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Threat case*



A STUDY  
of  
THE AUGLAIZE HYDRO-ELECTRIC DEVELOPMENT  
of  
THE DEFIANCE GAS AND ELECTRIC COMPANY

by

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1924  
✓

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Cambridge, Mass.

May 29, 1924.

Prof. A. L. Merrill,  
Secretary of the Faculty,  
Mass. Inst. of Technology.

My dear Professor Merrill:

This thesis is submitted to the Faculty  
of the Massachusetts Institute of Technology to  
fulfill, in part, the requirements for the degree  
of Bachelor of Science in Civil Engineering.

Respectfully submitted,

Adolpho Santos, Jr.

Edward Harmening Moll

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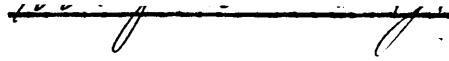

  


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SUMMARY

## PURPOSE OF THESIS

The following thesis presents a study of the Auglaize Hydro-Electric Development of the Defiance Gas and Electric Company, Defiance, Ohio. It is the object of the authors to make: first, a general survey of the plant, including the various factors affecting its operation; and second, to determine the probable power that could be developed at the site and compare it with the installed capacity.

## METHOD OF PROCEDURE

The authors spent a considerable portion of the summer of 1923 in the Auglaize valley, investigating the physical conditions at the power site, the equipment, and the development as a whole. For the study of the hydrology, the topography, and the other factors affecting the development of power, the authors also made use of various federal, state and private reports and publications.

## RESULTS AND CONCLUSIONS

As a result of this study, the authors came to the following conclusions:

a) That the site is overdeveloped

(1) That with the natural unregulated flow 4-500 kva. units would be a reasonable installation.

(2) That with 750 second feet from the Miami and Erie Canal 3-1000 kva. units would be a reasonable installation.

b) That on account of the topographical relief of the basin and the value of farm lands, it would not be economically feasible to build storage works of sufficient size to regulate the flow and increase the available power.

c) That the plant should be hooked in with a larger system in order to utilize more of the secondary power.

PHYSICAL CONDITIONS

## HISTORY

In the early part of 1911, the Defiance Press announced that several Defiance men had interested Toledo and New York capital in the utilization of the hydro-electric power available on the Auglaize River south of Defiance, Ohio. The Auglaize Power Company was soon incorporated for one million dollars and immediately took over the options on land and the power rights which had been secured by the original promoters.

The Auglaize plant was one of the three proposed plants to be built by the Auglaize Company in Northwestern Ohio. This plant was expected to furnish a constant supply of some 4,000 horsepower, 1600 of which was to be utilized by the City of Defiance.

The newspapers and prominent citizens welcomed the new project as a means of reducing the high lighting rates and of attracting new industries to the city by offering cheap and abundant electric power.

The contract for the construction of the dam and power house was let to the Ambursen Hydraulic

Construction Company of Boston, Massachusetts. The actual construction work was started in the late summer of 1911 and as favorable weather was encountered, it progressed rapidly. Coincident with the construction of the dam and power house, a transmission line was run down the river, through Defiance, and on to Toledo to hook up with the lines of the Toledo Rail and Light Company of Toledo, Ohio. This company had contracted to take all the excess power of the new plant, estimated to be some 2000 horsepower. Feeders were constructed off the main line to various small towns in the Maumee valley in order to increase the available market.

The plant was completed in the latter part of 1912 and put into operation.

The storm, which caused the Ohio Valley Flood of March-April, 1913, caused a flood of lesser magnitude, but of equal destructiveness in the Maumee and Auglaize valleys. The damages resulting from the flood to the Auglaize Power Company's equipment and dam, coupled with damages awarded farmers for ruined

land due to the breaking of the west wing wall of the dam," placed the company in a precarious financial position. This was aggravated by the fact that their credit was seriously impaired due to the fact that the amount of power developed did not reach the expectation of the promoters.

The Defiance Gas and Electric Company finally took over the entire physical properties of the Auglaize Power Company. Original investors in the Auglaize Power Company lost heavily as the securities of the Defiance Gas and Electric Company," which they received in return for their securities of the Auglaize Power Company," were not equal in value to their original investment. The plant was then made an integral part of the electrical division of the Defiance Gas and Electric Company and has," since then," been operated in conjunction with its other generating stations.

#### LOCATION.

The hydro-electric plant under consideration is located about four miles south of the City of Defiance, Ohio, on the Auglaize River which is a tribu-

tary to the Maumee River which, in turn, discharges into Lake Erie. The Auglaize has itself two large tributaries, namely, the Blanchard and Ottawa Rivers which enter it from the East. The drainage area (Appendix A) of the Auglaize occupies part of the northwest corner of the state of Ohio and a small portion of the adjacent state of Indiana.

A) Geology: The geology of a district and the accompanying topographical and statistographical conditions greatly modify its hydrological phenomena. The presence of surface waters and the flow of streams depend not only upon the amount and distribution of precipitation but also upon the geological structure and topographical relief of the drainage area. The character of the material and the dip of the strata; the structure, extent of outcrop and slope of the strata; all these have a marked influence upon the disposal of rain water. Again, the practicability and even the feasibility of the successful storage of waters depend upon the nature of the foundation of the dam built to impound or retain them, and the character of the banks and bed of the ponds or reser-

voirs thus formed. The presence of faulted, fissured, or otherwise uneven rock masses, or pervious and yielding materials may make such structures impracticable.

The Auglaize basin lies west of the Cincinnati anticline so that formations occur successively and more or less regularly in long narrow strips. The drainage area lies in glaciated regions and has the generally smooth and level plains characteristic of such areas. It contains large areas covered with a heavy limestone soil and glacial drift. The valleys are usually composed of a fertile alluvial soil. In some localities, where the drift was thin, it has been removed for stone quarrying.

The bed of the Auglaize has been developed on strata of limestone of approximately uniform resistance, and hence has the normal concave profile. At the dam site, these limestone strata are cracked and fissured to a marked extent, and as a result, the stability of the dam was once endangered. The evil was remedied, only temporarily it seems, by cutting off these cracks and fissures by placing a concrete cutoff wall

at the heel of the dam. The authors believe that, if the method of drilling into the foundation rock and forcing grout under pressure into the fissures had been followed, the requirement would have been fulfilled at less expense and much more satisfactorily from the point of view of the stability of the structure, as both the upward water pressure and percolation would have been greatly reduced. The fact that the limestone foundation is overlaid with glacial drift at the dam site was overlooked or not properly guarded against when the dam was originally built. The fact is that the west wing of the dam abutting against this drift was not connected with some impervious strata within the bank, nor was the yielding strata of the bank fully protected against possible erosion. The result was, that during the great flood of 1913, the flood waters rising over the abutment readily cut away into the drift, and the river cut around the end of the dam carrying part of it downstream. After this had happened, this part of the dam was reconstructed and a concrete core wall built well into the bank. The earth fill

around the core was then well protected by heavy rubble.

B) Topography: The topography of the basin of the Auglaize is in the main very simple and of little importance from a climatic standpoint, as might be inferred from the above sketch of its geology. The drainage area is located in that physiographic division of the United States known as "The Prairies". As before stated it lies in glaciated areas and consists mainly of nearly level plains or gently rolling elevations on which the rivers are long and sluggish. This typical sluggishness is very evident in the case of the Auglaize specially in its lower portions, as it would be expected.

The rich alluvial deposits, which cover the valley, is suitable for the formation of numerous springs which tend to keep a certain minimum flow in the streams even during periods of drought.

The valleys and plains of this region have great value from an agricultural standpoint but have little variation in climatic factors and conditions. There is little good timber remaining on account of the extent to which the timber industries were carried

on. Corn is the staple crop but general farming is also carried extensively.

The influence of Lake Erie, although positive and at times decided, along its shore and for some distance inland, probably does not extend as far as the Auglaize basin.

The Auglaize has itself two large tributaries, Blanchard and Ottawa Rivers, which enter it from the East. It has a length of about 74 miles and a total fall of 325 feet, or approximately a fall of 4.4 feet per mile.

C) Precipitation: The average annual precipitation for northern Ohio is slightly less than 36 inches, but the distribution varies materially (see Appendix H). The precipitation is greatest, in the main, in the more elevated portions of the section and conversely, it is least in the lower regions. Thus it is found that for topographic or other reasons in the Maumee valley, and especially in the Auglaize valley, conditions are favorable to lessened precipitation.

The precipitation data, for this area was taken from the Climatological Reports of the United States Weather Bureau.

This data was studied with the view of estimating the probable discharge of the Auglaize.

#### TEMPERATURE

The average temperature for the Auglaize valley is, for the year, between 49 and 50. The variation in the mean between stations maintained by the United States Weather Bureau is not large. This variation is about 3° F. There is, however, a large range between the highest and lowest temperature for the year. In a period of 37 years this range was recorded as 141 degrees at one of the stations. This range is due to the fact that the Auglaize valley is too far away from Lake Erie to feel the equalizing influence of the lake.

#### FROST AND ICE

The average date of the first killing frost is around the middle of October. However, due to the warm days, the ground is not frozen sufficiently to affect run off until the early part of November. The ice forms on the rivers in the latter part of November and the early part of December. This ice breaks up the middle of March or the first of April. Due to the

alternation of cold night and warm days," disastrous floods are caused by the simultaneous breaking up of the ice," thawing of the ground," and a heavy precipitation. It was such a combination which brought about the flood in the spring of 1913 which has already been referred to.

#### WIND

The prevailing winds for the year blow from the southwest. The average velocity of the wind is about 11 miles per hour," those in the winter averaging considerably higher than those in the summer. However," gales of 40 miles per hour or more are rare," even in the winter.

#### MARKET FOR POWER

The Defiance Gas and Electric Company," controls all the power sold in the Maumee and Auglaize valleys below Defiance," with the exception of that sold in Napoleon," Ohio," As Napoleon has a municipally owned plant," the company is barred from operating there. A main transmission line hooks all (Appendix A) the stations of the company together and so makes it possible for the whole system to be carried by one plant when [it is possible for the whole system to be carried by

one plant when] it is feasible.

The load is very diversified, lighting in the main in the small towns and a large industrial load in the two larger towns. Most of the industries in Defiance and Maumee are electrically operated, which makes the industrial load an important factor in the output of the system. A reciprocal agreement, which was recently discontinued, gave the company an outlet for all its surplus power to the Toledo Rail and Light Company. With the building of the Acme steam generating station of the latter company, this agreement was terminated.

The industrial load remains fairly constant and most of the variation in the load comes from a seasonal variation in the lighting load.

DEVELOPMENT

## SITE

The river, at the development, has a profile which is typical throughout its entire length. The banks, which are of heavy alluvial soil, are concave or slope steeply, often rising to considerable height. Storage, however, is out of the question, due to the value of the farm lands which would of necessity be overflowed.

The bed is flat or slightly concave, being composed of a nearly horizontal strata of limestone. It is cracked and fissured through the agencies of faulting and weathering. This feature, which was not given proper consideration in the construction of the dam, afterwards endangered the safety of the entire structure.

## DAM

The dam is of the hollow type, built by the Ambursen Hydraulic Construction Company of Boston, Massachusetts, under their patents. The Ambursen is one of the best known types of the hollow, reinforced concrete dams.

The engineers were faced with the problem of

placing the dam on limestone which was faulted and weathered. A trench for the foundation was blasted across the river until it was thought that the depth was sufficient to give them a watertight joint, subsequent development proved that the blasting opened seams through which considerable leakage developed.

The Auglaize dam is made up of a series of parallel buttress walls, set transversely to the axis of the dam and spaced 16 feet center to center. Deck slabs of reinforced concrete are cast on these buttresses as supports. The angle, which the upstream face makes with the vertical, is adopted so as to make the danger of sliding a minimum. It is the angle at which the friction, due to the weight of the structure plus the weight of the water on the upstream face, equals approximately the tendency of the water to push the dam downstream. In the Auglaize dam this angle is 45 degrees. (Appendix B).

The Auglaize dam may be divided into four sections: (1) the power house; (2) the tainter gate section; (3) the main dam; (4) the wing wall on

the west bank of the river.

The power house and wing wall sections are not made to carry overflows but the tainter gate section and the main dam are. The three tainter gates of 30 feet each abut against the power house. These gates are operated by electricity and are designed to pass water so as to protect the flashboards on the main section of the dam from going out.

The tainter gate section is formed by extending the buttresses downstream and then decking them over with reinforced concrete slabs.

The main dam has a height of 26 feet, base of 30 feet, top width of 4 feet, and 18 inch flashboards. Its length from the tainter gate section to the west abutment is 346 feet. It has a combined concrete apron and cutoff wall at its downstream side which effectively prevents erosion of the limestone at the heel of the dam as well as leakage of water which succeeds in getting by the upstream cutoff wall.

The wing wall, which runs from the west abut-

ment, has a concrete core with an earth fill around it well protected with heavy rubble on the upstream face. This wall is so designed that there can be an 8-foot crest on the dam before it is overtopped

#### STORAGE AND PONDAGE

Due to the fact that there is no reservoir except the natural bed of the river, the plant had practically no pondage available to run it for <sup>more than</sup> a portion of a day if the wheels were run at their rated capacity. Even the small pondage secured has been expensive due to the rich bottom lands which the company was forced to purchase and the roads and bridges which it had to re-locate and raise

This is typical of all low head developments which are located in flat country. This is doubly unfortunate in the case of this development as this lack of storage is not compensated for by a large and constant flow of water.

#### HEAD

The Allis-Chalmers wheels installed are rated at their full power and normal R.P.M. under a 22-foot head. The authors went over ten years of the sta-

tion log and found but a few times that this value was reached. The most likely value for the average head seems to be between 19 and 20 feet. As the wheels are forced to run, most of the time, at other than their best speed, it can be seen that they are not designed for <sup>the</sup> head available at the site.

### POWER HOUSE

The power house abuts the tainter gate section on the east and may be considered a portion of the dam in that it aids in the impounding of the water. The substructure, which is of reinforced concrete, rests on the same strata of limestone as the dam. The power house is constructed of a steel frame, with brick curtain walls, and concrete slab roof. The steel columns, which carry the roof, are used to carry a 45-ton crane, built by the Northern Crane Company.

The superstructure may be divided into three main parts. (Appendix C). The main section, which is of one story, contains the five generators and their auxiliaries on the main floor, the wheels being directly below the generators. The mezzanine floor of this section holds the instrument board and the

control apparatus.

The second section houses the transformers, lightning arresters, and oil switches. This section is of two stories and abuts the main section on the east. The oil switches are set on the second floor while the transformers and lightning arresters are set on the main floor.

The third section contains the boiler plant and storage for coal. This is on the downstream side of the second section. The boiler is used to heat the building and to keep the oil at the proper temperature for operation.

#### WHEEL SETTING

The wheel setting is of that type known as the open pit. Each wheel is set in a separate concrete pit 25 feet deep and 23 feet, 5 inches center to center. These pits are protected by means of iron racks and the water may be drawn out of them by closing gates, electrically operated, when it is necessary to work on the runners. Each pit contains a 72-inch, inward flow, vertical turbine, built by the Allis-Chalmers Co. The draft tubes are 28 feet

long and extend well under water. (See Appendix B).

#### TAIL RACE

The tail race channel from the wheels is cut out of the limestone which formed the original bed of the stream. The channel has sufficient capacity below the wheels but debris in the bed of the river directly below the dam causes the thread of the tail race to turn through a right angle and flow to the west bank of the river before continuing down the river. When one wheel is running, which might be said to be the normal operating condition at the plant, it is evident that the tail race is raised an appreciable amount by this debris. As water is at a premium the greater part of the year, the authors believe it advisable to remove this debris thus adding an appreciable amount to the head on the wheels. This has been estimated to be about 2 feet (Appendix.E.)

#### EQUIPMENT

The turbine installation consists of five 72-inch, Allis-Chalmers, inward flow, vertical runners, rated at 1450 horsepower per unit, at 94 R.P.M. under a normal head of 22 feet. The generators are

mounted on the same shafts above the runners and consist of the following:

(1) Three - 3 Phase.  
2300 volt,  
250 amperes  
25 cycles

and (2) Two - 3 phase  
2300 volt,  
277 amperes,  
60 cycles.

all manufactured by the General Electric Company. There are three exciters. The water-driven one is only used when the transmission line is dead and it is impossible to secure current in order to drive the motor-driven exciters. The water-driven exciter is driven by a small vertical, high speed runner made by the Allis-Chalmers Co. and delivers 1000 amperes at 125 volts. The two motor-driven exciters are driven by 2300 volt induction motors and deliver 600 and 1000 amperes, respectively, at 125 volts.

On the 6,600 volt line to Defiance there are 3- 1 phase, 400 kva. transformers. On the 66,000 volt line to Toledo, there is 1 - 3 phase, 1000 kva. transformers with one held in reserve. On the 13,200 volt line to Paulding, there are 3- 1 phase, 200 kva. transformers.

All transformers are of the core type, oil insulated, and water cooled. The water is circulated through the transformers by means of a pump which is connected through the station bus bar to the transmission line so as to insure constant operation.

The governors on the wheels are of the Allis-Chalmers oil pressure type. An auxiliary pump is used to maintain the pressure for operating these governors.

The electrical equipment is protected by horn gap arresters, mounted on the outside of the station as well as electrolytic arresters inside the station.

The gates, which close the pit off from the forebays, are operated through a rack and pinion, which is driven by a 23,000 volt motor.

#### TRANSMISSION LINES

The transmission system may be divided into three sections: (1) 6,600 volt line to Defiance; (2) 66,000 volt line to Toledo; (3) 13,200 volt line to Paulding, Ohio. (Appendix A).

The Defiance and Toledo lines are carried on the same line of towers to an automatic sub-station on the outskirts of Defiance. These towers are of steel set in concrete. A rigid tower is placed between every five or seven of the flexible towers. This is done to minimize the possibility of a large portion of the line going down due to the failure of one of the flexible towers.

The 66,000 volt line to Toledo is then run along the river, with feeders to the small communities which are supplied through automatic sub-stations which transform the high voltage down to 110 volts.

Through the sub-station on the outskirts of Defiance the entire system of four plants are tied together. This allows any of the four stations to feed into the 66,000 volt line and then to the consumers through transformers.

The third line, which carries current to Paulding, is relatively unimportant. It is carried on A-type of wooden poles. Farmers are supplied in groups of four or five through one transformer.

HYDROGRAPHIC SURVEY

## WATER POWER

The power that can be derived from a stream depends upon two factors, namely: the quantity of water which flows past any section per unit of time, and the distance through which it can be made to fall. Generally speaking, the former is beyond the control of man, but within economical limits, the latter can be regulated by the engineer.

In the development, which this thesis has to do with, both the head and the quantity available per unit of time are relatively small. As the head is fixed by the economic factors of the cost of overflowed land, it can easily be determined by an accurate line of levels run from the site up the river and the height of impounded water at any point figured by the back-water formula.

The determination of the stream flow available is an exceedingly difficult task and there is no accurate mathematical method so far devised. This is the factor which the following pages will discuss at greater length.

### STREAM FLOW

Stream flow or runoff is that portion of the rainfall that is not evaporated, lost by seepage into deep strata, or used by vegetation, and which finds its way into stream channels as surface water. The runoff is, therefore, a residual quantity and should be considered as such. Thus the runoff does not vary directly with the rainfall but rather tends to equal the rainfall less the losses given above.

For water power purposes, the average, maximum, and minimum values of the stream flow should be determined as well as possible from data at hand before the capacity of the plant is decided upon. The authors intend to do this for the site on the Auglaize and determine the available power at the site.

### AVERAGE FLOW

There is no mathematical law governing the relation between the flow of any given stream and its causes, and so it is impossible to predict with accuracy the flow at any given time in the future. However, assuming that the discharge in the future will

not deviate far from what it has been in the past," it is possible by means of stream flow records extending over a considerable number of years," to predict the average flow for any future year with a considerable degree of accuracy. Care should be taken that there is no material change in the surface conditions or any artificial storage has been created since the stream flow data on which the calculations has been based were made.

For this particular river daily records were kept for seven water years, starting with October, 1915. Using these records the average flow was found to be 1770 second feet. While this figure is valuable to check up stream flow data secured from other sources, it is almost valueless in itself.

For a successful water power development a continuous and adequate supply of water must be available or else auxiliary power must be had to supply any deficiency. Due to the economic factors which dictate the size of the development, it is not wise to develop too much of this so-called secondary power.

We must, therefore, consider the duration of the flow and also the minimum flow or that flow which will determine the primary power.

#### DURATION OF FLOW

The duration of the flow may be determined by plotting the stream flow data in the form known as a flow duration curve. A flow duration curve is plotted in one of two ways: first, by plotting the monthly discharge for a given period in order of their magnitude, against time; or, second, by plotting the average for a number of years, the values for each year being taken in order of their magnitude, against time. The second method is recommended by the Committee on Runoff of The Boston Society of Civil Engineers. The authors have, therefore, used the latter method.

The values of runoff for the various months are arranged in order of their magnitude for the various years (Appendix E). These values are then plotted, (Plot No. 1, Appendix D).

This duration curve is based on the seven years record of stream flow. The authors attempted to extend this record by securing a relation between: first,

the precipitation per month and the runoff; second<sup>w</sup>, the precipitation per season and the flow. The results obtained did not warrant the extension of the actual record and, therefore, the curve as plotted has been obtained from actual stream guagings.

The subject of runoff is by no means a simple one and is beyond mathematical analysis. Even approximate results call for a careful consideration of the factors affecting stream flow. These factors are many and are closely related, which makes it difficult to differentiate what influence each has upon the flow.

These factors are as follows:

- (1) Precipitation
- (2) Meteorological conditions
- (3) Geographical relations of the drainage area
- (4) Topography and geology
- (5) Surface and storage conditions
- (6) Artificial use and control

(1) Precipitation. It is evident that without precipitation there can be no stream flow. Precipitation might then be called the controlling factor of runoff. However, it must be realized that the other factors may affect runoff to such a degree that almost any portion of the precipitation may be lost to runoff.

As an extreme case we might take a desert where the meteorological conditions are such that practically 100% of the rainfall is lost to runoff.

For water power purposes the variation in yearly rainfall and the distribution within the years are of primary importance.

The average precipitation for the drainage area of the Auglaize River at the stations of the U. S. Weather Bureau is fairly constant. It ranges from 33.12 inches at Paulding to 36.80 inches at Lima. These averages were obtained from rainfall data taken for 37 years and may be considered to represent the extremes in averages for stations in the area.

The greatest annual rainfall in this period at Paulding is 42.76 inches, Lima 45.09 inches. The minimum rainfall at Paulding was 26.73 inches, Lima 30.30 inches. In spite of the uniformity of the rainfall the annual runoff varies considerably due to other factors which will now be discussed.

(2) Meteorological Conditions. The most important factors of meteorology that affect runoff are temperature and atmospheric movements. The temperature

affects the runoff by causing the temporary storage of water in the form of ice and snow, This storage is only released upon a rise in temperature and may cause large flows without accompanying precipitation. In the Auglaize drainage area there are three months in which the average temperature is under 32 degrees. Two other months are very close to this figure and can be counted upon to store a considerable proportional of their precipitation as frost and ice. The abrupt rise in the temperature and the spring rains which are prevalent in this area result in the streams being overflowed by disastrous floods. This may be seen by the fact that the rainfall for March is from 8 to 10% of the yearly while the runoff is from 41 to 53% of the yearly.

The atmospheric movements play an important part in the evaporation of the water in the summer when the stream flow is naturally small. The average velocity of the wind is low averaging but 11 miles per hour. Gales of any magnitude are rarely met with in this region.

(3) Geographical Relations. The important factors include the size, shape, and location of the drainage area. The size, 1480 sq. mi., of the Auglaize basin is such as to obviate the possibility of floods due to high concentration of rainfall. On the other hand, the fan-like shape of the area is conducive to floods as the discharge from the tributaries reach the main stream at about the same time. However, this factor is outweighed by the size of the area and floods of any consequence are known only in the spring as has been explained under Meteorological conditions. The drainage area lies parallel to the path of intense storms. This tends to increase the liability for severe floods. The great flood in 1913 was due to a combination of favorable meteorological conditions and a storm whose direction was down the Auglaize. This caused one of the most disastrous floods recorded on the river.

(4) Topography and Geology. This important feature of the drainage area has been fully discussed under the Physical Conditions and will not be gone into further here.

(5) Surface and Storage Conditions. The main surface conditions affecting runoff are the drainage and the soil covering. The tributary area is well drained as there are no swamps and most of the farm lands are tilled. This means that both the surface and the ground storage are small and tends to decrease the lapse between the time when the precipitation falls and the time that it appears in the streams as surface water.

The area is practically all cultivated, thus tending to increase seepage and to decrease evaporation of ground water.

(6) Artificial Use and Control. There is no artificial use or control on the Auglaize River above the present power development so that this factor does not enter into our problem.

From the above considerations it is seen that conditions are such as to cause small stream regulation, tending to high floods in the spring time, and small flows in the summer time. It appears that the controlling factors in this particular case are the meteorological conditions which tend to high seasonal concentration of flow thus making the river unsatisfactory

for power development without attendant storage.

#### MINIMUM FLOW

The primary flow is defined as that minimum flow which is available throughout the year. To determine this would require daily  $\frac{1}{2}$ -gaugings over a sufficient length of time to include a day with an absolute minimum. The lowest flow of which there is any record, occurred in the dry year of 1894. Mr. Martin Steinberger of Defiance, who was one of the original promoters of the Auglaize Power Company, made actual weir measurements in August, 1894, and obtained a flow of 13 second feet. For all practical purposes this may be considered the absolute minimum flow. It will be seen from the flow duration curve (Appendix D) that the monthly minimum for the 7-year record is 100 second-feet.

#### AVAILABLE POWER

Reducing the above data to theoretical power for a 20-foot head, we find that the average power available at the power site to be 4,050 horsepower or 3,000 kilowatts, which amount is available 35% of the time or 4.2 months of each year.

The average power for the lowest month on the flow duration curve gives 228 horsepower or 170 kilowatts, while this value reached the minimum of 148 horsepower or 110 kilowatts in the 7-year stream flow data available.

The minimum power that is to be expected for any day is 30 horsepower or 22 kilowatts, this being based upon Mr. Martin Steinberger's weir measurement of minimum uncontrolled flow.

#### MIAMI AND ERIE CANAL PROJECT

When the plant was first projected, it was intended to increase the primary power by diverting some water from the abandoned Miami and Erie Canal through Six-Mile Creek, which is a tributary of the Auglaize. The aqueduct, which carried the canal over the creek, was broken through and a small quantity of water was allowed to feed into the Auglaize. Due to an over-estimation of the quantity of water that could be obtained, a contract with the state for water was allowed to lapse after the Auglaize Power Company had spent some \$84,000 in dredging the canal. Maps and data

on the canal are not available except at the office of the Department of Public Works, Columbus, Ohio, so that the authors were not able to obtain complete information. However, two days spent on surveying the canal convinced the authors that it is feasible to secure a flow up to about 750 second feet by removing the canal locks and by dredging the canal and creek in their shallow places. The creek is very crooked and a considerable portion of the channel would require straightening. The authors did not feel qualified to make any cost estimates from the data at hand but feel that the project would be worth investigating in more detail.

#### CONCLUSIONS AND RECOMMENDATIONS

The authors believe that, although their study is based upon a comparatively short stream flow record of seven years, they are justified in concluding that the site is overdeveloped. It is their belief that for the natural flow of the stream an installation comprising 4-500 kva. units, designed to operate at their best efficiency under a 20-foot head, is all that is

warranted. Assuming a wheel efficiency of 80% and a generator efficiency of 94%, this would require 155 second feet which would be available about 42% of the time.

Since stream regulation by means of storage is out of the question due to the topography of the basin, the only way to increase the flow and thus justify a larger plant capacity would seem to be to secure water from the Miami and Erie Canal as previously outlined. Assuming the flow obtained to be 750 second feet, the authors believe that the installation of 3-1000 kva. units to be operated under a normal head of 20 feet would be warranted. Under the efficiencies assumed above this would require 2330 second feet which would be available 42% of the time.

With the present installation the authors recommend that the possibility of securing water through the Miami and Erie Canal could be further investigated. Assuming this flow as 750 second feet as above this would permit the operation of the five units 23% of the time. As the normal electrical out-

put of the Defiance Gas & Electric Company is under 5,000 kilowatts, 1500 of which are supplied by the Maumee Hydro-electric Plant of the company, which operates with a fairly constant supply of water and under excellent conditions, it would be necessary for the Auglaize Plant to be hooked in with some larger system in order to dispose of the secondary power which would be available.

APPENDIX A

MAP OF DRAINAGE AREA

AND

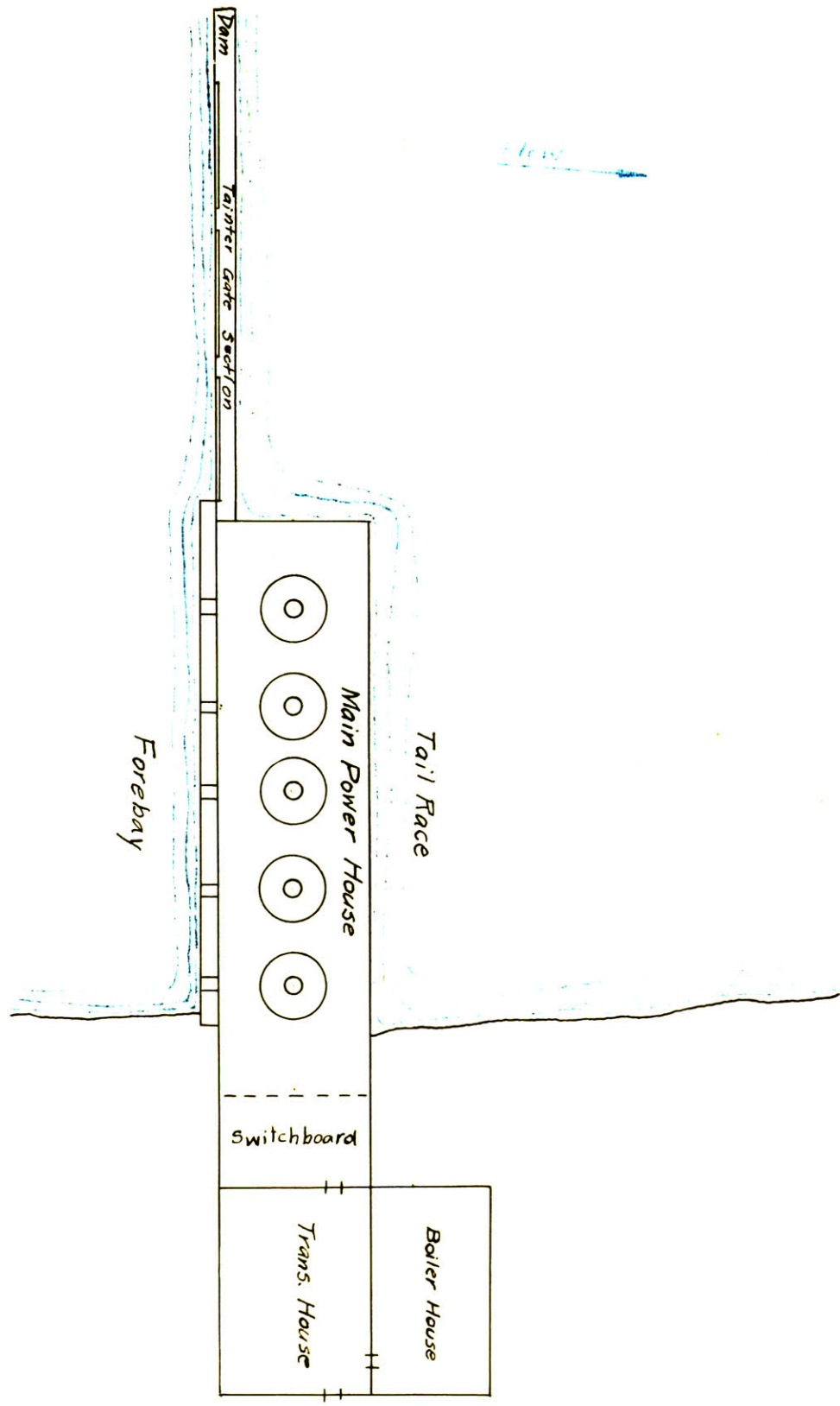
TRANSMISSION LINES

APPENDIX B

WHEEL SETTING AND CROSS-SECTION OF DAM

APPENDIX C

SKETCH OF POWER HOUSE



SKETCH of POWER HOUSE  
AUGLAIZE DEVELOPMENT  
Scale: 1"=40'

APPENDIX D

HYDROGRAPH AND FLOW DURATION CURVE

APPENDIX E

GRAPHS OF DAILY OPERATION

AND

CONDITION AFFECTING SAME

FOR YEARS 1914 AND 1915

APPENDIX F

FLOW DURATION TABLE

FLOW DURATION TABLE FOR AUGLAIZE RIVER AT POWER SITE

Year	Monthly Values											
15-16	65.60	150.00	327.00	946.00	953.00	1780.00	2260.00	2470.00	2520.00	3470.00	5010.00	9160.00
16-17	98.10	104.00	123.00	138.00	189.00	644.00	1140.00	1260.00	1790.00	1990.00	3480.00	4200.00
17-18	97.80	112.00	303.00	412.00	482.00	502.00	564.00	615.00	842.00	979.00	3200.00	5220.00
18-19	122.00	157.00	217.00	345.00	469.00	599.00	599.00	1080.00	1830.00	2150.00	3420.00	6420.00
19-20	217.00	219.00	284.00	365.00	604.00	956.00	1070.00	1650.00	1740.00	2560.00	4110.00	4930.00
20-21	89.30	89.80	137.00	200.00	458.00	1960.00	2160.00	2580.00	2940.00	3580.00	3610.00	6970.00
21-22	127.00	143.00	626.00	768.00	836.00	1250.00	1930.00	2270.00	2860.00	5300.00	5540.00	8640.00
Sum	816.80	974.80	2017.00	3174.00	3991.00	7691.00	9723.00	11925.00	14522.00	20229.00	28370.00	45540.00
Mean	117.40	139.26	208.13	453.43	570.14	1098.71	1389.00	1703.57	2074.57	2861.29	4052.86	6505.71

APPENDIX G

STREAMFLOW RECORDS

DAILY DISCHARGE IN SEC. FT. OF AUGLAIZE RIVER NEAR DEFIANCE,  
OHIO, FOR THE YEAR ENDING SEPT. 30, 1916

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	2340	420	889	3550	25900	899	7380	3890	957	557	342	29
2	2680	360	792	14700	24400	807	4240	1660	815	115	387	29
3	3160	385	1010	29600	13300	759	3430	3350	876	521	272	88
4	2660	387	775	32200	5560	726	1940	6490	877	44	174	30
5	1840	374	33	25200	3290	37	752	3600	1110	690	136	30
6	1160	312	336	16500	1940	851	558	3520	1440	600	27	31
7	1020	336	327	10200	1780	775	1020	5080	4140	584	157	108
8	956	359	315	5040	1170	1880	853	7650	6520	390	154	31
9	949	326	331	4000	759	2850	843	6170	6900	37	153	31
10	882	237	338	3160	629	2230	1040	3240	4930	219	152	105
11	816	380	312	2650	942	1490	1480	1440	3770	191	155	32
12	948	230	34	3350	894	1150	2840	1170	2220	157	148	85
13	867	235	341	8970	168	1300	1280	884	1910	201	28	76
14	734	223	334	13000	592	1120	1330	675	2260	168	160	57
15	958	211	435	11300	813	1130	1340	1180	1950	300	160	100
16	4330	167	345	7660	825	929	1010	1320	1180	51	143	32
17	3980	195	353	3490	865	840	1130	1020	1060	314	153	58
18	3910	318	630	2340	449	804	870	900	932	153	158	32
19	3670	696	1860	1420	672	534	804	853	1070	200	158	33
20	4420	3480	2450	1220	676	771	688	543	1100	159	30	33
21	2800	6640	1420	1860	680	780	735	344	3850	339	160	33
22	2210	4020	1170	6850	615	1970	1150	706	6260	461	162	33
23	1220	1500	1050	11800	1530	11000	1700	711	6990	287	149	33
24	693	1660	1080	8460	2500	14700	1440	770	3900	453	161	172
25	1020	910	456	4820	3320	13400	996	870	2760	625	160	98
26	988	1140	1200	3790	2550	6760	1770	970	892	418	143	83
27	826	863	3330	7700	1590	16000	7140	1290	958	550	29	106
28	902	356	2180	5950	1280	21800	11400	4290	832	538	164	102
29	852	963	2110	6480	1060	18900	10500	3500	769	329	147	116
30	801	911	1700	9070		16000	3840	655	769	88	90	143
31	610		1400	17600		13100		1320		375	29	
Max.	4420	6640	3330	32200	25900	21800	11400	7650	6990	690	387	172
Min.	610	167	33	1220	168	37	558	344	769	37	27	29
Mean	1780	953	946	9160	3470	5010	2520	2260	2470	327	150	65

DAILY DISCHARGE IN SEC. FT. OF AUGLAIZE RIVER NEAR DEFIANCE,  
OHIO, FOR THE YEAR ENDING SEPT. 30, 1917.

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	369	34	160	810	3920	2140	8300	705	1780	2400	171	129
2	163	56	27	801	2630	1600	13100	485	1900	1220	516	45
3	44	115	135	598	1940	1100	17400	426	1430	1000	164	33
4	47	221	28	673	1180	641	16400	330	1190	474	189	214
5	31	156	29	1230	1080	1320	11800	1380	644	546	32	291
6	32	31	77	4620	950	1230	11200	7660	865	469	186	241
7	108	24	29	7660	853	1150	12200	6640	1870	505	175	277
8	192	24	31	7660	910	1090	10200	3350	3380	433	169	31
9	32	302	319	5170	960	919	5180	1700	1470	801	167	117
10	103	79	123	3790	966	810	2960	1600	1310	816	165	32
11	468	24	67	2080	380	4760	2090	1370	1320	927	163	61
12	130	128	32	1500	476	8900	1510	1030	1110	391	104	33
13	65	40	106	1280	391	12200	1270	615	892	434	245	33
14	43	26	394	621	389	10900	1010	866	1230	429	27	34
15	54	103	283	1130	301	10200	602	707	1510	393	28	35
16	29	119	30	831	286	8560	1030	643	1130	423	338	35
17	29	86	73	995	129	5020	1220	649	636	401	29	74
18	56	43	31	937	11	3340	1080	431	756	402	30	62
19	229	128	31	603	232	2050	831	447	474	1150	80	86
20	399	49	31	469	277	1620	998	785	562	1020	58	36
21	654	81	32	41	287	1470	710	1450	661	787	84	36
22	77	113	32	222	456	1410	274	2510	666	392	108	93
23	20	117	32	237	579	1460	844	5280	473	646	124	169
24	59	606	33	296	795	4410	692	4980	455	642	31	182
25	157	24	92	752	3680	5310	603	3020	1750	522	45	328
26	48	98	40	1010	2590	2730	602	1720	1180	648	81	57
27	22	25	256	1100	2900	3110	598	1000	1080	731	74	84
28	34	38	248	759	2260	3450	475	1390	888	683	50	34
29	78	26	706	1060		1930	345	2800	1210	344	54	35
30	24	27	1320	2220		1640	619	3900	4100	236	307	208
31	24		1020	4380		1320		1900		305	287	
Max.	654	606	1320	7660	3920	12200	17400	7660	4100	2400	516	328
Min.	20	24	27	41	11	641	274	330	455	236	27	31
Mean	123	98.1	189	1790	1140	3480	4200	1990	1260	664	138	104

DAILY DISCHARGE IN SEC. FT. OF AUGLAIZE RIVER NEAR DEFIANCE,  
OHIO, FOR THE YEAR ENDING SEPT. 30, 1918

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	42	8550	668	471	157	1480	327	1050	573	14	28	134
2	228	5410	129	786	329	4910	389	1380	337	18	303	28
3	267	3090	31	719	18	6130	386	854	759	23	103	29
4	88	1260	48	695	265	3840	386	574	667	28	28	355
5	35	1350	49	643	282	1230	411	194	614	30	376	1040
6	49	1000	50	177	17	4610	658	597	607	31	357	1010
7	243	867	90	48	19	4430	144	556	748	253	264	948
8	70	663	325	49	157	3020	403	409	878	212	403	862
9	199	638	417	49	363	2210	404	419	1030	31	345	1140
10	219	572	302	51	236	3830	395	478	1430	31	96	455
11	83	122	186	302	610	6830	401	248	942	100	14	635
12	419	637	147	496	5500	5540	399	337	831	213	150	924
13	271	652	134	226	9900	4200	343	418	846	116	26	897
14	214	480	137	444	23200	7900	320	644	839	234	63	676
15	217	658	111	440	20000	10400	388	870	768	362	15	108
16	230	631	174	432	19800	8600	376	897	317	457	16	753
17	214	544	42	414	11600	4980	447	893	385	303	17	803
18	313	206	43	103	6450	3140	382	685	206	305	17	832
19	308	377	69	107	4460	1890	386	328	218	282	18	924
20	355	346	45	24	8420	1080	276	870	224	93	108	850
21	182	310	319	179	10100	1720	122	873	206	18	18	722
22	414	315	811	196	7250	1320	402	878	17	60	18	145
23	519	69	570	275	4360	1320	401	852	18	32	19	836
24	440	31	1450	287	3260	456	399	812	286	20	21	448
25	459	150	2130	312	3020	1240	396	643	418	21	23	315
26	546	55	1460	303	2230	1070	379	176	171	22	24	234
27	547	83	1360	93	2400	615	504	382	232	56	25	204
28	175	81	1210	218	1890	443	342	384	480	24	41	189
29	1900	161	1080	287		391	903	472	9	26	42	169
30	7730	58	416	280		365	903	111	7	26	26	248
31	9140		959	276		26		798		28	28	
Max.	9140	8550	2130	786	23200	10400	903	1380	1430	457	403	1140
Min.	35	31	31	24	17	26	122	111	7	14	14	28
Mean	842	979	483	303	5220	3200	412	615	502	112	97.8	564

DAILY DISCHARGE IN SEC.FT. OF AUGLAIZE RIVER NEAR DEFIANCE,  
OHIO, FOR THE YEAR ENDING SEPT. 30, 1919.

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	257	475	403	1120	687	867	837	937	342	872	313	29
2	297	420	897	3500	449	756	810	779	811	690	589	30
3	361	160	932	4180	627	908	782	847	910	787	384	31
4	22	479	978	2550	605	862	738	669	831	392	295	32
5	24	36	1060	1400	533	798	677	3060	494	329	302	33
6	82	57	765	1010	584	791	474	5300	612	255	557	33
7	24	37	612	1180	623	799	795	5080	719	159	996	354
8	25	116	415	1130	632	780	835	2670	430	100	931	188
9	26	447	401	1000	391	1120	805	1930	372	97	891	173
10	27	110	417	973	494	6850	808	1630	379	104	499	31
11	28	343	377	1020	532	9100	819	1640	570	317	627	31
12	29	490	596	755	488	6820	802	1920	327	227	377	32
13	57	485	896	368	506	5180	553	1650	497	317	344	32
14	57	473	6900	457	520	2460	842	1420	640	65	200	154
15	31	474	10800	638	655	6680	802	1150	441	263	237	32
16	32	576	11600	378	512	16900	5540	1210	416	115	113	100
17	32	527	7000	392	452	31900	7950	2430	57	36	374	49
18	33	934	4300	548	491	36100	10600	2550	167	36	233	33
19	50	981	1900	408	484	30000	8170	2230	230	37	282	33
20	289	894	1490	512	461	15700	5990	1440	403	332	276	33
21	48	1420	3520	567	479	8360	2520	2030	111	36	150	307
22	289	1520	7990	524	490	3770	1080	1960	478	36	151	164
23	369	1130	9600	309	563	1600	1720	2270	88	37	37	226
24	356	641	9200	664	839	1290	1820	1990	212	94	81	190
25	32	899	8000	744	868	970	1810	1470	381	38	393	273
26	403	901	4780	1190	873	909	1620	1890	268	38	343	288
27	1070	871	3830	1610	1000	1140	1310	1580	86	373	268	91
28	58	439	2440	1350	946	1730	1220	1210	718	87	204	372
29	51	865	1580	1200		1740	902	937	854	93	29	127
30	56	764	1330	975		1280	797	509	1220	64	39	171
31	345		1140	845		1020		476		291	180	
Max.	1070	1520	11600	4180	1000	36100	10600	5300	1220	872	996	372
Min.	22	36	377	309	391	756	474	476	57	36	29	29
Mean	157	599	3420	1080	599	6420	2150	1830	469	217	345	122

DAILY DISCHARGE IN SEC. FT. OF AUGLAIZE RIVER NEAR DEFIANCE,  
OHIO, FOR THE YEAR ENDING SEPT. 30, 1920

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	663	11000	8440	300	303	442	1080	1230	305	335	101	35
2	941	11100	4120	330	265	435	1030	1470	253	670	354	35
3	483	10300	2730	306	131	928	932	1610	170	853	347	36
4	495	7600	1170	313	73	4800	583	1200	145	648	364	261
5	363	3170	1250	313	144	7230	901	989	99	1050	357	106
6	546	2100	1110	309	116	8220	985	999	135	1230	373	117
7	547	2020	876	361	96	8190	1090	928	32	2540	320	447
8	637	1540	1110	245	124	4880	1060	855	67	5620	107	486
9	321	1260	1140	184	303	3450	789	724	192	3890	819	599
10	116	1460	1120	108	369	2400	315	972	195	2570	209	579
11	655	1060	1050	118	420	3180	503	1010	193	2160	10	399
12	524	1670	1070	216	494	7910	240	992	98	1360	11	40
13	1620	2210	664	214	916	12200	217	994	176	816	12	462
14	2320	1850	457	217	988	9550	365	1010	363	712	13	451
15	1760	1400	338	221	983	4850	914	947	191	1390	14	270
16	1120	918	421	217	1480	4380	1090	1010	201	1980	395	428
17	913	1090	579	54	1120	9140	8000	1260	120	1730	1460	422
18	780	876	526	102	1040	8640	14800	1070	168	1300	1460	355
19	499	962	420	227	1040	4040	11200	949	563	3710	1250	87
20	969	929	413	244	1020	4520	13300	927	376	6380	717	125
21	766	1020	435	73	919	2120	17800	924	838	4170	502	166
22	382	515	440	79	392	2750	17600	819	840	2160	637	166
23	224	156	430	104	327	2110	19800	742	488	1510	652	97
24	204	265	462	416	530	1740	14100	895	484	917	574	32
25	335	465	356	281	645	1360	8980	949	477	644	27	33
26	474	586	329	238	994	1160	3940	973	412	907	67	131
27	658	690	315	238	1020	1030	2050	964	277	869	30	33
28	1090	989	360	247	796	795	1650	959	157	403	31	48
29	8290	3100	335	220	469	1550	1450	559	163	411	32	34
30	11600	4380	337	258		2080	1180	383	351	523	33	35
31	11000		314	98		1420		328		533	34	
Max.	11600	11100	8440	416	1480	12200	19800	1610	840	6380	1460	599
Min.	116	156	314	54	73	435	217	328	32	335	10	32
Mean	1650	2560	1070	219	604	4110	4930	956	284	1740	365	217

DAILY DISCHARGE IN SEC. FT. OF AUGLAIZE RIVER NEAR DEFIANCE,  
OHIO, FOR THE YEAR ENDING SEPT. 30, 1921.

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	13	739	2080	844	1390	507	7290	9220	1130	332	31	33
2	35	994	3780	2910	1310	484	2930	10600	1150	268	385	33
3	106	1160	5490	5020	1340	835	1960	7050	939	262	419	33
4	36	1120	5520	3980	1380	1490	1480	3790	1060	549	28	75
5	149	904	7600	2770	2480	1430	1050	1640	766	562	29	151
6	301	438	8800	2170	6030	2710	782	1130	1190	263	30	84
7	89	361	6370	1800	8390	7180	542	995	1330	176	31	33
8	34	576	5100	2050	10500	10700	693	586	1240	163	31	171
9	35	576	2180	2300	11800	11400	4360	493	743	354	32	32
10	363	512	1780	2800	9870	13400	6340	404	249	29	60	354
11	35	382	1560	1800	6350	13700	4120	586	92	231	34	300
12	33	363	1400	1380	3870	10300	2300	436	19	254	35	29
13	33	315	1630	957	3070	9860	1790	573	250	160	313	31
14	33	332	1640	601	3940	10000	1360	815	53	27	131	31
15	36	383	1910	652	7370	8030	1300	529	49	28	34	32
16	34	588	2240	604	6110	5480	4060	598	267	28	34	32
17	233	331	1790	827	3380	5050	8500	503	24	28	79	181
18	33	325	1090	548	2940	3030	11400	335	252	77	155	279
19	34	327	1080	494	1880	1930	11500	268	25	26	248	31
20	34	273	979	443	1340	2110	7440	368	77	29	99	32
21	35	1120	758	333	1120	1270	4370	521	31	29	32	33
22	70	3820	770	2280	960	1150	1320	238	158	111	32	99
23	35	8030	1810	7310	914	1150	3020	329	52	29	33	34
24	35	12000	3110	8280	653	1770	1920	840	41	46	33	34
25	36	9010	2530	4270	692	5930	2840	10400	528	29	33	303
26	84	5770	1810	2980	703	8390	1650	15300	404	29	122	34
27	762	3460	1290	1510	658	8610	1110	9280	429	30	33	35
28	1180	1830	1150	1260	657	13800	1710	4770	532	30	60	35
29	1060	1610	904	1200		20200	2420	4710	331	30	33	36
30	803	1160	816	1290		20600	5900	2090	329	31	87	36
31	386		992	1380		13700		1660		31	33	
Max.	1180	12000	8800	8280	11800	20600	11500	15300	1330	562	419	354
Min.	13	273	758	333	653	484	542	238	19	27	28	29
Mean	200	1960	2580	2160	3610	6970	3580	2940	458	137	89.3	89.8

**DAILY DISCHARGE IN SEC. FT. OF AUGLAIZE RIVER NEAR DEFIANCE,  
OHIO, FOR THE YEAR ENDING SEPT. 30, 1922.**

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	36	364	1660	724	596	1310	22100	685	1400	468	542	70
2	327	514	1450	451	616	1020	22200	696	1000	58	276	255
3	35	1580	2050	828	2400	836	15900	566	886	354	306	307
4	35	1520	2570	817	3860	865	8850	1020	608	193	203	1340
5	78	1020	2070	2940	3280	771	5420	2030	709	184	254	3080
6	35	610	1460	5900	2610	784	2480	1600	609	210	68	1800
7	36	681	1130	4640	1720	1170	2220	1130	534	199	151	912
8	653	698	1030	2660	1280	2380	2460	1120	776	210	286	700
9	385	621	795	2320	1020	2550	3990	1010	934	287	238	510
10	137	630	665	1530	939	2280	4940	5830	983	1490	44	257
11	34	401	587	1220	860	4860	10300	7340	1870	1240	111	906
12	35	451	765	1020	993	6500	13600	7220	2490	1080	97	3020
13	36	812	1330	731	1120	6080	14300	6490	1520	1620	132	2800
14	36	1410	1750	610	1060	7020	11100	5760	1050	2230	32	1880
15	264	1580	2300	444	910	9940	12900	3040	837	2220	32	1020
16	306	1920	2270	629	758	12000	16300	2290	670	1160	32	552
17	98	2180	3010	716	574	8060	16600	1570	756	727	47	283
18	86	4830	5490	727	552	3960	15000	1300	470	675	48	478
19	46	9680	9990	623	440	2100	16200	5690	460	512	35	582
20	45	12400	7250	655	680	2160	16800	12300	383	461	505	567
21	35	12300	4360	1200	1870	2390	11100	17200	378	454	101	502
22	136	7720	2740	1160	2510	2610	4340	17300	424	318	33	333
23	431	4090	1910	1060	4960	2670	2340	11600	372	82	33	320
24	104	2670	1730	839	6780	4290	1920	7140	396	389	34	79
25	157	2710	1930	648	7120	6150	1570	5150	301	434	35	431
26	63	2720	2370	646	1960	6130	1240	8920	376	413	185	571
27	131	2470	1850	634	1260	8180	1130	11400	429	386	35	487
28	111	2310	1410	613	1250	11600	758	10900	464	436	36	465
29	94	2510	1010	446		13300	729	7530	480	379	36	547
30	308	2380	840	627		13500	433	3760	479	81	37	25
31	123		707	643		16700		2010		443	38	
Max.	653	12400	9990	5900	7120	16700	22200	17300	2490	2230	542	3080
Min.	34	364	587	444	440	771	433	566	301	58	32	25
Mean	143	2860	2270	1250	1930	5300	8640	5540	768	626	127	836

APPENDIX H

RAINFALL DATA

RAINFALL DATA for STATIONS in  
NORTHWESTERN OHIO

STATION	YEARLY MEAN Inches
Benton Ridge	35.82
Bowling Green	37.17
Defiance	33.83
Findlay	36.59
Fostoria	33.24
Lima	36.80
Napoleon	33.56
Ottawa	34.87
Paulding	33.12
Toledo	31.73
Van Wert	33.95
Wapakoneta	33.83
Wauseon	36.81

APPENDIX I

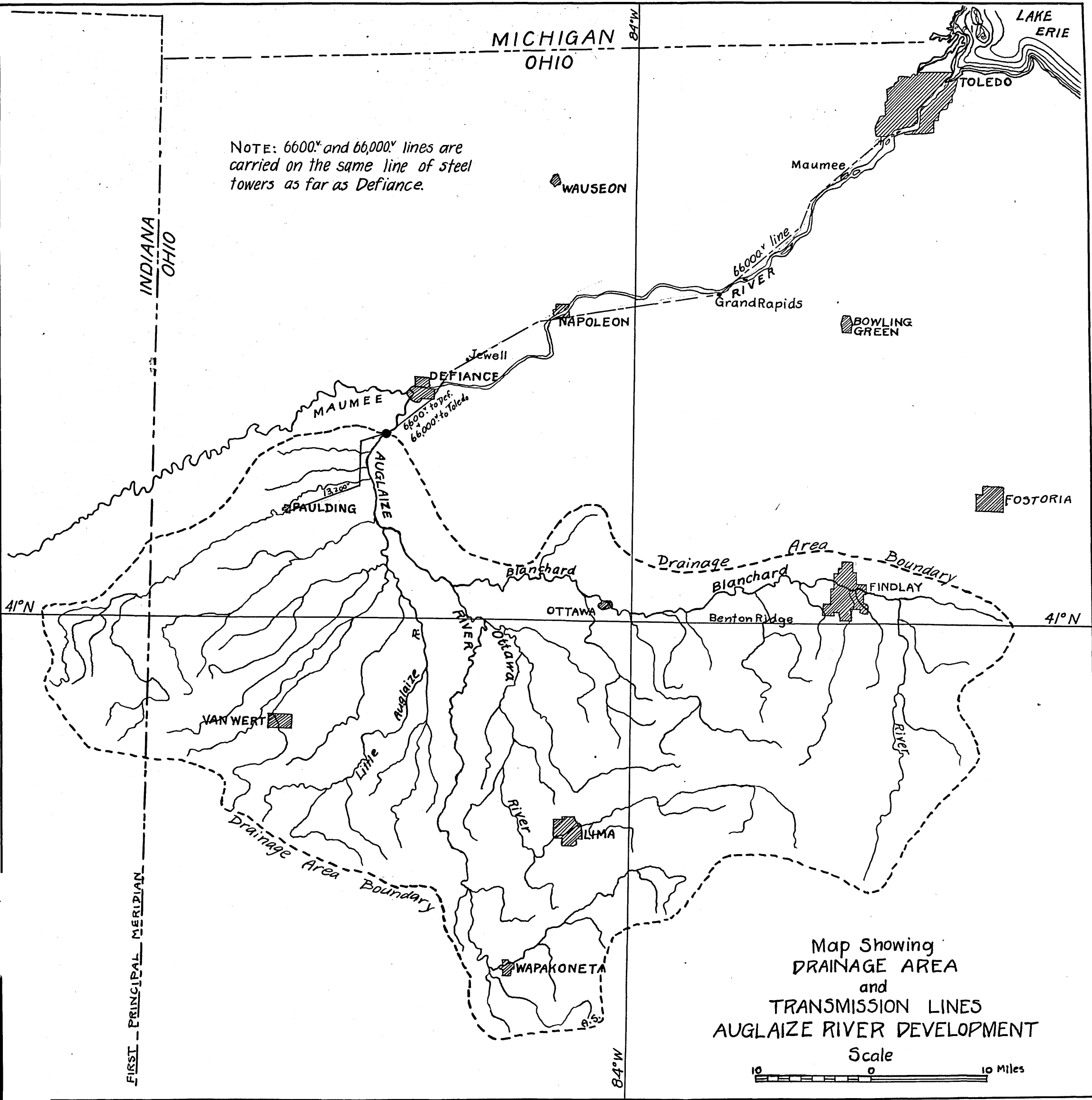
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BIBLIOGRAPHY

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GROVER, N.C. "River Discharge"
- LYNDON, L. "Hydro-Electric Power" (Vols. I and II)
- MEAD, D. W. "Water Power Engineering"
- RUSHMORE, D.B.  
and  
LOF, E.A. "Hydro-Electric Power Stations"
- SANTOS, L. J. "Hydraulica Applicada"

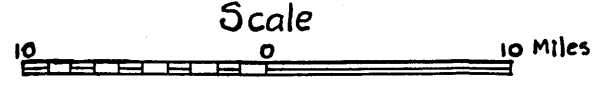
Water Supply Papers of the U.S. Geological Survey. Nos.  
280; 340-6; 334; 453; 473.

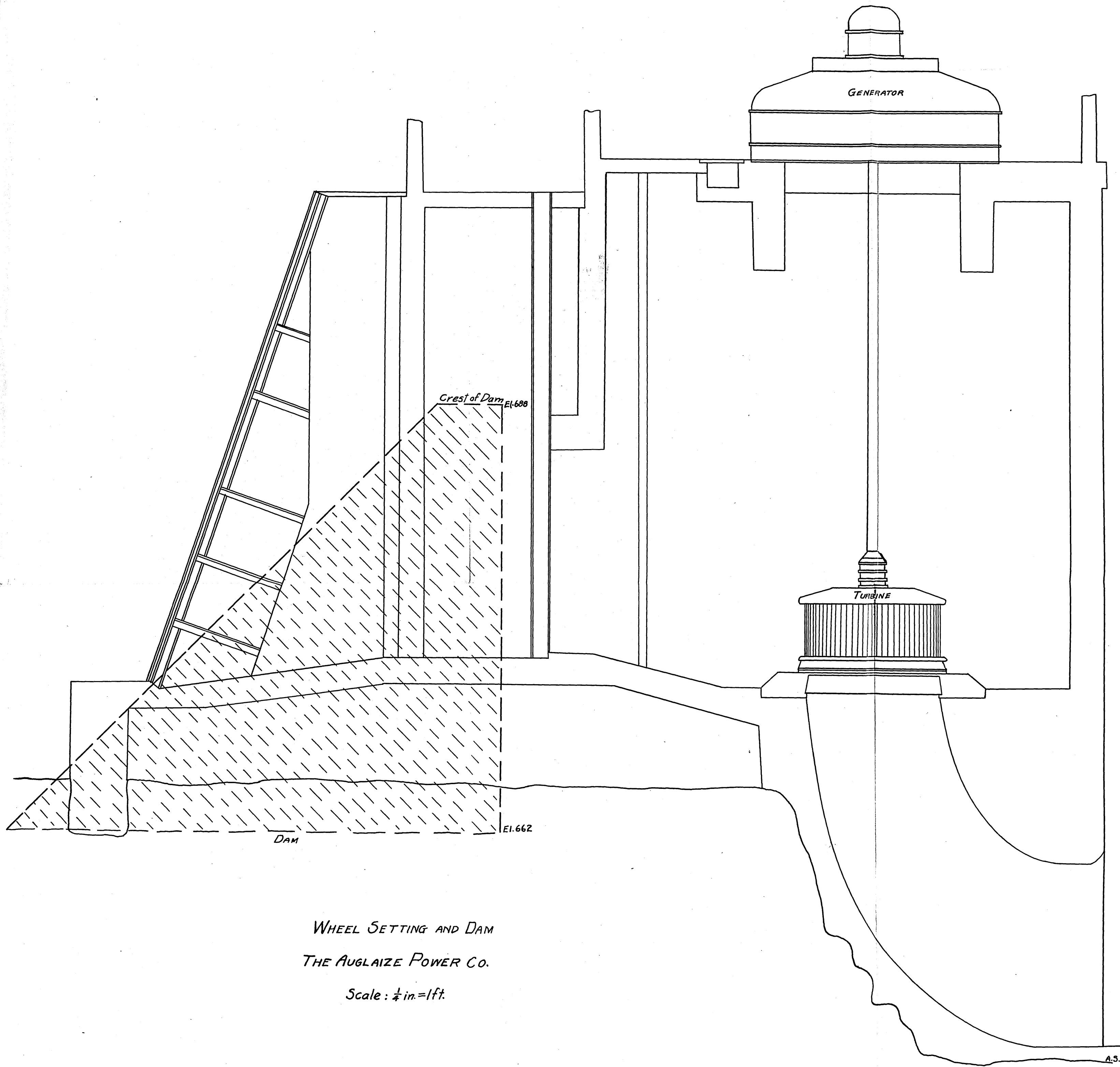
Report of the Committee on Runoff of the Boston Society  
of Civil Engineers.



NOTE: 66,000<sup>v</sup> and 66,000<sup>v</sup> lines are carried on the same line of steel towers as far as Defiance.

Map Showing  
DRAINAGE AREA  
and  
TRANSMISSION LINES  
AUGLAIZE RIVER DEVELOPMENT

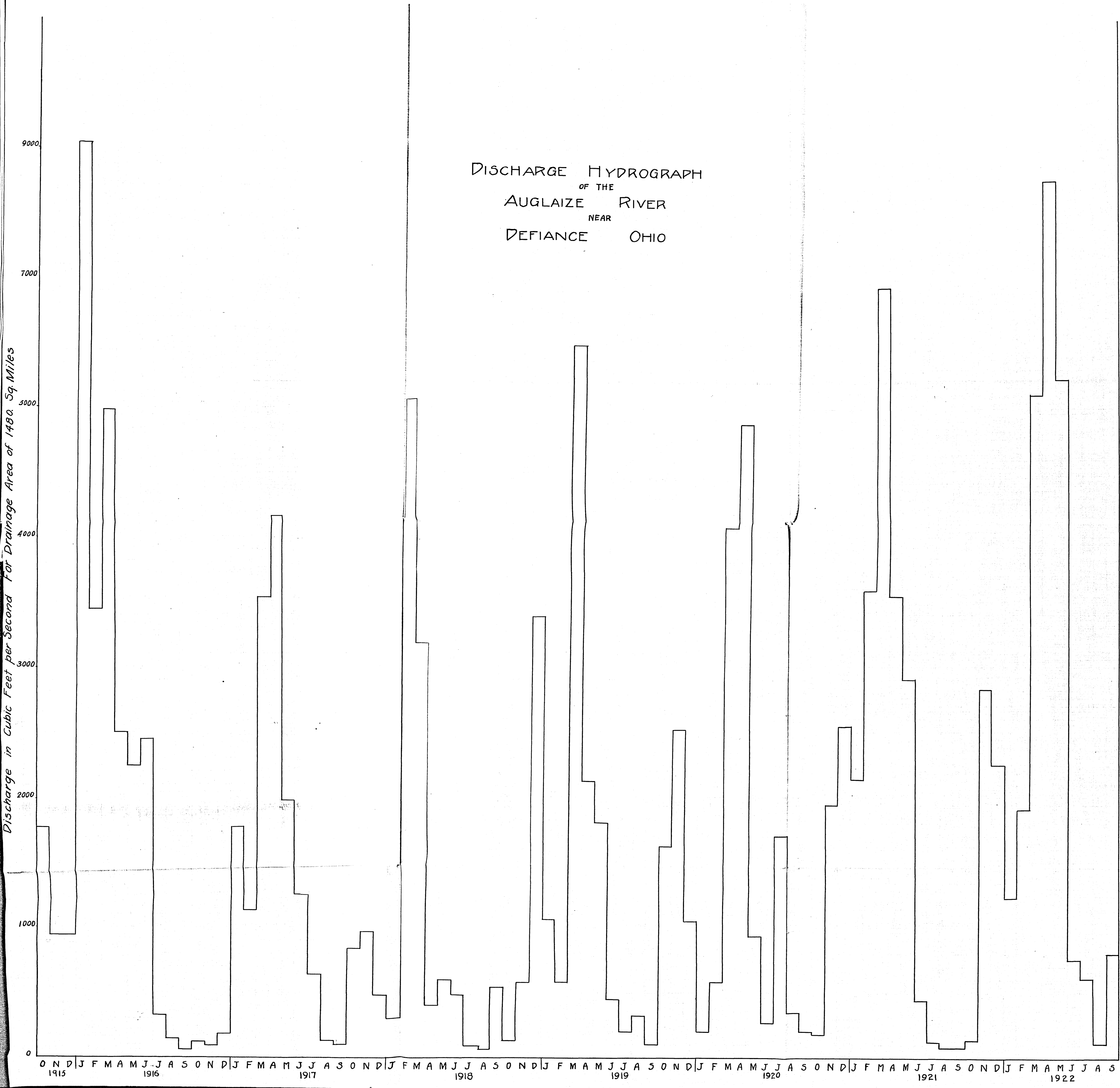




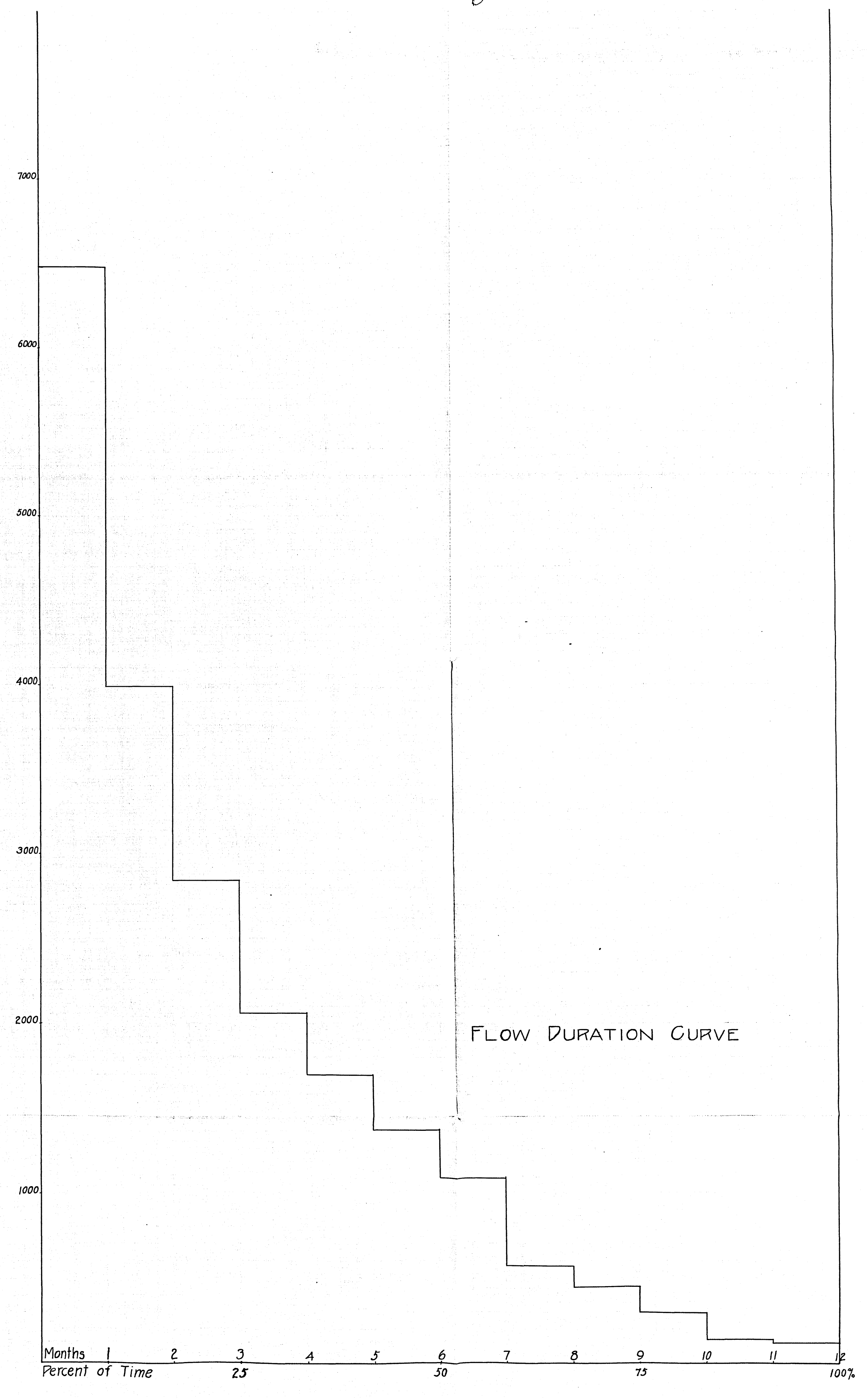
WHEEL SETTING AND DAM  
THE AUGLAIZE POWER CO.  
Scale:  $\frac{1}{4}$  in. = 1 ft.

Discharge in Cubic Feet per Second For Drainage Area of 1480 Sq. Miles

DISCHARGE HYDROGRAPH  
OF THE  
AUGLAIZE RIVER  
NEAR  
DEFIANCE OHIO



D

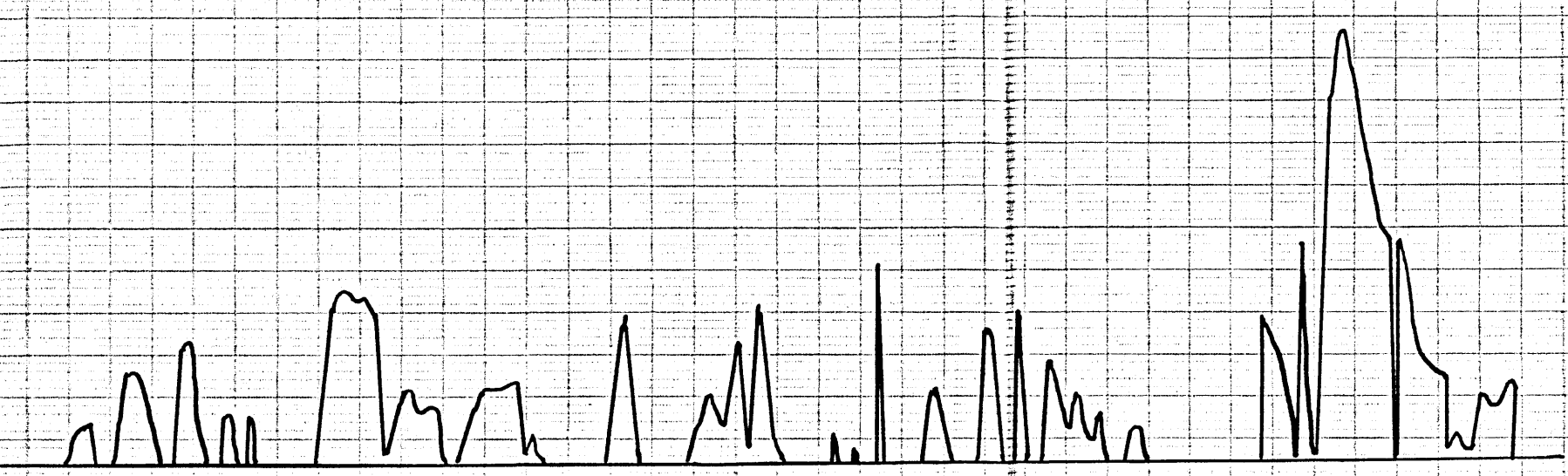


January February March April May June July August September October November December  
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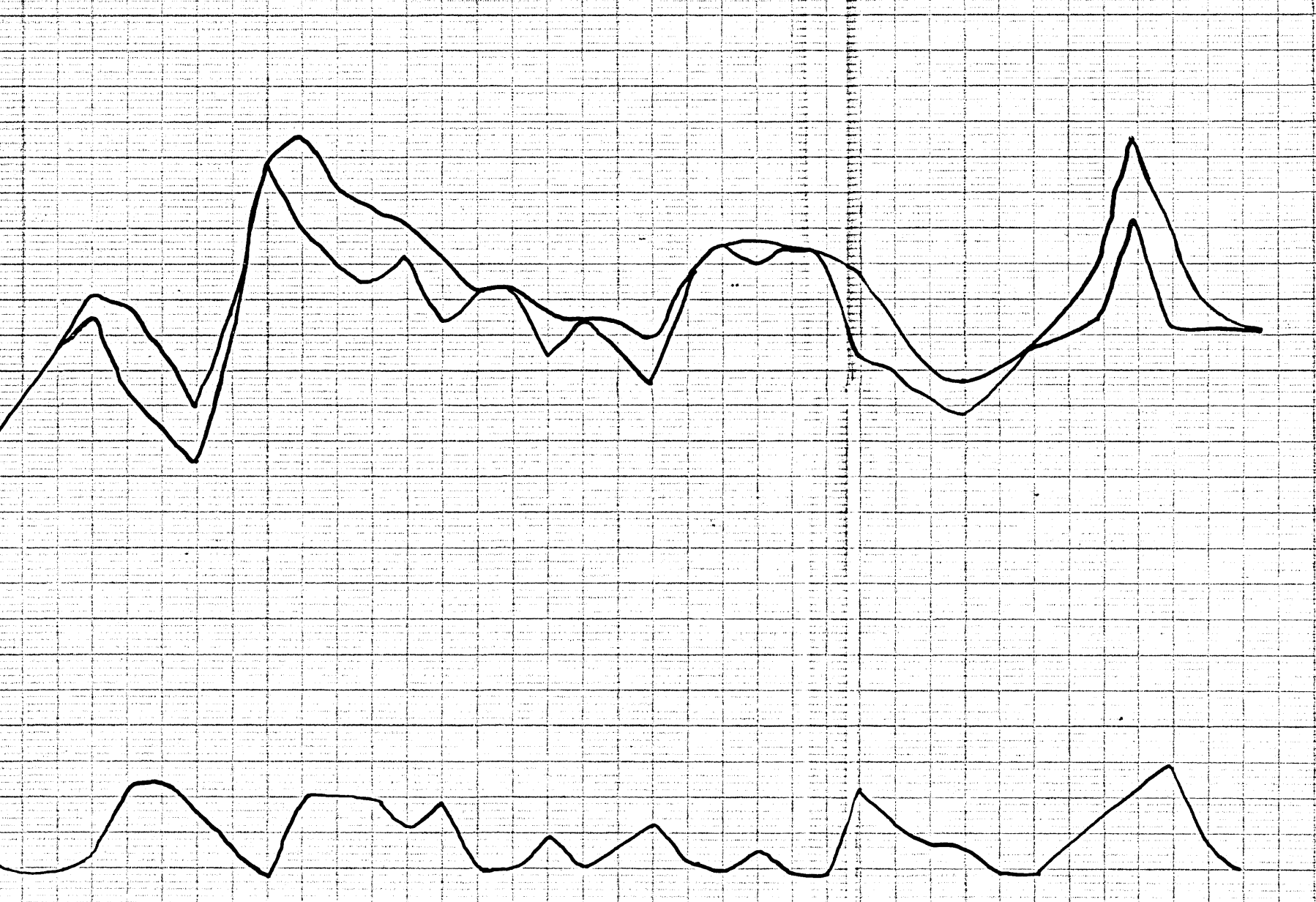
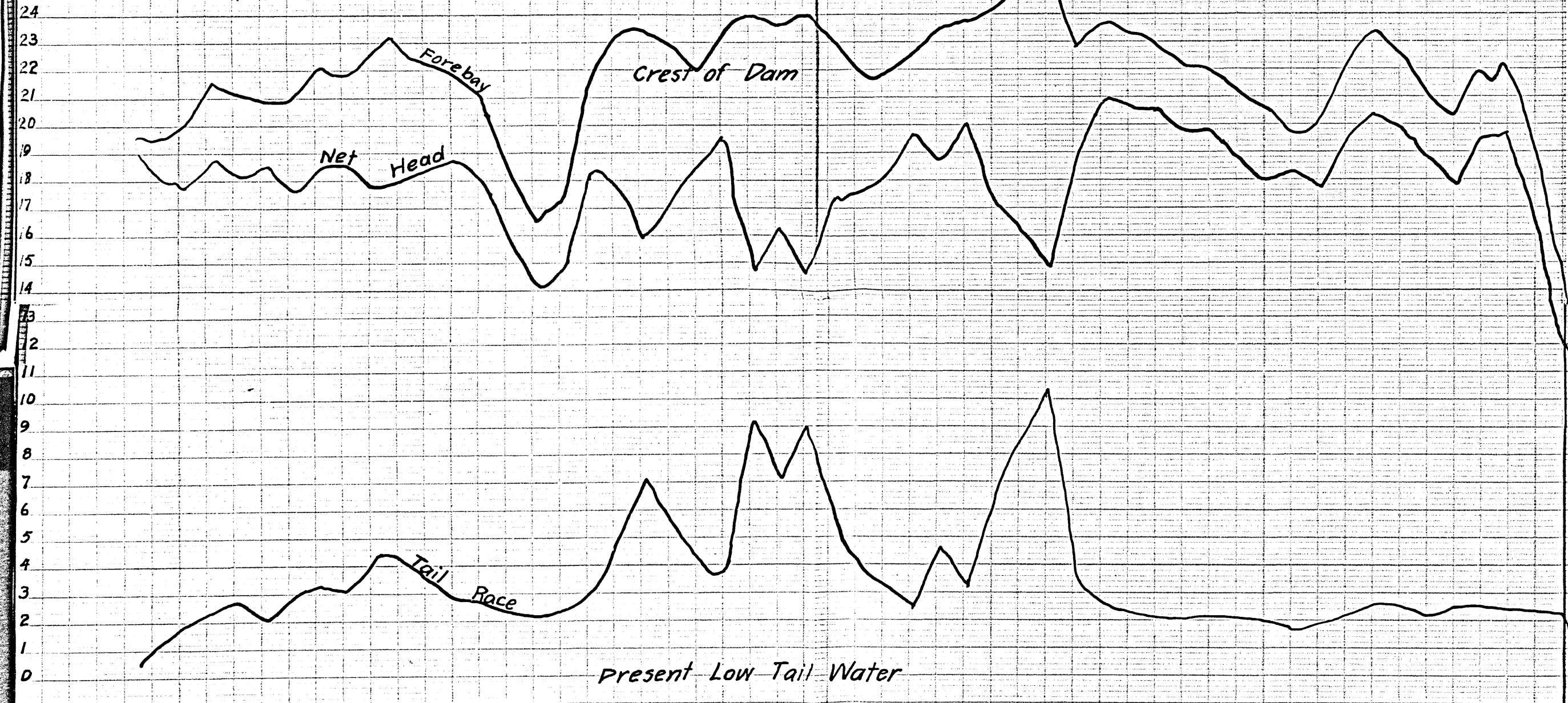
K.W.H. DAILY OUTPUT OF WHEELS



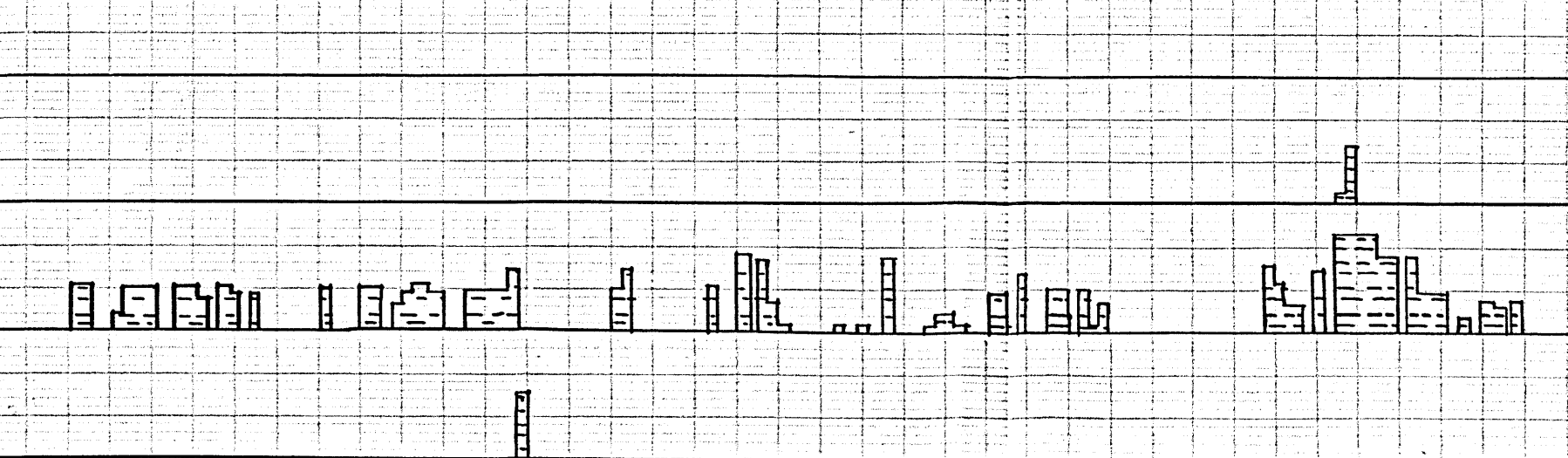
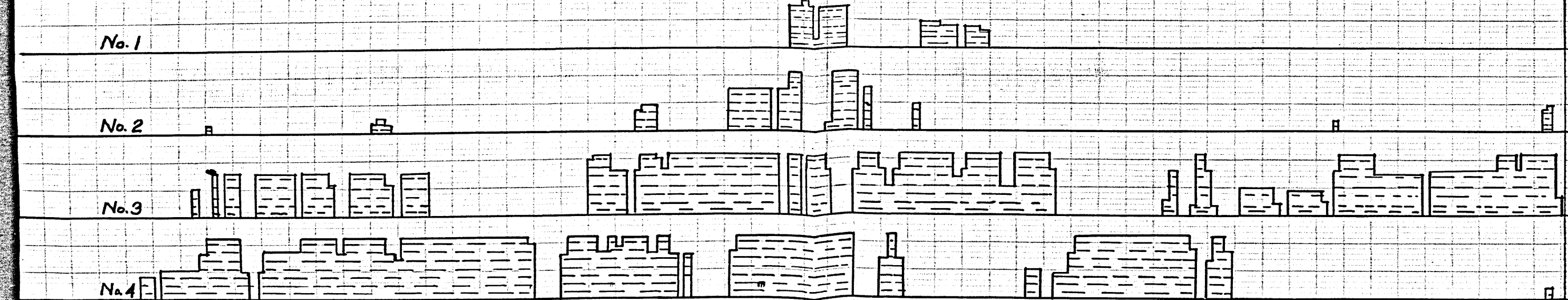
1914  
 THE AUGLAIZE POWER COMPANY  
 Graphic Illustration of daily operation  
 and conditions affecting same for the  
 year 1914 ~ From the Station Log.



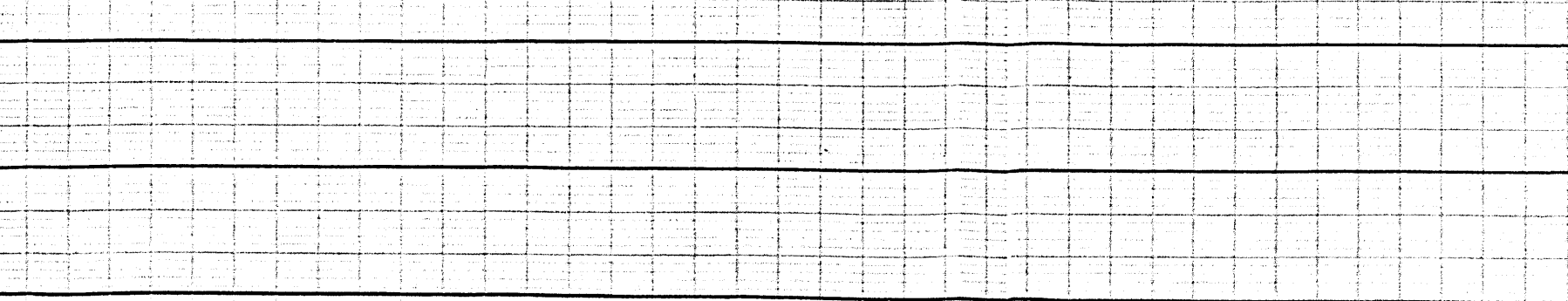
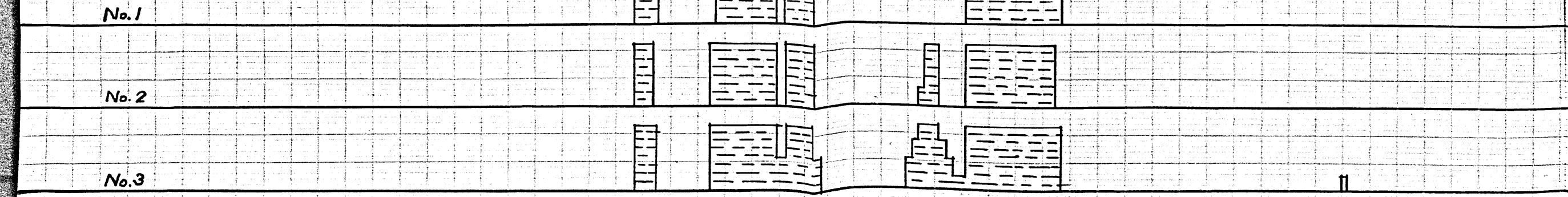
Feet WATER CONDITIONS



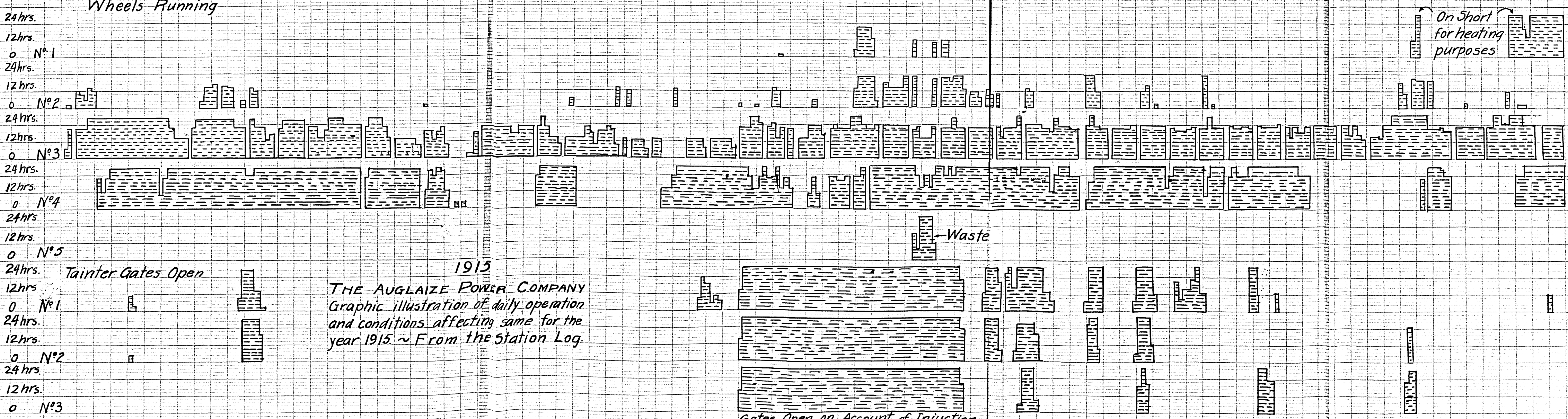
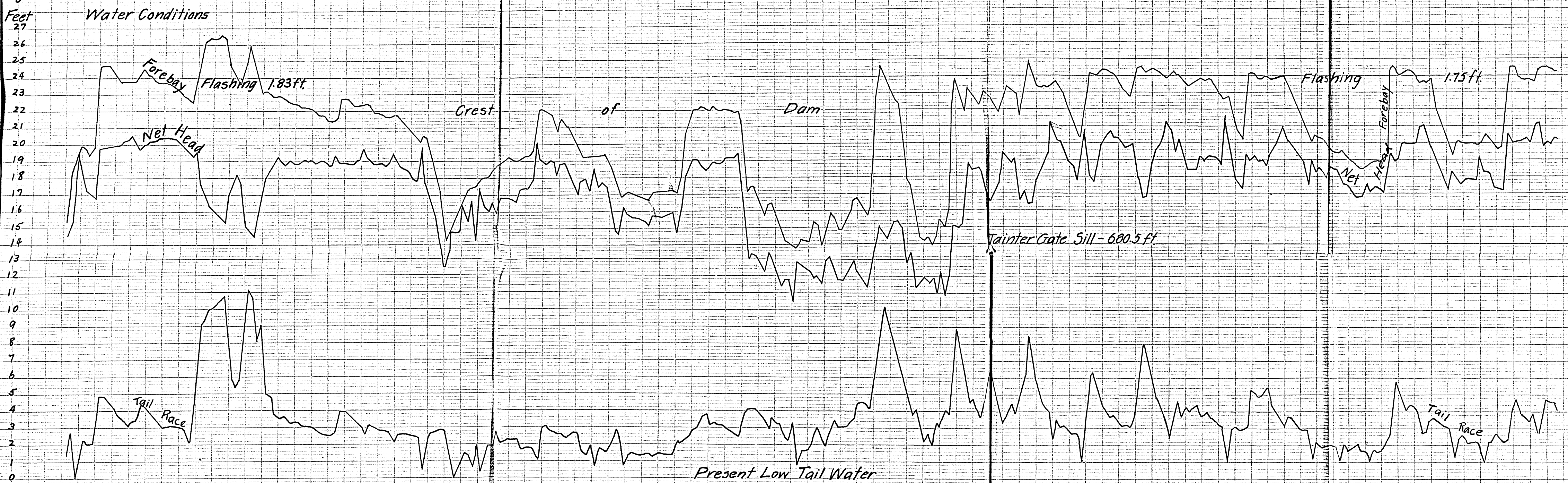
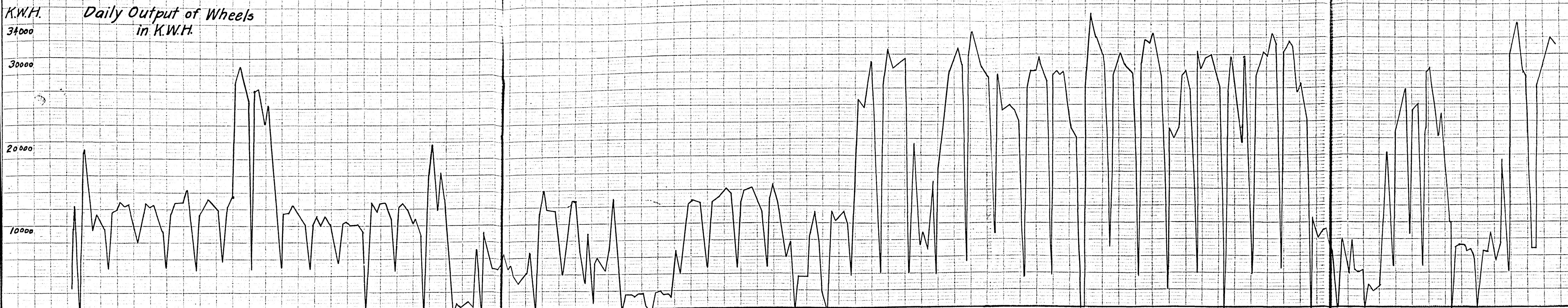
WHEELS RUNNING



TAINTER GATES OPEN



January February March April May June July August September October November December  
 1 4 8 12 16 20 24 28 1 5 9 13 17 21 25 29 2 6 10 14 18 22 26 30 4 8 12 16 20 24 28 1 5 9 13 17 21 25 29 3 7 11 15 19 23 27 1 4 8 12 16 20 24 28 1 5 9 13 17 21 25 29 3 7 11 15 19 23 27 31 4 8 12 16 20 24 28 2 6 10 14 18 22 26 30



1915  
 THE AUGLAIZE POWER COMPANY  
 Graphic illustration of daily operation  
 and conditions affecting same for the  
 year 1915 ~ From the Station Log.

Gates Open on Account of Injunction