THE ROLE OF REMOTELY SENSED AND RELAYED DATA IN THE DELAWARE RIVER BASIN

by

Richard W. Paulson
U.S. Geological Survey
Harrisburg, Pennsylvania

INTRODUCTION

For several years the U.S. Geological Survey has operated a system of water-quality monitoring stations in the Delaware River Basin that provides riverine and estuarine water-quality data to water-resources agencies in the basin. This report is a discussion of the planned integration of the existing monitoring and data processing systems with a data-relay experiment proposed for the Earth Resources Technology Satellite (ERTS)-A, which will be launched in 1972. The experiment is designed to use ERTS-A as a data relay link for a maximum of 20 hydrologic stations in the basin, including streamgaging, reservoir level, ground water level, and water-quality monitoring stations. This experiment has the potential for reducing the timelag between data collection and dissemination to less than 12 hours. At present there is a significant timelag between the time when the data are recorded at a monitoring site and the water-resources agencies receive the data. The timelag exists because most of these instruments operate in remote locations without telemetry, and the data records are removed manually, generally at a weekly frequency. For most water-quality monitoring, the data do not reach water-resources agencies for a period of 2 weeks to 2 months.

WATER-RESOURCES MANAGEMENT IN THE DELAWARE RIVER BASIN

Several governmental agencies are concerned with the daily status of the quality and quantity of surface and ground waters in the Delaware River Basin. The lead water resources agency in the basin is the Delaware River Basin Commission (DRBC), which was authorized by the Delaware River Basin Compact, Public Law 87-328. This Compact, whose signatory parties are the United States Government and the states of Delaware, New Jersey, and New York and the Commonwealth of Pennsylvania, became public law in 1961. It requires the DRBC to develop, adopt, and maintain a Comprehensive Plan for the orderly development of the basin's water resources. The Basin Commissioners, who are the governors of the four states and a Presidential appointee (currently the Secretary of the Interior), have a permanent staff that is charged with the management of the water resources of the basin. Projects and areas of research for the Plan include water supply, flood protection, stream quality, recreation, fish and wildlife, pollution abatement, and regionalization of waste treatment.

The largest single task undertaken by the DRBC has been the abatement of pollution in the Delaware River estuary. This abatement program is designed to improve the estuary's quality to meet the water-quality standards adopted by the Commission in 1968. The pollution-abatement plan includes "... the adoption of basin-wide regulations for implementing and enforcing the Standards, the assignment of wasteload allocations to each estuary discharger, and the establishment of a broad surveillance program to keep fulltime check on discharge effluents and stream quality" (DRBC 1968).

Engineering and computer studies of the estuary's capacity to assimilate oxygen-consuming waste provide the DRBC with a basis for assigning wasteload allocations to dischargers once water quality standards were adopted. Soon after the wasteload allocations were issued, estuary dischargers were required to submit, for DRBC approval, schedules of compliance showing how long it would take the particular discharger to complete waste-treatment facilities required to reduce wasteload to meet the allocation. Schedules of compliance by most estuary dischargers should be complete by 1970, and a measurable improvement in the water quality in the estuary is expected to be attained in "... the-early-to-mid-1970's" (DRBC 1969).

As a Federal-State Compact, the DRBC is a uniquely authorized regulatory agency that has adopted a plan for managing the water resources of the Delaware River basin, including pollution abatement in the Delaware River estuary. The pollution-abatement plan is expected to produce a measurable improvement in water quality in the next several years at a cost of several hundred million dollars. The water-quality monitoring program of the Survey is one of several sources of data for the Commission.

For many years the City of Philadelphia has been interested in the water resources of the Delaware River Basin and the water quality of the Delaware River estuary. Since 1946, the City's Water Department, which uses the estuary as a major water-supply sources, has spent ".... nearly $300 million to expand and modernize its wastewater system. About $100 million of this has gone into facilities that directly protect the rivers ...." (City of Philadelphia, 1970). In participating in the DRBC's pollution-abatement plan, Philadelphia ".... will expand its water pollution control plants and replace many of the older tributary sewers" at a cost that ".... may exceed $200 million in the next decade" (City of Philadelphia, 1970). The Water Department has supported the operation of the water-quality monitoring system to "....warn of industrial spills, temperature rises, salt water influx, sewage problems, ... other forms of pollution .... (and to provide) data for long-range prediction of river conditions." (City of Philadelphia, 1970).

A third agency concerned with the daily status of water resources in the basin is the U.S. Geological Survey's Office of the Delaware River Master. The River Master is charged with implementing a Decree of the United States Supreme Court, which resolved a conflict of water-supply need. Water is exported from New York City reservoirs in the upper reaches of the basin to the New York City water supply system. Because the water is exported from the basin it is not available (for other uses) downstream from the reservoirs. During periods of drought the conflicting needs for the exported water by New York City and downstream users have become acutely apparent. When this conflict was brought to the Supreme Court, originally in the early 1930's and again in 1954, the Court decreed limits of withdrawal of water by New York City and a minimum level of streamflow downstream from the reservoirs. Thus, on a daily basis, and in accordance with the decree, the River Master prescribes releases of water from New York City reservoirs to maintain the required level of streamflow and monitors withdrawals from the reservoirs for New York City's water supply.

State health and natural resource agencies, municipalities, and Federal agencies, including the Army Corps of Engineers and the Federal Water Quality Administration also have need for water resources information in the basin.

DELAWARE RIVER BASIN WATER-QUALITY MONITORING AND DATA-PROCESSING SYSTEMS

The Geological Survey's water-quality monitoring system is composed of continuously operating instruments that record dissolved oxygen concentration, temperature, specific conductance at 25° C, and pH at 11 sites in the basin. (See fig. 1) The system, which is cooperatively supported by the Survey, the City of Philadelphia Water Department, the Delaware River Basin Commission, the Delaware Geological Survey, and other local, state and Federal agencies, provides water resources agencies with data on stream quality in the major rivers of the basin in addition to the Delaware River estuary and Delaware Bay.

Many of the monitors operate in remote locations where seasonal ranges in temperature and humidity are large, where sediment, algae, and other debris in the water adversely affect sensors and water-sample transfer systems, where ice and wave motion can damage sensors in the stream, and where vandalism contributes to equipment failure. For example, two of the stations frequently operate for long periods of time between servicing visits because they are on islands in the Delaware River estuary and Bay and are very difficult to service, especially during the winter months when high winds and ice make conditions very hazardous. A continuing effort is made to protect the instruments from environmental hazards, and field calibration checks are run on the instruments at every opportunity. Nevertheless, although monitors work well most of the time, they do fail occasionally. As will be discussed subsequently, data must be continuously screened for equipment failures, some of which cannot be detected in the field.

Data collected by monitors are recorded either on an analog strip chart or a 16-channel paper tape. These data records are retrieved from the monitors weekly by a technician who performs calibration tests on the instruments. The data records are returned to the Survey's Current Records Center (CRC) in Philadelphia where they are computer processed. At the end or each calendar month, data are processed to produce two computer printouts, examples of which are shown in figures 2 and 3. The printout in figure 2 contains a listing of all the hourly values of one water-quality parameter at one station. Figure 3 is a listing of daily statistics including the daily maximum, mean, minimum, range, and standard deviation, the number of missing hourly values for each day of the month, and a comparison of each day's data with recently adopted DRBC stream quality objectives (standards). Frequently, data for a particular calendar month are not completely processed until 2 weeks to 2 months after that month. The timelag varies within this range as a function of the performance of the monitors.

Although the monitors work very well most of the time, the initial steps in the data-processing system presuppose that malfunction may have taken place during the period between calibration checks. Briefly, the data at the beginning and end points of the data record are compared to independent field analyses of the four monitored parameters, and the data record is computer graphed for human screening. Human intervention in the system serves two purposes. The first purpose is to detect and eliminate spurious data from the data record, and the second is to provide a feedback loop of equipment performance back into the monitoring system. The feedback loop is necessary because some monitor malfunctions can only be detected in the data record. For example, an electronic component that behaves erratically at infrequent intervals may not be detected during a routine calibration check but may produce spurious data that can be detected by human or computer screening. Initial screening of data is made a few days after a data record is retrieved, and the feedback loop can then be closed quickly to prevent continued malfunction of the monitor.

Therefore, the data-processing system provides rapid initial screening and release of data, on a monthly basis, to water resources agencies.

The value of the large mass of water quality data presently being collected is diminished because of the timelag between data collection and dissemination. In recognition of this, efforts are made to disseminate some of these data more rapidly. The monitoring station at the Benjamin Franklin Bridge (Pier 11 North) is in one of the most heavily polluted reaches of the estuary and is near the Survey's CRC office. This station is serviced daily, and preliminary water-quality data are released via teletype (figure 4) to several agencies. A summary of water-resources conditions is also placed in a telephone recorder each day and agencies can dial the recorder directly for information. These releases provide the DRBC with data from a key estuary station. A second kay station is at Reedy Island Jetty, Delaware, where the quality of the water tends to improve after passing through the more upstream Philadelphia-Chester reach of the estuary, where water quality tends to be low. This station also is a key station because it is in the salt water intrusion zone of the estuary and because a large nuclear electric generating station, potentially capable of altering the thermal regime of the estuary, is being constructed near the station. In response to the key role of the station, the DRBC has requested that the Survey install landline telemetry from the Reedy Island monitor to the CRC during fiscal year 1971. Upon installation of telemetry, the daily release in Figure 4 will be expanded to include these data.

In addition to the daily teletype summaries, preliminary weekly and monthly summaries also are released for data not yet completely through the CRC processing system.

AN APPROACH TO PROCESSING SATELLITE-RELAYED HYDROLOGIC DATA

It is expected that a maximum of 20 hydrologic sites in the basin will be instrumented with radio telemetry at the time of launch of ERTS-A. The 20 sites will include most, or all, of the water-quality monitors in Figure 1, plus key stream-gaging stations and reservoir and ground-water level stations. Data from these sites will provide water resources management agencies with indices of water-quality, streamflow, reservoir levels, and ground-water levels. In at least one instance the radio telemetry will provide a redundant communications link with a station, because by March 1972 the Reedy Island monitor will have landline telemetry. The landline telemetry will help to provide a sound basis for measuring the utility and accuracy of three modes of operation; (1) no telemetry, (2) conventional landline telemetry, and (3) satellite relayed telemetry.

Radio-telemetry instrumentation, which is still under development, will be designed to broadcast a brief data message from each station once every 90 or 120 seconds. Although the data will be telemetered continually, data will be relayed only when the satellite passes over the stations and is simultaneously in view of both the radio transmitter at the station and a receiving station, called an acquisition site. The acquisition site for data relayed from the Delaware River Basin is at the National Aeronautices and Space Administration's (NASA) Goddard Space Flight Center in Greenbelt, Maryland. Figure 5 gives the four or more periods of time, during the daily passes of the satellite over the basin, when a hydrologic station and the acquisition site are both in view of ERTS. A data message is broadcasted every 90 or 120 seconds; so, there will be 5 to 7 data messages sent during a 10-minute period of mutual visibility every 12 hours. Seventeen days are represented in figure 5 because the orbital pattern is repeated at a 17-day frequency.

The NASA Goddard Acquisition Site will have a very high probability of receiving satellite-relayed data from each of the Delaware Basin stations at least once every 12 hours. These data will be processed and relayed by NASA to the CRC on the Bell system teletype network, which is the system the CRC uses for data dissemination. After the CRC receives data from a water resources station the data will be screened before dissemination.

The screening process for data from a particular station, while highly speculative at present, will probably include a comparison of the data with data recently received from the station. This comparison will be done at estuary stations at least because the day to day changes of water-quality conditions usually are small. On the other hand, daily changes in stage can be large at stream-gaging stations, especially during periods of heavy rainfall.

It also will be useful to compare the data with summaries of recent historical data at a station. Summaries for Delaware estuary stations are becoming available as a result of a recent CRC effort to provide water resources agencies with comparisons of recent water-quality conditions to the new DRBC stream-quality objectives. Figures 6, 7, and 8a and b are examples of computer-generated summaries for dissolved oxygen concentrations, temperature, and specific conductance.

The dissolved oxygen concentration summary (Merk, 1970) presented in figure 6 has time as the ordinate, or vertical coordinate. The water year (October 1-September 30) is broken down into 122 periods of 3 days each. The abscissa or horizontal coordinate is dissolved oxygen concentration, in milligrams per liter (mg/l), from 0 to 15 mg/l. The period October 1, 1964 - September 30, 1969, or water years 1965-69, is summarized on the graph. The summary indicates the maximum and minimum concentration recorded for each 3-day period during the 5-year period, plus statistical information on the distribution of the 15 daily means. The DRBC stream quality objectives are also plotted to provide a comparison of these data to the objective of the DRBC pollution abatement program. Thus, dissolved oxygen data received from this station can be referenced to this graph to determine whether or not the data are in the range of variation recently experienced. Of course, the graph will have to be updated as water quality conditions improve in the estuary.

The summary for temperature in figure 7 follows the same general format as the dissolved oxygen graph, except statistical information on the distribution of 15 daily-maximum values (rather than daily means) is plotted with the extremes. As the DRBC stream-quality objective for temperature is stated as the permissible daily maximum rather than the daily average, as is the case for dissolved oxygen, statistical information on the daily mean is given for dissolved oxygen.

Because specific conductance (an indication of total dissolved solids in the water) is not as seasonally dependent as are the two previous parameters, the computer summaries for this parameter were not ordered by season. The largest contribution of dissolved solids to the estuary comes from ocean salts that disperse upstream. The upstream limit of these salts can differ significantly from the vicinity of the station at the Benjamin Franklin Bridge to the station at Reedy Island, a distance of about 50 miles. The strength of salinity intrusion into the estuary is strongly correlated to fresh-water inflow to the estuary. Figures 8a and 8b show two computer summaries of specific-conductance data (Paulson, 1970). The graph in figure 8a contains cumulative frequency distributions of the daily maximum, mean, and minimum specific conductances that were measured at the Reedy Island station for all days in the period October 1, 1964 to September 30, 1969, when the daily mean flow of the Delaware River at Trenton, N. J. was within 250 cfs (cubic feet per second) of the flow level of 2,000 cfs. Figure 8b is the same graph for that station for the flow level of 11,500 cfs. Notice that the vertical 50 percentile line crosses the daily maximum curve at about 18,800 micromhos (about 33% the salinity of ocean water) in figure 8a, but the 50 percentile line intersects the daily maximum curve at about 9,300 micromhos (about 15% of the salinity of ocean water) in figure 8b. The Delaware River estuary is a large body of water and does not respond instantly to changes in fresh water inflow. In fact, its response is more adequately described as sluggish. The graphs in figures 8a and 8b are crude summaries, and the basis for a more refined summary -- based on antecedent conditions -- must be determined by further research. Yet, the graphs do provide an expected range for 20 flow intervals that have been summarized for each estuary station.

When the CRC receives satallite-relayed data they will be screened against the hydrologic range and variability of historical station data before being released. Criteria may have to be established to flag data when the hydrologic condition is an extreme condition or outside the range of a permissible level, as established by water resource management officials. Flagging of the data may be provided as a service to management officials.

CONCLUSION

Frequently, water resources management agencies have difficulty taking action against unfavorable water-resources conditions because of lack of data or knowledge of the condition and of the lack of means to affect a change. The result may be a persistent undesirable condition, such as pollution, or -- as in early 1960's during the Northeast drought -- an imperiled water supply in part of the Delaware River Basin. Difficulty may also be met in coping with short-term natural disasters such as the severe flooding, and concomitant loss of life and property, that occurred in August 1955 when two hurricanes swept across the Delaware River Basin.

In meeting its obligation under the Delaware River Basin Compact, the DRBC has a Comprehensive Plan to develop the water resources of the basin. The Plan will provide the DRBC with the means of safeguarding the basin's water resources. In order to implement the Comprehensive Plan, the DRBC has encouraged and directly supported the system of hydrologic stations maintained by the Survey in the basin and has supported the installation of telemetry at key locations. Thus, progress is being made to overcome some of the conditions that constrain water resources officials from managing the basin's water resources.

The satellite data relay experiment discussed herein will determine whether satellite relay data will be adequate to meet the data needs for responsible river basin management. It should provide the basis for determining whether or not data collected once every 12 hours from a tidal estuary is sufficient to meet these needs when the large ranges of particular parameters are weighed against time of collection within a tidal cycle. For some parameters, such a measure may not be adequate, while for others it may.

The experiment will also provide impetus to develop an operational system of real-time data processing and dissemination to handle the large quantity of data that will be obtained from the stations in the basin. A library of the characteristics of hydrologic conditions at each site will be developed as reference material for screening the data as it enters the CRC. Where possible, digital computer techniques for data summarization and screening will be developed. Human intervention in the system will probably be necessary to maintain quality control on the data.

Finally, as water resources agencies develop the means for managing river basins, the results of this experiment will demonstrate the relative merits of satellite relay of data verus conventional means of data telemetry and will provide a basis for the development of operational satellite relay of hydrologic data.

REFERENCES

Delaware River Basin Commission, 1968, Annual Report; Trenton, N. J. 21 p.

________________1969, Annual Report, Trenton, N. J. 21 p.

City of Philadelphia Water Department, 1970, Clean Streams for Philadelphia, the City's $500 Million River Cleanup, Philadelphia, Pa. 36 p.

Merk, Charles, F., 1970, A graphical summary of dissolved oxygen data for the Delaware River estuary for water years 1965-69; U.S. Geol. Survey open file report, 15 p.

Paulson, Richard W., 1970, A graphical summary of specific conductance data for the Delaware River estuary, as correlated with Delaware River flow at Trenton, N. J.; U.S. Geol. Survey open file report, 120 p.

Water Quality Monitor Site

1. Delaware River near East Stroudsburg, Pa.
2. Delaware River at Easton, Pa.
3. Lehigh River at Easton, Pa.
4. Delaware River at Bristol, Pa.
5. Delaware River at Torresdale, Philadelphia, Pa.
6. Delaware River at Benjamin Franklin Bridge
7. Schuylkill River at Philadelphia, Pa.
8. Delaware River at Chester, Pa.
9. Delaware River at Delaware Memorial Bridge
10. Delaware River at Reedy Island Jetty, Del.
11. Delaware River at Ship John Shoal Lighthouse

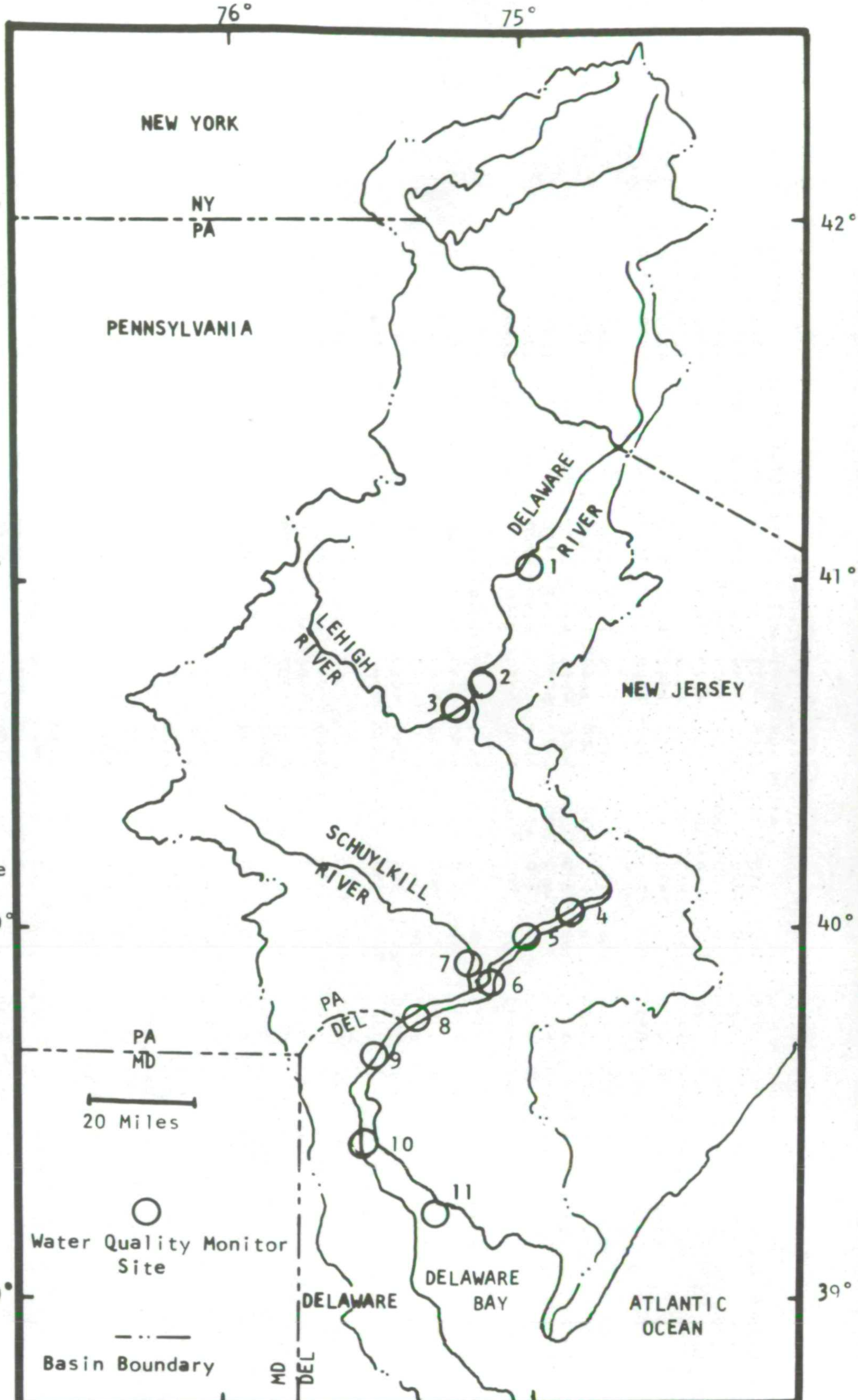


Figure 1.- Map showing location of U.S. Geological Survey water-quality monitors in the Delaware River Basin.

HOURLY VALUES OF SPECIFIC CONDUCTANCE IN MICROMHOS

DELAWARE RIVER AT DEL MEM BRIDGE STATION NUMBER 01-4821.00 MILE POINT 68.70 NOVEMBER 1969

HOUR/DAY NO.	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319
100	3840	3500	4440	4560	4540	4800	4600	5640	5540	6660	6760	5980	4360	3360	2280
200	4180	3840	3960	3880	3980	4000	4600	5040	5100	5560	6300	6160	4940	4180	3580
300	4920	4220	4180	3480	3400	3460	3800	4460	4720	5120	5940	4580	5340	5260	4160
400	5780	5180	4600	3940	3220	2860	3220	3760	4020	4700	4840	4720	4100	5140	4480
500	6480	5800	5120	4580	3520	2480	2820	3060	3340	4020	4360	4220	3780	4220	4540
600	6080	6600	5320	5380	4800	2920	3080	2780	2760	3400	3540	3560	3220	3800	3720
700	5800	6340	6320	5880	5100	3900	4220	3400	2700	2900	2780	2740	2820	3360	3600
800	5420	5760	6500	5860	6200	4560	4900	4560	3640	3060	2320	2120	2140	2820	3340
900	5080	5620	5640	5900	6540	5300	5960	5680	4500	4220	2720	1920	1480	2120	2560
1000	4380	5440	6040	5560	6060	5460	6700	6420	5000	5060	3760	2560	1500	1640	1920
1100	3880	4720	5300	5420	5640	5320	6740	7160	6000	6140	5200	3820	2580	1700	1340
1200	3520	4160	4820	4680	5380	4700	5680	7100	6580	7240	6000	5160	3620	2760	1160
1300	3820	4060	4080	3900	4620	4480	5120	5420	6640	7540	7560	5960	4520	3480	2260
1400	4980	4420	3740	3340	3940	4080	4880	5400	5980	6540	7400	7820	5400	4640	2980
1500	5480	5260	3960	3060	3320	3500	4320	5180	5460	7060	6060	6720	6460	6240	4160
1600	6380	6200	4460	3340	2880	2960	3700	4380	4940	6260	5360	5460	6400	6260	4500
1700	7040	7640	5760	4560	3240	2580	2960	3560	4080	5220	5360	5060	4860	6200	5380
1800	7100	8820	6520	5280	3960	2780	2820	2780	3500	4560	4360	4660	4520	5160	4860
1900	6420	7800	7320	6140	4580	3860	3360	2720	2840	3660	3360	3880	4120	4880	4140
2000	6080	6760	7440	6800	5400	3980	4640	3360	3040	2980	2460	2900	3180	4540	4060
2100	5780	6800	6240	6700	5800	5120	5540	4560	3900	3400	2140	1980	2500	3620	3340
2200	4940	6360	6340	5640	5860	5600	6100	5500	4700	4560	2780	1740	1700	2980	2440
2300	4420	5440	5780	5660	5180	5860	6500	6500	5960	5000	3780	2240	1540	2200	1880
2400	3880	4960	5140	5140	5160	4840	6040	6560	6600	6240	5040	3780	2160	1900	1260

HOUR/DAY NO.	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334
100	1080	940	1780	2500	3300	2340	2120	2880	2540	2220	2200	1860	1600	1420	880
200	1260	880	1240	1900	2420	2120	2180	2220	1920	2280	2280	2140	1860	1820	1480
300	2300	1300	1080	1420	1800	1580	1600	2180	1900	1720	1960	2040	2040	2080	1500
400	2780	1660	1640	1320	1280	1140	1200	1520	1560	1600	1760	1540	1860	2220	1860
500	3580	2080	2440	1760	1000	780	840	1040	1060	1280	1400	1440	1500	1760	1920
600	3640	3220	2960	2720	1100	900	700	740	700	900	1020	1140	1440	1640	1420
700	3400	3780	3640	3360	1700	1460	960	580	520	600	640	840	980	1460	1520
800	2920	3600	4140	4200	2580	1720	1680	840	520	520	540	580	700	1060	1200
900	2760	3080	3360	4660	3580	2640	2160	1560	920	700	580	580	520	740	860
1000	2200	2700	3400	5100	3700	3060	2780	2100	1380	1440	1240	840	640	600	620
1100	1660	2420	2900	3980	3900	3540	3480	2600	2020	1600	1400	1400	960	700	580
1200	1120	1800	2440	3500	2960	3140	3700	2980	2440	2320	1820	1620	1320	1440	1020
1300	880	1420	1960	3280	2900	2620	2780	2880	2720	3260	2260	2320	1860	1700	1340
1400	1280	1180	1540	2440	2600	2480	2460	2300	2520	2720	2460	2980	2300	2320	1760
1500	2320	1460	1260	2040	1900	1880	2420	2180	2160	2320	1880	2580	2940	2900	2300
1600	2600	2280	1440	1820	1380	1400	1740	1800	1980	2120	1980	2000	2260	2960	2680
1700	3260	2980	2500	1980	940	960	1260	1200	1420	1700	1580	1860	2060	2560	2740
1800	3740	3820	2960	3260	880	760	860	860	980	1140	1160	1620	1980	2140	1900
1900	3820	4620	3740	3780	1440	920	720	600	640	840	800	1100	1480	2060	2180
2000	3000	4320	4600	4520	2200	1560	840	620	540	600	520	780	980	1480	1860
2100	2780	3600	4460	5620	2640	1820	1560	860	620	620	420	580	740	1000	1260
2200	2400	3420	3580	5160	3100	2700	2220	1460	1100	980	540	500	580	700	1000
2300	1800	3000	3380	4400	3140	2960	2660	1880	1340	1440	1120	780	660	600	680
2400	1400	2400	3000	4120	2360	2940	2840	2280	2020	1920	1280	1300	880	560	580

Figure 2.-A computer listing of hourly-value data for 1 month.

DISSOLVED OXYGEN DAILY STATISTICS IN MILLIGRAMS PER LITER

DELAWARE RIVER AT BRISTOL STATION NUMBER 01-4646.00 MILE POINT 119.21 JUNE 1969

DAY NUMBER	MAXIMUM	MEAN	MINIMUM	RANGE	STD. DEV.	NO. OF VALUES MISSING FOR THE DAY	DEV FROM DRBC STRM QUAL OBJ
152	6.9	6.3	5.8	1.1	0.3	0	-0.2
153	6.2	5.6	5.3	0.9	0.2	0	-0.9
154	5.3	5.0	4.8	0.5	0.2	0	-1.5
155	5.0	4.4	4.2	0.8	0.2	0	-2.1
156	4.5	4.0	3.8	0.7	0.2	0	-2.5
157	3.9	3.5	3.2	0.7	0.2	0	-3.0
158	3.4	3.0	2.8	0.6	0.2	0	-3.5
159	3.2	2.8	2.5	0.7	0.2	0	-3.7
160	3.6	2.9	2.5	1.1	0.3	0	-3.6
161	3.7	3.0	2.6	1.1	0.3	0	-3.5
162	3.7	3.1	2.6	1.1	0.3	0	-3.4
163	3.4	3.0	2.7	0.7	0.2	0	-3.5
164	3.6	3.1	2.8	0.8	0.2	0	-3.4
165	3.8	3.1	2.7	1.1	0.3	0	-3.4
166	3.5	3.0	2.6	0.9	0.3	0	-3.5
167	3.8	3.0	2.6	1.2	0.4	0	-2.0
168	5.8	4.5	3.1	2.7	0.8	0	-0.5
169	6.4	5.8	4.8	1.6	0.5	0	0.8
170	6.6	6.3	5.9	0.7	0.2	0	1.3
171	6.6	6.3	6.0	0.6	0.2	0	1.3
172	6.4	6.2	6.1	0.3	0.1	0	1.2
173	6.3	6.1	5.9	0.4	0.1	0	1.1
174	6.3	6.0	5.6	0.7	0.2	0	1.0
175	6.7	6.0	5.6	1.1	0.3	0	1.0
176	6.2	5.9	5.5	0.7	0.2	0	0.9
177	6.0	5.6	5.0	1.0	0.2	0	0.6
178	5.7	5.4	5.1	0.6	0.1	0	0.4
179	5.5	5.3	5.1	0.4	0.1	0	0.3
180	6.1	5.5	5.0	1.1	0.3	0	0.5
181	6.2	5.5	5.1	1.1	0.3	0	0.5

MONTHLY STATISTICS

	MAXIMUM	MEAN	MINIMUM	RANGE	STD. DEV.	NO. OF VALUES MISSING
	6.9	4.6	2.5	4.4	1.4	0

FREQUENCY

SUBCLASS (LOWER BOUND)	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5
HOURS IN SUBCLASS	120	118	41	28	33	87	122	155	16

NO OF OBSERVATIONS = 720 TOTAL OF VALUES = 0.334360E 04 TOTAL OF SQUARED VALUES = 0.168473E 05

Figure 3.-A computer listing of daily-statistics data and deviations from Delaware River Basin Commission stream-quality objectives for 1 month.

GEO SURVEY-PH
710-670-3438

WE WISH CONF WITH:

510-650-0815
510-650-0814
510-681-7455
510-681-7478
510-685-9564
END

FM: US GEO SURVEY PH

TO: GEO SURVEY TNT, GEO SURVEY HBG, WB-TNT, WB-HBG, DRBC

SUBJ: DAILY WATER QUALITY OF DELAWARE ESTUARY AT
BEN FRANKLIN BRIDGE (PIER 11 NORTH) PHILA PA

DATE	D.O.(MG/L)	TEMP.(F)	SPEC.COND.(MICROMHOS)	PH
10/1	0.5 - 0.0	76 - 75	399 - 352	6.7 - 6.6
10/2*	0.4 - 0.0	75 - 75	398 - 362	6.7 - 6.7

* PROVISIONAL MAX AND MIN VALUES (MIDNIGHT - 8AM)
END/CRC

GEO SURVEY-PH

Figure 4.-A daily teletype release of Delaware River estuary water-quality data.

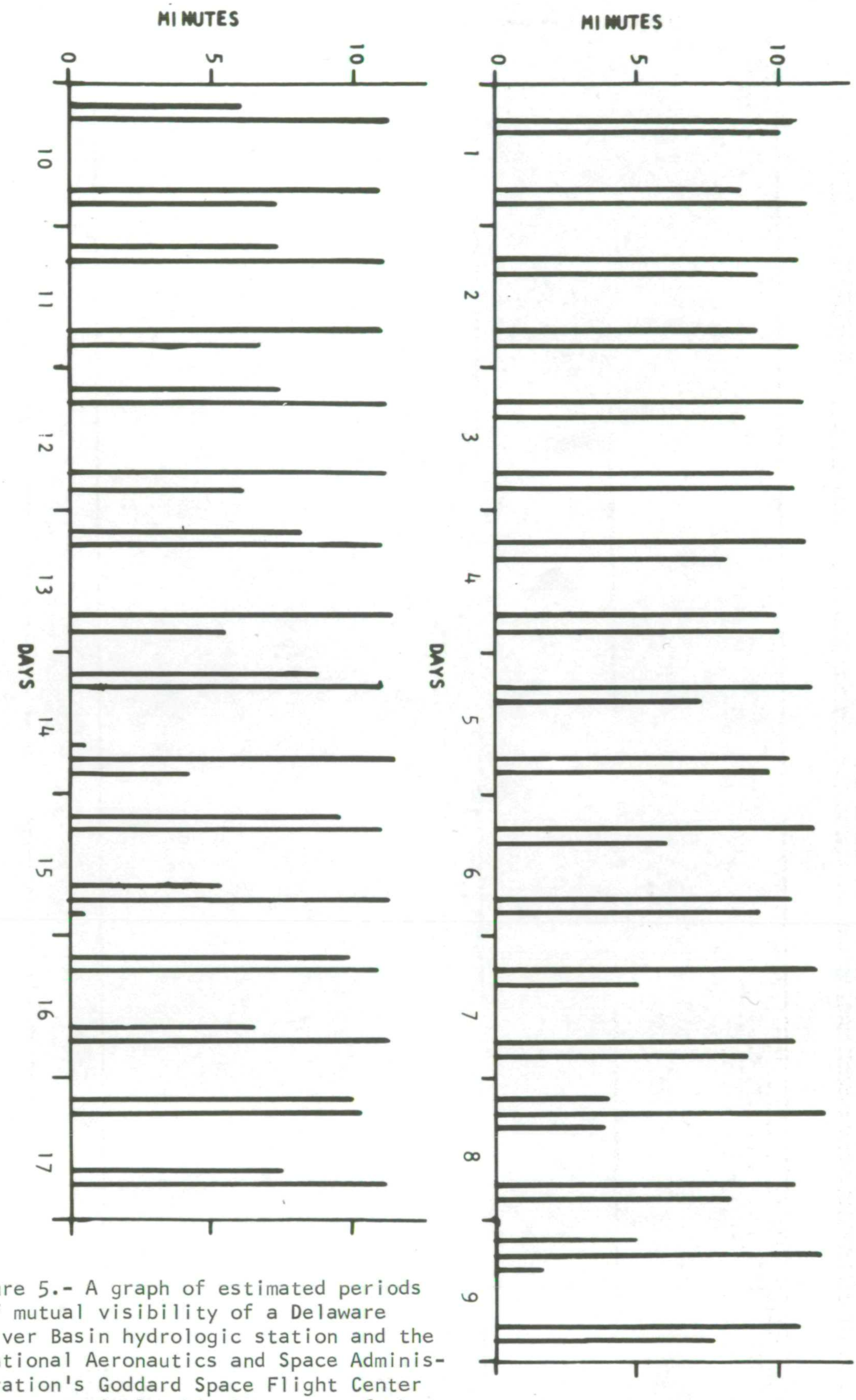


Figure 5.- A graph of estimated periods of mutual visibility of a Delaware River Basin hydrologic station and the National Aeronautics and Space Administration's Goddard Space Flight Center from a typical orbital pattern of the Earth Resources Technology Satellite.

SUMMARY OF DISSOLVED-OXYGEN CONCENTRATION OF THE DELAWARE RIVER AT PIER 11 NORTH FOR WATER YEARS 1965-69, WHERE (+) IS THE MAXIMUM VALUE FOR EACH THREE DAY PERIOD DURING THE FIVE YEARS, (-) IS THE MINIMUM VALUE, (*) IS THE MEAN VALUE OF THE FIFTEEN MEANS AND (.) IS THE VALUE ONE STANDARD DEVIATION FROM THE MEAN. THE DELAWARE RIVER BASIN COMMISSION STREAM-QUALITY OBJECTIVE IS DENOTED BY (S).

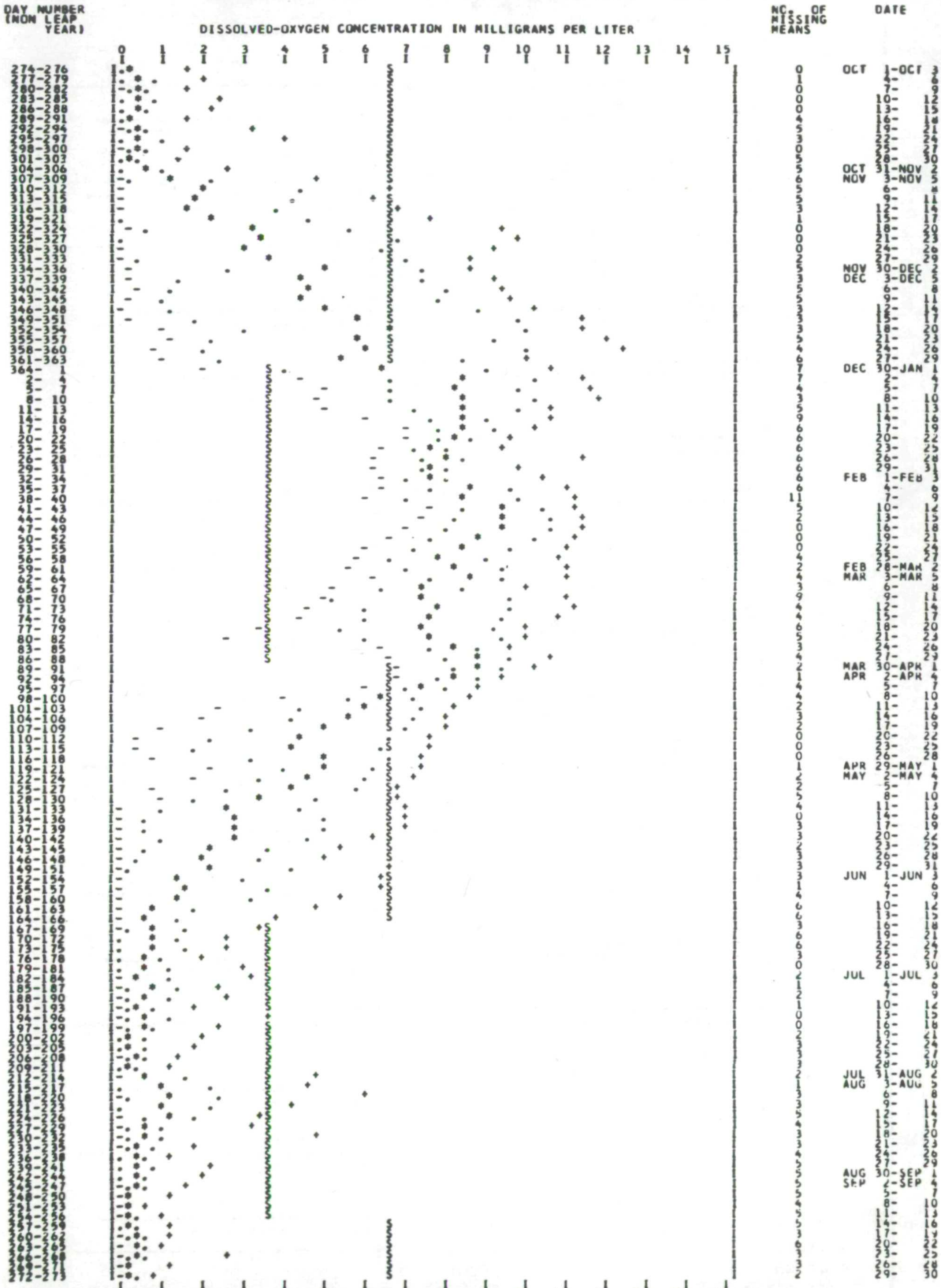
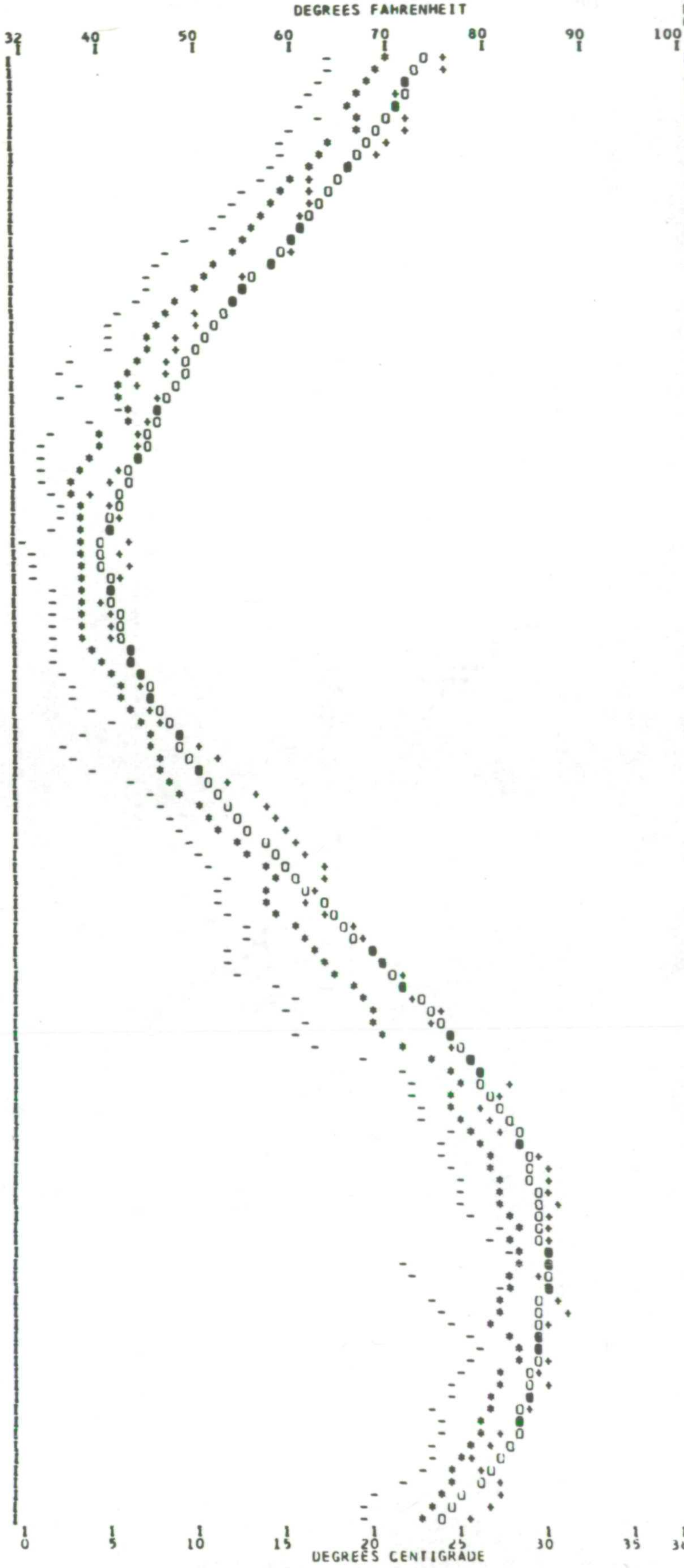


Figure 6.-A computer summary of dissolved oxygen concentration data.

SUMMARY OF TEMPERATURE DAILY STATISTICS OF THE DELAWARE RIVER AT PIER 11 NORTH FOR WATER YEARS 1965-69, WHERE (+) IS THE MAXIMUM VALUE FOR EACH THREE-DAY PERIOD, (-) IS THE MINIMUM VALUE, AND (*) IS THE AVERAGE OF THE FIFTEEN MAXIMUM VALUES. (O) DENOTES THE DELAWARE RIVER BASIN COMMISSION STREAM-QUALITY OBJECTIVE.



DAY NUMBER (NON-LEAP YEAR)	MAXIMA EXCEEDING OBJECTIVE	NO. OF DAILY MAXIMA	DATE
274-276	5	15	OCT 1-OCT 3
277-279	2	15	4- 6
280-282	0	15	7- 9
283-285	0	15	10- 12
286-288	0	15	13- 15
289-291	3	14	16- 18
292-294	3	11	19- 21
295-297	3	15	22- 24
298-300	2	15	25- 27
301-303	0	14	28- 30
304-306	0	14	OCT 31-NOV 2
307-309	0	15	NOV 3-NOV 5
310-312	0	15	6- 8
313-315	0	15	9- 11
316-318	0	15	12- 14
319-321	0	15	15- 17
322-324	1	15	18- 20
325-327	0	15	21- 23
328-330	0	15	24- 26
331-333	0	14	27- 29
334-336	0	12	NOV 30-DEC 2
337-339	0	12	DEC 3-DEC 5
340-342	0	11	6- 8
343-345	0	11	9- 11
346-348	0	12	12- 14
349-351	0	12	15- 17
352-354	0	12	18- 20
355-357	0	12	21- 23
358-360	0	12	24- 26
361-363	0	9	27- 29
364- 1	0	9	DEC 30-JAN 1
2- 4	0	12	2- 4
5- 7	0	12	5- 7
8- 10	0	12	8- 10
11- 13	0	11	11- 13
14- 16	0	9	14- 16
17- 19	0	9	17- 19
20- 22	0	12	20- 22
23- 25	2	12	23- 25
26- 28	0	12	26- 28
29- 31	5	12	29- 31
32- 34	6	12	FEB 1-FFB 3
35- 37	3	12	4- 6
38- 40	3	10	7- 9
41- 43	0	15	10- 12
44- 46	0	15	13- 15
47- 49	0	15	16- 18
50- 52	0	15	19- 21
53- 55	0	15	22- 24
56- 58	0	13	25- 27
59- 61	0	14	FFB 28-MAR 2
62- 64	0	15	MAR 3-MAR 5
65- 67	0	15	6- 8
68- 70	0	14	9- 11
71- 73	0	15	12- 14
74- 76	0	15	15- 17
77- 79	0	12	18- 20
80- 82	3	14	21- 23
83- 85	6	15	24- 26
86- 88	0	15	27- 29
89- 91	1	15	MAR 30-APR 1
92- 94	3	15	APR 2-APR 4
95- 97	2	14	5- 7
98-100	4	15	8- 10
101-103	5	14	11- 13
104-106	4	15	14- 16
107-109	6	15	17- 19
110-112	6	15	20- 22
113-115	5	15	23- 25
116-118	3	15	26- 28
119-121	0	15	APR 29-MAY 1
122-124	0	14	MAY 2-MAY 4
125-127	1	14	5- 7
128-130	1	15	8- 10
131-133	0	15	11- 13
134-136	0	15	14- 16
137-139	1	13	17- 19
140-142	0	15	20- 22
143-145	0	15	23- 25
146-148	1	14	26- 28
149-151	0	13	29- 31
152-154	0	15	JUN 1-JUN 3
155-157	0	15	4- 6
158-160	0	15	7- 9
161-163	0	14	10- 12
164-166	3	15	13- 15
167-169	3	15	16- 18
170-172	0	15	19- 21
173-175	0	15	22- 24
176-178	0	15	25- 27
179-181	0	15	28- 30
182-184	1	15	JUL 1-JUL 3
185-187	3	15	4- 6
188-190	3	15	7- 9
191-193	2	15	10- 12
194-196	3	15	13- 15
197-199	2	15	16- 18
200-202	1	14	19- 21
203-205	1	14	22- 24
206-208	0	12	25- 27
209-211	0	15	28- 30
212-214	0	13	JUL 31-AUG 2
215-217	0	12	AUG 3-AUG 5
218-220	3	14	6- 8
221-223	3	15	9- 11
224-226	2	13	12- 14
227-229	0	12	15- 17
230-232	0	12	18- 20
233-235	1	12	21- 23
236-238	3	14	24- 26
239-241	1	15	27- 29
242-244	0	14	AUG 30-SEP 1
245-247	2	14	SEP 2-SEP 4
248-250	0	14	5- 7
251-253	0	15	8- 10
254-256	0	14	11- 13
257-259	0	14	14- 16
260-262	0	15	17- 19
263-265	2	15	20- 22
266-268	6	15	23- 25
269-271	6	15	26- 28
272-273	4	10	29- 30

Figure 7.-A computer summary of temperature data.

THIS IS A PLOT OF THE CUMULATIVE FREQUENCY DISTRIBUTION OF DAILY MAXIMUM, MEAN, AND MINIMUM SPECIFIC CONDUCTANCE AT THIS STATION FOR ALL THE DAYS DURING WATER YEARS 1965-69 WHEN THE DAILY MEAN FLOW OF THE DELAWARE RIVER AT TRENTON WAS WITHIN 250 CFS OF 2000.CFS

STATION REEDY ISL

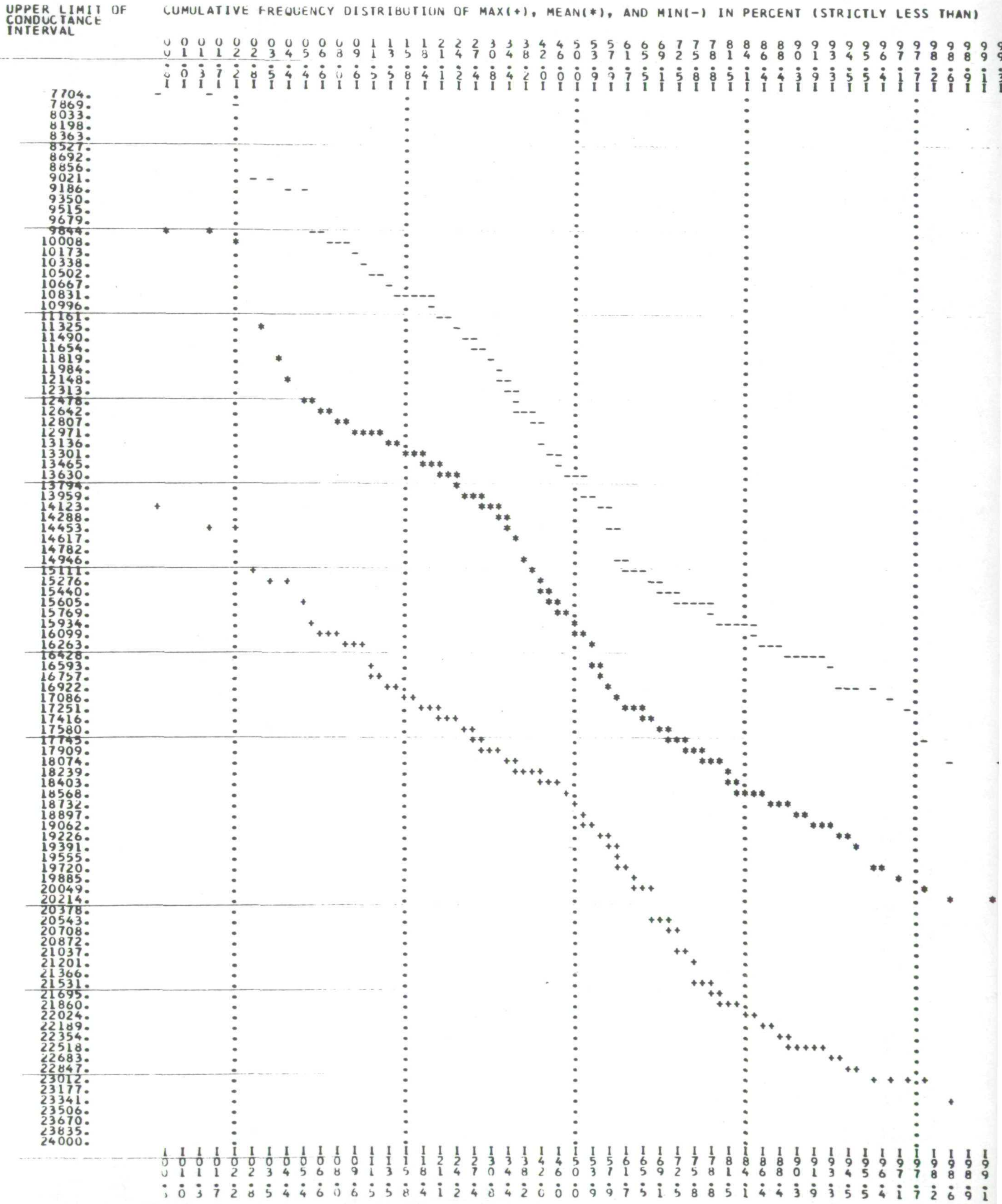


Figure 8a.-Computer summaries of specific conductance data.

THIS IS A PLOT OF THE CUMULATIVE FREQUENCY DISTRIBUTION OF DAILY MAXIMUM, MEAN, AND MINIMUM SPECIFIC CONDUCTANCE AT THIS STATION FOR ALL THE DAYS DURING WATER YEARS 1965-69 WHEN THE DAILY MEAN FLOW OF THE DELAWARE RIVER AT TRENTON WAS WITHIN 250 CFS OF11500.CFS

STATION REEDY ISL

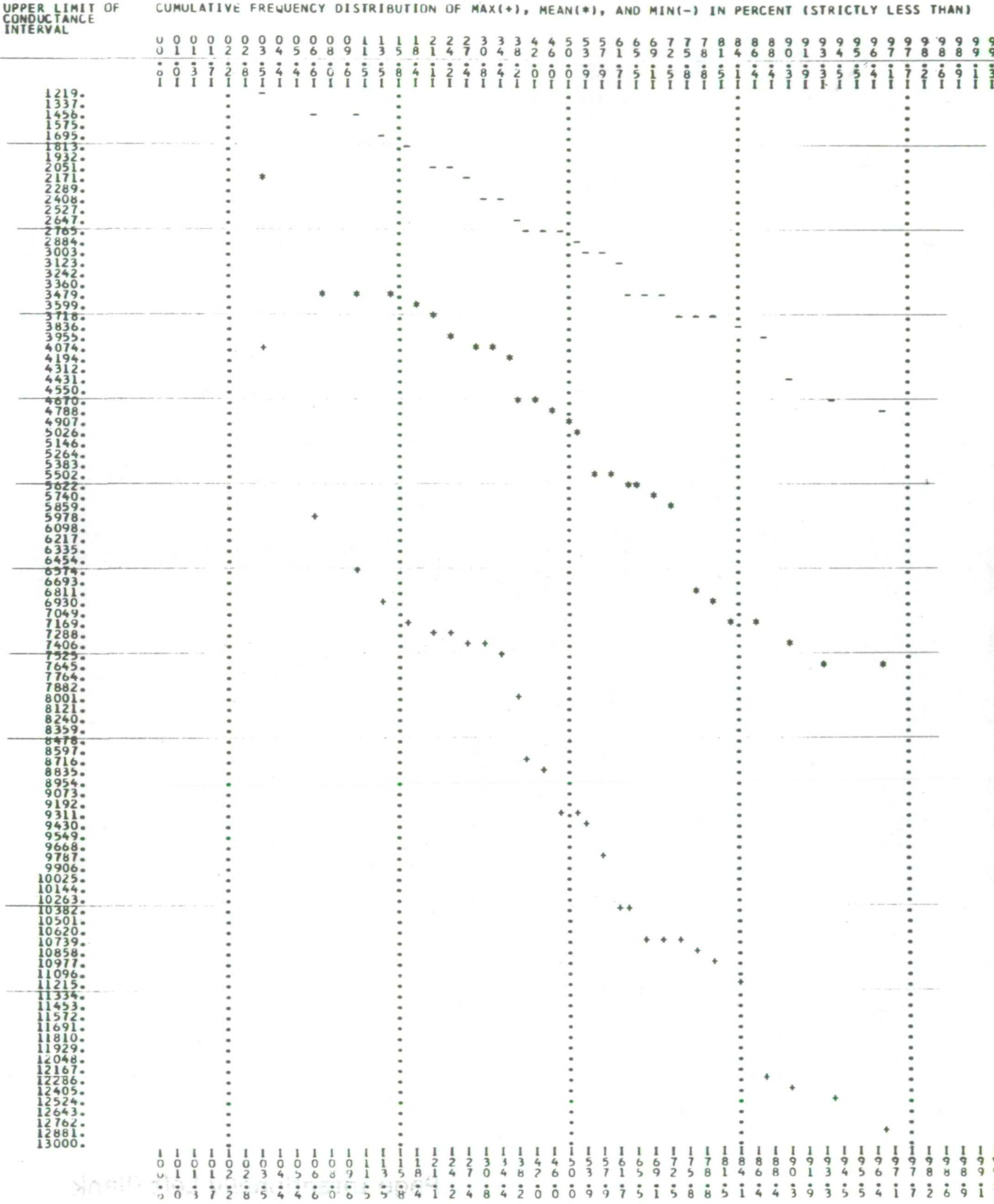


Figure 8b.-Computer summaries of specific conductance data.