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STONEWALL JACKSON LAKE

WEST FORK RIVER, WEST VIRGINIA

GENERAL DESIGN MEMORANDUM

APPENDIX IV

RESERVOIR REGULATION

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STONEWALL JACKSON LAKE
WEST FORK RIVER, WEST VIRGINIA
GENERAL DESIGN MEMORANDUM

APPENDIX IV
RESERVOIR REGULATION

1. General.- The authorized Stonewall Jackson Lake project is a combined flood control, water supply and water quality control project with associated general recreational development. Its proposed location is on the West Fork River, a headwater tributary of the Monongahela River. The flood reduction which can be effected by this reservoir will be of greatest magnitude along the West Fork River, with most benefit in the cities of Weston and Clarksburg. Farther downstream, it would combine with two existing dams, Tygard and Youghiogheny, to provide flood protection to the Monongahela River Basin, although its influence in these areas would generally be small. Release of impoundment to increase low flow for water supply and the improvement of stream water quality will be a year-round function. Both the cities of Weston and Clarksburg consequently would have a guaranteed water supply source. Present sources are deficient for future needs. The lake, with a normal moderate drawdown by Labor Day provides excellent potential for recreational development.

2. Basic Data.- Stream flow data used in development of the storage and release schedule for the Stonewall Jackson Lake are available for the stream gaging stations on the West Fork River near the damsite at Brownsville, W. Va., 102 square miles, and for Butcherville, W. Va., 181 square miles. The Butcherville data, proportionally modified for the greater area, were used as damsite flow for the water years 1920-1947. The Brownsville records were used for the periods of 1947 to date. A summary of climatologic and stream gaging stations, runoff data and other records used in this study are presented in Appendix III, Hydrology.

3. Runoff data for the water quality control points of Clarksburg and Fairmont, W. Va. were used in the development of the low flow release schedule. Continuous stream flow records are available for Clarksburg with a drainage area of 384 square miles, from 1923 to date. Flow records for Fairmont were available at Lock and Dam 15, Hoult, W. Va. for the periods 1915 to 1926 and 1938 to 1967. For the period 1926 to 1938, daily lockmaster gage height records are on file. By means of these stage records and applicable stage discharge relationships, it was possible to extend flow records over the missing period. Dam 15,

Monongahela River has a drainage area of 2,389 square miles. This area, modified by the controlled tributary area of 1,184 square miles above Tygart Dam, has an uncontrolled drainage area of 1,205 square miles. The daily flow values were subsequently adjusted to reflect the effect of Tygart reservoir operations as established by a computerized simulation for the period prior to its initial operation in 1938.

4. Losses due to evaporation from the surface of Stonewall Jackson Lake were computed by the method explained in Appendix III, paragraph 29 with further adjustment to reflect the difference between pan evaporation and the probable reservoir evaporation. The mean air temperatures for the U.S. Weather Bureau station at Weston were used in the computations. The monthly evaporation coefficient (Kf) was derived from data for the evaporation station at Confluence, Pennsylvania, which is located in the Youghiogheny River basin approximately 80 miles northeast of the Stonewall Jackson Lake drainage area. Reservoir evaporation rates were assumed as 70 percent of the computed pan evaporation rates.

5. Most water of the Upper West Fork basin is of relatively good chemical quality. It is moderately hard predominately containing calcium and sulfate. Mineralization of the stream appears to be higher than any other of the headwater tributaries of the Monongahela River basin. Although mine acid drainage occurs in some minor tributary areas, the presence of mineral acidity has not been found in the stream within the limits of the future impoundment. Aquatic life intolerable to continuous or severe water quality degradation are present in this reach. Stream quality deteriorate progressively between Weston and the mouth of the West Fork River at Fairmont, W. Va.

6. Seasonal temperature stratification will occur within the reservoir impoundment. No appreciable chemical stratification is expected as chemical qualities of stream water at the damsite have shown no marked deviation during all seasons throughout 10 years of twice monthly testing.

7. A large amount of sediment transportation and a highly turbid inflow can be expected during periods of flood runoff, some of which will move out of the reservoir as early flood storage drawdown. Experience at other District reservoirs indicates that there should be no appreciable permanent carry-over of suspended sediment into the low flow drawdown seasons.

8. Since it is believed that temperature of impoundment will be the most likely factor to deviate from preimpoundment

stream characteristics, operation for this parameter to attain natural stream temperature will be primary for maintaining the ecological balance of the downstream reach of the river although consideration will also be given to other elements if necessary during quality control operations.

9. Generally, in the summer and fall seasons, water temperature will be highest in the top 15 or 20 feet of the impoundment (epilimnion) with a decrease in temperature below this depth to significantly cooler bottom (hypolimnion) temperatures.

10. The vertical temperature differential within the impoundment will vary with climatological factors, reservoir dimensions and alignment, local topography, total impoundment volume, rate and temperature of inflow, rate and level of outflow, and withdrawal facilities. The upper layer, or epilimnion, in the summer and fall seasons, should normally be within the 60° to 80° Fahrenheit range. The epilimnion is readily responsive to the same variables of climate that affect the characteristics of the water in the preimpoundment channel. The temperature of the epilimnion should therefore be closest of all storage to natural stream temperature although diurnal variations will be less. Because of the shallow depth of the reservoir, the warmer temperatures of the epilimnion will be predominant throughout much of the impoundment.

11. The temperature in the bottom, or hypolimnion, may be in the 40° to 55° F. range, although this may depend to a great extent on the level of withdrawal. The two most similar impoundments, Berlin and West Branch Mahoning River, used for low water augmentation in the Pittsburgh District, like Stonewall Jackson have maximum depths not exceeding 70 feet. The similarity between these two existing reservoirs, however, does not pertain to their design or to conditions of operation. West Branch releases low flow augmentation from higher level sluices while Berlin discharges from sluices at the bottom of the dam. The thermocline during 1970 in these two reservoirs, with their near opposite withdrawal levels, was markedly different. Surveys in August of this year showed surface temperatures near 80° F. at both sites. The inversion differential (thermocline) at West Branch with high level withdrawal was about 30° while at Berlin where all water was discharged from the bottom, the total differential was only 8° in its more than 65-foot depth.

12. Although water withdrawal from the epilimnion may be advisable to simulate natural downstream temperatures, operating

conditions or subsequent model studies or theoretical postulations may indicate the desirability of withdrawal separately or conjunctively from lower levels which may have other qualities or characteristics.

13. Since the depth of both the opilimnion and the thermocline is related to the lake surface and will vary in elevation as the volume of storage increases or decreases throughout the low flow drawdown seasons, the level of withdrawal must also have the capability of a like change if the potential for accurate control is necessary. The use of fixed multi-level gates to attain this end is not considered acceptable. Because radical changes in temperature are possible within a 15 to 20 foot range, many separate gates at fixed intervals would be needed to attain a satisfactory degree of control. The capability of fixed gates to operate effectively is also modified as the seasonal decrease in operating head will impair their ability to always release at a desirable rate. The use of many gates to effect a fine degree of control would also introduce extremely difficult design and operating factors.

14. Maximization of the potential for selective withdrawal from a narrow zone with the impoundment, where the water may be stratified with specific quality characteristics, can be best obtained through a wide discharge orifice having a relatively small height. The flow pattern from the stored mass of water will then tend to be more lateral and less vertical. (Ref: WS TR H-69-10 "Mechanics of Flow from Stratified Reservoirs in the Interest of Water Quality") To provide the capability for this type of withdrawal and to simplify design, it is proposed to use two shafts flanking the spillway for the full height of the dam on its upstream face. These shafts would have a 10 foot wide opening for 37 feet below summer pool on their upstream sides. Inside plan dimensions of the shafts would be about 11 feet by 7 feet. Flow into the shafts would be accomplished by a vertical separation of adjoining bulkheads. The required rate of withdrawal for quality control operation would generally necessitate separations of 1/2 to 2-1/2 feet, although they might be a great as 6 feet. Elevation of inflow into each shaft would be controlled by raising and lowering the bulkheads in the desired withdrawal range. The bulkheads could be designed either for a full hydrostatic head to prevent failure from uncoordinated gate openings or for only a differential between reservoir and shaft of about 1.5 feet plus safety factor if a high degree of operation control is provided. The flow ratings for submerged opening between bulkheads with sharp edges is shown on Plate 1. Some decrease in opening or in operating head differential might be effected by modification of

edges to provide more effective flow conditions. Rate of discharge from the reservoir would be gate regulated at each shaft bottom. The open bulkhead slot in the shaft would extend from elevation 1073 to elevation 1036, 2.5 feet below minimum pool. Below this level the shaft would be closed to the reservoir. There would normally be sufficient water below this level for about two weeks of full low flow augmentation if repairs or maintenance of the bulkhead assembly required complete drawdown in the shaft. The slight changes in the hypolimnion characteristics which might be expected below elevation 1036 would indicate that variable outflow level control would not be warranted in the bottom closed portion of the shaft. Storage and release computations developed and discussed later in this appendix have been used in selection of bulkhead sizes and their most effective arrangement. The individual bulkheads can permit double level withdrawal from above and below the thermocline through one shaft, or for more complex multi-level withdrawal by variable arrangements of the bulkhead openings in both shafts. If necessary, one of the low level flood storage release conduits at partial opening could be used for withdrawal of colder water in normal times or for coordinated withdrawal during periods of severe drought when the reservoir level would be very low.

15. One 2' x 3' sluice at elevation 1018 will be provided at the bottom of each shaft to conduct low water releases through the dam. The stage discharge relation for these gates is shown on Plate 2. Each of these gates will have a capacity to discharge the total normal scheduled low flow augmentation throughout the entire range of shaft withdrawal with a maximum capacity of 310 c.f.s. when the lake is at summer pool level, and 170 c.f.s. at the low drawdown elevation 1038.5.

16. When possible, it is proposed to use both shafts for releases as this will provide better stratified withdrawal by halving the slot opening between bulkheads and doubling the effective slot width. By use of both shafts it will also be possible to provide a higher rate of stratified withdrawal during the summer months when minor rises would otherwise cause excessive impoundment above the summer pool level using only a single shaft. The two shafts will also enable stratified release to be accomplished if repairs would make one shaft inoperative.

17. A 1.5-foot maximum differential between the lake level and the water in the shaft has been adopted as the acceptable limit for operation purposes, although some deviation is possible. Plate 3 has been developed from Plates 1 and 2 to show the restriction imposed on sluice gate opening by a slot opening of

this magnitude. Constraints of bulkhead design could make conservative conformance to this relationship imperative when the project is in operation. The storage capacity within the shaft is only about 80 cubic feet per foot of elevation. If the discharge from the shaft is in excess of inflow into the shaft, due to either the gate being opened more than the slot or conversely if the slot is closed more than the gate, drawdown on shaft bulkheads could occur. With proper initial slot opening, release of storage with a set sluice gate opening can entail no great deviation in head as gate flow will decrease with lower head and a more favorable head differential between lake and shaft level will develop. Some difficulty could arise with a rising pool as sluice gate capacity would increase with the higher head while slot capacity would be more constant as it operates only on the head differential between lake and shaft. This however is not believed to be very significant. The most critical condition which might be assumed would occur with the standard project flood. In this flood, maximum rate in pool rise would be 13.5 feet within 24 hours. As an example of the effect of such a flood event, it can be assumed that a storm inception the maximum contemplated flow of 310 c.f.s. with a 5.2-foot slot opening and 3-foot sluice gate position, lake elevation 1073, initially existed. A 13.5-foot rise in pool level above the sluice gate would increase its discharge from 310 c.f.s. to 360 c.f.s. The head differential on the 5-foot slot opening would only increase from 1.5 feet to 2.0 feet to provide this same flow. Although this differential would not be critical, with minimum surveillance, gate operations to prevent the change could be easily made within this time. Automatic sluice gate operations related to head differential between lake and shaft could also be easily made within this 24 hour period. As an added measure of safety of bulkheads are not designed for full hydrostatic head pressure release gates would be provided in the towers at about bulkhead seat elevation 1036. so that additional water would enter the shaft if the head differential became critical.

18. The manner of operation of the three bulkheads in the low flow control shaft is illustrated on Plate 4. The plate shows the relative profile of the shaft and arrangements of the bulkheads at variable positions over the open slot in the shaft. The base of the shaft and the invert of the 2' x 3' sluice is at elevation 1018, while the slot sill is at elevation 1036. The bulkheads will control flow from about elevation 1075.7, two and one-half feet above maximun summer conservation level, to elevation 1038. Slot openings adequate for passage of the scheduled maximum water quality flow through one shaft have been used. This is shown with a single two-foot opening and also with two one-foot openings.

Use of both shafts would reduce the need for openings this wide and would, of course, provide an extremely flexible means of drawing from two or more levels of impoundment.

19. Storm and flood runoff not required for later water-use purposes or beyond control by the stratified withdrawal facilities will be released by means of three low level sluices with 3.5' x 7' gates, invert elevation 1014. Maximum reservoir release is limited by the initial flooding stream flow of 2,300 c.f.s. between the damsite and Weston. Slightly higher flows could be released in an emergency without appreciable damage as the carrying capacity of the channel increases to 2,800 second-feet at Weston. Downstream of the damsite, 2,800 c.f.s. would cause only minor overbank flow in untenanted low lying areas.

20. Deflectors at the downstream ends of the low flow and flood control sluices will provide sprayed discharged 13 feet and 19 feet respectively above the level stilling pool with good aeration and high oxygen content.

21. <u>Reservoir Control in the Pittsburgh District</u>.- There are 13 existing Federal reservoirs in the District. There is one reservoir in the advance stages of construction and another in the initial stages of construction in the Allegheny River basin. Nine of the existing reservoirs are above Pittsburgh and provide low flow regulation and partial flood protection along the Allegheny, Monongahela and Ohio Rivers. The other four existing reservoirs are in the Beaver River basin. The nine reservoirs above Pittsburgh would combine their effects 25.5 miles below Pittsburgh, with the four Beaver River basin reservoirs for regulation of Ohio River floods and low flow regulation. Five of the reservoirs in the Allegheny River basin provide flood control only while the other eight reservoirs in the Pittsburgh District have the potential for both flood control and low flow augmentation. Table 1 presents the pertinent features for these reservoirs and the proposed Rowlesburg Lake Project. Also shown are the two reservoirs under construction and the authorized Muddy Creek reservoir and Rowlesburg Lake project.

22. The two existing Federal reservoirs in the Monongahela River basin, Tygart and Youghiogheny, are multi-purpose. They provide low-flow augmentation along the Monongahela and Ohio Rivers. There is one other multi-purpose reservoir proposed for the Monongahela River basin in addition to Stonewall Jackson. It is the Rowlesburg Lake project on the Cheat River. Of the seven existing Allegheny River basin reservoirs only two are multi-purpose. They are the Allegheny and East Branch reservoirs. There are two reservoirs under construction and another authorized in the Allegheny River Basin. Of these three, only one is currently being constructed as a multi-purpose reservoir.

TABLE 1

Authorized and Existing Federal Reservoirs
in the U.S. Army Engineer District, Pittsburgh, Pa.

Reservoir	Drainage Area Sq. Mi.	Type		RESERVOIR STORAGE Flood Control (Min.) Acre-Feet:	In. of R.O.	Low Water (Max.) Acre-Feet:	In. of R.O.
Allegheny Basin							
Allegheny	2,180	FC, P, LW & R	Summer	607,000	5.22	549,000	4.72
			Winter	940,000	8.09	216,000	1.85
Union City*	222	FC	All year	48,300	4.08	0	0
East Branch	72.4	FC, LW & R	Summer	19,000	4.92	64,300	16.66
			Winter	38,700	10.03	44,600	11.55
Muddy Creek***	61.5	FC	All year	19,700	6.00	0	0
Woodcock*	45.7	FC, R, & LW	Summer	15,250	6.25	4,000	1.64
			Winter	18,900	7.75	350	0.14
Tionesta	478	FC & R	All year	125,600	4.93	0	0
Mahoning	340	FC & R	All year	69,700	3.84	0	0
Conemaugh	1,351	FC	All year	270,000	3.75	0	0
Loyalhanna	290	FC & R	All year	93,300	6.03	0	0
Crooked Creek	277	FC & R	All year	89,400	6.06	0	0
Monongahela Basin							
Stonewall Jackson***	102	FC, LW, R & WS	Summer	26,480	4.90	45,050	8.30
			Winter	38,550	7.10	32,990	6.10
Tygart	1,184	FC, LW & R	Summer	178,000	2.82	99,900	1.58
			Winter	278,000	4.40	0	0
Rowlesburg***	936	FC, R, P, & LW	Summer	250,800	5.03	571,500	11.45
			Winter	299,600	6.01	522,700	10.48
Lake Lynn**	1,413	P	All year	72,300	.96	0	0
Youghiogheny	434	FC, LW & R	Summer	99,500	4.30	149,300	6.45
			Winter	151,000	6.52	97,800	4.23

TABLE 1 (Cont)

Reservoir	Drainage Area Sq. Mi.	Type		RESERVOIR STORAGE Flood Control (Min.) Acre-Feet:		In. of R.O.	Low Water (Max.) Acre-Feet:	In. of R.O.
Beaver Basin								
Berlin (1)	274	FC, LW,	Summer	38,300		2.60	37,200	2.80
		WS & R	Winter	61,300		4.16	24,900	1.87
Mosquito	97.4	FC, LW,	Summer	21,700		4.18	69,400	13.36
		WS & R	Winter	33,000		6.35	58,000	11.17
West Branch	80.5	FC, LW & R	Summer	22,000		5.13	52,900	12.33
			Winter	33,200		7.74	41,700	9.72
Shenango (2)	589	FC, LW & R	Summer	151,000	(2)	6.57	29,900	1.30
			Winter	180,900	(2)	7.87	0	0

FC - Flood Control   LW - Low Water Regulation   P - Power   WS - Water Supply

* Under Construction   R - Recreation

*** Authorized   ** Private Power

(1) Includes flood control storage in Lake Milton.

(2) Based on Uncontrolled Area of 431 square miles between Pymatuning and Shenango Dams.

23. The East Branch Reservoir provides about 150 to 200 c.f.s. to the normal summer and autumn flow in the Clarion River and consequently the Allegheny River. The Allegheny Reservoir provides an additional flow varying from 500 to 2,500 c.f.s. to the Allegheny and Ohio Rivers. The impending Woodcock Creek reservoir augmentation will average only 15 to 20 c.f.s. The Tygart reservoir low flow releases insure a minimum flow of 340 c.f.s. for the upper reach of the Monongahela River, adding about 280 c.f.s. for the upper reach of the Monongahela River, adding about 280 c.f.s. during the average summer season. The low flow release from Youghiogheny Reservoir is dependent on the storage available and the uncontrolled flow at Connellsville, Pennsylvania. During low-flow periods, the augmentation will vary between 500 and 700 c.f.s. The release from all of the above reservoirs combine to help augment the Ohio River. During periods of low flow, their augmentation can be as high as 3,000 c.f.s.

24. The total drainage area above Pittsburgh is 19,117 square miles, of which only 6,935 square miles will be controlled by the nine existing plus the three authorized Allegheny River basin reservoirs. This represents about 36.9 percent of the total area above Pittsburgh, Pennsylvania. Even with Rowlesburg and Stonewall Jackson Lake projects in operation, the controlled area would still be less than 50 percent. Since there is still a large percent of the area uncontrolled, the reservoirs can only provide partial flood protection downstream to Pittsburgh and along the Ohio River. The effect of flood reduction at Pittsburgh, by the existing reservoirs, varies with magnitude of flooding and the primary source of its generation whether the flooding was greatest primarily in the Monongahela River Basin or Allegheny River Basin or was general over the whole area.

25. Preimpoundment Studies.- Preimpoundment studies in the West Fork River basin have been initiated during the past year to determine water quality and biota now existing in the stream and to evaluate future conditions which may develop. Biological observations include the macrobenthos, periphytan and tychoplankton communities.

26. A moderate amount of land in the West Fork basin above the damsite is used for farming and grazing with the remainder forested. The vegetal cover distribution is shown on Plate 3, Appendix III. Stripmines outline much of the upper basin with principle areas in the Skin Creek, Sand Fork and Ward Run basins. Several coal mines presently in operation are a stripmine near Emmart, West Virginia, a stripmine between Bendale and Brownsville, West Virginia and a shaft mine in the Little Skin Creek basin.

27. Excluding the headwaters, the West Fork River is generally very turbid as a result primarily of soil erosion. Frequent precipitation within the basin causing runoff charged with a large load of soil particles and mine wastes maintain the turbid appearance. The soil particles are apparently of such shape, area and density to decrease settling velocity and thus remain suspended for some distance downstream even though there are two concrete dams between Brownsville and Weston which reduce water velocity and increases depth. Because of the soil erosion and mine drainage the West Fork River is more mineralized than the Cheat River and most of its tributaries in the upper basin.

28. The water quality of the West Fork River has been monitored at Brownsville, West Virginia bimonthly since 1954. As part of the preimpoundment investigation thirteen additional water quality testing sites were established on the West Fork River and major tributaries above, within and below the impoundment area. Samples are occasionally collected from special sites within the upper basin.

29. Range and percentage of values within specific intervals for chemical parameters from bimonthly samples, 1954 to 1970 are presented in Table 2. As evident from the grouped year data the maximum and minimum values have remained similar for the past 16 years. However, the data suggest that the distribution of pH values during 1966-1970 shifted to a higher range compared to earlier year groups. A corresponding shift in the distribution of carbon dioxide values to a lower range is also evident because of the inter-relationship between pH and carbon dioxide. Distribution of alkalinity values in 1966-1970 is similar to 1954-1959 while in 1960-1965 a larger percentage of values were in the lower ranges. Hardness has increased slightly in the last five years. From these data the water quality appears to have improved during the past five years. As evident from the pH values no mineral acidity or carbonate alkalinity was found.

30. Percentage distribution of chemistry values for various ranges of stream flow are presented in Table 3. Cursory examination suggests that very little relationship exists between magnitude of stream flow, pH, free carbon dioxide and total alkalinity. There appears to be a slight inverse relationship between flow and hardness. Maximum and minimum flow that occurred during 1954 to 1970 was 5,900 c.f.s. and no flow respectively. At the time of sample collections flow ranged from 0.13 to 2,090 c.f.s. At the low flow pH was 6.5 units, free carbon dioxide 7 mg/l as $Ca\ CO_3$, total alkalinity 34 mg/l as $Ca\ CO_3$ and hardness 34.2 mg/l and at the high flow 6.6, 9, 23 and 17.1, respectively.

TABLE 2

Water Chemistry of West Fork River
at Brownsville, West Virginia

Parameter:	YEARS			
	1954-1959	1960-1965	1966-1970	1954-1970
pH (units)				
Maximum	7.1	6.8	7.0	7.1
Minimum	5.8	5.9	5.8	5.8
Interval				
Less than 6.0	2.9	4.5	2.8	3.3
6.0-6.5	52.1	53.6	28.7	45.6
6.5-7.0	42.9	42.0	64.8	49.2
Greater than 7.0	2.1	0.0	3.7	1.9
N	140	112	108	360
Total Alkalinity ($mg/l\ CaCO_3$)				
Maximum	50	57	45	57
Minimum	10	7	5	5
Interval				
Less than 10	0.0	1.8	2.8	1.4
10-15	12.8	41.1	10.2	20.8
15-30	60.7	41.1	63.9	55.5
Greater than 30	26.4	16.1	23.1	22.2
N	140	112	108	360
Free Carbon dioxide ($mg/l\ CaCO_3$)				
Maximum	35	14	17	35
Minimum	5	4	2	2
Interval				
Less than 5	0.0	1.8	12.0	4.2
5-10	0.7	39.3	79.6	36.4
10-15	90.0	58.9	6.5	55.3
Greater than 15	9.3	0.0	1.8	4.2
N	140	112	108	360
Hardness ($mg/l\ CaCO_3$)				
Maximum	51.3	51.3	115.0	115.0
Minimum	17.1	17.1	17.1	17.1
Interval				
Less than 20	44.3	71.4	31.8	49.0
20-40	44.3	24.1	31.8	34.3
40-60	11.4	4.5	20.6	12.0
60-80	0.0	0.0	10.3	3.1
Greater than 80	0.0	0.0	5.6	1.7
N	140	112	107	359

Note: Data Computed from by-monthly samples. Where intervals are indicated, data is expressed in percent of time.
N = Number of samples

TABLE 3

Percentage Distribution of Chemistry Valves at Different Magnitude of Flow in West Fork River at Brownsville, West Virginia

Flow (cfs)	N	Hardness mg/l $CaCO_3$ Less than 20	20-40	40-60	60-80	Greater than 80
Less than 10	84	38.1	44.0	11.9	3.6	2.4
10-49	105	43.8	38.1	13.3	1.9	2.9
50-99	41	51.2	24.4	14.6	7.3	2.4
100-499	99	54.5	30.3	12.1	3.0	0.0
500-999	20	75.0	20.0	5.0	0.0	0.0
Greater than 1000	10	80.0	20.0	0.0	0.0	0.0

Free Carbon Dioxide mg/l $CaCO_3$

Flow (cfs)	N	Less than 5	5-10	10-15	Greater than 15
Less than 10	84	1.2	52.4	41.7	4.8
10-49	106	1.9	29.2	60.4	8.5
50-99	41	7.3	39.0	53.6	0.0
100-499	99	6.1	32.3	59.6	2.0
500-999	20	10.0	30.0	60.0	0.0
Greater than 1000	10	10	20.0	70.0	0.0

Total Alkalinity mg/l $CaCO_3$

Flow (cfs)	N	Less than 10	10-15	15-30	Greater than 30
Less than 10	84	0.0	9.5	45.2	45.2
10-49	106	0.9	17.0	54.7	28.3
50-99	41	0.0	34.1	53.6	9.8
100-499	99	3.0	26.3	64.6	6.1
500-999	20	5.0	30.0	60.0	5.0
Greater than 1000	10	0.0	30.0	60.0	10.0

pH (Units)

Flow (cfs)	N	Less than 6	6.0-6.5	6.5-7.0	Greater than 7.0
Less than 10	84	2.4	32.1	63.1	2.4
10-49	106	3.8	46.2	50.0	0.0
50-99	41	4.9	39.0	51.2	2.4
100-499	99	2.0	58.6	37.4	3.0
500-999	20	10.0	40.0	45.0	5.0
Greater than 1000	10	0.0	60.0	40.0	0.0

Note: Data computed from bimonthly samples (1954-1970) N = Number of samples tested.

31. Results of data collected from the preimpoundment upstream water quality testing sites are presented in Table 4. Data are expressed for combinations of stations above the damsite (8, 9, 10, 11, 12 and 13) and below the damsite (4, 5, 6 and 7) for August, September and October, 1970. Stations 5, 8 and 13 are on major tributaries and the remainder on the West Fork River. Values for the combination of stations above the damsite are fairly comparable to the data from 1954 to 1970, although upstream samples have expanded the range for pH and hardness. The minimum pH value of 3.92 is questionable since stations upstream and downstream of this area had a pH above 6.0 units. Generally average turbidity increased longitudinally downstream and was lowest in September. Hardness and conductivity followed the same pattern but were lowest in August. Dissolved oxygen concentration was always above 7 mg/l except at station 4 where values dropped to 4.4 mg/l. This station is about two miles downstream of Weston and the lowered values indicate an oxygen demand by organic sewage effluent on other oxidizable substance. Sewage pollution is also indicated by the fairly high concentration of orthophosphate and mitrate nitrogen at the downstream stations. It is not known if commercial fertilizer is applied to farm land in the upper basin.

32. According to the literature on water quality criteria an average free carbon dioxide concentration of 20 mg/l throughout the year may be harmful to fish and fresh water with dissolved oxygen concentrations greater than 5 mg/l. At lower concentrations less carbon dioxide may be harmful. In U. S. waters that contain a good fish fauna, 95 percent have less than 5 mg of free carbon dioxide per litter.

33. A limited number of analyses were performed on samples collected at special sites and during climatological changes in September and October. These data are presented in Table 5. Glady Fork and Curtis Fork basins contain stripmine areas. The Curtis Fork samples indicate a considerable reduction in iron and manganese concentration from source to mouth probably resulting from chemical precipitation or by dilution. From 21 October to 22 October magnitude of water flow significantly increased as a result of precipitation within the Skin Creek basin. Three samples were collected during this period at the mouth of Skin Creek (WF #8), at the mouth of Little Skin Creek and upstream of the confluence of Little Skin Creek and Skin Creek. Chemical composition change resulting from drainage in Skin Creek basin at different magnitudes of flow is indicated by WF #8. At Brownsville water flow before precipitation on 21 October was 16 to 20 c.f.s. and the pH was 6.7, conductivity 270 umhos/cm, total iron 0.62 mg/l and manganese 0.01 mg/l. Flow increased at Brownsville to 250 c.f.s.

on 22 October and analysis showed that the pH decreased 0.2 units, conductivity decreased approximately 50 percent and iron and manganese concentrations increased about four times. Although the latter two parameters increased and indicate flushing from mining areas, there was little change in pH, demonstrating a sufficient chemical buffering system. Station 4 (WF #4) at Butcherville, representing the combined water chemistries of the West Fork River and the principal tributaries draining stripmine areas, showed no change in pH, a decrease in conductivity, and an increase in the iron and manganese concentrations. Variation in conductivity and concentration of iron and manganese was less than within the individual tributaries.

TABLE 4

Water Chemistries on West Fork River
and Tributaries August - October, 1970

	Temp. (°F)	pH (Units)	Turb. JTU	Dissolved Oxygen (mg/l)	Free CO_2 mg/l ($CaCO_3$)	Min. Acid mg/l ($CaCO_3$)	Total Alk. mg/l ($CaCO_3$)	Hardness mg/l ($CaCO_3$)	Spec. Conductivity umhos/cm	Total Iron mg/l	Total Manganese mg/l	Nitrate Nitrogen mg/l	Orthophosphate mg/l
Stations 4, 5, 6, 7													
Aug.													
Max.	75.0	6.45	57	8.2	25	0	35	157	240	6.50	14	.90	.20
Min.	70.0	6.05	29	5.6	13	0	16	40	75	2.70	0	.75	.08
Ave.	72.3	--	38.5	7.1	18	0	21.3	76.3	132.5	4.63	3.5	.85	.15
Sept.													
Max.	78.5	6.92	7	--	10	0	31	193	280	3.80	69	--	.24
Min.	74.0	6.28	3	--	5	0	14	80	153	.52	21	--	.02
Ave.	76.4	--	6.3	--	7.5	0	24.8	121.3	193.3	1.53	45.3	--	.10
Oct.													
Max.	59.0	6.78	70	8.9	13	0	31	293	510	2.60	93	3.70	.22
Min.	55.0	6.30	2	4.4	7	0	25	89	220	.38	21	.75	.105
Ave.	56.6	--	20.7	7.5	8.8	0	27.5	145	305.8	1.38	52.8	1.53	.143
Stations 8, 9, 10, 11, 12, 13													
Aug.													
Max.	70	6.60	36	9.4	21	0	24	63	100	2.54	83	.85	.08
Min.	60	3.92	5	7.4	9	0	0	34	55	.72	16	.15	0
Ave.	67.8	--	16.3	8.1	13.5	0	15.8	42.7	76.7	1.62	45.5	.66	.035

TABLE 4 (Cont)

Stations 8, 9, 10, 11, 12, 13 (cont)	Temp. (°F)	pH (Units)	Turb. JTU	Dissolved Oxygen (mg/l)	Free CO_2 mg/l ($CaCO_3$)	Min. Acid mg/l ($CaCO_3$)	Total Alk. mg/l ($CaCO_3$)	Hardness mg/l ($CaCO_3$)	Spec. Conductivity umhos/cm	Total Iron mg/l	Total Manganese mg/l	Nitrate Nitrogen mg/l	Orthophosphate mg/l
Sept.													
Max.	76.0	7.00	4	--	7	0	44	91	170	1.44	33	--	.02
Min.	69.5	6.62	2	--	5	0	30	64	132	.65	14	--	0
Ave.	74.3	--	2.7	--	6.2	0	34.3	73.8	152.7	1.01	21.8	--	.008
Oct.													
Max.	55.0	6.92	52	9.2	18	0	41	128	330	2.76	40	3.05	.135
Min.	49.3	6.48	1.8	7.4	6	0	21	43	120	.24	1	0	0
Ave.	52.4	--	12.8	8.3	9.1	0	30.9	82.9	211.4	1.27	20.4	.85	.059

TABLE 5

Water Chemistries at Miscellaneous Stations
in the West Fork Basin, September and October, 1970

Location	Date	pH (Units)	Conductivity (umhos/cm)	Fe (mg/L)	Mn (mg/L)
Glady Fork	15 Sep 70	--	--	0.94	0.09
Curtis Fork #1 (Headwater)	15 Sep 70	--	--	3.10	0.64
Curtis Fork #2 (Mouth)	15 Sep 70	--	--	0.12	0.04
Glady Fork Seep	22 Oct 70	6.7	820	--	--
Glady Fork (Strip mine pond)	22 Oct 70	3.4	310	--	--
Skin Creek (Upstream of Confluence of Little Skin Ck)	22 Oct 70	6.7	150	--	--
Mouth of Little Skin Creek	22 Oct 70	6.3	150	--	--
WF #8 (Mouth of Skin Creek)	22 Oct 70	6.5	130	2.76	0.04
WF #8 (Mouth of Skin Creek)	21 Oct 70	6.7	270	0.62	0.01
WF #4 (Butcherville)	19 Oct 70	6.4	320	1.90	0.05
WF #4 (Butcherville)	22 Oct 70	6.4	280	2.24	0.09
WF #5 (Stonecoal Creek)	19 Oct 70	6.6	510	0.38	0.07
WF #5 (Stonecoal Creek)	22 Oct 70	6.7	275	2.60	0.03
Sand Creek	21 Oct 70	4.6	700	--	--
Ward Run	21 Oct 70	3.5	650	2.68	0.10

34. A concurrent study of the biota was initiated at six of the water quality testing sites. The biological stations selected were in riffle areas, a habitat type where the greatest biological diversity would be expected and where organisms (stoneflies, mayflies and caddisflies) intolerant of severe water quality and substrate degradation are generally found. Biological samplings included the benthos, periphyton and tychoplankton communities. Information on the fish life is tentatively planned for 1971.

35. Results of the study to date indicate a fairly high degree of biological diversity and conditions capable of supporting fish life at three of four stations above the damsite. Benthic animals found, predominately belong to the insect group and include mayflies, stoneflies, caddisflies, damselflies, dragonflies, dipterans and neropterans. The fourth station on the Right Fork demonstrated a smaller degree of diversity with pelecypods the dominant benthic animal. This decrease in diversity indicates that some environmental condition acts as a controlling factor in regulating the kinds of organisms present. A cursory survey of the basin provided no obvious condition responsible for the sparcity of streambed animals. Several fowl producing farms are in the upper basin and there is probably some raw sewage effluent from a meagre number of residences upstream. Coal mining operations in the area have not been extensive.

36. There are two stations below the damsite. One station is located near the Weston water treatment plant and the other at Butcherville. Samplings at the first station indicated Caddisfly larvae and dipteran larvae were the dominant groups of benthic animals. At Butcherville some degradation of the water quality and substrate habitat occurs as a result from both mine drainage from Stonecoal Creek and Weston sewage effluent. Case building caddisfly larvae and various families of dipterans were common in large numbers. Although there is some deterioration of water quality and bottom habitat, there is some degree of recovery evident in this area of the West Fork. Bryozoans were noted at this station in relatively large masses and according to the literature, on fresh water invertabrates, are never found under polluted conditions and only sparingly where the quantity of dissolved oxygen falls below 30 percent saturation. A study by the Taft Sanitary Engineering Center demonstrated a good diversity of streambed organisms (twelve different kinds) downstream of Jane Lew, West Virginia indicating conditions suitable for supporting fish and other animal life. Both mayfly and caddisfly forms were found. As suggestive by the data there is a sequential improvement of environmental conditions downstream of Butcherville to Jane Lew.

37. Periphyton growth was greatest at Butcherville indicating nutrient enrichment from the Weston sewage effluent. Although the slack water areas created by the two small dams have not been extensively studied there appears to be a sufficient reduction in flow and increase in depth to permit development of a plankton population. Chaoborus larvae which are usually found in lakes and large ponds were observed. With impoundment of the West Fork there should be a considerable reduction in turbidity throughout this section. The increase in water clarity should improve the plankton production in this area. Conversely with increased water clairty plankton blooms may occur.

38. Availability of Runoff for Water-Use Impoundment.- Impoundment of water to be used for water quality control, low-flow augmentation, and water supply must be accomplished during the late winter and early spring high runoff periods. The natural flows during the summer and early fall seasons are too low to satisfy projected water supply needs and to dilute residual pollutions sufficiently to provide stream water that will meet established water quality standards. Higher flows needed to meet these water quality standards and to supply suitable water supply demand must, therefore, be provided from prior impoundment of excess runoff.

39. Mass runoff curves shown on Plates 5 and 6 were plotted from stream runoff data for the reservoir tributary area, as discussed in paragraph 3, for the months January through April, 1930 to 1967. The curves indicate the amount of total storage available for impoundment if the total runoff was retained by the reservoir within these months. They indicate that with complete impoundment, the maximum summer conservation pool could be attained 7 years in 8 with impoundment initially at minimum pool level on 1 January.

40. Water Quality Control Factors.- The State of West Virginia has coordinated with the Federal Water Quality Administration in establishing quality standards for its stream in compliance with the Federal Water Quality Act of 1965. Enforcement of its standards should prevent further deterioration and result in ultimate improvement of the West Fork, Monongahela and Ohio River flows.

41. The standards establish minimum flow values in streams to be used as a basis for design and discharge control of any effluent. Treatment facilities for this control must be adequate to assure that minimum standards of quality can be maintained when these minimum flows occur. This critical flow has been

considered as equal to the average minimum flow that has occurred on the stream at the point of treated discharge, during sevel consecutive days of any one year and has had a recurrence interval once in 10 years.

42. A review of flow records for all stream flow stations (established for 10 or more years) within the Commonwealth of Pennsylvania, shows that flow is in excess of the 10 year, 7 day mean low flow about 98 or 99 percent of the time. This duration of flow is more significant than the 7 day frequency of equal magnitude. It is inconceivable that this important low flow control could be purely arbitrary value based solely on chance of occurrence. Rather, it must be assumed that the selection has been made to assure maintenance of definite biological and ecological characteristics dependent on qualities of the streams and is consequently related as a base to the higher normal flow pattern that will occur. It also sets a low limit, infrequently reached and almost always exceeded, above which treatment facilities can hopefully be operated without harm to the desired stream conditions

43. Although the exact end point to which quality can be reduced without detriment to the stream biota may not be known, it is certain that a reduction in dilution by a deficiency in the contributing stream flow can be as devasting as an increase in the pollution. Persistent minimal conditions can prevent recovery from the effect of deteriorated water quality and result in the ultimate destruction of the biological community. If such persistency causes widespread destruction, stream recovery could carry over an extreme length of time.

44. Because of these factors, it is readily apparent that if the desired stream conditions are to be sustained, the magnitude and duration of controlled stream flow related to minimal standards cannot be safely maintained at this low level more frequently nor for longer periods of time than that applicable to the natural environment.

45. For the same reasons, the total impoundment assigned to low flow augmentation in the reservoir is an even more critical value. It must have only a rare chance of being deficient as its loss during a drought cannot readily be overcome. It cannot provide desirable flow in all of 9 years and not in the 10th. If it should fail extensively throughout the 10th year, as previously discussed, the total biota destruction would not be a one year in ten event but rather a two or more years in ten. Once storage has been depleted, the basin can depend on the natural flows. These flows will be far below the minimum values which will have been related to minimum quality standards and design of treatment facilities.

46. Unfortunately, despite efforts to provide all treatment that can be reasonably attained, incremental pollution becomes cumulative and dilution of stream flow eventually is necessary if quality standards are to be actually attained in lower reaches of river systems. The Federal Water Quality Administration has determined that despite future treatment of pollution at the source, the West Fork River will need more flow augmentation to maintain these standards, with a recurrence of runoff as low as that of record. Table 6 presents recent and projected flow schedules which this agency believes are necessary at Clarksburg, West Fork River.

TABLE 6

Low Flow Schedule for Water Quality Control
West Fork River, Clarksburg, W. Va.

Months	Schedule Year			
	1960	1985	2000	2010
January	10	20	38	56
February	11	21	39	57
March	12	22	41	59
April	14	25	44	63
May	19	30	50	72
June	25	38	63	96
July	30	45	75	115
August	27	40	72	100
September	21	32	54	80
October	16	26	45	68
November	12	22	40	60
December	10	20	36	55

47. The average values of the above table were used to develop minimum flow curves for continuous interpretation of the data for any time of the year. The curves have some point deviation from the table for better shape and conformance to variations in seasonal air temperatures. These curves are shown on Plate 7.

48. The reservoir storage capacity of the Stonewall Jackson Lake is not sufficient to maintain a high minimum flow schedule for the main stem of the Monongahela River. Basically it can provide required low water augmentation of the West Fork River with a substantial degree of control on the Monongahela River at Fairmont. On the West Fork River at Clarksburg the minimum

flows projected to year 2010 would vary from 55 c.f.s. in December to 115 c.f.s. in July. Since runoff from the local area between Weston and Clarksburg may on occasion be high enough to require only a very low augmentation from the dam, it is possible that Weston could be deprived of sufficient water if Clarksburg were the sole control point. In order to eliminate this possibility, a corresponding minimum flow schedule varying from 25 c.f.s. in the winter to 45 c.f.s. in the summer has been established for Weston. To provide more widespread benefits from storage withdrawal for water usage, provisions were also made for some augmentation specifically for the Monongahela River when it falls below certain predetermined levels. This extra release from Stonewall Jackson will help to improve the water quality in the upper Monongahela River. The upper Monongahela River minimum flows that will be maintained by Stonewall Jackson reservoir will vary from a minimum of 420 c.f.s. to a maximum of 1,000 c.f.s. depending on the storage level of impoundment. The minimum flows and criteria for maintaining these minimums are explained in paragraph 59 of this appendix.

49. Water Supply Factors.- The Weston-Clarksburg area now has a municipal and industrial water supply demand of about six mgd. The sources of supply are not all dependable or fully satisfactory. It is expected that future water supply needs will increase appreciable. The estimated magnitude of these future needs have been presented in Appendix XII, Water Supply. They are related to an escalation if population growth and industrial expansion in the area up to the year 2020. Table 7 presents the estimates of water supply needs for the urban area of Weston and Clarksburg. These water supplies have been considered to be made available by use of river flows below the dam with augmentation to supply any deficiencies.

TABLE 7

Estimated Water Supply Demand and Withdrawal From
West Fork River Near
Weston and Clarksburg, W. Va.

	Weston		Clarksburg	
Year	CFS	MGD	CFS	MGD
1965	1.62	1.05	8.18	5.29
1969	1.36	0.88	7.41	4.79
1980	2.16	1.40	8.90	5.76
2000	3.77	2.44	17.53	11.34
2010	5.30	3.43	23.78	15.38
2020	7.41	4.79	29.27	18.92

50. A storage allocation for water supply to fulfill year 2010 needs has been formulated as part of water-use impoundment in the Stonewall Jackson Lake. As a guarantee that the scheduled water supplies will be always available to each of the communities, determination of the reservations for each has been made independently. For these computations a 30 percent consumption of water by the users was considered, with 70 percent of withdrawals available to augment river flows in downstream reaches. An analysis by this office of actual records of the water and sewerage treatment plants at Warren, Ohio indicated consumptive losses to be between 30 and 40 percent during the low flow season. These values confirm similar studies by others.

51. A review of stream flow records indicate that enough storage to provide water supply in the drought year of 1930 would be an adequate reserve. The flow record is too short, however, to be certain of the true probability of recurrence of a drought of this severity. More critical years could and may occur at any time. Storage for a more critical year would be highly problematical, though. Providing for the assumed eventuality is considered reasonably conservative. Computations for the year 1930 were consequently made for each of the tabled water supply demands. These computations provided at least a minimum of 5 c.f.s. in the stream in the upper reaches of the West Fork River and the total water supply requirement for Weston and Clarksburg.

52. Plate 8 shows the increasing need for water supply storage for Clarksburg and Weston as population and industry grows during the next 50 years. Total storage requirements are those needed in a reservoir at the Stonewall Jackson site during a drought year similar to that which occurred in 1930. Scheduled water supply demands are those shown in Table 7.

53. At present, Clarksburg has a water storage system estimated at 2,600 acre-feet and Weston at 350 acre-feet. Primarily, within channel storage is provided in the West Fork River. It is estimated that at present only about 90% of this storage is still available. With a headwater reservoir for water supply only, this storage potential could probably be maintained. However, with a multipurpose project at the Stonewall Jackson site, they should no longer be considered as river flow will provide their needs and stream impoundment per se will be incidental.

54. The curves on Plate 8 show both the storage required in Stonewall Jackson Lake with and without the present existing water supply reserve sources. They show the total storage for a reservoir

for Weston alone, Clarksburg alone and one for their combined needs. They show that the Weston demand has already increased to the point where their present supply would be inadequate in the 1930 drought and although Clarksburg's supply is presently adequate they could possibly be deficient in the year 1985. The plate also shows that sufficient storage in the reservoir to provide a minimum outflow of five c.f.s. below the dam would assure Weston of an adequate supply until the year 2008 and Clarksburg until 1985 without crediting these areas with existing storage.

55. Total gross storage required in Stonewall Jackson Lake to reasonably assure all water supply demand for the two communities in year 2010 is 9,000 acre-feet.

56. Storage Allocation and Water Release Schedule.- Storage within the reservoir is reserved for three basic purposes: flood control, water-use and permanent storage. Flood control and the water-use reservations are variable. The storage allocation for these purposes, throughout the yearly cycle of operation and the schedule for release of the impounded water are shown on Plate 9. Minimum flood control storage reservation marked Zone A on Plate 9 varies from 4.9 inches of rainfall runoff in the summer to 7.1 inches in the winter-spring season when floods are most frequent and impoundment may be accumulative because of generally high stream runoff and frequency of storm recurrence.

57. Water-use impoundment totaling 8.29 inches of rainfall runoff is available below the maximum summer conservation level. In the winter, impoundment specifically for this purpose will not exceed 6.1 inches. Minimum conservation storage initially equal to 0.6 inch of runoff provides some assurance for emergency use and for possible displacement of storage capacity by sedimentation.

58. Decrease of the assigned minimum conservation storage by sedimentation would not be critical to operation of the reservoir or to accomplishment of its storage functions as it represents a very small increment of total use volume. Its primary purpose is to provide a water level which affords protective submergence of the low level sluice installations. These gates will not be adversely affected by sedimentation as their use annually during flood storage drawdown will prevent approach deposition.

59. The storage and release schedule of Plate 9 is divided into zones within which different procedures for controlling the water will be followed. Guidelines of the zones in the spring season, which define the time and filling rate for water-use

impoundment, have been determined by the use of the mass runoff curves shown on Plates 5 and 6. Their definition for drawdown is based on the simulated water-use withdrawal using fixed operational controls without resorting to hindsight. They maximize use of available runoff storage and minimize the possibility of a year of deficit operation. The definite operating procedure for each zone is as follows:

Zone A - Flood Storage - This zone includes all the reservoir capacity above that reserved for water-use storage and is reserved entirely for flood impoundment. When flood runoff is retained within this zone, the rate of reservoir outflow will be regulated to provide maximum possible reduction in downstream flood stages. Release of excess flood storage will be made after downstream stages have fallen to a safe level. Maximum release shall not exceed bank-full capacity of 2,300 c.f.s. Drawdown to the next lower Zone B, should be accomplished with five to ten days. The stratification shaft gates could be used at their combined maximum capacity of 620 c.f.s. to partially offset the effect of bottom withdrawal if scheduled drawdown rates exceed this amount in the summer season.

Zone B - Transition - This is the stabilization and transition zone wherein the rates of reservoir releases, used to evacuate Zone A flood storage, are gradually reduced. Such operations are designed to eliminate radical downstream flow changes and afford more leeway for transition to normal scheduled operations as emergency operations cease. Storage of excess minor runoff may also be accomplished within this zone. It provides a two and one-half-foot range for delayed drawdown or minor pool fluctuation. While storage is within this zone, release of water may be accomplished through the stratification withdrawal shafts at a combined maximum rate of 620 c.f.s. This procedure will be used during the months of April through October when quality control is most significant and water stratification occurs within the impoundment.

Zone C - Drawdown - When the reservoir pool level is within this zone, storage will be released to provide the water quality and water supply schedule at Clarksburg and Weston. In addition, if the flows in the upper Monongahela River at Fairmont, W. Va., after other upstream augmentation, would fall below 1,000 c.f.s. sufficient water will be released to attain this magnitude. Rate of release must also be scheduled to effect drawdown at least to winter pool by 15 December.

Zone D - When the storage level lies within the limits of this zone, water shall be released to maintain the water quality and water supply schedule at Clarksburg and Weston. As in Zone C water shall also be released for additional augmentation of low Monongahela River flows. The minimum regulated flow at Fairmont for this zone is 800 c.f.s.

Zone E - When the storage level is within this zone water shall be released to maintain the water quality and water supply schedule at Clarksburg and Weston. A minimum flow of 600 c.f.s. will be maintained at Fairmont, W. Va.

Zone F - With below normal runoff, the storage level will probably fall into this zone due to high low flow augmentation demand. Water shall be released to maintain water quality and water supply at Clarksburg and Weston. A minimum flow of 420 c.f.s. will be maintained at Fairmont, W. Va.

Zone G - If impoundment falls within this zone water will be released solely for water supply for Clarksburg and Weston.

Minimum flow release within all zones would be 5 c.f.s.

60. Flood Operation Control Factors.- The location of the Stonewall Jackson Lake project at the head of the basin makes it effective primarily for flood reduction on the West Fork River. Tributary area above the dam comprises about 11.5% of the total uncontrolled West Fork basin area. It will also operate, however, in conjunction with the Tygart and Youghiogheny reservoirs for control of Monongahela River floods and will be coordinated with all reservoirs in system operation. Storage of flood waters within the evacuated portion of the water-use impoundment zone will increase the reservoir flood storage potential beyond the minimum 7.1 inches of rainfall runoff impoundment reserved for winter usage. Flood control storage operations will be closely integrated with meteorological conditions which could result in severe weather and sufficient runoff to cause the West Fork River, or the downstream system to which it contributes, to rise to a critical level. Flood control storage should begin coincidental with any precipitation which is expected to produce sufficient runoff to cause any one of the following:

a. Discharge of West Fork River at Butcherville to exceed 4,400 c.f.s. in five hours.

b. Discharge of West Fork River at Clarksburg to exceed 6,300 c.f.s. in 19 hours.

c. Discharge of Monongahela River at Maxwell Locks and Dam to exceed 85,000 c.f.s. in 39 hours.

d. Discharge of the Ohio River at Pittsburgh to exceed 110,000 c.f.s. in 53 hours.

61. A flow of 200 c.f.s. would be released during such storage periods when the reservoir storage is above the selected maximum winter or summer pool levels within Zone A of the storage and release guide. A decrease in this amount may be advantageous at times when water is being impounded for water use. Flood storage would continue until such time that the: West Fork River at Butcherville has crested and discharge is below 4,400 c.f.s. and falling; Clarksburg has crested or will crest within 8 hours and predicted discharge will be below 7,500 c.f.s. and falling within 16 hours; no adverse conditions will be effected on the Monongahela and Ohio Rivers.

62. When flood waters recede and there is a diminution of flood potential, impounded flood storage release would begin. Release from storage would be coordinated with streamflow in the rivers so that increased discharge would arrive downstream after passage of the critical stages without causing a recurrence of them. These releases would also be coordinated with those from the other Pittsburgh District flood control reservoirs for a progressive downstream program of controlled river stages. Flood storage release from Stonewall Jackson reservoir would be in maximum increments of 300 c.f.s. at not less than four hour intervals. This will approximate natural stream rise conditions. Outflow would be limited so as not to exceed the rate of inflow or the safe downstream channel capacity of 2,300 c.f.s. Flood release outflows would continue until the excess storage is evacuated or until recurrence of critical meteorological or river conditions warrant a return to flood impoundment. Rate of outflow reduction at such times would also be at a maximum of 300 c.f.s. in 4 hours. The time between operations would be increased to provide a slower rate of head change on the banks if conditions are favorable. The need for this action is not critical as banks are stable and have shown little erosion during flood recessions.

63. During the summer months, with the reservoir at maximum summer conservation pool level, excess inflow and storage would be quickly passed. If outflow on these occasions for low-flow augmentation should exceed the 200 c.f.s. maximum rate selected for outflow during

flood impoundment, no decrease in outflow would be initiated until a storm, believed to be capable of producing sufficient runoff to cause high water or flood conditions had commenced. During the low-flow augmentation period, July through October, storage operations solely for flood control would normally be of limited occurrence.

64. Water-Use Operation Guides.- The release of water for water quality improvement, low-flow augmentation, water supply and drawdown of excess storage will be controlled by the storage allocation and release guide of Plate 9. This guide as previously noted is zoned for flood control, low-flow regulation, water supply and minimum storage. The low-flow storage zone is further apportioned into additional zones, for periods of abundant, normal, below normal and drought runoff. The adopted guide curve, based on the selected storage allocation, provides for a maximum summer conservation level elevation of 1073.2 (48,170 acre-feet) to be attained by 10 April of each year. The guide also provides for a maximum winter conservation level at elevation 1068.2 (36,100 acre-feet). The minimum pool provided is at elevation 1038.5 (3,120 acre-feet).

65. The runoff and reservoir regulation studies indicate that the impoundment from the winter to summer conservation level should be attained between the end of February and 10 April. This will eliminate the necessity of storage during any periods in late spring when lower flows in the Monongahela tributaries may be below normal and concentration of mine acid flow is greater. It will also make possible a fairly constant level in the reservoir during the fish spawning periods.

66. Flow release will vary with the daily downstream predetermined needs for use and maintenance of quality standards. Water quality will be monitored periodically to assure compliance with standards and permit temporary deviations from schedules. Low flow forecasting will be employed so that frequent fluctuations in low-flow releases can be avoided, especially in times of probable maximum downstream river need.

67. Drawdown during the summer-autumn low-flow season will be dependent on the demand from storage for low-flow use, water supply requirements and on the amount of basin runoff. Runoff in excess of downstream demand will be retained during the recreational season so long as the maximum summer conservation level is not exceeded. During a dry year, the summer drawdown will usually start during late May while in a normal year the drawdown will usually start in early June. In a year of above normal rainfall and runoff, the maximum summer conservation level may be

maintained until approximately mid-June. Deliberate drawdown of the lake to winter conservation level would begin in mid-September when recreation use is declining and the runoff is usually low. The winter pool level must be attained by mid-December. This drawdown provides for greater flood storage capacity and is also somewhat beneficial to fish life, as it is believed to aid in the aeration and regeneration of their spawning areas by exposing the shallow silted bottom to weathering and oxygenation and curtails or destroys deleterious aquatic plant growth.

68. Growth of stemmed grasses, legumes or weeds, on the flatter silted areas which become exposed in the summer or fall could result in increased forage or cover for fish when the reservoir refills the following year. A program for seeding of selective varieties could be employed if such a program is shown to be feasible.

69. System Analysis.- The proposed plan for impoundment and release of water for flood control and water use has been examined for its applicability during the 37 years of the period 1929 to 1966. The computations were divided into two interrelated phases. They included specific detailed analyses of operations during 30 flood periods including the highest and representative floods in the lower ranges and a generalized system simulation continuous throughout the 37 years of record which employed daily runoff, rainfall and lake evaporation, with the reservoir storage and release schedule. The computations encompassed several drought years including the 1930 to 1934 drought period which is the most critical of record in the entire Pittsburgh District watershed.

70. Flood Control Operations.- Although continuous determinations of reservoir impoundment were made in the system programming for continuous storage and release in the reservoir throughout the 37 years period of record from 1929 to 1966, the more detailed analyses of significant floods were needed to assure the effectiveness of the control programs and determine specific storage impoundment levels. These involved, not only continuous impoundment scheduling, but also gave consideration to all of the downstream flood factors and the flood regulation schedules. The synthesized extreme flood of July 1888 was also examined. The maximum elevations attained in the reservoir by these computations were used to develop an all year partial series flood storage frequency curve shown on Plate 10. The upper definition of the frequency curve has been influenced by the storage level of the spillway design flood, the standard project flood, and the reservoir design flood. The curve indicates that the reservoir

would reach to about elevation 1076.4 about 20 times in 100 years and reservoir full level about once in 190 years.

71. Specific computations were also made for minor rises and other higher floods during the period of May through October, when impoundment rose above summer pool elevation 1073.2. During such times the stratified water withdrawal shafts would have been used to the 620 c.f.s. maximum limit of their scheduled outflow capability, in the 2.5 foot storage range between elevation 1073.2 and 1075.7. The partial series storage frequency of these events is also shown on Plate 10. Values from the shorter 37 year period of detailed computations were used for this latter curve.

72. The curves of Plate 10 indicate that inundation one foot above summer pool will occur every year, but only once every 2.5 years during the summer-fall recreation season. Inundation of 2.5 feet to the upper limit of the operating zone between flood storage and low-flow impoundment will have an all year frequency of 3 years but will occur only once in 6.8 years during May through October. The clearing elevation 3 feet above maximum summer conservation level will be exceeded once in 4.2 years but only once in 14.3 years when vegetal growth is at its maximum.

73. Flood Control Evaluation.- The effectiveness of this reservoir on reducing flood stages at downstream locations was determined by routing changes in flow magnitudes, due to reservoir storage, on the 30 specifically investigated floods. The reductions were determined for this reservoir acting by itself and in combination with the existing reservoir system.

74. The Muskingum coefficient method of flood routing was used with terminal routing points of Weston, Clarksburg; Monongahela River at Dams 7, Maxwell, 4 and 2; at the Pittsburgh Point; and at the Ohio River Dams Montgomery, New Cumberland, Pike Island and 14. Only a few representatives floods were routed below Maxwell as most of the modifications during downstream high flows were too small to warrant more than an average estimate. A typical storage and release operation during a high flood is depicted on Plate 11 which shows the inflow, outflow and impoundment during the flood of 7 March 1967 when storage level reached elevation 1077.1.

75. The effect of these storage and release operations at Stonewall Jackson Dam on downstream flood stages is illustrated on the hydrograph of the West Fork at Clarksburg. Plate 12 shows the stage hydrograph as further modified by the Stonewall Jackson reservoir. It may be observed that subsequent drawdown release of excess reservoir storage reached Clarksburg at a safe level of flood recession.

76. Appraisal of reservoir modification on the rivers within the limits of the Pittsburgh District was related to all floods of record. Average reduction curves were developed for the previously enumerated stations along the West Fork and Monongahela Rivers. These stations are all used regularly in flood damage and reservoir benefit evaluations of the Pittsburgh District. The relation curves were derived by plotting natural peak flow versus reduced peak flow for each of the floods of record in the period, as modified by existing reservoirs and by the Stonewall Jackson Lake project in conjunction with these existing reservoirs. These relationships for the damage index stations along the West Fork and upper Monongahela Rivers are shown on Plates 13, 14 and 15.

77. The stage frequencies used in the evaluation of flood damage and reservoir benefits have also been developed for the same flood damage index stations on the West Fork River below the proposed damsite and on the upper Monongahela River. Modified frequency curves were obtained from the natural frequencies by use of the natural versus reduced flood flow relationships. Stage-discharge relations at each index station were used to convert flow frequency to stage frequency. The stage-frequency curves are shown on Plates 16, 17 and 18. They illustrate the reduction by existing reservoirs and their reduction combined with that of the Stonewall Jackson Lake project. The method of computing the natural frequency curves was previously discussed in Appendix III, Hydrology. The dashed curves on these plates represent the effects of variable flood storage capacities and were developed for plan formulation as discussed in Appendix I of this memorandum.

78. <u>Water-Use Storage Operations</u>.- Since water quality control is becoming an ever more important aspect of reservoir regulation, the Stonewall Jackson Lake project will be operated to insure the release of water having the best possible quality for downstream augmentation during low flow periods in the West Fork and Monongahela Rivers. The Stonewall Jackson reservoir, in conjunction with the other Federal reservoirs, will be operated to increase the base flow of the Monongahela River from Fairmont on downstream. Many water quality problems inherent in low flows will be alleviated by the augmentation of these reservoirs. Since it is anticipated that the river itself will be used is the water supply source for Weston and Clarksburg additional stream flow augmentation for their needs will be released conjunctively with low-flow augmentation.

79. The water-use regulation schedule, as presented, has been examined to determine its effectiveness during the entire

37 years studied. As previously mentioned, to assure a complete water balance, computations involved the storage and release of reservoir inflow and considered rainfall and evaporation over the lake area continuously throughout the filling and emptying cycles. They are a part of the system analysis of daily operation of all three reservoirs in the Monongahela River basin extending through the period 1929 to 1966. The computed releases augmented the flow at Clarksburg and Fairmont in compliance with the regulated flow schedule on Plate 7 and the storage and release schedule of Plate 9.

80. These computations show that if the proposed schedule is followed exactly within this period, the lake level would on one occasion, have fallen to a minimum elevation of 1038.0. This is 180 acre feet or 0.5 feet below the assigned minimum pool level. This small negative increment is not considered significant in these review computations as it represents only 0.4 of 1 percent of total drawdown. No safety factor, however, is provided against more severe drought conditions unless the augmentation schedules are lessened at such times. This, of course, would decrease quality control effectiveness.

81. More significant than the specific storage adequacy shown by this study is whether there is a guarantee of enough storage to provide for conditions which may be later encountered. There is no assurance that this past period of actual record represents the true periodicity of future drought conditions and that more critical or more frequent drought events will not occur. A frequency analysis has consequently been made of the annual storage drawdown and the statistical probability of more critical conditions determined. The results of this analysis is presented on Plate 19. It shows that although application of the water-use schedule to the 37 years of record indicates that storage for this purpose would be fully used only once in about 25 years, the deviation in annual values from the norm indicate that there is a reasonable chance that it could be totally depleted as often as once in about 10 years.

82. In addition to this consideration it is possible that short term deviations in downstream runoff, ineffectual forecasting or operation action, or overreaction to low flow conditions would result in greater water-use and consequent depletion of storage. It is believed self-evident that an increase in scheduled outflow to induce more frequent drawdown would endanger the claimed quality control effectiveness for the reservoir and is not conservatively acceptable.

83. Predominant use of the lake for recreational purposes will generally occur during the months of May through October. Consequently, the effect of drawdown at this time is particularly significant. The curves of Plate 20 were determined from the 37-year operation analysis. The curves are plotted to show month and elevation of reservoir impoundment for years with above normal (wet year), normal and below normal (dry year) runoff. Above normal or wet year values have been considered as those with month end elevations within the high quartile. The below normal or dry year values are those in the lowest quartile. The normal values are those that are exceeded by as many higher elevations as there are lower elevations. The curves are plotted as the normal differential of these classifications. They indicate that during a normal year the lake level will fall about 4.0 feet by Labor Day, representing a loss of about 360 acres in lake area.

84. The water released from the reservoir for water quality operations will effect a marked change in the magnitude and duration of West Fork River flows below the dam. The critical quality deterioration, from acid mine drainage, which has occurred with previous minimal flow conditions should be practically eliminated as far downstream as Clarksburg by the high rate of dilution provided by reservoir release. Below this point the effectiveness would be deminished because of the acid contributing streams.

85. The reservoir system operational simulation showed the more critical water quality schedules for year 2010 at Weston and Clarksburg could be provided along with water supply needed at that time, but flows on the Monongahela River were frequently below the maximum schedule. At Weston, because of its proximity to the day, flow was frequently nearly equal to dam outflow. At Clarksburg, local tributary runoff had more influence on flow magnitude frequency and the generally acceptable 70% return of withdrawals used in these computations also contributed to the maintenance of water quality flow schedules. Additional augmentation for Monongahela River deficiencies provided a significant increase in minimum flow magnitude at Fairmont.

86. The flow duration curves of Plate 21 illustrates the change in flow regime below the dam during the months of May through October when recreation use of the stream will be greatest. Control of minor rises, when the lake is at the maximum conservation level, by use of the two stratification withdrawal shafts at a maximum rate of 620 c.f.s., will reduce occurrence of flows greater than this amount from about 5 days to less than 1 day per season.

Such flows now cause a rise in excess of 2 feet in the stream at Brownsville, W. Va. These curves also show that the river below the damsite will always be about one-half to one foot in depth while previously it became almost dry. Fluctuations one foot above this level will occur for less than 30% of the time.

87. Temperature.- Since the low flow shafts can be operated to withdraw water within a 620 c.f.s. range with 5 or less feet of bulkhead opening throughout the upper 35 feet of lake depth and 95% of water use impoundment, full selective temperature control from augmentation storage can always be provided. Even during the most critical drought year, lake levels will not fall below this range until the reservoir has become isothermal late in the season and level of withdrawal is no longer significant.

88. Augmentation.- Within the period of review, the years of 1930 to 1935 were the driest five consecutive years. Records indicate they may have been the driest within the 55 year period at Butcherville. These years of drought were general over the whole tri-state area of Pennsylvania, West Virginia and Ohio. The Ohio River at Pittsburgh was the lowest for its record and the Monongahela River above the Cheat River became almost dry. Water reserved for power generation in Lake Lynn was released as an emergency measure to provide enough flow for maintenance of navigation in the Monongahela below the mouth of the Cheat River.

89. The generalized effect of reservoir storage and release on the West Fork and upper Monongahela River flow magnitude is defined on the low flow frequency curves of Plate 22 and 23. These curves have been developed from the lowest annual 7 consecutive day flow with flow augmented by Stonewall Jackson at Clarksburg and further augmented by the Tygart reservoir at Fairmont. They show that this reservoir will provide an average low flow increase at Clarksburg of about 55 c.f.s. and that minimum flow would be above 57 c.f.s. nine years in ten with corresponding values of 80 c.f.s. and 420 c.f.s. respectively at Fairmont. Although Monongahela River flow augmentations combined with those for the West Fork assure a generally high rate with only intermittent low values at Clarksburg the opposite is true at Fairmont. The curves at Clarksburg are not truly indicative of probable severity of flow deficiency as they do not intimate the possibility of recurring low flows with one year or extension of the low flows for longer duration. Whereas, the curves would indicate that the augmented seven day minimum of 420 c.f.s. at Fairmont would occur only once in 10 years, in the years of 1930 and 1953, the computations indicate that they have occurred continuously for a total

of 128 and 51 days respectively. It must be evident, therefore, that if a quality criteria has been established for 7 days in 10 years, such curves may not truly indicate a flow value wholly acceptable for stream flow quality evaluation nor for one week in the 520 weeks of a ten year period.

90. The significance of annual 7-day minimum flows in relation to biological dilution is further minimized as scheduled flows for the West Fork River are varied throughout the year. A low magnitude flow during the winter season can be less critical than a high flow during the summer.

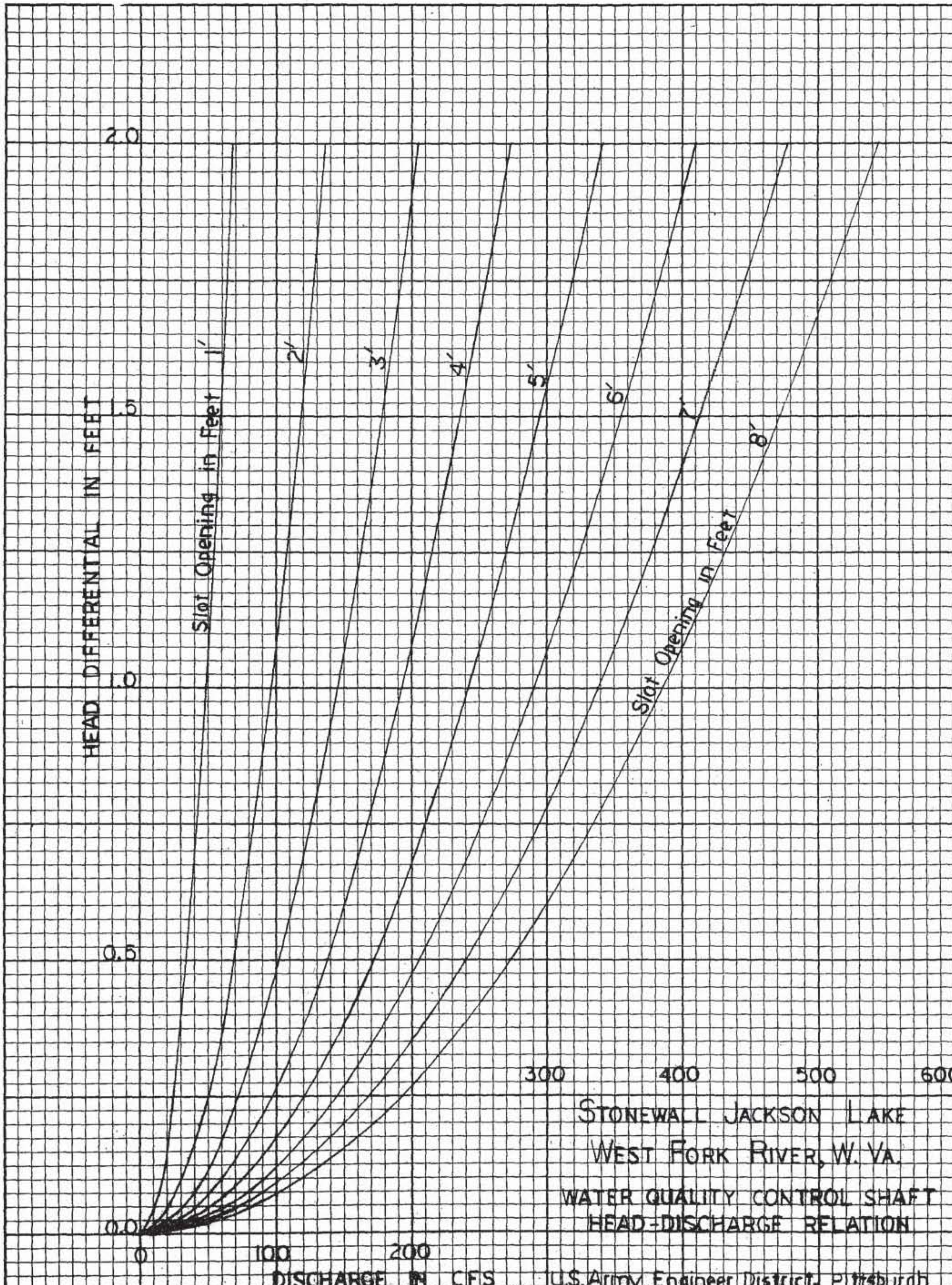


PLATE I APPENDIX IV

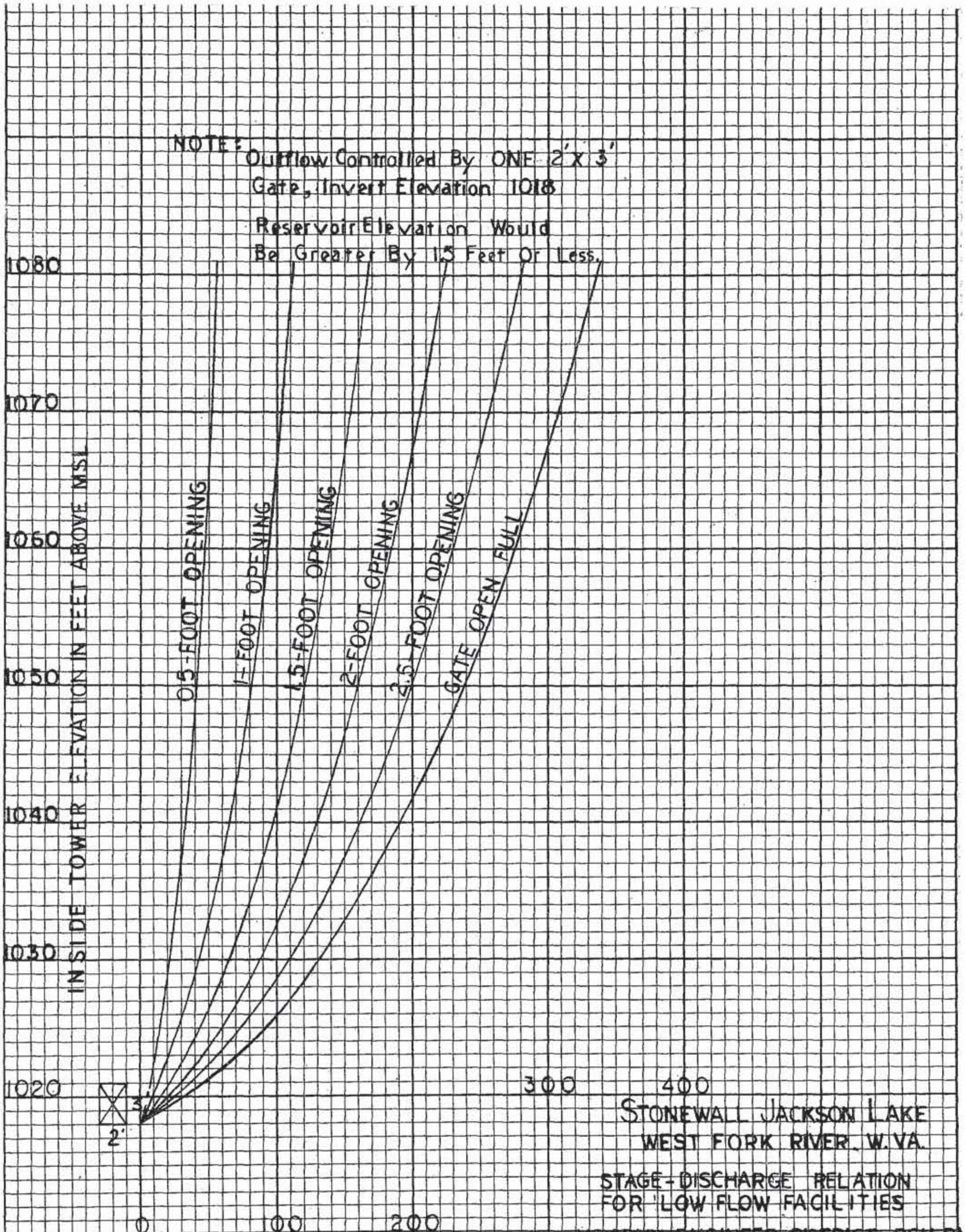


PLATE 2 APPENDIX IV

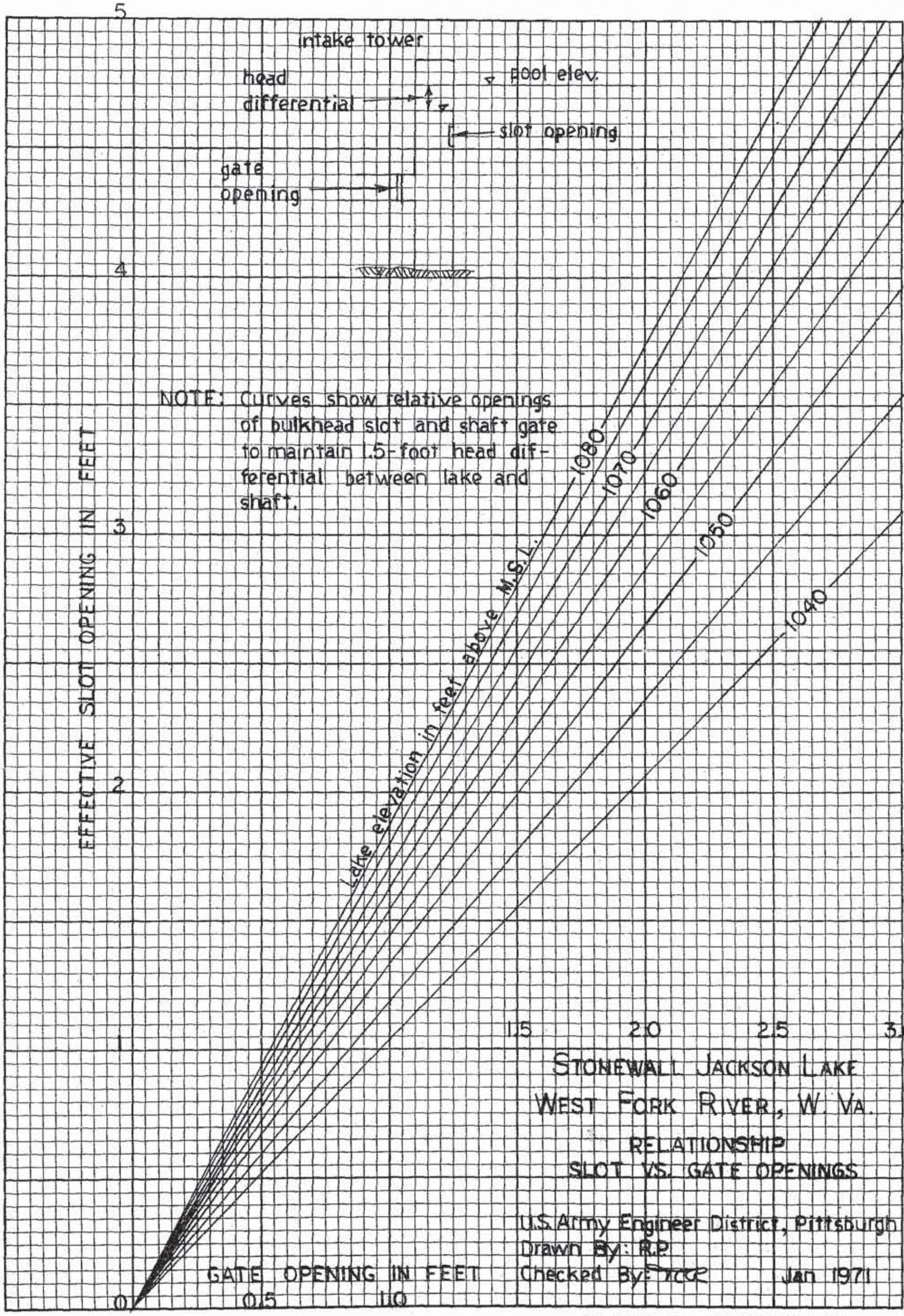
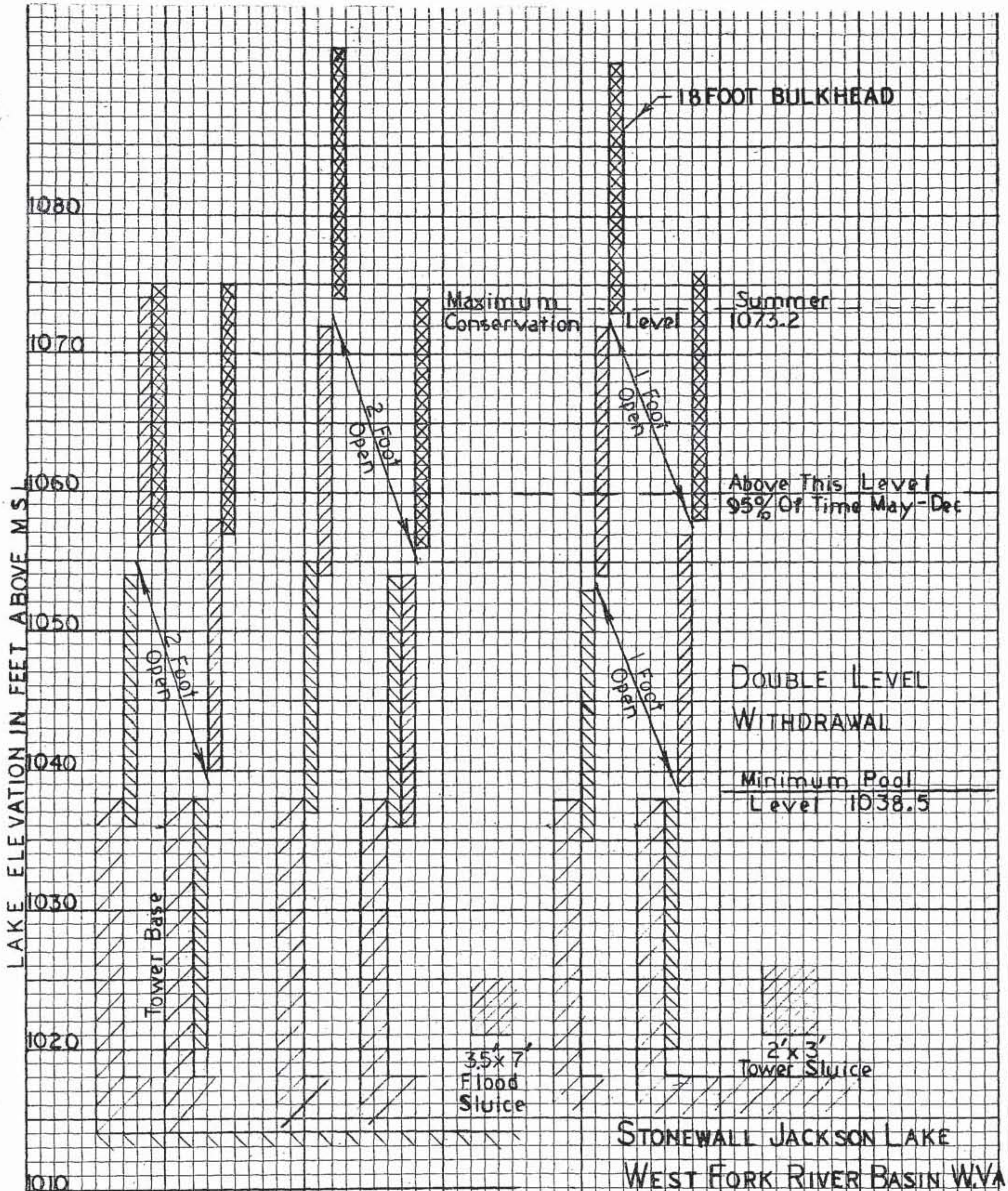
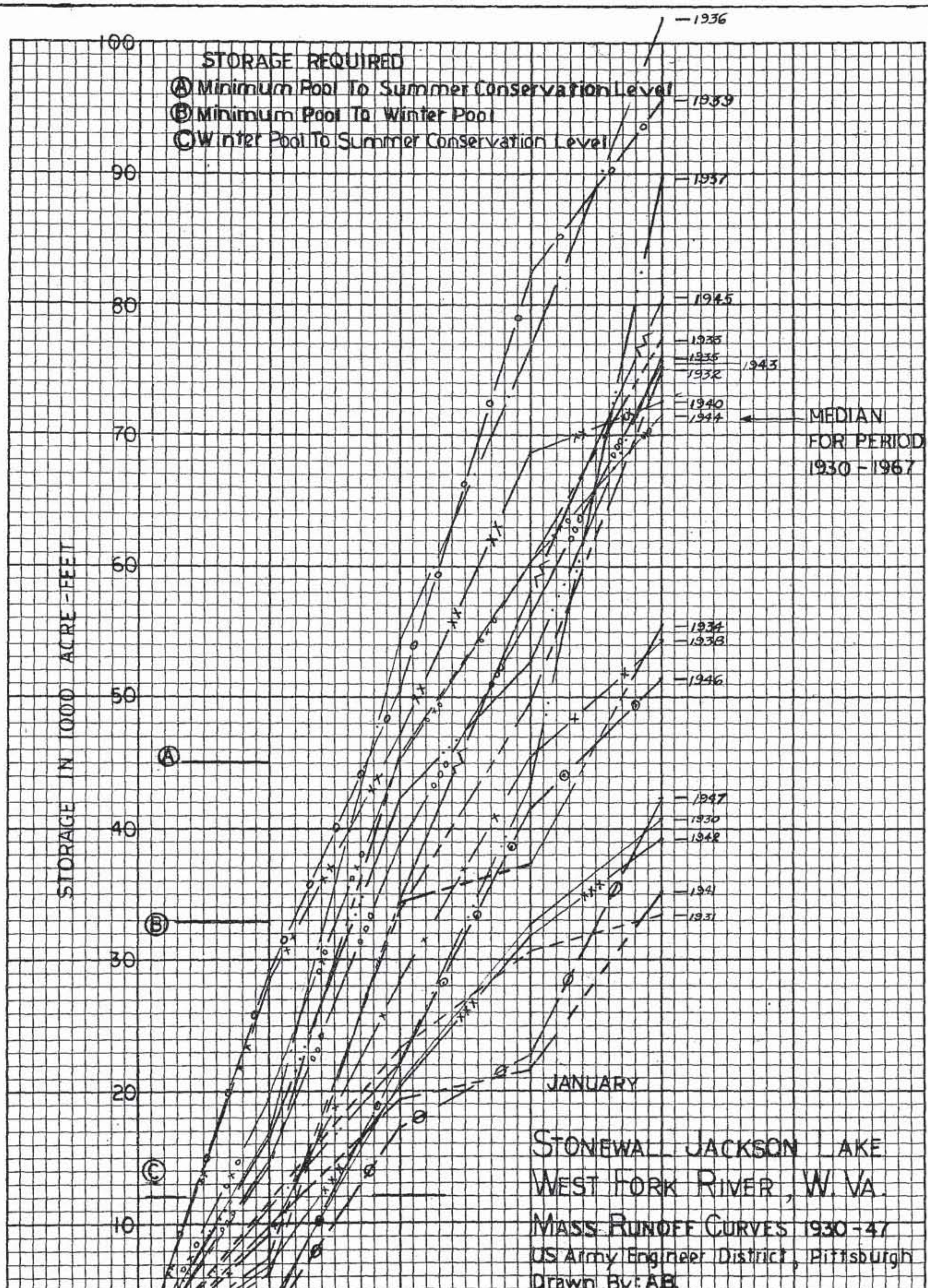


PLATE 3 APPENDIX IV

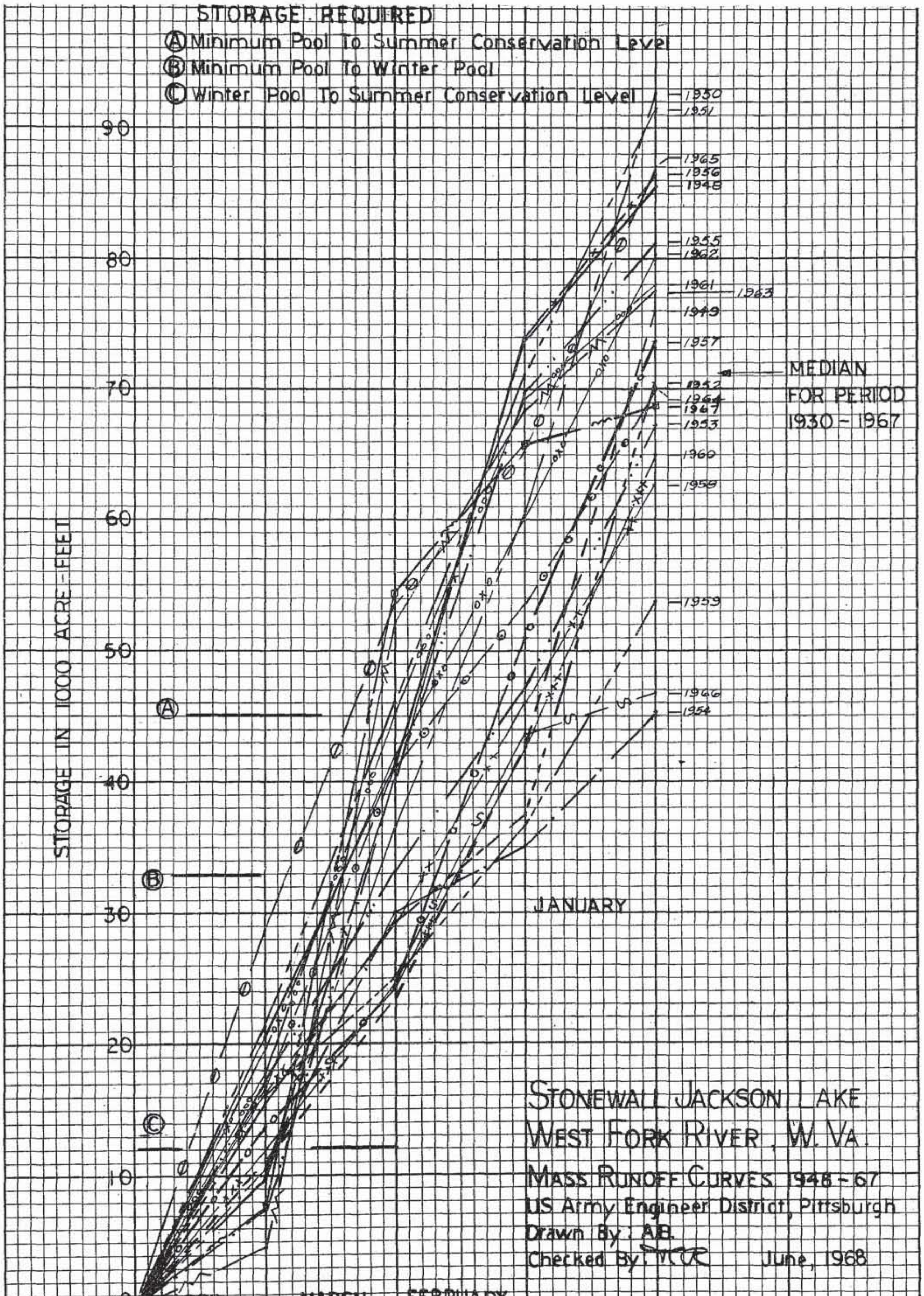


STONEWALL JACKSON LAKE
WEST FORK RIVER BASIN W.VA.
VARIABLE LEVEL WITHDRAWAL ARRANGEMENT
US Army Engineer District Pgh., Pa.
Drawn By: AB
Checked By: VCR June 1970



STONEWALL JACKSON LAKE
WEST FORK RIVER, W. VA.
MASS RUNOFF CURVES 1930-47
US Army Engineer District, Pittsburgh
Drawn By: AB
Checked By: TCC June, 1968

PLATE 5 APPENDIX IV



STORAGE REQUIRED
Ⓐ Minimum Pool To Summer Conservation Level
Ⓑ Minimum Pool To Winter Pool
Ⓒ Winter Pool To Summer Conservation Level
STORAGE IN 1000 ACRE-FEET
90
80
70
60
50
40
30
20
10
0
Ⓐ
Ⓑ
Ⓒ
APRIL
MARCH
FEBRUARY
JANUARY
1930
1951
1965
1956
1948
1955
1962
1961
1963
1949
1957
1952
1964
1967
1953
1960
1958
1959
1966
1954
MEDIAN FOR PERIOD 1930 - 1967
STONEWALL JACKSON LAKE
WEST FORK RIVER, W. VA.
MASS RUNOFF CURVES 1948 - 67
US Army Engineer District, Pittsburgh
Drawn By: AB
Checked By:
June, 1968

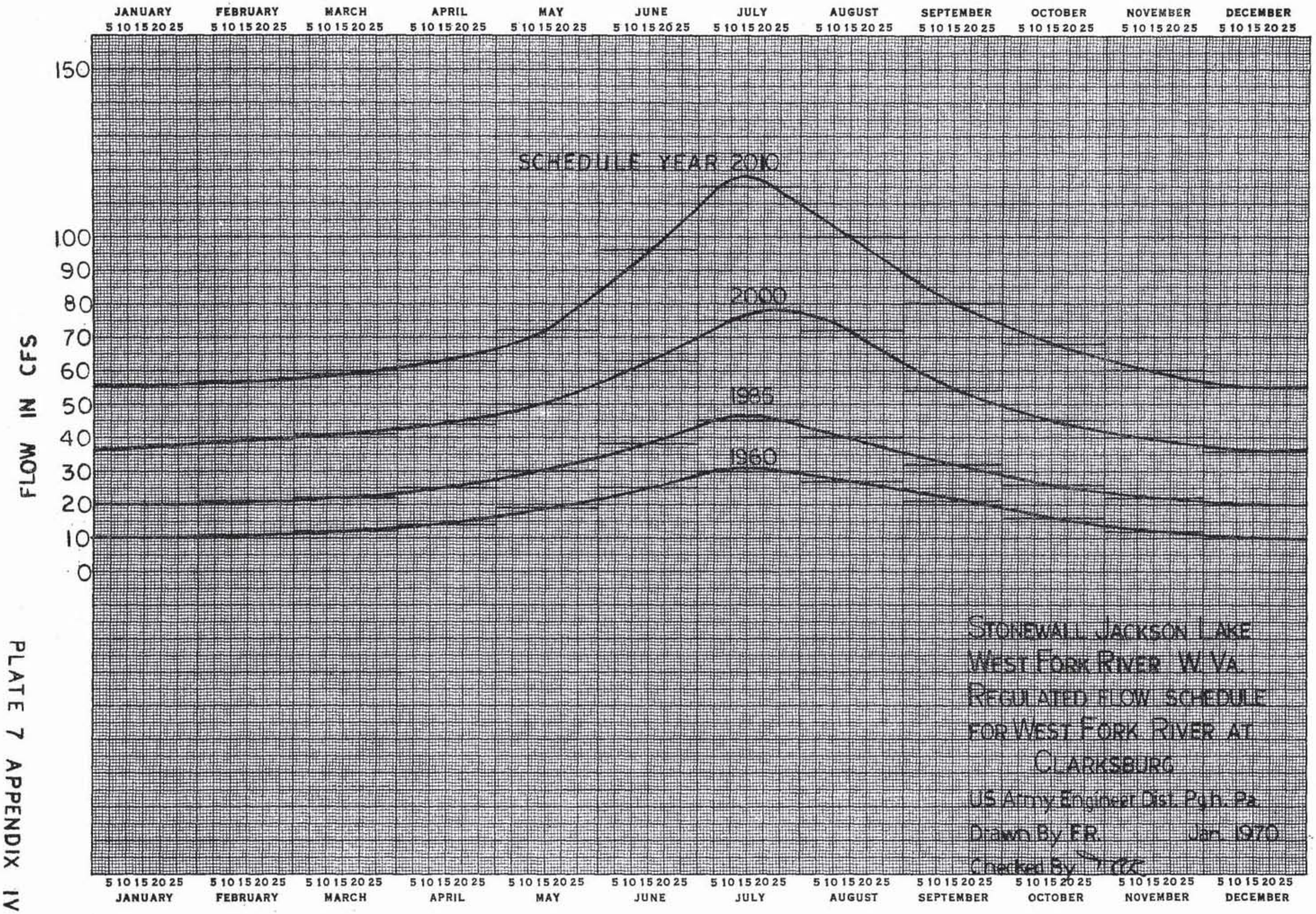


PLATE 7 APPENDIX IV

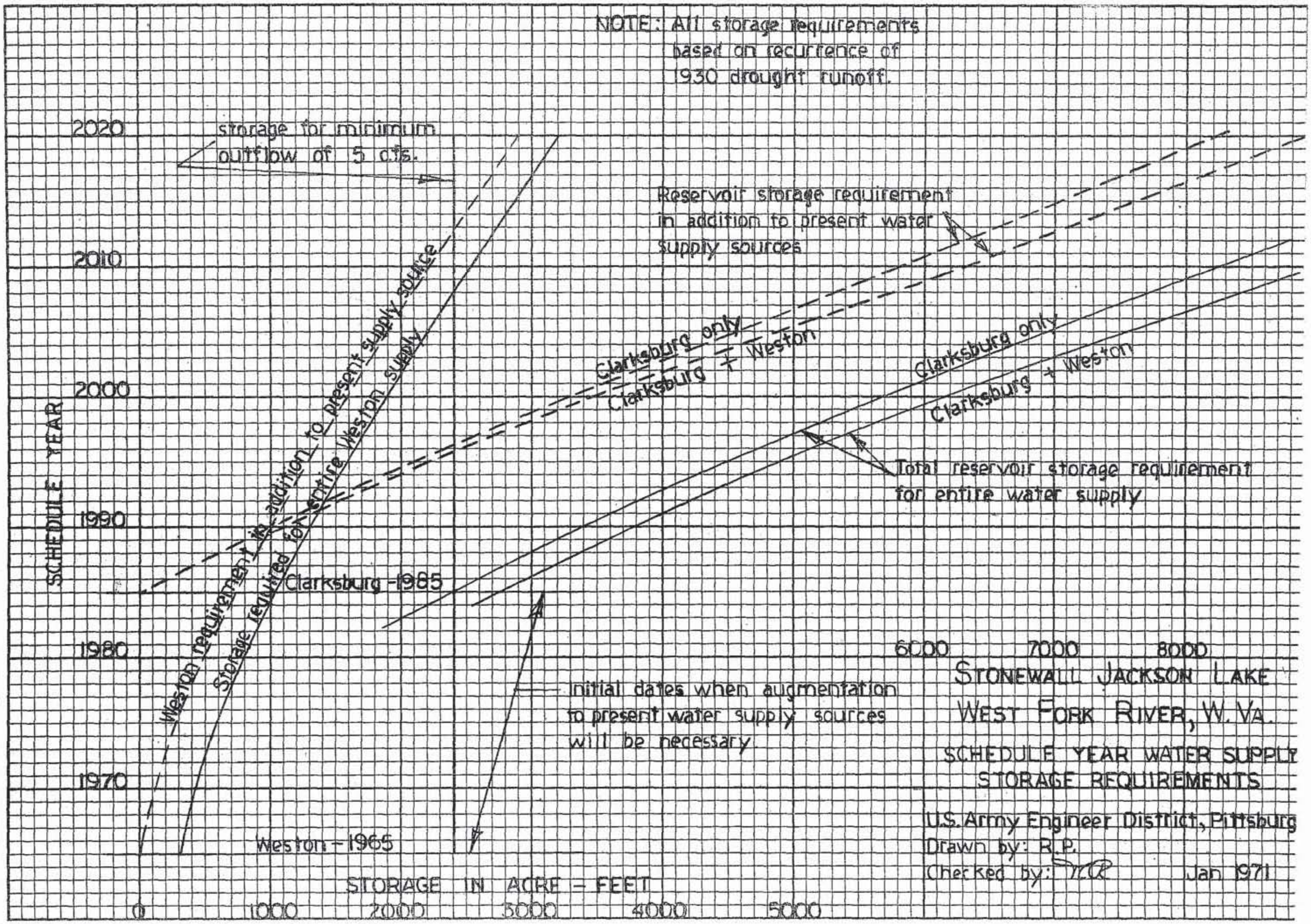


PLATE 8 APPENDIX IV

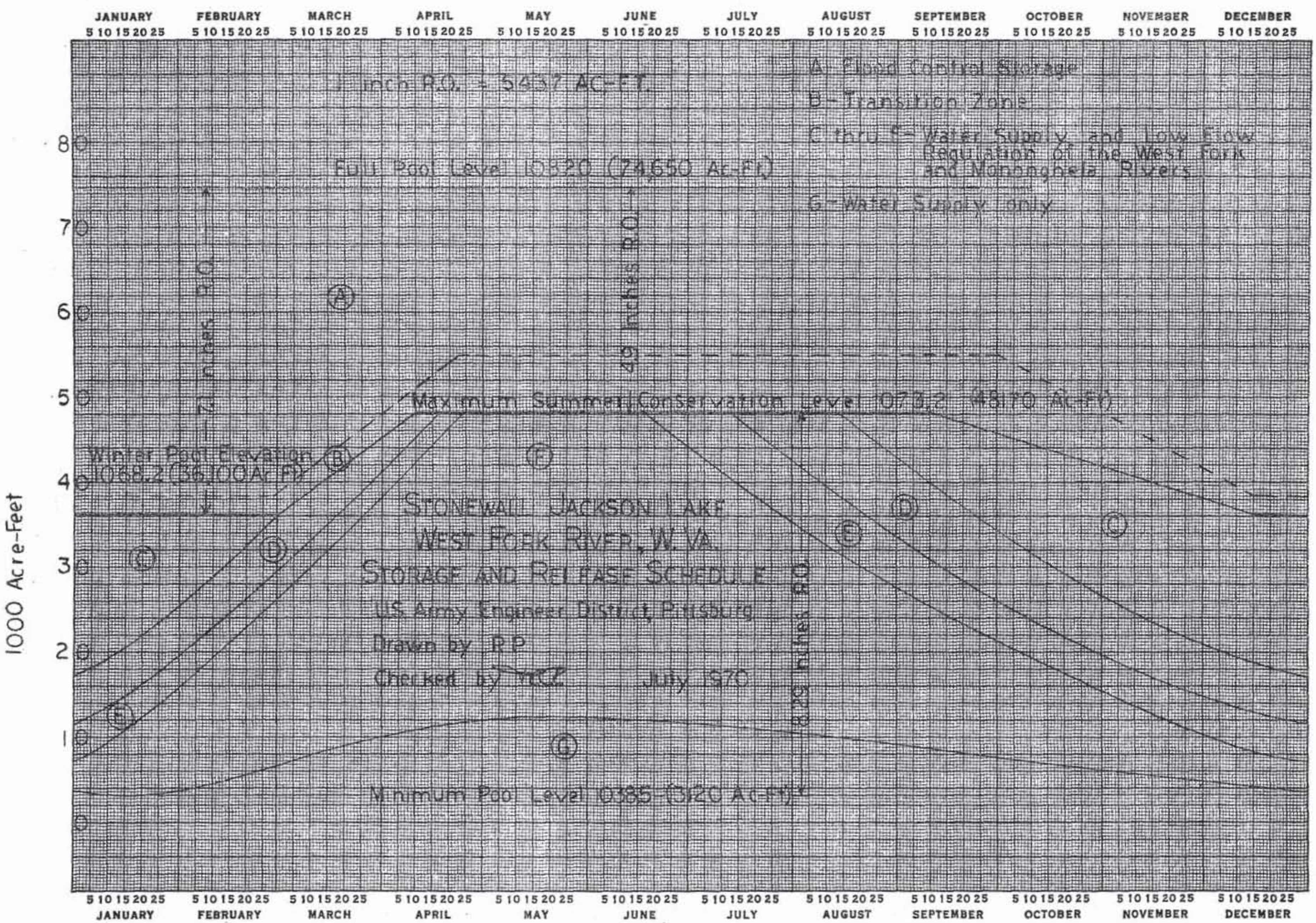


PLATE 9 APPENDIX IV

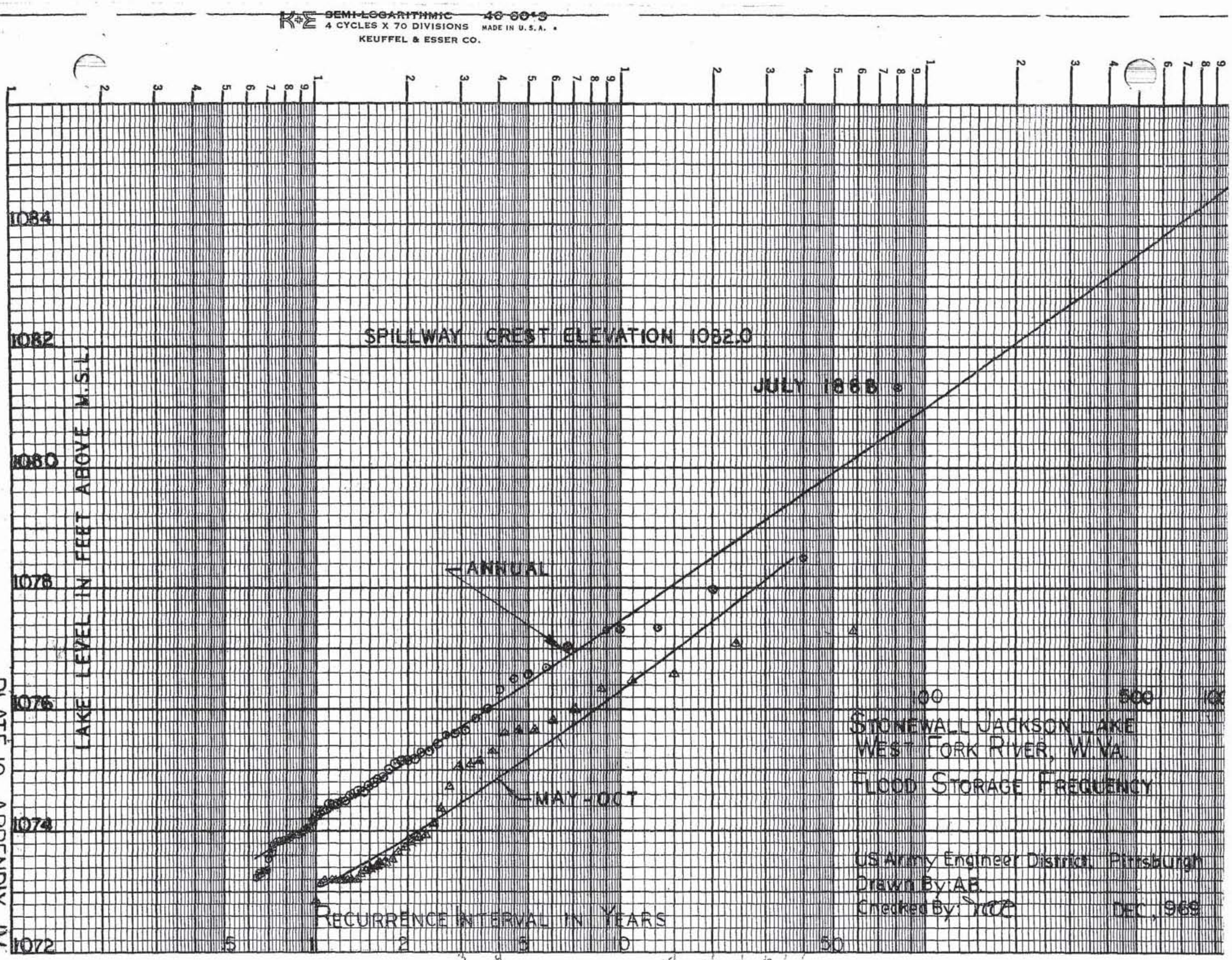
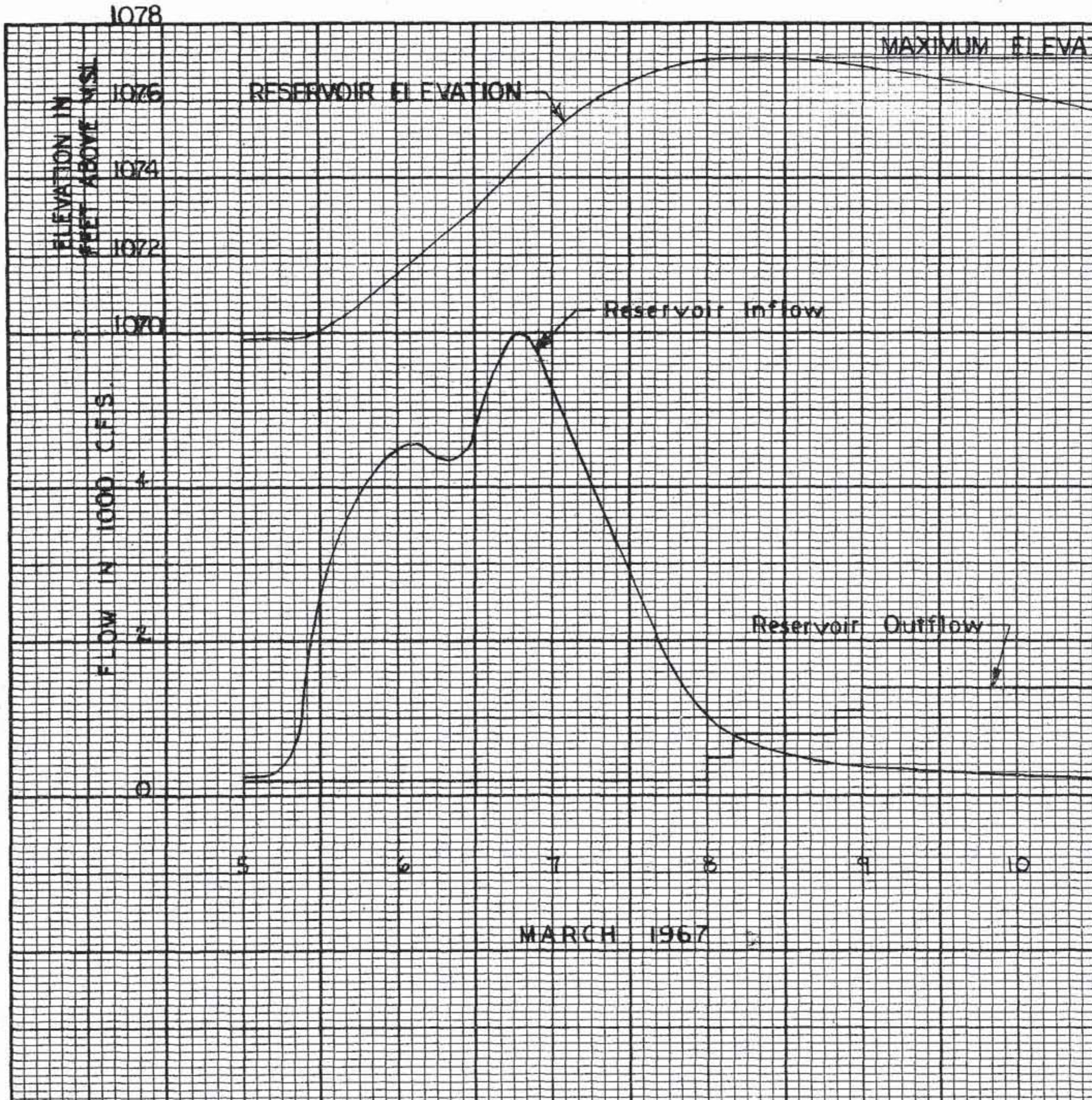


PLATE 10 APPENDIX IV



STONEWALL JACKSON LAKE
WEST FORK RIVER, W. VA.

WEST FORK RIVER AT
BROWNSVILLE, W. VA.
7 MARCH 1967 FLOOD

US Army Engineer District, Pittsburgh
Drawn by RP
Checked by [signature] Jun 1970

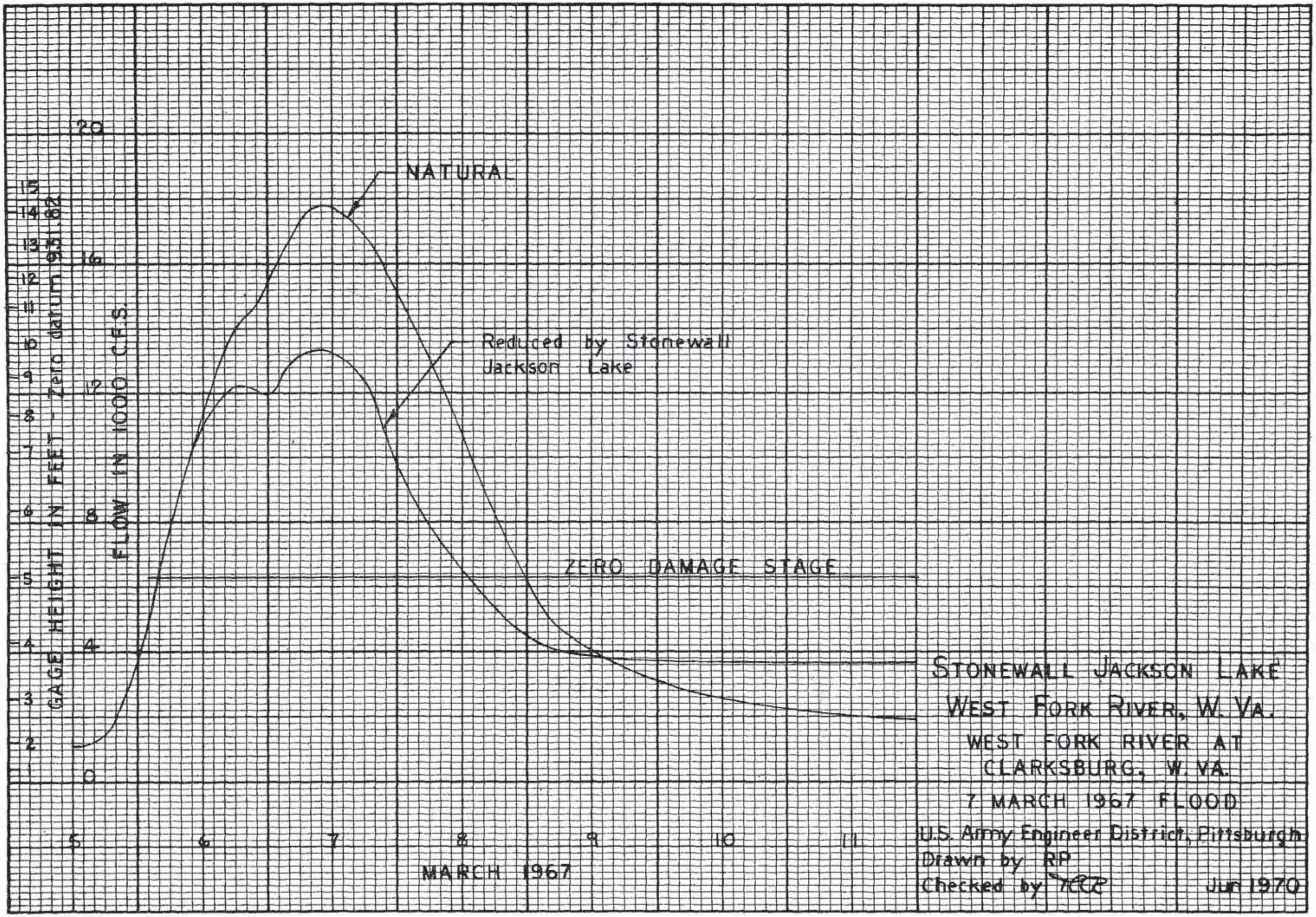


PLATE 12 APPENDIX IV

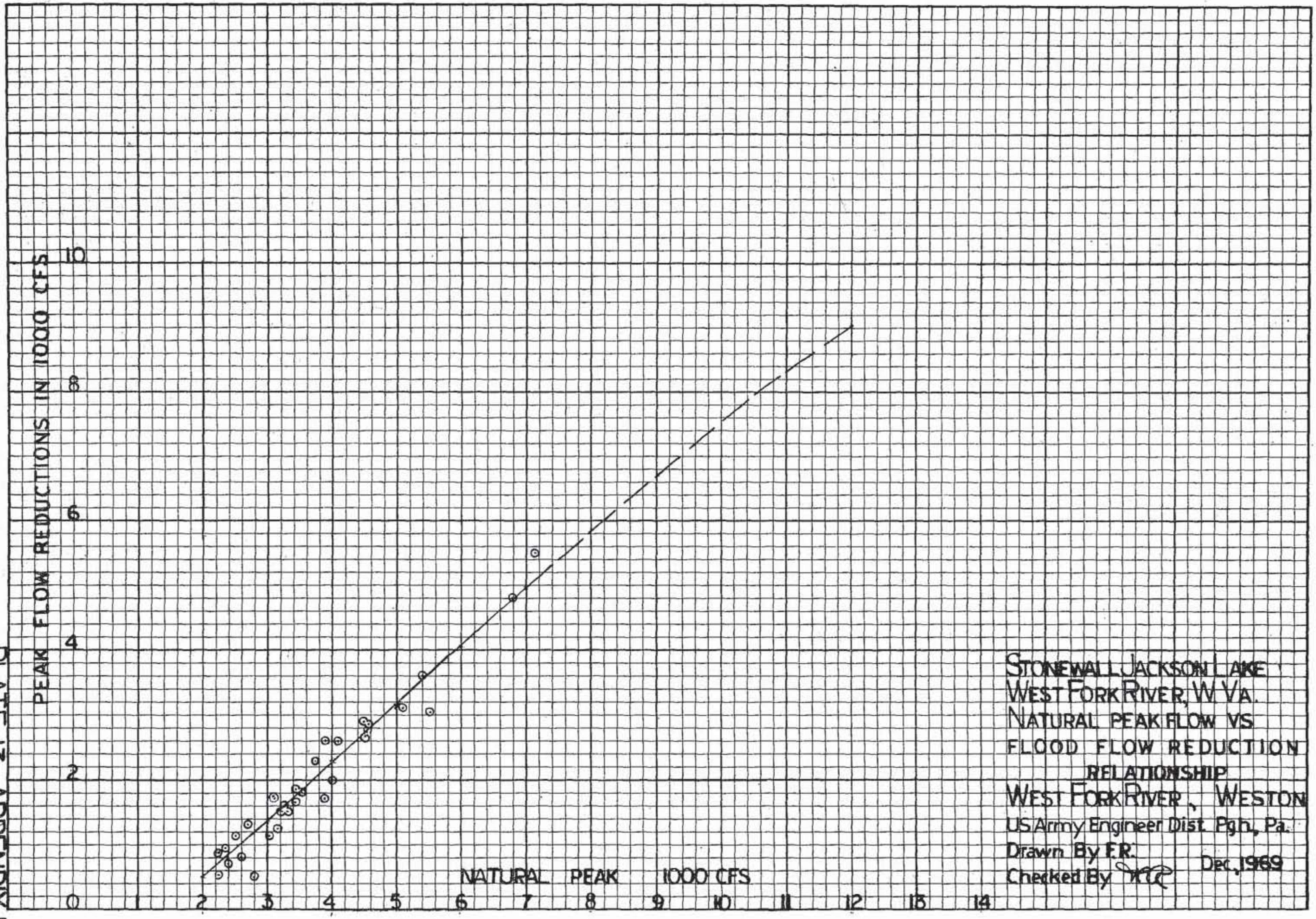
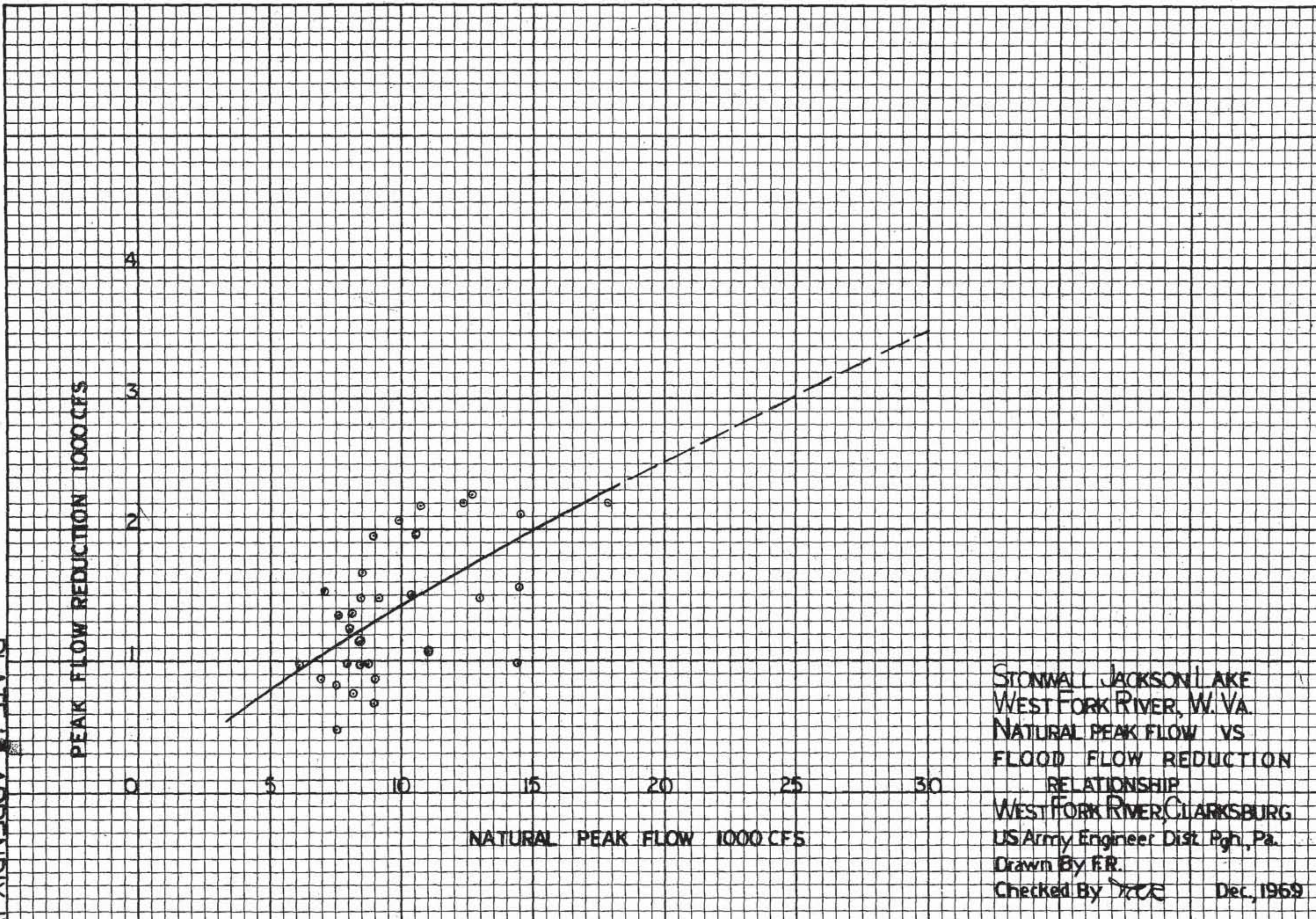


PLATE 13 APPENDIX IV



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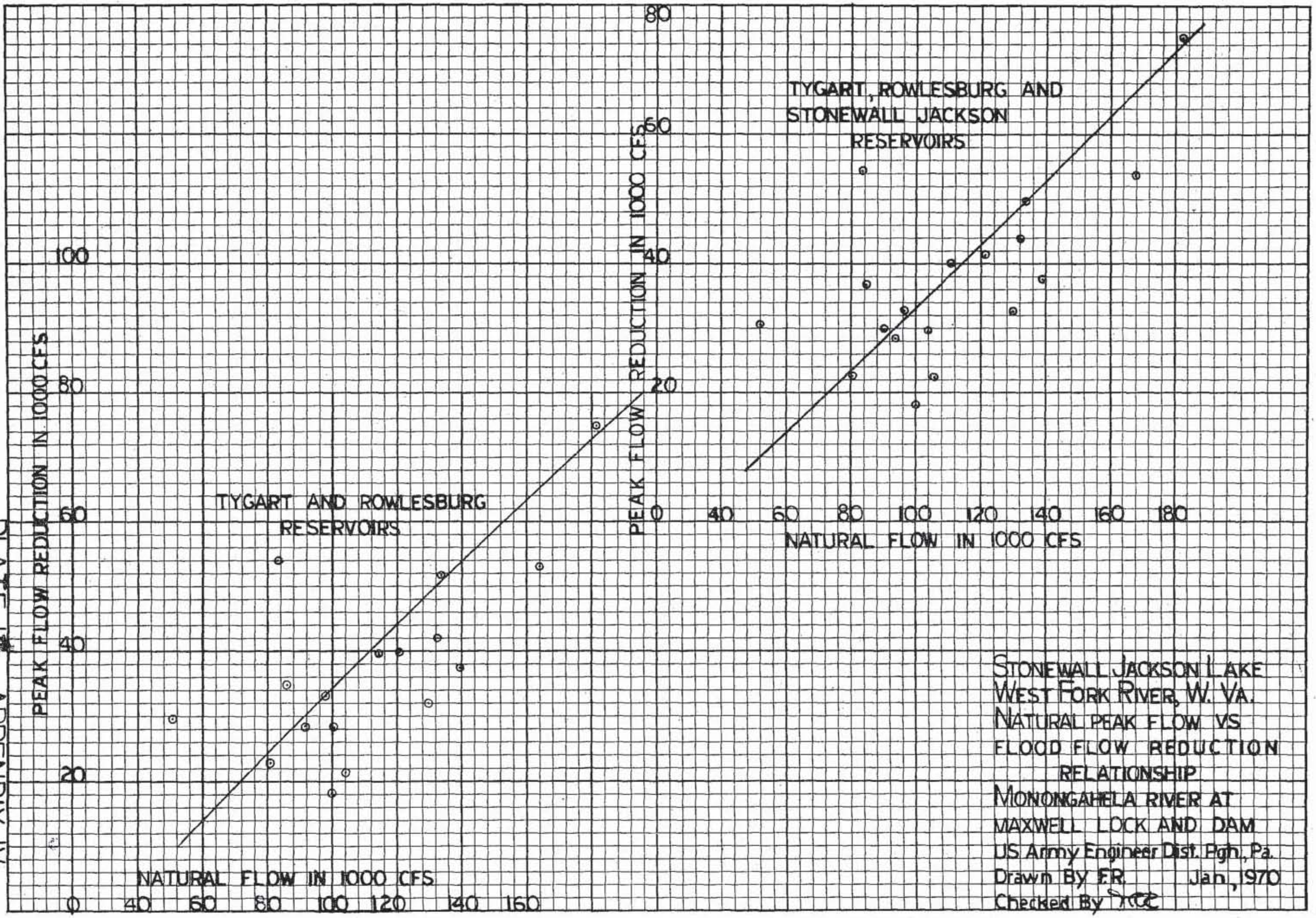
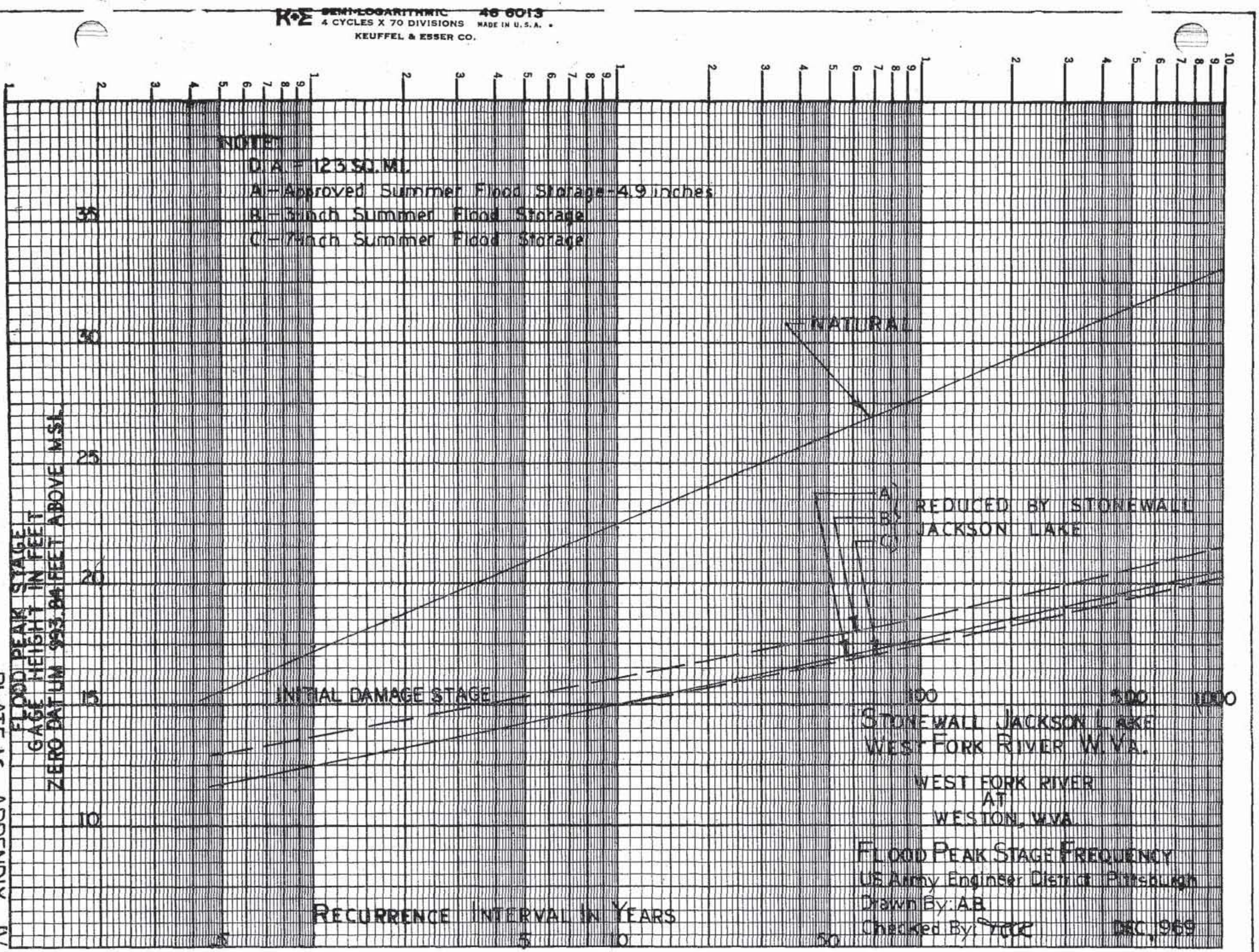


PLATE 15 APPENDIX IV



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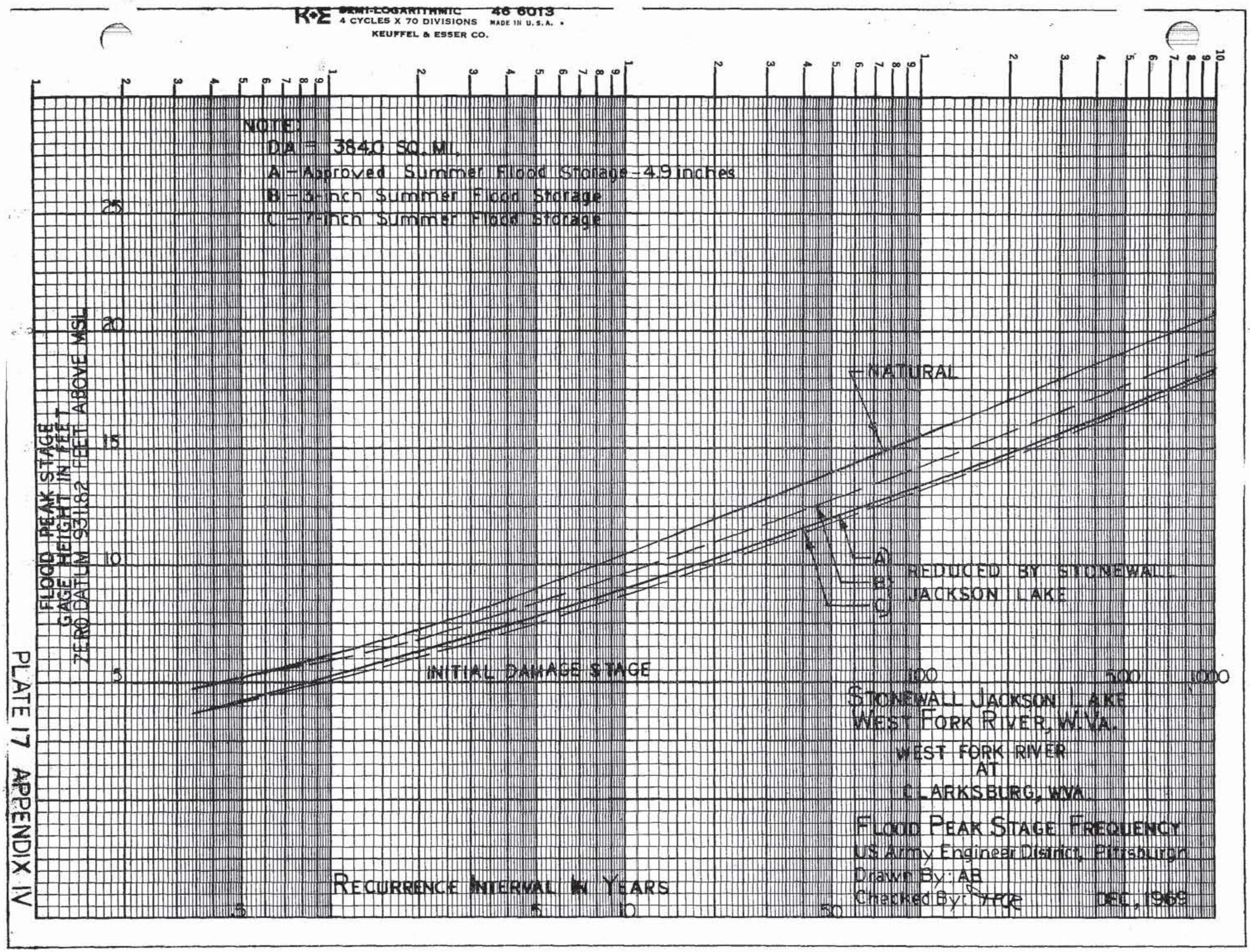


PLATE 17 APPENDIX IV

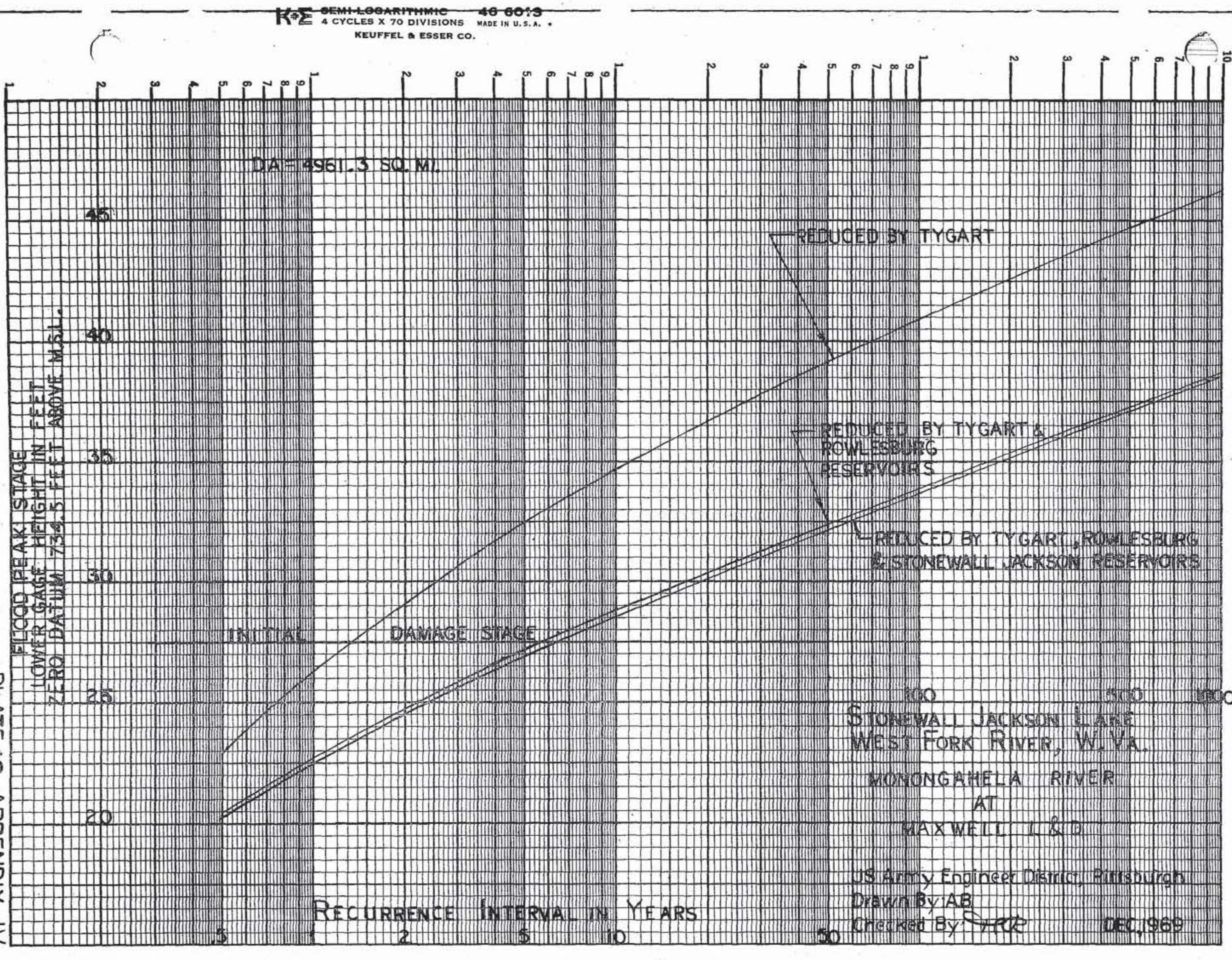


PLATE 18 APPENDIX IV

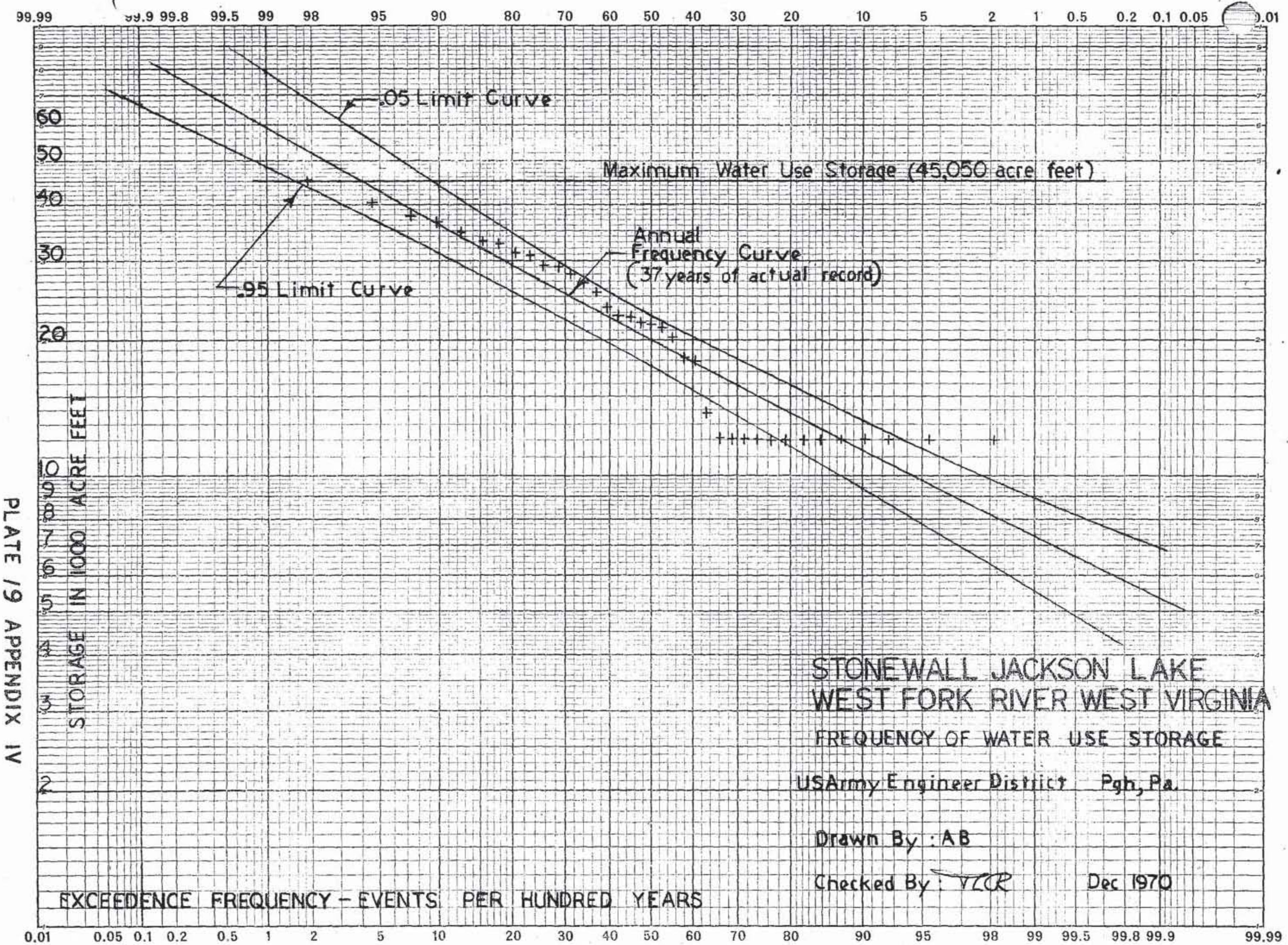


PLATE 19 APPENDIX IV

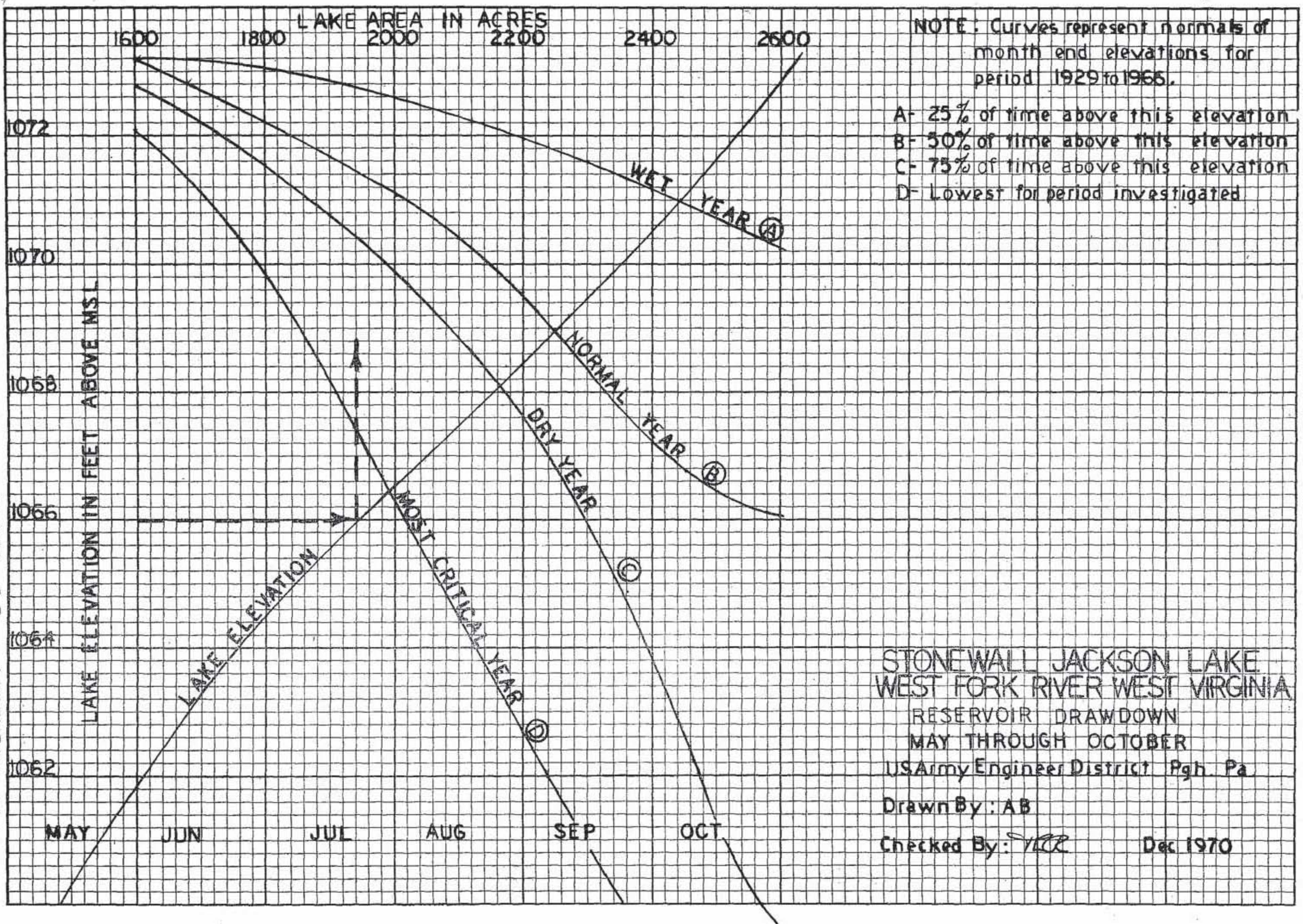
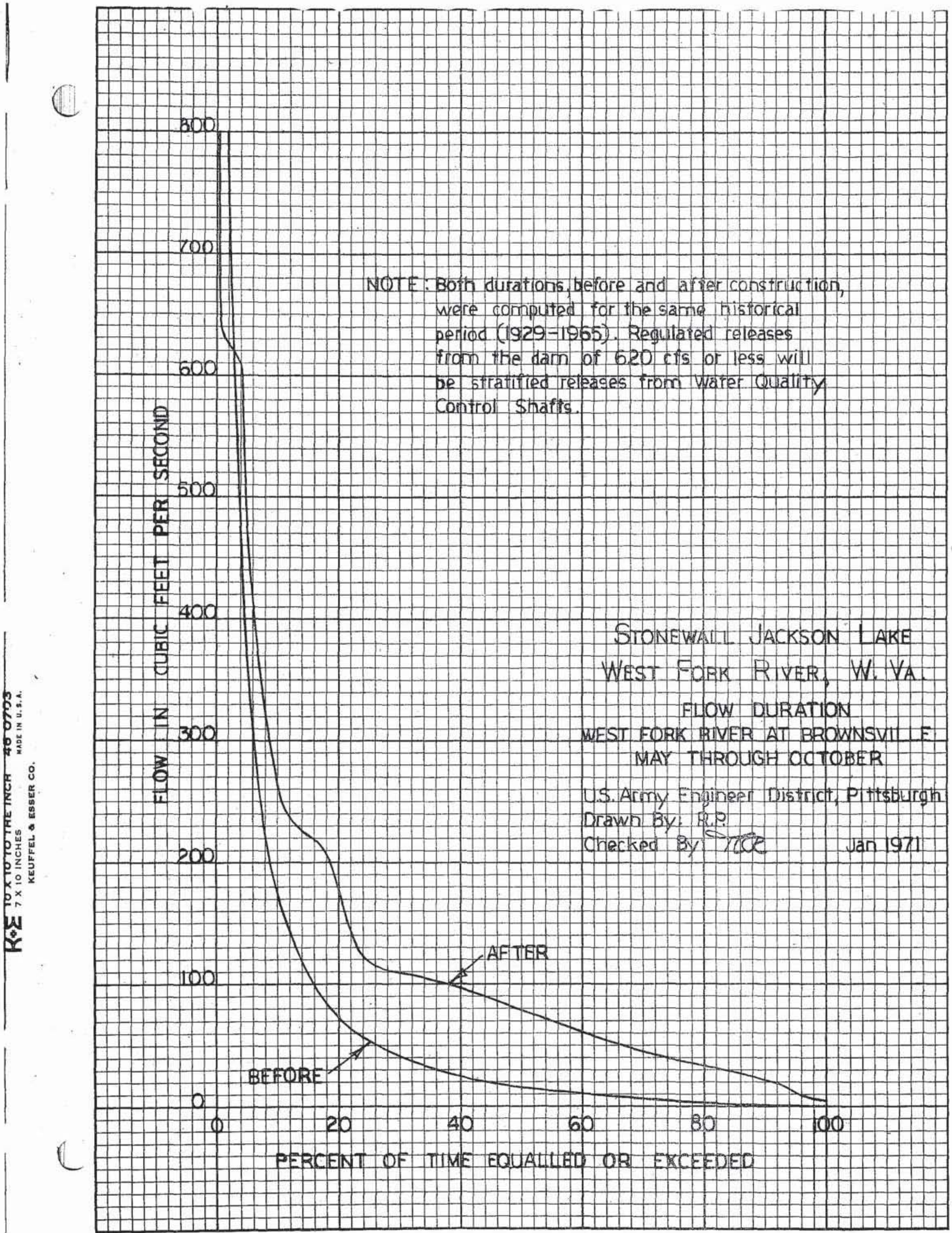
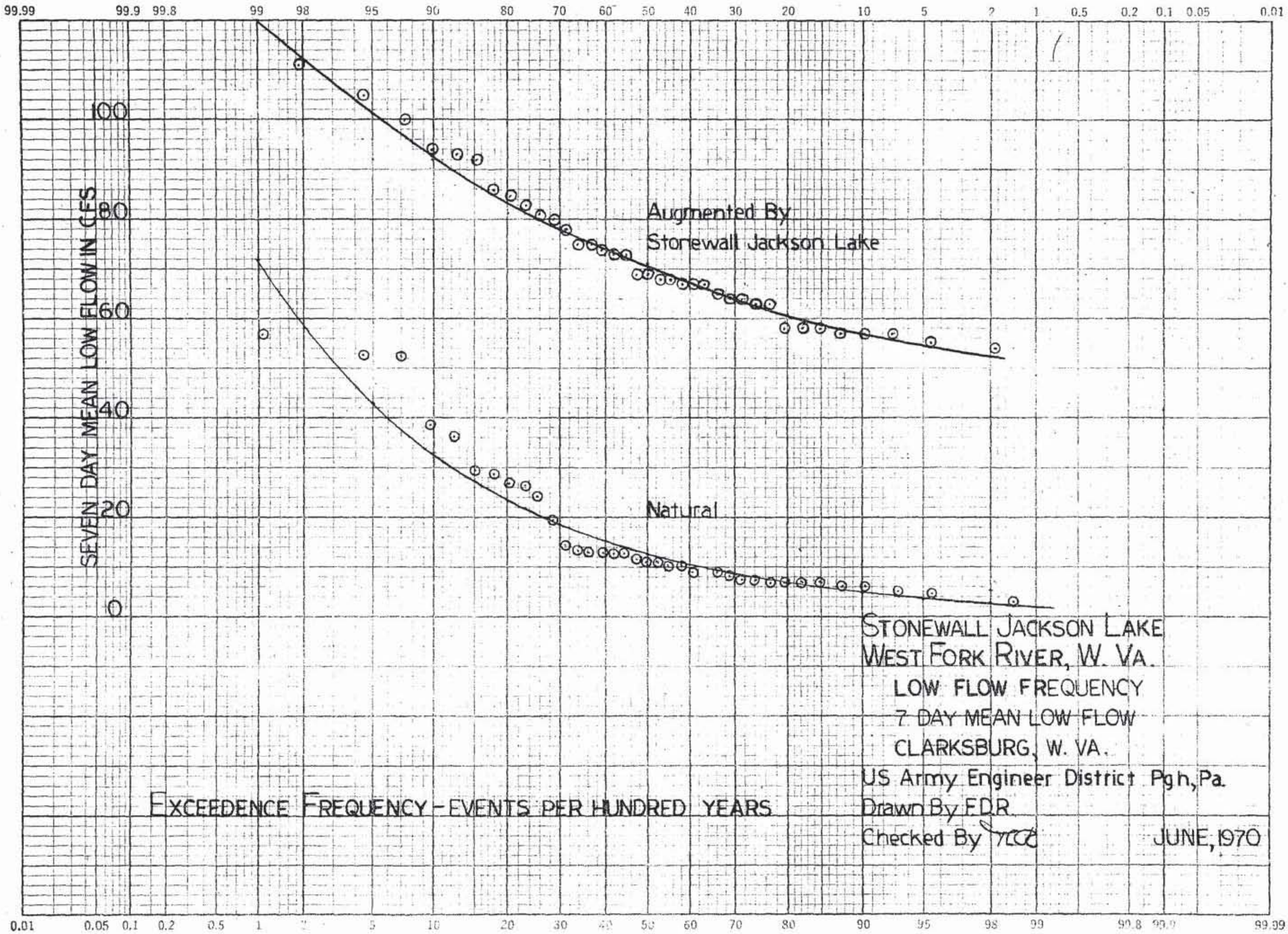
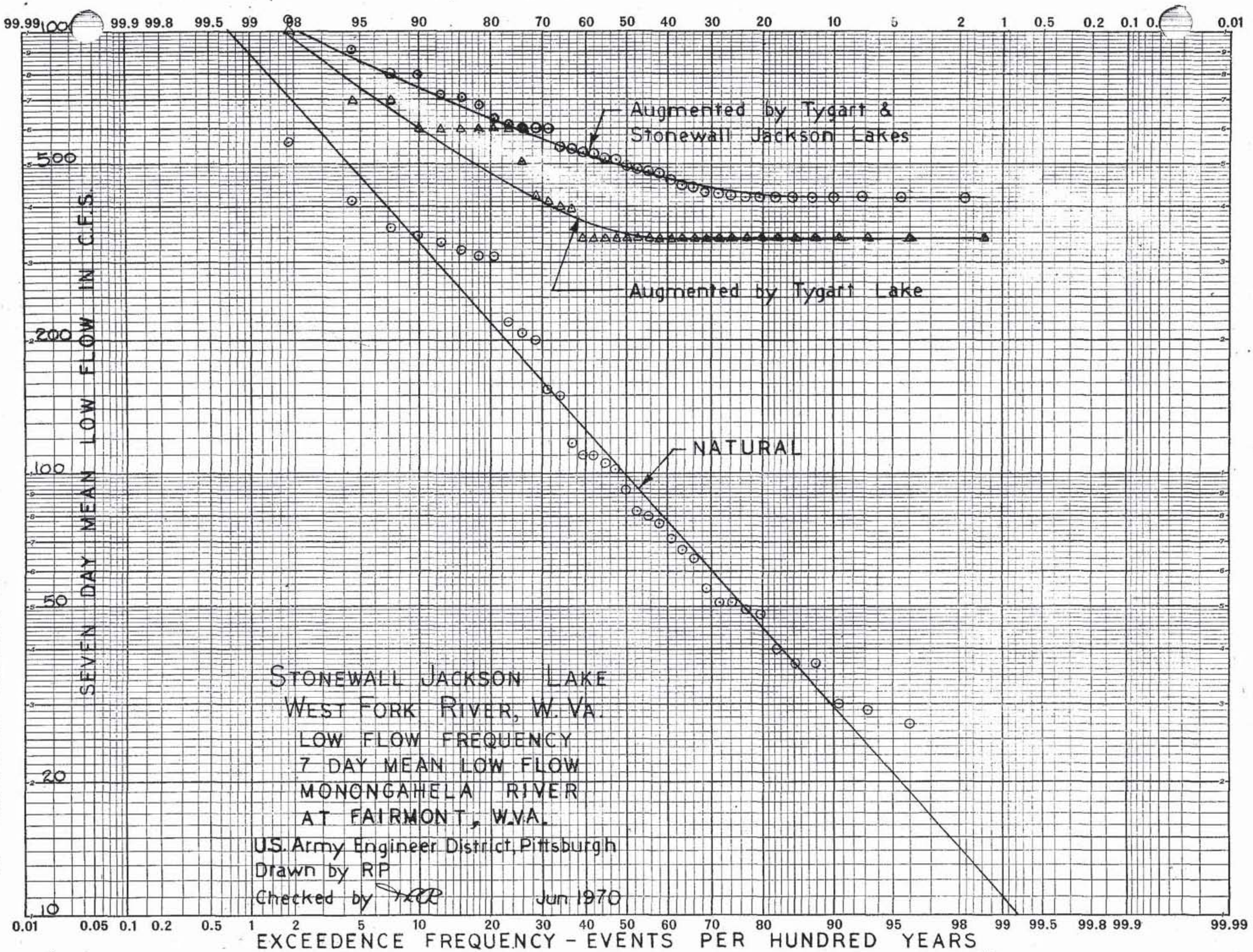


PLATE 20 APPENDIX IV


NOTE: Both durations, before and after construction, were computed for the same historical period (1929-1965). Regulated releases from the dam of 620 cfs or less will be stratified releases from Water Quality Control Shafts.
STONEWALL JACKSON LAKE
WEST FORK RIVER, W. VA.
FLOW DURATION
WEST FORK RIVER AT BROWNSVILLE
MAY THROUGH OCTOBER
U.S. Army Engineer District, Pittsburgh
Drawn By: R.P.
Checked By:
Jan 1971
FLOW IN CUBIC FEET PER SECOND
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
PERCENT OF TIME EQUALLED OR EXCEEDED
AFTER
BEFORE
K+E 10 X 10 TO THE INCH 46 0703
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.


SEVEN DAY MEAN LOW FLOW IN CFS
Augmented By
Stonewall Jackson Lake
Natural
EXCEEDENCE FREQUENCY - EVENTS PER HUNDRED YEARS
STONEWALL JACKSON LAKE
WEST FORK RIVER, W. VA.
LOW FLOW FREQUENCY
7 DAY MEAN LOW FLOW
CLARKSBURG, W. VA.
US Army Engineer District Pgh, Pa.
Drawn By F.D.R.
Checked By
JUNE, 1970


Augmented by Tygart & Stonewall Jackson Lakes
Augmented by Tygart Lake
NATURAL
SEVEN DAY MEAN LOW FLOW IN C.F.S.
EXCEEDENCE FREQUENCY - EVENTS PER HUNDRED YEARS
STONEWALL JACKSON LAKE
WEST FORK RIVER, W. VA.
LOW FLOW FREQUENCY
7 DAY MEAN LOW FLOW
MONONGAHELA RIVER
AT FAIRMONT, W.VA.
U.S. Army Engineer District, Pittsburgh
Drawn by RP
Checked by
Jun 1970