Water Power of Halifax County, Nova Scotia: Part I, Dartmouth Lakes Power.—By F. W. W. Doane, C. E., City Engineer, Halifax.

(Read 13th May, 1907.)

It is not the purpose of this paper to present any novel or improved ideas in hydraulics or hydro-electric power, but first to call attention to the undeveloped possibilities in our well-known water courses, and second to describe somewhat in detail the water power available from a water shed in the county of Halifax, a portion of which is partially developed, the remainder almost as nature formed it.

To the average man a water power is necessarily something with a big dam across an imposing stream. Indeed, many engineers are accustomed to look for large watersheds and high heads, overlooking entirely the possibilities of the small streams. In the House of Assembly a short time ago, it was stated that there are no water powers in Nova Scotia worthy of the notice of the government. This assertion may or may not be correct, yet while all of the larger powers have been discovered, and many of them harnessed, there still remain many falls on our streams which have escaped notice or have been considered too unimportant to develop. Many hydraulic powers are in use, but are not furnishing anything like the quantity of power which they are capable of developing.

The board of trade last year, in a quarterly report, regretted the lack of cheap powers for industries in Halifax, but went no farther in a search for a remedy. Mr. Yorston, in his paper read before the Institute last year, stated fully the possibilities of the power on the Mersey River in Queens County. A portion of the dormant power in the Gaspereau Valley is being developed for transmission to the neighboring towns, Wolfville and Kentville, while the latent energy of the tides of the Bay of Fundy still await the master hand of the engineer, the promoter, and the capitalist.

With the rapid growth of the demand for power, and the necessity for obtaining that power as cheaply as possible, we can no longer afford to ignore the possibilities of the minor hydraulic powers, many of which are yet undeveloped, while others now in use are not developed to their full capacitv.

We have no mountain streams with great heads in Halifax County, but there are many streams which contain possibilities which would justify investigation at least.

At twenty feet head it takes a wheel a couple of feet in diameter and a flow of about 3,500 cubic feet of water ner minute to give 100 horse-power. At eighty feet head a 10-inch wheel will do the same work on one-quarter of the quantity of water, while with a very high head a mere brook may suffice to give a power that may be worth at least developing for local use.

Minor powers are not uncommon in any hillv district, but the small flow diverts attention from them. Yet this very class may have possibilities in the way of storage of water that would make them most attractive. In some cases where a number of square miles of watershed are available, it may be possible by the construction of dams to form storage lakes or increase the capacity of existing natural reservoirs, and by this means create a useful power where only a moderate stream flowed before.

There is, of course, a limit to the minimum quantity of continuous water power that is worth considering, whether for local use or in connection with electric transmission. The governing features of the problem are the general cost of development and equipment, the cost of transmission, and the cost of operation.

In hydraulic work the cost of conduits from the dam to the power house is generally the controlling item, and this is again determined by the distance necessary to be covered and the available flow.

If the cost can be kept in the neighborhood of $100 per horse-power, the outlook for an economical short transmission is good, since this means an annual charge of no more than $10 or $12 per horse-power for the motive power. The cost of wheels and generators with their equipment will run generally from $25 to $30 per kilowatt in cases where raising transformers are not needed, the usual case for small powers. All of this can be approximated very readily, as also can the cost of the necessary buildings.

The heaviest charges in small work come in the operating expenses and in the pole line. Pole lines for light wires need not cost more than $250 to $300 per mile, exclusive of wires and right-of-way. The latter, in working on a small scale, is commonly along the highway, so that the cost is small; but the cost of wire, unless the line is short, may add considerably. Still, at a given voltage, the cost of copper per kilowatt transmitted is a constant, and the only relatively fixed item is the cost of stringing, which varies only slightly with the size of wire until the larger sizes are involved. For mechanical reasons, however, it is not desirable to string wire smaller than No. 4 or No. 5, so that the minimum cost of conductor is somewhere about $500 per mile. Fortunately, the depreciation charge against bare wire is practically negligable, and wire of this minimum size will carry comfortably the output of the class of plant considered.

In hydro-electric plants the operating expense is largely one of fixed charge, while with steam plants it is made up of fixed charges coupled with variable items of coal, water, oil, waste and incidentals. With the hydro-electric plant, consequently the cost per horse-power per year is almost constant, regardless of whether supplied one hour a day or twenty-four hours a day. Repairs are about the only variable, and they may be considered as increasing in direct proportion to the load factor. Labor, oil, waste, etc., are nearly the same, irrespective of the proportion of light loads to full loads. With the steam plant, on the contrary, the items of coal, labor, etc., increase rapidly with the load factor, and hence the cost per horse-power per annum increases in almost the same proportion.

The cost of attendance is the most serious outlay in small stations. It means, generally, the pay of at least three men, and occasional extras—not less than $2,000 per annum, even for a very small plant. At 100 kilowatt capacity this would come to at least $20 per kilowatt per year, which added to the other charges, is pretty nearly prohibitive. At 200 kilowatt capacity, the operating charge gets down to reasonable figures. In a rough estimate, one will not go far wrong in saying that for electrical purposes a water power of 250 to 300 horse-power on steady flow is worth considering. Anything below this is of little account, except for local utilization, and the usefulness of the power increases rapidly above this point.

If the situation is favorable for storage, a good deal can be done with small streams; but unless the above amount can be made available without going to heavy expense, there is not much that can be done. If two or more such powers are available they can be often worked together to advantage. There are powers near the limiting size that have been passd over as too small, and these are the ones which ought to be carefully looked after in the interest of small places and small industries.

The fundamental fact that faces the engineer of a hydro-electric plant is that the total amount of hydraulic power available is, once for all, a fixed quantity. Of the rain that falls in the drainage area of the stream a certain proportion finds its way into the stream and that is all that is there available. Taking a series of years, too, the distribution of this available water through the year is approximately uniform, so that one can state broadly the total normal power per year, and that its distribution through the year follows a certain power curve. In some streams this curve is very regular, in others extremely irregular, showing torrents at certain seasons and rivulets at others. The task of the engineer is to take the power curve and do with it the best he can in earnings, attacking the problem with all the resource at his command.

No hydro-electric plant of limited capacity should be studied at the present time without considering the use of auxiliary power. Oftentimes such a study would result in the rejection of auxiliaries altogether. At other times, after all has been done that is possible in obtaining the best available storage, there may remain a feature of the problem which may be economically handled only by steam or gas auxiliaries. But a short time ago, the presence in any hydro-electric system of steam or gas auxiliaries, was considered a confession of weakness in the hydraulic system. Fortunately this false idea is fast losing ground, and it is recognized that the best of engineering is shewn by their use, and in consequence, hydro-electric opportunities are being utilized which were previously neglected.

Streams of comparatively constant flow, by the installation of steam or gas auxiliaries, are enabled to supply heavier loads than would be otherwise possible, though perhaps the most important use for auxiliaries is found in cases where the normal stream flow is very materially reduced during short periods of the year, by reason of special conditions in the watershed.

It is not reasonable to develop a hydro-electric station when a steam or gas station could be built which would supply the same territory at a lower cost, but it is also unwise to condemn a hydro-electric development because the cost per unit of capacity is high, when at the same time it can develop cheaper power than can be done in any other manner.

In the province of Ontario, the government has appointed a hydro-electric power commission, whose duty it is to develop and supply electric energy not only to municipalities requesting it, but also to any railway or to a private company distributing electricity.

In the annual report of the New York state water supply commission, that body strongly urges the state control of waters. This refers not only to such a regular examination f water supplies for potable purposes as shall insure the detection of any serious change in their quality, but also to the larger problem of the regulation of stream flow in order to prevent floods. The commission believes that it is unwise to allow the appropriation of potable waters for power purposes, except under such state supervision and regulation as is at present exercised in the case of water-works plants. The diminution of floods, the report states, could be brought about by the construction of reservoirs which need not flood public forests, an act prohibited by the constitution, and the waters stored in these reservoirs might be made a source of revenue. The portions of the report recently made public do not reveal any definite plans for legislation to carry out the suggestion, but the general proposition that the state should exercise an equitable supervision and control over the unappropriated waters of the state meets with public approval. The time is coming quickly when water powers and water supplies will be appraised much higher than now, and any failure to secure state control of them, so far as they are now unappropriated, may be unfortunate.

It is becoming daily more and more apparent that the coal mines, steamers and railroads cannot supply a permanent and continuous generation of power so readily as the rivers. The experience of the past has brought this home to all classes and sections of the Dominion, till in some parts of the country we are now appealing to our courts and legislative bodies to relieve us from the perils of fuel famine. These conditions are but the natural outgrowth of a national improvidence which in the past has consumed our store of domestic fuel for power purposes and has allowed to run to waste the easily available power resources of the water which constantly falls upon our hills, and will continue to fall while the earth is habitable.

Cheapness of power has long ago been demonstrated for the hydro-electric plant and transmission line; reliability is now being proved. The duplicate line has already become an established factor in the system, and attention has been turned to the duplicate plant as well. The advantages of the duplicate source will be the next study.

Not only is the unreliability in the supply of coal aiding in the development of hydro-electric projects, but the price also is exercising a great influence. We do not have to go far afield to hear tales of scarcity of fuel and closed plants in consequence of strikes, car famine, etc., and every consumer of coal knows that there has been a permanent increase of about 50 per cent. in the cost. This price will not be reduced, but in all probability will continue to advance, so that it may be claimed that the hydro-electric plant, which will begin by paying expenses, must necessarily become a source of profit in the near future.

Water Power of the Dartmouth Lakes.

The nearest water power to the city of Halifax is that owned by the Starr Manufacturing Company, in Dartmouth. Until very recently this power was not controlled entirely by one company. By the amalgamation of the Starr Company and the Dartmouth Rolling Mills Company, the whole water power becomes the property of the new company, and it is now possible to develop it to its full capacity.

The drainage area from which this power is obtained includes the watershed and water surface of five lakes. Beginning at a divide a short distance south of Cranberry Lake, which lies on the south side of the Preston Road, about three and one-half miles east of Dartmouth, the surface slopes northwardly and westwardly. Cranberry Lake empties by a stream about one-third of a mile in length, crossing the Preston Road into Lake Loon, which in turn drains into Lake Charles, about one mile and one-half westwardly as the crow flies. From Lake

Charles the surface slopes both northwardly and southwardly, Lake Charles being the highest of the chain of lakes utilized in the construction of the Shubenacadie Canal. While no longer needed for canal purposes, the masonry of the old locks is still in good condition, and is used by the Starr Company in connection with their storage dams.

When the lakes are overflowing, Lake Charles has an outlet at both ends, but except in time of freshet, the outlet is southwardly into Second Dartmouth Lake. The stream between Lake Charles and Second Dartmouth Lake is about seven-eighths of a mile in length, and passes through two of the old locks. From Second Dartmouth Lake the water flows directly into First Dartmouth Lake. From the latter, it is let down through Sullivan's Pond as it is required. Penhorn Lake, lying south of the Preston Road, about a mile and a half east of Dartmouth, drains into the Second Lake. Oathill Lake, situated about three-quarters of a mile eastwardly from the town, and south of the Preston Road, empties into First Lake.

From a map in the possession of the Deputy-Commissioner of Public Works and Mines, the areas have been obtained as follows:—

Lake Loon watershed	840	acres.	
Lake Charles watershed	3400	"	
First and Second Lakes watershed	3060	"	
Total area of lakes and watershed	7300	"	= 11.4 sq. miles
Lakes only:			
Cranberry Lake	23	acres.	
Loon Lake	190	"	
Reservoir below Loon Lake	23	"	
Lake Charles	337	"	
First and Second Lakes	441	"	
Other lakes	36	"	
Area of lakes	1050	"	= 1.6 sq. miles
Area of watershed, not including lakes	6250	"	= 9.8 sq. miles

The country is rough and broken, a portion being wooded, and a large proportion waste land.

After passing through the Starr Manufacturing Company's works, the water, previous to the amalgamation of the two companies, was used again at the electric light station below Portland Street.

For this purpose the water was carried to a point opposite the light station by a flume 4 ft. 6 in. wide, and 15 in. deep. When examined by the writer the water was flowing about 14 in. deep with an inclination of .002 feet per foot. Under those conditions the sluice would discharge 1134 cubic feet per minute. From the flume the water was taken by a 4 ft. pipe to a 20 in. crocker turbine, working under a head of 18 ft. 4 in. At 75 per cent. efficiency the wheel would develop 29.25 horse-power.

The water running the Starr works is drawn from Sullivan's Pond through a 44 in. pipe, 417 feet long, with a discharging capacity of 12,900 cu. ft. per minute. The wheels work under 31 ft. head. The shop is run by a 30 in. wheel, "standard" make, purchased from T. H. Risdon & Co., Mount Holly, New Jersey. The grinding room machinery is kept in motion by a 10 in. "American" turbine manufactured by the Dayton Globe Iron Works Co., Dayton, Ohio. A 22 in. "special" new American turbine (Dayton make) has been used to operate electric generators for lighting the town.

The catalogue capacity of these wheels is:—

Size	Head in ft.	Revolutions.	Horse-power.	Cu. ft. of water used.
30 in.	31	262	83.4	1674
10 in.	31	681	21.8	465
22 in.	31	326	116.7	2492

A comparison with the theoretical horse-power of the water used shows that the wheels are rated at higher efficiency than they can reach in practical work. The large wheel is rated at 85 per cent. efficiency and the other two at 80 per cent.

At 75 per cent. efficiency	1674	cu. ft.	at 31	ft. head	=	73.5	horse-power.
75 "	"	465	"	31	"	=	20.25	"
75 "	"	2492	"	31	"	=	109.5	"

The Starr Company was under contract to supply power to the Electric Light Company up to 100 horse-power from sunset to midnight, and 30 horse-power from midnight to dawn. It is estimated, therefore, that the average quantity of water consumed per day in developing power was:—

1674				
465				
2139	cu. ft. per minute	x 60 x 9 hours	= 1 153,560	cu. ft. per day.
2492	" "	x 60 x 6 "	= 897,120	" "
1134	" "	x 60 x 5 "	= 2,390,880	" "

This quantity used at an equal hourly rate for twenty-four hours would produce 73 horse-power at 75 per cent. efficiency. Adding the 29.25 horse-power developed below, the total 24-hour power would be 99.25 horse-power. For nine hours it would produce 195+29.25=224.25 horse-power.

Assuming for the present that the quantity of water used daily is correct, it is not developing the total horse-power that it is capable of producing. If, instead of the present system, all of the water were carried in a pipe from Sullivan's Pond to a wheel at the electric light station, there would be a head of at least fifty feet. The above quantity of water would then develop at 75 per cent. efficiency, 116.75 horse-power for twenty-four hours, or 314.25 horse-power for nine hours. The nine-hour power would be an increase of 90 horse-power, or 40 per cent. In order to obtain this additional power it would be necessary to convert the hydraulic plant now running the Starr works into a hydro-electric plant.

The same water used for power at the Starr works is available for the development of power at the foot of First Lake, as Sullivan's Pond, through which water is drawn from First Lake for the Starr Company's plant, is comparatively very small, and has practically no watershed. When First Lake is full, there is a head of about twelve feet above Sullivan's Pond. Assuming that First Lake can be maintained at overflow level every day of the year, and that the quantity hereinbefore estimated is available, a wheel at the canal lock would develop at 75 per cent. efficiency, 28 horse-power for 24 hours, or 77.5 horse-power for 9 hours. If Sullivan's Pond could be raised 12 feet, this additional power would be available at the Starr works without electric transmission.

The quantity of power that could be taken from the estimated available water by carrying it in a pipe from First Lake to a wheel at high-water mark would not be greater than that developed by a wheel at the Canal lock at the foot of First Lake, and another at high-water mark, operated by water drawn from Sullivan's Pond. The total would be about 390 horse power for 9 hours, or 145 hore-power for 24 hours.

The fall in the stream from Lake Charles to Second Lake affords another opportunity to increase the total capacity of this power. This portion of the old canal is known as Port Wallis Locks. The upper lock gate is closed, and holds the water up to the level of Lake Charles. There is a fall in the lock of about 19 feet, and at the lower lock about 10 feet. Estimating the available portion of the rainfall over the watershed draining to this point at two feet, a wheel at Port Wallis Locks would develop 25 horse-power for 24 hours or 66 horse-power for 9 hours.

The quantity of water available, depending not only on the rainfall but on the possibility of storage, it is of the greatest importance to know what can be done to hold the water draining through the old canal. The writer is not familiar with Lake Loon, and has had no opportunity to ascertain the storage possibilities of this lake. It is stated, however, that a rise of three feet would cause the water to flow in another direction.

Lake Charles can be dammed at both ends. At the south end there is a good location for a dam. The lake could be raised six feet by a structure about 100 feet long. At the north end the dam would be from 100 to 200 yards in length. At one point on the Waverley Road the highway would have to be raised, as it is not much above the present overflow level of the lake. Raising Lake Charles six feet would increase the storage capacity about 90,000,000 feet, or about 40 days' supply for the Starr works. This additional storage would be nearly one-third of the estimated available rainfall, and there is no doubt in the mind of the writer that the storage in this power system can be increased so that the whole run-off in a dry or ordinary year can be held and used as required.

The contract with the Electric Light Company began January 1st, 1898. In 1894, which was a very dry year, the water failed, but all the wheels did not stop again for want of water until 1905, which was the dryest year on record.

In 1904 the shop ran by steam from August 5th to September 10th.

In 1904 the electric lights ran by water without stop.

In 1905 the electric lights ran by steam from September 14th to November 22nd.

In 1905 the shop ran half water, half steam, from August 29th to September 14th.

In 1905 the shop ran by steam from August 14th to Dec. 1st.

The Starr Manufacturing Company has an auxiliary steam plant, as may be inferred from the foregoing statement, which they use in case of emergency, or when once in ten years water fails. This plant affords a good illustration of the advantages of the auxiliary system, which permits a larger horse-power development on the available water than would be possible without it. In its absence the daily capacity of the plant would be reduced, and there would be danger of complete shut-down in case of accident or shortage of water.

The estimate of the quantity of water used daily at the Starr works is based on information given by the manager. If correct, the proportion of the rainfall is much larger than the usual estimate. 2,390,880 cubic feet of water every day, equals 872,671,200 cubic feet a year, which, spread over 7,300 acres, would be 33 inches, or 59 per cent. of 55,927, the average rainfall in Halifax. It is, therefore, probable that the estimated capacity is in excess of the actual capacity. The estimated capacity based on the manager's data is:—

At high-water mark (9-hour day) 365 days	314.25	h. p.	
At first lock	75 5	"	
At Port Wallis locks	66	"	
	457.75	"	
Possible nine-hour power under present development....................	224.25		
Possible increase	233.5	"	104 p. c.

It would be very interesting to know positively the exact quantity of water used by each wheel at the Starr works, and the exact total time run during one year, so that the run-off determined by Mr. Johnston and that at the Starr works could be compared.