been obsolete for many years but has been retained because it will still work. The success of a company-run electrical scheme depends on the dividends which the balance of revenue over expenditure and capital charges enables it to pay, after providing for contingencies. This margin is increased by enlarging the sphere of operations and the sales; and the sales are increased by judiciously lowering the rates charged for energy so as to bring in new consumers. While the same careful provision for the future in the matter of depreciation and reserves is necessary in a Government concern—indeed, without it, the real position can never be gauged—there is no necessity to pay regular dividends beyond the provision of the ordinary rate of interest on capital. If there is a further surplus in a particular year the rates charged for energy should be lowered in the following year, thus increasing the demand on the concern and its utility to the public and increasing the industrial prosperity of India. The indirect benefit from the expansion of industry and amenities of life will, it is submitted, take the place of a direct return in cash. As regards reserve funds, it may at first sight appear absurd that an undertaking with Government behind it should require such a fund; but reflection will show that what is sound finance in company management will not be the reverse in this case. The reserve fund, as is often the case in companies, can be "invested in the business" and used for extensions; and, by having it, the management and progress of the undertaking will be strictly comparable with other similar but purely commercial concerns.

PART III.—PROGRESS OF THE SURVEY.

11. Reconnaissances by the Chief Engineer and the Electrical Adviser.—During the course of their tour, indicated in the introduction, Messrs. Bull and Meares made reconnaissances of a number of possible sites; either because information indicated that they were favourable; or for purposes of instruction; or, again, because their opinion was specifically asked, especially in the case of Native States. In every case a special report was written, and the following is therefore a précis of the work only. In some cases the Report was a criticism or second opinion on an existing report.

(i) ALWAR.

The proposal for a storage weir at Bara (Preliminary Report, p. 46) appears likely to offer some 250 e. h. p. with a carry over sufficient to meet a year of deficient rainfall. Precipitation varies from 10 to 37 inches. Further observations are required to determine the run-off factor.

(ii) ASSAM.

Um Tru River.—A reconnaissance of the Um Tru River (*vide* Appendix V, page 68, of Preliminary Report) was made in company with Mr. Blenkinsop. A tentative enquiry for a concession for this site had been received by the local Administration. The river has a fair perennial discharge and two series of falls and rapids, with possibilities of considerable storage also. The data collected were only approximations and several alternative methods of development were found possible (as Figure vii or viii), the relative merits of which could only be determined by survey. It appeared probable that some 1,600 + 900 e. h. p. could be obtained at two sites, and a survey of the ground coupled with the collection of further data as to rainfall and run-off, was recommended. (Map 78 N 16 and 0 13.)

(iii) BARODA.

Sankheda Taluka Project.—The project originated by Mr. A. Loving, A.I.E.E., for developing the Orsang and Heran Rivers by means of a large storage lake in the Unch River was visited in February 1920 and fully reported on. The site is only 24 miles from Baroda city, where there is believed to be a demand for several thousand horse-power for mills and town supply. Except in the worst famine years this power can be obtained from the project. A storage (already surveyed) of some 7,000 million cubic feet is proposed, fed by the 3 rivers named, by means of short canals. (Figure v with canal through watershed instead of tunnel.) The preliminary levels and the run-off (based largely on actuals at the Jojwa canal headworks) are favourable, though the question of carry over or other reserve for years of very deficient rainfall requires further investigation. The maximum fall obtainable is unfortunately only 110 feet, near Sankheda, but on the actual working

NOTE.—The maps referred to are the Degree Sheets and 1" sheets published by the Survey of India.

hours this will give all the power required when starting with a full reservoir. In most years there will be a large surplus in the monsoon (Map 46 F, 11, 12, 15, 16).

(v) BENGAL.

Jaldaka River.—Certain questions regarding a lease for the water power of this river (see Preliminary Report, page 69) were discussed with the Chief Engineer, Bengal. The river has been further examined by the applicants for a concession and the results of the original reconnaissance were confirmed. The General Electric Co., (India), Ltd., are now surveying the site in detail.

Tista River.—An application for a concession was made to the Government of Bengal, and certain matters in this connection were referred to the officers of the Survey. (Preliminary Report, p. 70 and addendum.)

The suggested utilization of the *Damodar* and *Barakar Rivers* and the *Usri Nala* at certain reservoir sites investigated by the Irrigation Branch, Bengal, has proved impracticable.

In his report on the "Methods of Coal Mining in India" Mr. Treharne Rees has urged the construction of large central generating stations in Raniganj and Jherria. Judging by some of the estimates of the cost at which power can be sold to collieries, given before the subsequent Coal Committee, there is an opening for hydro-electric power even in competition with waste fuel. Electricity sold at 0.75 anna a unit for industrial purposes is unlikely to make headway when it could probably be delivered in the area at a small fraction of that cost.

No further reconnaissances were made in Bengal during the year, as no staff was available.

(v) BHOPAL STATE.

City Lakes.—A small scheme for utilizing the two city lakes, prepared by Mr. H. P. Gibbs, M.I.E.E. (on the lines of figure x), was examined and proved favourable. Certain further proposals were made as to details, and the whole scheme was reported on. (Map 55 E.)

The Gadaria Nala.—This, running parallel to the railway from Bhopal to the Narbada, was examined with a view to its utilization for the new industrial city near Budni. Data were insufficient to form an opinion on, but the prospects were more favourable than appeared from accounts previously received. Survey and further collection of data were recommended in a detailed report, in which various alternative methods of development (as Figure -vii, viii or x) were shown to be possible. (Map 55 F 9.)

(vi) BIHAR.

The *Hundrugah falls* on the Subarnarika R. were visited, where investigation is proceeding. There appears to be a probability of

obtaining, with storage, a minimum flow of about 1,000 cusecs with a fall of 700 feet or say 60,000 e.h.p. continuously. The Chandil site (Preliminary Report, p. 72) is reported to be practicable, but prohibitive in cost.

(vii) BOMBAY.

Tapti River.—The rapids in the Tapti at Bhusaval were examined following on a preliminary reconnaissance by Mr. Bowers. Further survey is required before the best method of development can be decided on (Figure vii or viii), but there appears a likelihood of obtaining some 1,500 or more e.h.p. from this source. (Map 46 0 16.)

(viii) BURMA.

Only a flying visit could be paid to Burma during the year, but, as reported elsewhere, investigations are proceeding. A copy of the Report dated 12th September 1907 by Mr. Alexander, referred to on pages 37, 38, 76, 77, of the Preliminary Report, has been obtained. In addition to the Heho River Mr. Alexander refers to the Bala Chaung at a point two miles below its junction with the Tagyit R. south of Banhat, where a fall of 212 feet exists in 3.8 miles and some 2,800 h.p. is said to be available. Also the headwaters of the Panlaung 31 miles north-west of Jhamakan and 27 miles from Kalaw on a bearing of 348° were examined by him. Here the Ngok and Singaung Chaung enters a lake near Kanbyin at 21° by 96° 31'. The lake has seven outlets below high water, through fissures in the limestone, but these can all be stopped. With an open channel a head of 745 feet is obtainable with 1,200-feet of pipe line. The lake can be raised and it is stated that 350 cusecs are obtainable, giving 21,000 e.h.p.

(ix) CENTRAL PROVINCES.

It is to be regretted that the possibilities of the *Pench River* and its neighbours (Preliminary Report, pp. 86, 87; Silewani Ghat) could not be fully examined in the current year as Nagpore can absorb a large amount of power. Mr. Batchelor has taken exception to the Summary of his proposals in the Preliminary Report and believes that 470 cusecs could be obtained on 900 feet head, giving a development up to 60,000 kilowatts of plant at a capital cost of Rs. 163 per kilowatt for the hydraulic development. The Penganga R. (Preliminary Report, p. 86) may be capable of development at the great double loop bordering on Hyderabad. There is a total fall of some 1,250 feet if it can be developed, but it has not been examined yet (Map 56 E. & I.).

(x) COORG.

Bara Pale River.—As a preliminary measure a photographic enlargement was obtained of the contoured map of the area where this river passes through a long gorge with a steep fall; and examination of the ground was recommended. Type of development probably as Figure i. No visit could be arranged this season (Map 48 P. 16 square 6 upper part).

(xi) INDORE STATE.

Kanar River.—A scheme dependant on storage above a natural water fall on the Kanar River was examined and reported on (Type of Figure v). It could be developed probably for some 350 e. h. p. for use in Indore city, but the cost is likely to prove prohibitive. (Map 55, B 2.)

Narbada River.—The rapids in the Narbada near Maheswar were examined and development was reported to be out of the question. The cold weather fall of some 20 feet disappears entirely in the rains, and the river has been known to rise as much as 53 feet at Mandlesar a few miles upstream. Any barrage across the river sufficiently high to be of use would cause the surrounding country to be submerged. (Map 46, N 12.)

The Patalpani Waterfall.—Was reported to be useless, owing to its deficient catchment area of a few square miles only. (Map 46, N 14.)

(xii) MADRAS.

Palni Hills, Kodaikanal.—Application has been made for a concession for the Gundar and Pambarai streams; but a reconnaissance showed that the applicants' proposals were impracticable. Further examination lower down may prove more favourable but no discharges have been taken as yet. The Parappan River was also examined and found practically useless. Arrangements have been made to take discharges of the rivers in the Palni Hills—(Map 58, F 8)—see Preliminary Report page 90.

(xiii) N.-W. FRONTIER PROVINCE.

No work is being done for reasons explained in the Preliminary Report, and the district was not visited.

(xiv) PUNJAB.

Sutlej River.—The Khatol gorge (Preliminary Report, page 97) was examined. Development is possible on the lines of Figure x but in view of the work proceeding lower down the Sutlej River detailed investigation is not called for yet. A report has been written on the site. (Map 53, E 14.)

Sutlej River, Chaba.—The proposed extension site of the Simla works was visited and found practicable but not very favourable as a permanent dam would be essential, costly and liable to destruction from the rocks in the river.

(xv) RAJGARH, C. I.

Newaj River.—This river was examined near Rajgarh but it was found that both the fall and the dependable discharge from storage were too small to be capable of economic development. The collection of further data regarding the river higher up was suggested.

(xvi) RAMPUR—BASHAHR.

Nogli River.—A reconnaissance was made of this river showing considerable possibilities of development on the lines of Figure i; but there would be no outlet for the power that could not be better served from the Sutlej River scheme. For Rampur itself a smaller and cheaper development is possible, though unlikely to mature. A report was sent in to the Durbar. (Map 53, E 11.)

(xvii) TRAVANCORE.

The *Periyar Lake* was visited as the suggestion made on p. 91 of the Preliminary Report is being seriously considered and offers no insuperable difficulties of construction. A lease has been granted to Mr. Garrett.

12. General lines of investigation in Provinces.—As recommended in paragraph 34 of the Preliminary Report, the past season's work has been concentrated mainly on reconnaissance, more particularly in areas where there is a prospect of power being utilized where found and the result of these reconnaissances is to emphasize the fact that in India the prospect of power depend in 95 per cent. of the sites examined on the prospects of storage and here the paramount necessity of accurate information both about the actual rainfall and the proportion discharged from the catchment area is shown; to determine the physical possibility of a given site holding a certain quantity of water is at the most a matter of a few months field work but the collection of data to warrant the assumption that that quantity of water will be available is a matter of years, and here the survey is handicapped as, except where the possibility of irrigation has been considered, records of the discharges of streams are practically non-existent, and this being so through the rainfall may be known the run off, is largely a matter of assumption: about 70 new rain-gauges have been put up in catchments under examination but as mentioned in para. 5 some form of self-recording gauge at a moderate price is badly wanted. The collection of a suitable staff of upper and lower subordinates has been a matter of difficulty, but some surveyors and levellers have been set to work by the various officers in charge of the survey. Instruments, as already mentioned, were only with difficulty (if at all) obtained. Even tents have not always been procurable. The fact that field work is limited by the season and the weather has also a bearing on the progress of the work, as suitable employment has to be found for the subordinate staff during the off season in order to keep it together. This will be no doubt in the form of rainfall and run-off observations, stream gauging and the like, wherever the locality makes it possible.

For next season's work arrangements are being made to recruit a certain number of temporary Engineers in England.

The estimates of power in the subsequent paragraphs have been based on the following data.

Fall.—The height has been observed from reduced Aneroid readings except where levelling is specifically indicated.

Discharge—Is the minimum perennial discharge due to stream flow, stream flow augmented by storage or storage alone.

Power.—The resultant power is the minimum continuous power that can be developed from the turbines assuming an efficiency factor of 80 per cent. and 100 per cent. load factor.

It has not been considered desirable to burden the report with details of communications, but they are on record for all sites on which a report is given and can be supplied on application to the Local Governments concerned.

13. Assam Provincial Survey.—Mr. Blenkinsop reports that in the course of the season Mr. Stevenson of the Assam-Bengal Railway made reconnaissances of the more promising areas through which the proposed Assam-Burma Railway northern link is being surveyed, between Margherita and Myitkina (Map 92 A); his reports show that power can probably be obtained by storage (as Figure v or vi) in the *Patkai Range* of hills sufficient for the electrification of the line, if this alignment be selected.

One site is 42 miles from Margherita, where the *Nooyong Swamp* has an area of 30 square miles with a lake in the middle. On the north side a tunnel $1\frac{1}{4}$ miles long would give a fall of 2,000 feet. Without passing through the watershed a fall of 1,000 feet is obtainable.

The *Sympna Nala* offers a similar but smaller site of $1\frac{1}{4}$ square miles storage area with a drop of 1,600 feet.

The *Mongseang Lake* is smaller still, but offers a fall of 2,000 feet.

The *Someswari River* (Preliminary Report, p. 68) has also been examined in view of the sanctioned survey of the Bagmora-Sipi-Jhankera railway to the Darwanagiri coal area.

The *Um Tru River* as already noted (para. 11) is being investigated in some detail as it appears to have ample power for Gauhati, Shillong, and the proposed Pandu-Shillong Railway.

Certain possible sites for storage on the *Cherrapunji Plateau*, referred to in the Preliminary Report on pages 40, 54 and 67, and draining into the Shella River, are being contoured. The first examined had a capacity of some 700 million cubic feet, with a moderate dam height, and the work is proceeding.

Other reconnaissance work is also in hand, including the survey of the site at *Maibang*, Assam-Bengal Railway (Preliminary Report, page 67).

14. Bihar and Orissa Provincial Survey.—Work has been hampered by the difficulty in getting subordinate staff, but more definite information has been obtained about most of the sites mentioned on pages 70—73 of the Preliminary Report rendering it unnecessary in several cases to go any further with them, and one good new site has been located.

Burhabulong River.—There is a sheer fall of 730 feet, and with a 2-mile flume some 200 feet more can be got, but the discharge runs down to 15 cusecs and storage will be a difficulty. No rock has been found and the dams would have to be of earth, and unless they were 120 to 150 feet high the requisite storage could not be obtained. Most of the land to be submerged is cultivated, and the power station site is very difficult to get at. Development would be expensive.

Sankh River.—The catchment area is smaller and the fall higher than they were reported, being 22 square miles and 350 feet respectively. With a tunnel 1,800 feet long the head could be increased to 500 feet, but 1,000 e.h.p. is probably as much as the site is good for even then.

Subarnarika River.—Two good reservoir sites have been found near Tati and Rosam villages above the Hundrugagh fall and are being surveyed in detail. Owing to difficulty in the alignment of the flume it may not be possible to get more than 550 feet fall, but with a minimum discharge of 500 cusecs and possibilities of more, the site would be good for 30—50,000 e.h.p.

Of the other streams catalogued in the Preliminary Report, only the Kanchi and Karo Rivers will probably repay further investigation; it is not proposed to do any work on the others.

Dumragarhi.—There is a fall of 500 feet on this stream about 1½ miles from Jonha station on the Purulia-Ranchi Railway. Reservoirs could be constructed on the Raru, Ganga, and Dumragarhi streams to give a discharge of 200 cusecs and an outturn of 9—10,000 e.h.p.

This outturn could be increased by bringing in the surplus water of the Subarnarika from the reservoirs described above through short tunnels into supplementary reservoirs in the valleys of these streams, and more detailed investigation is required to prove which is the best way of developing power from the Subarnarika.

15. Bombay Provincial Survey.—The prospects of power in Bombay Presidency are very great, but in many of the areas of the Western Ghats irrigation appears to have a prior claim. Whereas the irrigable areas are mostly in the Deccan to the east of the hills the steep fall required for power from storage works often involves crossing the main watershed and discharging the tail waters on the west or coast side. The possible storage sites have been investigated to a considerable extent and the results have been published in Mr. Beale's Deccan Irrigation Survey. Mr. Bowers had the advantage of working under Mr. Beale in this investigation, and is well acquainted with many of the sites. Some of those found unsuitable for irrigation purposes may be useful for power.

Mr. Bowers reports that sites in Bombay may be divided under two groups of rivers—

- (a) those flowing west into the Arabian Sea.
- (b) those flowing east into the Bay of Bengal.

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Generally speaking the rivers in the former group are not required for irrigation purposes, but if storage sites for large power schemes should be found on the Mahi, Narbada and Tapti Rivers the perennial supply thus assured could be used for irrigation purposes in Guzarat by means of pick-up weirs. These may be divided up under four heads—

- (i) The large perennial rivers of Guzarat believed to have rapids capable of cheap low-fall development on the low water flow, and to be capable of being further extended use by means of storage. (Type of Figure x.)
- (ii) Rivers of the Dangs, Southern Guzarat and Thana District. These are not perennial but have fair sized catchments with a rapid fall in a short length into low-lying country. They appear likely to be capable of development on medium heads from storage works, by means of canals. (Type of Figure i or v.)
- (iii) Rivers of the Colaba and Ratnagiri District, having small catchments but large rainfall. These are unfavourable as storage can probably only be obtained at great cost and with high dams, owing to the rapid bed slope in the high ground; while lower down there is insufficient fall.
- (iv) Rivers of the Kanara District. These have good catchment areas above the Western Ghat line of heavy rainfall, and flow through the Ghats in a series of waterfall and rapids. Some are perennial and offer immediate facilities for development, with extensions from storage in view; others would require storage works from the start.)

The waters of the rivers in Group B, flowing east, are generally earmarked for irrigation purposes. Storage higher up than the irrigation headworks will therefore be necessary in every case, or alternatively pick-up weirs constructed below the headworks to allow the water utilized for power to be retained until required for irrigation.

Reports have been received on the following rivers.

Mahi River.—There are no falls on this river, the fall would have to be got from the dam. There is any quantity of water available for storage and the power scheme would be combined with irrigation. Some 4,000 e.h.p. could probably be obtained with a 50 feet fall from the dam near Kadana. (Map 46, E 15.)

Panam River.—Tributary of the above has a catchment area of 977 square miles above the dam site but runs dry in February. Power would be developed off the dam with a head varying from 50 to 90 feet and would be of the nature of 4,000 e.h.p. constant but an irrigation scheme must be worked in with it or it will be too expensive. (Map 46, E 12, 16.)

Nerbudda River.—There are rapids at Mokhida in Rajpipla State but they only give a fall of 25 feet in five miles, the minimum discharge is 590 cusecs. The same difficulties would arise here as at Maheshwar in Indore (para. 11 xi). (Map 46, G 9, 13.)

Karjan River.—Tributary of above, has a catchment area of 400 sq. miles. There is a good reservoir site about 3 miles south-east of Nanded and some 114 feet of fall with a channel of $2\frac{1}{2}$ miles. Some 3,000 e.h.p. could be developed but it would be too expensive unless an irrigation scheme was combined with it. (Map 46, G 9.)

Tapti River.—The rapids at Bhusawal are mentioned in para. 11, VII, in addition to these there are rapids near Raygad with a fall of 60—70 feet in $3\frac{1}{2}$ miles. The minimum discharge is 45 cusecs but storage may be difficult to arrange for; if the Bhusawal scheme realizes, there would be a constant minimum flow of some 160 cusecs and 1,000 e.h.p. could be generated. (Map 46, G 15, K. 3.)

Gira River.—Tributary of the Purna. A good storage site has been found with a catchment area of 60 sq. miles, rainfall varying between 60 and 80 inches. A channel $2\frac{1}{2}$ miles longer will render available a fall of 380 feet and this with storage to give a discharge of 143 cusecs will enable 5,000 e.h.p. to be supplied. (Map 46, H 9, 13.)

Dhodar River.—Another tributary of the Purna. A good storage site is available 8 miles from the last site with a catchment of 58 sq. miles and the same average rainfall. A channel $2\frac{1}{2}$ miles will bring 174 feet of fall into play and with storage to give 135 cusecs some 2,500 e.h.p. can be depended on as a minimum. (Map 46, H 9, 13.)

Barda River.—Another tributary of the Purna. There is a site on this river in the same country as the two previous sites where there is a fall of 370 feet. No channel will be required and some 450 e.h.p. can be developed. This amount of power would be useful locally for forest industries. (Map 46, H 9, 13.)

There are two unnamed streams which fall into the Khapri River, which is itself a tributary of the Ambika River, on which sites have been found.

(a) A fall of 350 feet on a stream near Awah with a catchment area of 7 sq. miles and rainfall as for the previous three sites. A channel of $4\frac{1}{2}$ miles would be necessary to utilize the storage and produce some 500 e.h.p. which could be applied to local forest industries. (Map 46, H 9, 13.)

(b) A stream with a catchment of 24 sq. miles in the same rainfall area as the previous four sites; $1\frac{1}{2}$ miles of channel will bring in a fall of 280 feet and storage can be obtained to give 50 cusecs which will ensure 1,250 e.h.p. There are other falls lower down on the Khapri which could also be combined with this scheme to raise the output to some 18—1,900 e.h.p. (Map 46, H 10, 14.)

As will be seen from the map references all these five projects are close together and could be easily combined. They are all within 50 miles of Surat and other manufacturing towns in the district which will provide a market for the 11—12,000 e.h.p. available.

Kalinadi River.—(Preliminary Report, p. 74.) The Lalguli falls on this river are 370 feet as observed but 10 miles of flume would render 900 feet of fall available, bringing in the Vincholi Rapids, the average rainfall over a catchment area of 274 sq. miles is 87 inches, with a

minimum of 53 inches. The lowest discharge of the river recorded in May 1919 was 35 cusecs and as measured in March 1920 100 cusecs, 3,000 e.h.p. could be developed without storage. Two good reservoir sites however have been found, one on the Kalinadi and one on the Pandri close by which would together contain 28,000 million c. ft. and power of the order of 90,000 e.h.p. could be developed. There is no demand for irrigation. (Map 48, I 11, 12, 15.)

Tattihalli River.—Tributary of the above, by combining the Lalguli falls of 370 feet with the fall in this river a total fall of 730 feet can be obtained and an extra catchment area of 450 sq. miles brought in. The average rainfall is 40 inches but the minimum is 20 inches. A flume 9 to 10 miles long would be required and 15—20,000 extra e.h.p. could be brought in. The two power house sites are close to one another. (Map 48, I 12, 16.)

Kaneri River.—Tributary of the Kalinadi, a flume 10 to 12 miles long will bring in a fall of 1,100 feet, the catchment area is 145 sq. miles. There are no records of discharge nor of rainfall within the catchment. There is a good site for a reservoir and a possible outturn of 30,000 e.h.p. is a fair assumption. (Map 48, I 12.)

Gangavali River.—(Preliminary Report, p. 74) also called the Bedti River. The Magod falls are 380 feet high; a flume $1\frac{1}{4}$ miles long with $\frac{3}{4}$ mile of tunnel will increase this to 650 feet. There is a catchment area of 760 sq. miles above the reservoir site with an average rainfall of 44 inches running up to 90 inches; the discharge of the river in March 1920 was about 10 cusecs; allowing for a monsoon flow of 600 cusecs for 3 months. 30,000 e.h.p. can be developed. (Map 48, J 9, 13.)

Sonda River.—Tributary of the above. There is an actual fall of 350 feet; this can be increased to 1,100 feet by a flume 5 miles long. The catchment area 194 sq. miles with an average rainfall of 94 inches. The discharge in March 1920 was about 25 cusecs. There is a good reservoir site and the scheme would be good for 10,000 e.h.p. on the natural fall or 37,000 e.h.p. with the flume. This scheme could easily be combined with the previous scheme as the power house sites are within 3 miles of one another. (Map 48, J 9, 13.)

Tadri River.—(Preliminary Report, p. 75.) The Lushington Falls are 380 feet high. A flume 10 to 12 miles long would increase the available fall to 1,300 feet. There is a catchment area of 240 sq. miles with a rainfall of 107 inches and a minimum fall of 70 inches. The discharge of the river in March 1920 was 40 cusecs. There is a reservoir site that would hold 13,000 million c. ft. but this would entail a dam 250 feet high. It may be possible to find a second site. Power of the nature of 50,000 e.h.p. can be developed here. (Map 48, J 11, 15.)

Bene Nala.—a tributary of the above. The Hebre falls are 520 feet high, a flume 5 miles long would increase this to 1,200 feet. There are no records of rainfall in the catchment but it is an average ghat catchment area of 23 sq. miles; storage can be had and the scheme should be good for 8—10,000 e.h.p. (Map 48, J 10.)

(From the reports on these seven sites in Kanara it will be obvious that the possibilities of power are very great and far in excess of the local requirements, as there is no large industrial centre within ordinary reach; power however has an attraction for industries, and the fact that this amount of power can be had may very likely lead to a large industrial development in the neighbourhood of Hubli and Dharwar which are within a 50 miles radius of the centre of the district.)

The following are the sites left for reconnaissance; they are placed in geographical and not alphabetical order

GROUP A, FLOWING WEST.

Pur and *Damanganga Rivers* in Surat District and *Vaturna* and *Bhatsa Rivers* in Thana District. These all have large catchments in the heavy rainfall Ghat area. Falls in the two last named were indicated in the Preliminary Report, pages 74, 75 (Map 47 E).

Amba, *Kundalika* and *Savatri Rivers* in Colaba District and the *Maldoti*, *Shastri*, *Muchkundi* and other streams in Ratnagiri District. Nothing is at present known of these except for the Marleswar Temple falls on the Maldoti in latitude 17° 50, longitude 73° 50.

GROUP B, FLOWING EAST, WITH TAPTI TRIBUTARIES.

Panjhra River, tributary of Tapti. A storage has been examined at Pankheda and might be used for power with a pick-up weir at Ner for irrigation.

Mosam River, tributary of Tapti. Reports have been received of a number of *bandharas*, with falls up to 20 feet, which might possibly be combined.

Girna River.—If the proposed Panjhan dam were constructed a large power scheme would be possible, with a pick-up weir at Saigon for irrigation.

Godaveri River—and tributaries in Nasik District. As the water stored in the Dharna reservoir at Nadgon is not required for irrigation till it reaches the pick-up weir at Nandur, some use might be made of it for power. It would also be possible to use the proposed Aundha storage at Muknha to increase the supply for power scheme on the Vaitarna (*supra*).

Pravara and Mula Rivers.—(See Preliminary Report, pages 74, 75.)

Bhima River—and tributaries in the Poona District. These rivers have already been investigated by Messrs. Tata and it is doubtful whether power and irrigation can be combined from them.

Nira River.—See Preliminary Report, page 75. The new Bhatghar dam will be completed about 1926. When visited by the Chief Engineer it was observed that the original intention to build sufficient pipes into the dam for the future power possibilities of the lake had not been carried out; a discharge of 600 cusecs will be available for some 8 months; to supply power for 12 months it would be necessary to provide compensating storage and then by utilizing the Ing Falls some

4,400 e.h.p. could be generated but probably at a prohibitive cost. If irrigation interests would permit of the water of the Nira or Gunjawani Rivers being diverted over the Ghats a fall of 1,700 feet could be obtained and the Lake Whiting Scheme could be set aside.

The *Krishna River*—and tributaries in the Satara District.

Venna River—has a catchment of 4 square miles on the Mahableshwar plateau and with the fall of 1,100 feet some 250 e.h.p. could be supplied and if the amenities of the place permitted more storage could be obtained and 2,500 e.h.p. generated. (Map 47, G 9, 13.)

Urmodi River.—Somewhat similar conditions prevail here; the catchment area is 8 square miles and there is a fall of 1,200 feet. It has yet to be decided whether the best treatment would be to enlarge the existing lake or to make a new reservoir lower down the valley. (Map 27, G. 14.)

For the *Koyna Valley*, see Preliminary Report, table 5, page 38.

Ghatpraha and *Malapraha Rivers* with their tributaries in Belgaum District. See Preliminary Report, pages 107 and 74, respectively. Small falls are reported on the latter river near Shivayog Mandir in Badami Taluka, Bijapur District.

Generally speaking the water stored or to be stored on the eastern side of the Ghats is required for irrigation there, and there are therefore objections to taking it through the watershed to the western side. Canal falls have not yet been further examined.

Ronda Falls, Bhandadara.—Lake Arthur Hill has a capacity of nearly 11,000 m. c. ft. and a fall of some 340 feet is obtainable in $4\frac{1}{4}$ miles below the dam. As however there are four months when no water is run-off for irrigation it would be necessary to provide some 3,000 m. c. ft. of compensation storage in one of the available sites above the lake. If this were done an eventual development of some 20,000 e. h. p. is possible, though it is unlikely to be required for many years. There are however local demands for power for the Belapur Sugar plantation and elsewhere within easy transmission distance, e.g., Igatpuri, Nasik, etc. (Map 47, E and Topo sheet old, No. 194.)

Sind has four perennial rivers, namely, the *Nazarani*, *Gaj*, *Harbab* and *Salari Rivers*; but no information is at present available regarding them.

16. Burma Provincial Survey.—As will be realized from a perusal of the list of sites, pages 76—83 of the Preliminary Report, there are more possibilities of power in this Province than in any other; distances are great and communications difficult and to ascertain what all these possibilities are worth will be a matter of several seasons' work, but a lot of rough reconnaissance has been done this year giving sufficient data to eliminate many sites from the list as not worth further investigation at present and to add as many more as being more hopeful; in addition to this detailed reports have been received on the following sites and survey is proceeding in Tavoy but no report has been received up to date.

Heho River.—Preliminary Report, page 76. Detailed survey has proved that the possibilities of this site have been overestimated. The fall is better, 770 feet having been ascertained against 672 feet estimated, but with a rise of 5 or 6 feet in the main channel near the falls in the small valley a considerable amount of water is carried off by "Ye-ngoks" or disappearing streams, and an examination of the main Heho valley revealed similar conditions: it is probable therefore that the storage of a large or even moderate quantity of water may be impracticable on account of the numerous passages by which water can find its way into Lake Sule. A flume 3,500 feet long will be required and good sites for forebay and power house can be found.

Pan laung River.—Preliminary Report, page 81. Reconnaissance shows that there are four sites where power can be developed, the fall varying from 800 to 2,200 feet with a length flume from 2,000 feet to 17 miles. The minimum permanent discharge without storage is in the neighbourhood of 200 cusecs, so that the sites are good for between 13 and 39,000 e. h. p. on a 100 per cent. load factor. Thedaw station on the Rangoon-Mandalay Railway is only 30 miles away and the Thazi-Kalaw Road 20 miles so that this may prove an attractive proposition for industries. (Map 93, C 12, 16, D 1, 5).

Zawgyi River.—Preliminary Report, page 83. The Mong Hing Falls 10 miles north of Lawk Sawk are 400 feet high, the site has been surveyed in detail and prospects are most favourable, the discharge observed in April 1920 was 300 cusecs and as the season was a dry one this may be taken as near the minimum. The catchment area above the falls is 400 square miles and the rainfall 45 inches. A flume 3,300 feet long could be run on practically flat ground to a bend of the river where there is an excellent site for a regulating reservoir, with a capacity of 15 million cubic feet and forebay. The pipe line would be about 2,300 feet long of which 1,600 feet of light section would be on an easy grade and end in a surge tower. There is a good site for a power house and some 10,000 e. h. p. could be cheaply developed as a minimum. (Map 93, C 15, 16.)

17. Central Provinces Provincial Survey.—Mr. Davies was not finally deputed for duty on the Hydro-Electric Survey till December 1919 and even then had to continue to work as Under Secretary to the Local Government for some time; his report therefore deals with only three-months work and about six weeks field work; this necessarily limited the scope of the enquiry, which was confined to the following schemes, four of which are mentioned in the Preliminary Report (pp. 84—87) and the other two have come to light since it was issued.

Bina River.—This scheme was suggested by Mr. Batchelor but his estimate is too optimistic based as it is on the run off likely to be available in one fairly good year while with the moderate rainfall prevailing in these catchments it is essential to consider the conditions that would prevail after two successive years of bad rainfall. Applying this test the effective storage would be about 4,200 million c. feet and with the available fall of 80 feet the scheme would be good for 1,000 e.h.p. continuous on a load factor of 100 per cent.

If it had been feasible to divert the water into one of the tributaries of the Betul River the fall could be increased to 120 feet but the water of the Bina River is reserved for irrigation in the Khurai Doab and water taken from the Bina must be returned to it; this also puts the lower reservoir site out of count as a source of power as no fall can be obtained if command is to be obtained for this doab.

Indravati River.—The work done this year confirms the main figures given before. There is a good foundation for a masonry dam and 63 feet of height will impound 40,000 million c. ft. Greater height would entail the submergence of part of the town of Jagdalpur; the scheme lies wholly in Bastar State and arrangements would have to be made about land. The direct fall is 90 feet but a flume 15 miles long will increase this to 300 feet. The discharge in March 1920 was over 1,300 cusecs and the scheme should be good for 70—80,000 e.h.p. There is a plentiful supply of limestone within easy reach and given better communications the manufacture of nitrates could be undertaken; the site at present is 200 miles from a railway but the alignment for a proposed narrow gauge line passes within 15 to 20 miles of the site for the dam. (Map 65, E 12, 16.)

Nahara River.—Allowing for a carry over in the two worst years effective storage of 3,000 million c. ft. can be reckoned on; 5½ miles of flume will bring in a net fall of 660 feet, the amount of fall being limited by the necessity of getting command for irrigation. A canal 15 miles long will carry the tail waters to the Waingunga Canal and thus some 2,000 additional acres of sugar-cane can be secured worth 60,000 a year. This would justify capital expenditure of 12 lakhs and some 5,000 e.h.p. can be generated.

Pench River.—Work was begun on the examination of Mr. Batchelor's proposals to which reference is made on page 87 of the Preliminary Report and about which he has published a pamphlet. There is no doubt that the water and fall both exist but some months survey work will be necessary to determine the best way of bringing the water to the fall and the amount of water available. Here also as in the Bina River scheme the run-off requires more critical examination, a power scheme cannot be based on assumptions that may cause a shut down of several months when two bad years come together.

As far as this year's work goes the indications are that it may be better to move the dam on the Pench some 5 miles further down stream. The tunnel from this valley to the Kulbehra valley might then take direct out of the reservoir, the water from which will be passed down the Kulbehra River to the reservoir site near Rohna from which a 20-mile canal and 4-mile pipe line will carry the water to the power house site. More rain gauges are wanted in the catchments of both rivers, but as far as can be judged from existing data, on a 900-foot fall some 12,000 e.h.p. should be a fair assumption with 100 per cent. load factor. (Maps 55, J 12, 15, 16; 56, K 13.)

Machna River.—A good reservoir site has been found 11 miles north-west of Betul with a catchment area of 140 square miles. With a

water into the Tapti. The rainfall is small and 2,000 e.h.p. is as much as can be expected from the scheme. (Map 55 G, 13.)

Nagdoari River.—This river has a minimum discharge of 30 to 40 cusecs and the net fall that can be obtained is 750 feet. A tunnel of about a mile and a quarter and a pipe line 1 mile long will be required. With storage the scheme should be good for 4,000 e.h.p. The site is 5-6 miles west of Pachmarhi. (Map 55, J 7.)

18. Madras Provincial Survey.—Mr. Sneyd reports that he spent the earlier part of the season on a thorough reconnaissance of certain sites in Jeypore State, within transmission reach of the growing port of Vizagapatam which the Bengal Nagpur Railway are about to develop. He has sent in reports on promising sites as follows:—

Kolab River.—Tributary of Godaveri, at Bargra, Karaput Agency, Vizagapatam District (Map 65 J, 18)—see Preliminary Report, addendum to List of Sites. The developments contemplates the diversion of the river into an open channel at a point where it approaches the edge of a ghat, 800 feet high and passing the waters over this ghat, returning the tail waters to the same river. The river makes a long bend of 5 miles here, which can be negotiated by a tunnel 150 yards long only. The minimum discharge is about 100 cusecs, more or less; the catchment is 631 square miles; the average rainfall is between 53 and 59 inches. With a dam of 100 feet height and 1,500 feet long some 1,640 million c. ft. can be impounded, and the run-off is ample to fill this in the worst years. *The whole plateau abounds in good reservoir sites.* The site can develop some 6,500 e.h.p. continuously without storage and 13,000 e.h.p. with it. A full reconnaissance report has been received, and is most favourable except for some difficulties as to communications. (Preliminary Report, addendum, page 107.) The Kolab has further possibilities lower down.

Machkand River.—Tributary of Godaveri, at Duduma, Jeypore Agency, Vizagapatam District (Map 65 J, 21). The development contemplates the diversion of the river into a short open channel, whence a pipe line will lead from a forebay to the power station. The minimum discharge is believed to be about 104 cusecs; catchment area 904 square miles; average rainfall from 53 to 75 inches at 4 stations. With 100 foot dam 1,200 feet long some 3,300 million c. ft. can be impounded and the run-off is ample to fill this in the worst years. There is a natural waterfall here of 540 feet and 580 feet head can be obtained altogether. The site may be expected to yield some 5,200 e.h.p. continuously without storage and 15,000 e.h.p. with storage. (Preliminary Report, page 90, and addendum to List of Sites.)

Several other possible sources of power are indicated in the Vizagapatam District, where practically all the conditions are favourable if load can be found. There are mineral possibilities and presumably the Jeypore State would welcome the development of these and of the power generally for its own benefit as well as that of the Vizagapatam area. There is no appreciable prospect of irrigation in the area.

(*Varani River*.—Tributary of the Haladi River, South Kanara.

The Kunchi Kal Abbi Falls of 1,400 feet on this river offer good possibilities of power. The minimum flow of the river is put at 20 cusecs. The catchment area is only 18 square miles but the rainfall is round about 100 inches. A good storage site can be found capable of holding 250 million cubic feet. The catchment and submerged areas are in Mysore, the falls and power house in Madras. The site should be good for 5,000 e.h.p. continuous and development cheap as only 1½ miles of channel are required. Additional power could be obtained later by diverting the Malatte Hole into the Narahi River.

The power house site is 20 miles from Coondapur and 65 miles from Mangalore. (Map 48 K.)

An article in the "Madras Mail" describes a somewhat similar site discovered by Mr. H. D. Rice and situated some 10 miles east of Bhatkal and said to be good for 28,000 e.h.p. continuous, assuming a rainfall of 250 inches with a run-off of 50 per cent. There is obviously plenty of power in this neighbourhood but there would not seem to be room for more than one good scheme: the three Governments of Mysore, Madras and Bombay are concerned both with the power and the territory involved and a joint agreement about the site and method of development would seem the right solution.)

Ayyar River.—Kollimalai Hills, a storage site to hold 700 million cubic feet has been found by Mr. H. W. Perry who is responsible for the discovery of this scheme and has done a lot of work on reconnaissance. The direct fall is 2,000 feet and the minimum flow measured in April 1920 was 7 cusecs. Rainfall records are scanty but 40 to 60 inches is a fair assumption. Rain gauges are being put up. The site should be good for 5—6,000 e.h.p. continuous and there is a good market for power in Trichinopoly some 35 miles away. (Map 58, I 11, 12.)

Palni Hills.—In addition to the Gundar River (para. 11, xii) the following sites present possibilities. The rainfall in these hills is about 60 inches:—

- (a) *Porahdalar River*.—There is a fall of 1,500 feet and an estimated minimum flow of 5 cusecs. A reservoir would be expensive and would not yield more than 10 cusecs. The site might be good for 2—4,000 e.h.p. continuous, the amount depending on more accurate observations of the amount and duration of the stream flow.
- (b) *Kunbar River*.—The water of this river is largely used for irrigation and the construction of a reservoir must interfere with this. Some 1,500 feet of fall can be used and the river may be good for 2,000 e.h.p. continuous.
- (c) *Pinjikave Reservoir*.—A fine site alluded to in old reports of 1869-70; the catchment area is 30 square miles and by diverting the water into the Boddinayakanur valley a fall of 5,000 feet can be obtained; the minimum rainfall at Kodaikanal is 45 inches. There are good facilities for irrigation and the combination of irrigation and power

should make this site one of the best worth developing in this part of the Presidency. The minimum yield should be 10,000 e.h.p. with 100 per cent. load factor. (Map 58 F, 8, 12.)

Nagavalli River.—This river has a perennial flow of at least 100 cusecs and the scheme would depend on this as no site for a reservoir can be found. The fall is 120 feet at Royagedda and 1,000 e.h.p. would be the least continuous outturn. The power house site is within 2 miles of the alignment of the proposed branch of the Bengal Nagpur Railway from Parvatipur to Raipur. (Map 65, M 8.)

In addition to the above the following schemes alluded to in the Preliminary Report have advanced a stage further.

Kundah River.—(Preliminary Report, page 90.) A concession has been given to Messrs. Tata for the use of the water of this river. Power will be supplied in bulk to Coonoor, Wellington and Ootacamund for lighting and Coimbatore will furnish a market for power for commercial purposes.

Siruwani River.—(Preliminary Report, page 92.) As a corollary to the above the water of this river is to be reserved for water supply purposes only.

Periyar Project.—An agreement has been arrived at between the Madras Government and Mr. Garrett and a lease has been given to him. (Preliminary Report, page 91.)

Chandravauki River.—(Preliminary Report, page 89.) This should be the Epitolala Fall on the Chandravauki River. Examination has proved that there are no possibilities here. Storage would be very expensive and the fall is only 70 feet.

Gundar River.—(Preliminary Report, page 90.) No site for a reservoir can be found. Minimum flow about 5 cusecs with falls of 800 feet, hardly worth survey in view of the possibilities at other sites close by, described above.

19. Punjab Provincial Survey.—As stated elsewhere, Mr. Nicholson's services were again required by the irrigation branch before he had begun the work of reconnaissance. He called attention to the Jhelum and Kishenganga Rivers (Preliminary Report, p. 95) at their junction where he believes 600 feet head could be obtained by tunnelling through the watershed. Unfortunately the power house would be in Kashmir.

Mr. Lindley, Executive Engineer, suggests additional outlets for power from the 50 feet fall on the Upper Jhelum canal (Preliminary Report, p. 99) at Rasul, for irrigation by pumping (from the water lagged area at Raniweh) from Miani to Shahpur and for lifting sweet water from the river to irrigate and wash the salty tract between Pind Dadan and Khushab.

The Sutlej Hydro-Electric Project (Preliminary Report, p. 96) is being surveyed and examined in detail by Lt.-Col. Batty, R.E., D.S.O., under the direction of the Chief, Engineer, Buildings and

Roads Branch, Punjab; meanwhile as power will be required for the construction of the Bhakra Dam, and to develop it for that alone might be expensive, a scheme has been worked out for using some 2,000 cusecs on the 32 feet net fall available in the river at Nangal to develop some 6,000 e.h.p. Of this Simla will probably be ready to take about 1,100 h.p. for the new water supply scheme involving pumping against a lift of 4,000 feet, the Kalka-Simla Railway would require about 2,000 e.h.p. for its electrification and the balance would be used on construction work. An anonymous writer in the "Pioneer" of December 31st, 1919, urged that the States of Patiala, Nabha and Jhind (especially the first named) had a lien on all the power obtainable from the Sutlej in the neighbourhood of the Bhakra dam site, and could utilize it for subsoil pumping and the prevention of water logging. If the demand for these purposes is in the neighbourhood of the 80,000 e.h.p. actually available as an *absolute minimum* the project is assured of success. At the same time it is abundantly clear that so large a series of pumping schemes would not and could not all be carried out at one time; there would be ample power available for the needs of the Punjab as well. If it should happily turn out that the demand is in excess of the minimum supply the latter can be very greatly increased by the provision of storage at known sites upstream of the Bhakra Dam. In any case the above minimum will seldom occur, and will then only last for a very short period; and it must be remembered that the volume of stored water which will give 10,000 horse power for a year on a particular head will give 120,000 horse power for a single month.

The Chief Engineer, Irrigation Branch, notes that it is proposed to utilize the power of Canal falls at the following sites:—

Upper Chenab Canal Toganwalli Fall, site No. 2, page 97 of Preliminary Report. A lease has been granted for the generation of electrical power for lift irrigation from wells and general agricultural purposes, the lessees are Sir Zulfiqar Ali Khan and Sir Dalip Singh.

Rai Bahadur Ganga Ram proposes to utilize the power of the Renala fall on the Lower Bari Doab canal for lift irrigation of uncommanded land and the proposal is under consideration.

A syndicate, known as the Punjab Hydro-Electric and Industry Development Association, has obtained from Government a concession to develop and work four falls on canals in the Punjab, and a Company is about to be formed to take over and work this concession.

The falls in question are—

- (a) Joyanwala, on the Upper Chenab canal.
- (b) Gujranwala, on the Upper Chenab canal.
- (c) Bhimber Weir, at the tail of the Upper Jhelum canal.
- (d) Rasul, on the Upper Jhelum canal.

A fifty years' lease of the use of these falls has been granted, on terms which include the payment of a small yearly sum until the undertaking has reached the profit paying stage, and thereafter of a percentage of the profits earned, as payment for the use of the water.

The lease contemplates that the works may be taken over by Government under certain conditions and after certain periods have elapsed, and lays down the conditions under which the works would be taken over.

It is estimated that 3,000 h.p. can be developed at each of falls (a) and (b) on which there is a drop of 7 and 9 feet respectively: 6,000 h.p. can be developed at fall (c) on which there is a fall of 15 feet; and 12,000 h.p. can, under certain conditions, be developed at the Rasul falls.

Falls (a), (b) and (c) are on the canals themselves, but at Rasul the water in the Upper Jhelum canal is to be dropped back into the river Jhelum, which runs just below, down a drop of 50 feet. A portion only of the water in the Upper Jhelum therefore can be used at this fall; but this water would not be entirely lost for irrigation purposes, as it can be taken out of the river again by the Lower Jhelum canal, the headworks of which are immediately below the point at which the power station will be built.

It is proposed to join the power stations at these falls together by a transmission line which will be about one hundred miles in length, and as the lease provides that the Upper Jhelum and Upper Chenab canals shall never be closed at one time for repairs, except in cases of extreme emergency, power will always be available on this transmission line from one or more of the power stations.

It is proposed to supply electricity to all towns on the route of the transmission line, and those near it, which towns will be served by the power which is continuously available, and it is also hoped to develop loads which can be served intermittently, such as pumping for irrigation purposes, which will be served by the excess power which is not continuously available.

The pressure of transmission along the main transmission line will probably be about 100,000 Volts, and it is proposed to continue the line, at some lower pressure, to the Salt Range, where it is proposed to establish two manufacturing companies, one for cement and the other for calcium carbide. It is also hoped to supply power to the Khewra salt mines, which are shortly to be fitted up with machinery for power working.

The conditions will enable electricity to be sold at a very cheap rate for purposes which only require an intermittent supply, far cheaper than it can be obtained from any other source, and it is hoped that the scheme will benefit both the industries of the Punjab and the promoters of the undertaking.

The present promoters are all local men, and it is hoped to raise the bulk of the capital required to develop the scheme locally, so that all the profits of the undertaking will remain, quite rightly, in the Punjab.

20. United Provinces Provincial Survey.—Mr. Lyle was appointed in charge of the Survey in September 1919 and Major Cairns, R.E., was appointed later on to assist him, but want of instruments and subordinate staff hampered progress. Survey work was actually begun in December and the following ground has been covered.

Belan River.—Preliminary Report, page 100. More detailed survey has discovered further possibilities in the Mukha Dari site but the objection due to the necessity of submerging good land still holds good: the catchment area is 290 square miles with a rainfall of 46 inches, assuming a run off of 25 per cent. 7,740 cubic feet could be stored giving a discharge of 220 cusecs. By diverting the water into the Sone river a fall of 300 feet can be obtained, but a difficult line 10 miles long would be required to render this effective. The site would be good for 5—6,000 e.h.p. but development would be expensive. (Map 63, L 9, 10.)

Bakher River.—Tributary of the above. Further investigation has modified the figures given in the Preliminary Report, page 100. Some 6,000 million cubic feet can be reckoned on from the 220 square miles of catchment above the Sirsi reservoir site giving a constant discharge of 168 cusecs. Assuming half the reservoir head to be useful the available fall is 155 feet and 2,300 e.h.p. could be developed with a pipe line of 4,000 feet without any flume. This should be a cheap scheme as the cost of the main reservoir would be shared with the Irrigation scheme and the only extra work necessary would be a small subsidiary reservoir to hold 165 million cubic feet to increase the supply to the Irrigation requirements of 228 cusecs for three weeks.

Both this and previous site are within 50 miles of Benares, 70 miles of Allahabad and 30 miles of Mirzapur. (Map 63, L 9.)

Karamnassa River.—Preliminary Report, page 101. A reservoir site has been found above the Deodari fall of 180 feet where 12,000 million cubic feet could be stored, but owing to irrigation demands for the Ghaghar Reservoir only 8,400 million would be available for power purposes; this would give a discharge of 240 cusecs which could be used for power and picked up for irrigation in the Benares State at the existing dam near Chakia, and the cost of development would thus be reduced: there is a second fall of 140 feet at Chandpattar $4\frac{1}{2}$ miles below the Deodari fall and these two falls could be combined with a total head of 425 feet giving some 8,500 e.h.p., or developed separately with outturns of 4,500 and 4,000 e.h.p. respectively.

An extra 450 h.p. could be obtained from the Gurwal Nadi at the Deodari fall.

The sites are about 40 miles from Benares. (Map. 63, P. 5.)

Chandraprabha River.—Preliminary Report, page 100. A reservoir site is being surveyed about $1\frac{1}{2}$ miles above the 400 feet fall near Baraur: with a catchment area of 107 square miles and a proved run off of 33 per cent. on an average rainfall of 46 inches, 4,000 million cubic feet can be stored and the site would be good for 4,000 e.h.p. with a $2\frac{1}{2}$ miles flume. This could be brought in to supplement the Karamnassa power scheme if required. (Map 63, P. 5.)

Reconnaissance is in progress in the Naini Tal and Almora Districts on the Kosi, Ramganga and Sarda rivers. The Board of Communications in the United Provinces are emphasizing the importance of a ropeway from Kathgodam to Almora *via* Bhim Tal and Ramgarh and power will be required for this and other similar schemes.

In addition to the pioneer work of the survey one Hydro-Electric Scheme has passed from the stage of discussion to that of sanction.

The water of the Naini Tal Lake is to be used on a fall of 1,400 feet to generate 300 Kilowatts. The scheme is estimated to cost about 10 lakhs. Some 700,000 units will be generated at a cost of 2.55 annas per unit. The power will be used for lighting, domestic purposes, and the electrification of the water supply.

It is not anticipated that it will be necessary to raise the level of the lake for some years. These figures have been supplied by the courtesy of the Chief Engineer, Buildings and Roads Branch, Public Works Department.

The Chief Engineer, Irrigation Branch, notes that the following schemes for utilizing the power of Canal falls are likely to be carried out in the near future.

Bhola Falls.—Page 104, Preliminary Report, will be employed to run three 250 k.w. sets to generate some 2½ million units in the year for use in Meerut.

Sumera Falls.—Page 104, Preliminary Report, here three sets of 200 k.w. will be worked and power delivered in Aligarh.

Palra Falls.—Page 104, Preliminary Report. 400 k.w. are to be generated here for use in Khurja, 8 miles away, where there is demand for flour and lime mills and for cotton ginning and pressing as well as for lighting and domestic purposes and water supply.

Ghuna and Sarkari Falls.—Preliminary Report, page 105. The power from these falls will be used in Saharanpur, about 300 k.w. being required.

It is hoped that it may be possible to relieve the Agra Canal of the demand for the Parks by generating power at the Malakpur and Chota Kosi Falls on the Agra Canal and pumping from the Jumna or from reservoirs. Transmission distance would be 20 to 30 miles.

Rewa State.—Investigations have been carried on in this State by the officer in charge of the Survey in the United Provinces, but partly owing to shortage of staff and partly to the formalities attendant on entry to the State work was not begun till late in the season, but there are certainly three rivers with good possibilities for power.

Odda River.—There is a storage site at Babuti with a catchment area of 280 square miles above it. 500 feet of fall can be brought into play of which 415 feet is a vertical drop. The site should be good for 10,000 e.h.p.

Goorma River.—There is another good fall of 450 feet here of which 420 feet are sheer. The catchment area above the fall is 150 square miles and some 4,000 million cubic feet could be stored. The site should be good for 4—5,000 e.h.p. Both these sites are within 50 miles of Allahabad. (Map 63, H 9, 13.)

Tons River.—Mr. Joyner reported some years ago that there were three falls on this river from which 30,000 e.h.p. could be developed. The fall near Poorwa is shown in the frontispiece to the Report. Survey work is in progress.

The results of a rough reconnaissance are to show that there are great possibilities at this site: there is a good storage site about 1 mile above the fall and from the catchment area of 2,000 square miles it should be possible to impound 55,000 million cubic feet with a dam 120 feet high. The vertical fall is 146 feet, and taking advantage of head available in rapids above and below the fall, a total fall of 400 feet can be obtained. The power available should be in the neighbourhood of 50,000 e.h.p.

In addition to this, within a 12 mile radius on the Beshar and Maha rivers, tributaries of the Tons, it should be possible to develop 18,000 and 10,000 e.h.p.

The sites are within 60 miles of Allahabad and 130 miles of Cawnpore. (Map 63, H 1, 5.)

Arrangements have been made between the Government of United Provinces and the Chief Commissioner, Delhi, for the survey in detail of the *Jumna River project* under the direction of the Chief Engineer, Delhi (Preliminary Report, Table 5, page 39). Should the existing concessionaires decide not to proceed with the work, for the purpose of smelting the iron ores found in the locality, it is doubtful if they can sell power to Delhi and the other cities along the line of transmission at a rate which will compete with fuel power. On the other hand, if both the Sutlej and Jumna projects should be constructed by the State, an immense area would be served and the possibility of linking up the two schemes would not be remote. From site to site, *via* the plains, is only a matter of 120 miles. The permanent electric supply of Imperial Delhi and its Cantonments is already under examination by Col. J. S. Pitkeathly, C.V.O.; the remainder of the towns that can be served lie in the United Provinces.

21. Summary.—The positive results recorded in the eight preceding paragraphs are a tribute to the enterprise of the officers in charge of the Survey, but until additional staff can be recruited and an adequate supply of survey instruments assured it will not be possible for the work to proceed on more satisfactory lines; meanwhile the Nitrogen Products Committee has issued its Final Report and urged the importance of a source of nitrogen products in England both for military and agricultural purposes which shall be independent of the necessity of importation from abroad. Whether the agriculturist in India will ever be able to afford the cost of artificial manure for ordinary cultivation is a moot point, but if any increase in the production of sugar is to be seriously considered some form of fertilizer will be an important factor as the Dutch have appreciated in Java.

The question of utilizing water power is attracting attention all over the world. Canada has increased the number of watts installed per head of population from 148 shown on page 13 of the Preliminary Report to 200.

A survey of water power resources has been carried out in British Guiana showing possibilities of 800,000 h.p. on the three main rivers:

and coming nearer home the Water Power Survey Department of the Dutch East Indies notes that the minimum estimate of power in the islands without storage is 5½ million h. p. of which 60,000 are developed or under construction while projects are in hand for 660,000 h.p. of which 500,000 are to be devoted to the production of nitrogen fertilizers mainly for sugar cultivation.

It remains to be seen as the result of the work of the survey in the course of the next year or two to what extent it will be found possible to utilize the latent possibilities of power in India at a reasonable cost.

APPENDIX I.

"ADDENDUM TO ELEMENTARY NOTE," FROM THE PRELIMINARY REPORT.

Useful Hydraulic Data (in round numbers generally).

Flow.

1 cusec flow = 1 cubic foot per second = 62.4 lbs. per second,
 = 60 cubic feet per minute = 3,744 lbs. per minute.
 = 374 gallons per minute,
 = 3,600 cubic feet per hour,
 = 86,400 cubic feet per day,
 = 2.6 million cubic feet per month,
 = 31½ million cubic feet per year.

Gallons per minute = cusecs × 374

Cusecs = $\frac{\text{Gallons per minute}}{374}$

Regulating Storage.

100,000 cubic feet stored will give 1.16 cusecs for 24 hours

"	"	"	"	"	2¼	"	"	12	"
"	"	"	"	"	4½	"	"	6	"
"	"	"	"	"	9½	"	"	3	"
"	"	"	"	"	27¾	"	"	1	hour

Main storage.

31½ million cubic feet stored is equivalent to 1 cusec for a year; but owing to evaporation and percolation more storage would actually be required. In round figures:—

1,000 million cubic feet									
									stored will give 30 cusecs continuously for a year.
"	"	"	40	"	"	"	"	9	months.
"	"	"	60	"	"	"	"	6	"
"	"	"	90	"	"	"	"	4	"
"	"	"	120	"	"	"	"	3	"

Reservoirs.

1 acre = 43,560 square feet.

1 acre of water 1 foot deep = 43,560 cubic feet.

= 1 acre foot.

1 square mile = 640 acres = 27.88 million square feet.

1 square mile of water 1 foot deep = 1 square mile foot,
 = 27.88 million cubic feet, which will (in practice) give a flow
 of about $\frac{3}{4}$ cusec for 12 months, $2\frac{1}{4}$ cusecs per 4 months or
 3 cusecs for 3 months.

Catchments.

1 inch of rain = 100 tons per acre or = 3,600 cubic feet per acre.
 = 1 cusec per acre per hour.
 = 64,000 tons or 2.33 million cubic feet per square
 mile.

In practice, however, only a percentage, and often a small percentage, will reach the reservoir ;

Power from flow.

On the practical basis assumed throughout this report

$$\frac{\text{Cubic feet flow} \times \text{head in feet}}{11} = \text{electrical horse power.}$$

If 15 is the divisor, the result is in kilowatts.

On small projects 12 and 16 may be used.

Power from storage.

(i) Regulating.
$$\frac{\text{Thousands cubic feet stored} \times \text{head in feet}}{42} = \text{e.h.p. hours.}$$

If the divisor is 56, the result is in kw. hours or B.O.T. units.

(ii) Main.
$$\frac{\text{Millions cubic feet stored} \times \text{head in feet}}{370} = \text{e.h.p. years.}$$

If the divisor is 500, the result is in kw. years.

Millions cubic feet \times head in feet \times 17 = B.O.T. units.

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