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GENERAL CRITERIA FOR SELECTING HYDROELECTRIC GENERATING PLANT SIZE AT MULTIPLE-PURPOSE PROJECTS

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NOTE: This text is subject to editorial revision.

Introduction

The paper provides a general background on the development of power by Federal agencies. The role of the Corps of Engineers as one of the agencies in this program is briefly discussed. The several types of projects with power are defined and the objective of the multiple use concept of development of water resources is stated.

The basic engineering data needed to determine the power potential are listed and items that could affect the power potential are noted. The criteria for planning power installations are stated in general terms. The procedures used in determining the annual cost of power facilities and the associated benefits are discussed in some detail. Studies to determine the economic feasibility of making provisions for future power additions are outlined.

Two examples of general procedures used in sizing power plants are given and the cost-allocation analyses are presented to illustrate the advantages of multiple-purpose concept in water resource development.

/General criteria

General criteria for selecting hydroelectric generating plant size at multiple-purpose projects

The installed power capacity of the United States amounted to 174 million installed kilowatts at the end of 1959, with about 31 million kilowatts or 18 per cent consisting of hydroelectric capacity. This important segment of power capacity has been developed by Federal and non-Federal interests with the Federal portion amounting to about 14 million kilowatts.

Development of power by the Federal group is made in conjunction with other water resource activities involving navigation, flood control, irrigation, and other related purposes involving the public's welfare. Mainly, there are three Federal agencies involved in power development, namely; (1) the Tennessee Valley Authority, which constructs and operates power and multiple-purpose projects and markets power in the Tennessee Valley and adjoining area; (2) the Department of the Interior, which constructs and operates projects for irrigation and related purposes in the western United States and acts as the power marketing agent for its own projects as well as for those of the Corps of Engineers; and (3), the Army's Corps of Engineers, which constructs and operates projects for navigation, flood control, power and related purposes on a nationwide basis. The following discussion is concerned primarily with the hydroelectric phase of water resource development.

The Civil Works program of the Corps of Engineers is carried out in accordance with specific directives from the Congress. Surveys and studies of river basins or individual projects are authorized by acts of the Congress or resolutions of its Public Works Committees. The survey plans and estimates are prepared by one of the Corps' 40 District offices, reviewed by the Board of Engineers for Rivers and Harbors, and submitted to Congress with the recommendations of the Chief of Engineers and the comments of other Federal agencies and the States. After projects are approved and authorized for construction by the Congress, funds may be requested for detailed planning and construction

/as part

as part of the public works program proposed each year by the President. The public works program planned, constructed and operated by the Corps of Engineers is extensive. The part of this program that is discussed in this paper concerns the 32 projects that have hydroelectric power facilities installed. See Table I. These projects have a total name-plate capacity of 6,576,400 kilowatts in service as of 1 May 1960. This is the largest amount of hydroelectric generating capacity under any organization in this country. The program now underway, upon completion of additional generating facilities totaling 3,904,000 kilowatts, will bring the total capacity in service to 10,480,400 kilowatts.

The projects at which generating facilities are installed range from run-of-river to storage type and from single projects on a stream to an interconnected series of projects in a basin. The run-of-river power projects provide for reservoir storage limited to that necessary for the accumulation of off-peak flows at night or over weekends and are usually located at navigation dams or at dams constructed especially to reregulate flows from storage plants having peaking power facilities. The term storage project refers to the type of development which provides considerable reservoir capacity that is used to increase flows during low flow periods for power generation and to control floods during flood time. In areas where excessive run-off is seasonal in nature a storage project may utilize the same storage space for power and flood control purposes. At other storage projects, space provided for power use is separate from that for exclusive flood control use.

The multiple use concept is used in the development of river basin projects since it is more economical to combine several purposes in a single development. This approach is in keeping with the objective of providing the best comprehensive development of water resources.

The basic engineering data needed to determine the power pontential of projects include such items as observed or computed values of stream flow, reservoir area and capacity curves, tailwater rating curve, etc. A record of stream flow should be of sufficient length to include an extremely dry season in order to evaluate the dependable power available. An analysis of mass curves of stream flow for the

/storage projects

storage projects and flow duration curves for both run-of-river and storage projects will be of assistance in making the power study. Other water uses that affect the water available for power have to be considered, such as: water supply; navigation needs; depletion of supply by irrigation needs; water for fish preservation and migration facilities; minimum flow releases for pollution abatement; and evaporation, seepage and leakage losses. Other factors to be considered are sedimentation in the reservoir, pool fluctuations for mosquito control, recreational use of the reservoir and downstream degradation and aggradation.

Foundation and topographic conditions are determining factors in selecting a dam site and also have a bearing on the height of dam to be constructed. The extent of development in the area to be used for a reservoir will have an economic bearing on the height to which a dam should be built.

The power installations at projects constructed by the Corps have been planned in general on the basis of the power being marketed in an existing interconnected power system serving an extensive area. Therefore, hydro projects in transmission range of load centers compete with each other for sequence of development and with alternative sources, such as fuel fired steam plants, in supplying the market. The characteristics of the load to be served and the types of power facilities that supply the existing market are basic elements needed in determining the size of the installation to be provided.

In areas where the present market is supplied mostly by other hydroelectric developments, the size of the initial installation is limited in general to about the present load factor of the market. In areas where the existing power supply is mostly fuel fired sources, extensive studies are made in which possible peaking generating from the proposed project is allocated in the daily and monthly peak load demand of the system.

/Provisions are

Provisions are made in the initial project for additional power facilities to be added in the future when projected load growth during the economic life of the project and possible changes in the market characteristics indicate a future need that can be met economically.

Basic engineering data and power market studies provide the tools to arrive at a preliminary estimate of the power potential of the project. Subsequent studies of various schemes to increase the power output or to provide more economical power are made to determine the best overall installation considering initial and possible ultimate conditions during the economic life of the project. Estimates of cost of various proposed power schemes are made to add to the other cost data to obtain the overall project cost. Contingencies, engineering, design, supervision, administration and interest during construction are added to obtain the required investment. The annual charges on the investment cost of the project are used to compare with the prospective annual benefits over the economic life of the project. These charges consist of interest on the investment, amortization, provisions for replacement of facilities that have a useful life shorter than the economic life of the project, and operation and maintenance charges. In economic feasibility studies for power facilities, an additional cost is included which is equal to taxes that the Federal, state and local Governments would forego receiving as a result of Federal development of the power in lieu of an alternative that would most likely be constructed in the absence of the Federal development.

The average annual value of all tangible benefits that accrue to the project purposes and that can be given a monetary evaluation are determined. All gains, assets, or values, whether in goods, services, or intagibles which result from the construction, operation, or maintenance of a project, are identified with the purpose served. The flood control, navigation, irrigation, and water supply benefits, if applicable, are measured by standard methods. Power benefits are evaluated in collaboration with the Federal Power Commission and are based on the cost of equivalent power from the most economical alternative new source of power that could render the same service

/in the

in the area concerned. The cost of the alternative source of power is expressed as an annual charge and consists of two values; a capacity charge and an energy charge. The capacity charge is made up of fixed charges on the investment and fixed operating, maintenance, administration and general expenses. Fixed charges on the investment consist of interest and amortization on the cost associated with the construction of an alternate power source, insurance, and taxes that are assessed against the utility that are passed on to the consumer. This latter item, in case a public non-Federal plant is the alternative power source, is a payment made to local governments in lieu of taxes. Fixed operating, maintenance, administrative and general expense consist of the annual costs that are incurred by a plant that is staffed and ready to produce power. In case of a fuel fired steam plant, this includes the fuel cost incurred in being ready to operate. The sum of these charges is the at-plant annual capacity cost of the alternative source of power and is expressed as a cost per kilowatt of capacity. The at-plant energy cost consists of cost of fuel used in producing energy and variable operation and maintenance charges and is expressed as cost per kilowatt-hour of energy. The annual charges for substation and transmission line are added to the alternative at-plant capacity value to obtain the at-market capacity value. The capacity and energy unit values are adjusted for transmission losses. The at-market capacity value is increased from 0 to 10 per cent to reflect the advantages of greater reliability and speed of the hydro project in meeting changing load demands. The hydro site unit values are obtained by subtracting substation and transmission charges for a line from the market to the hydro site. In the event that the alternative source of power is another hydroelectric power plant, costs of power from the two hydro projects are compared to each other or to an alternative annual steam plant costs to determine the most economical hydro project.

The capacity from a hydro project is divided into dependable and interruptible classes for evaluation. When detailed power studies

/are not

are not made, the dependable capacity of a storage project as a minimum is that available at all times from the hydro plant, that is, the output capability of the plant at minimum head. The unit value of this dependable capacity equals the alternative source unit capacity value. Capacity in excess of dependable is utilized during periods when water is available in excess of that available in the critical water period used in determining dependable capacity. Also, in some areas excess water is always available during certain seasons of the year. This extra capacity is classified as interruptible capacity and is equal to the difference between the dependable capacity and the installed or nameplate capacity of the power plant. The unit value of this interruptible capacity varies with percent of time available but for preliminary purposes of evaluation, is assumed as having a unit value equal to one-half of the alternative source unit capacity value.

When detailed power studies are made for storage projects, the dependable capacity to be evaluated is the output capability of the hydro plant at the time of system peak demand. The availability of interruptible capacity, if any, is determined and its unit value estimated, based on the time and length of availability.

The normal capability of run-of-river projects is usually reduced in flood periods due to high tailwater. The dependable capacity credited to the plant is not decreased, however, for any part of the loss of capability that can be made up by surplus capacity simultaneously available during high-flow periods at hydro storage plants in the system. The plant dependable capacity evaluated is the lesser value of capability during low-flow periods or the capability during floods. If the load-carrying capability of the plant is related to the characteristics of the load to be supplied, then the capability at the time of the peak load is evaluated as dependable capacity.

The unit value of energy from the alternative power source is used as the unit value of energy from the hydro project and is applied to the average annual energy produced at the hydro project.

/If other

If other hydro plants are located downstream from a storage project under study and benefits accrue to those plants from upstream storage, the net benefits are credited to the upstream project for purposes of determining its justification.

Power benefits credited to a project may include an allowance for the equivalent annual value of anticipated future benefits from deferred increments of ultimate installations. Both the future benefits and the future costs are considered in such analysis. In computing benefits and costs of a future installation, the values applicable to the initial installation are used but are adjusted to reflect the effect of deferral of additional costs and benefits. The equivalent 50-year annual cost of a future installation is obtained by computing the present worth of the added annual cost. The incremental average annual cost of operation and maintenance (adjusted for cost of major replacements when necessary) is multiplied by the appropriate factor and added to the present worth incremental annual cost of constructing the additional facilities to obtain the total incremental annual cost. The benefits of a deferred installation are obtained by multiplying the undiscounted annual benefits by the appropriate factor, as follows:

Time of beginning of operation of future units (Number of years after initial operation)	Multiplier to apply to future annual benefits and operation and maintenance charges to get average annual value over entire 50-year project life (2 1/2 per cent interest rate)
5	0.836
10	0.693
15	0.563
20	0.450

The incremental benefits and costs are added to the initial installation benefits and costs to obtain the total benefits and costs of the project over its economic life. Incremental and overall costs and benefits are compared in arriving at a decision on the amount of power installation to be provided.

/The total

The total benefits of all purposes served by the project are summed up for ready comparison with the annual charges. A favourable ratio, part of which is based on the costs and value of the power, indicates that the project is desirable from a standpoint of overall benefit. The maximum installation of power facilities limited however by the utilization of the capacity in the system load, should be at the point at which the benefit added by an increment of power based on the value of power from the least expensive alternative power source equals the annual charge for the increment of power.

When more than one water use is involved, as in the case in a multiple purpose project, an allocation of costs among the project water uses is made. This allocation determines the portion of project costs for each function and is based on the general principle that (1) each function should carry the separable or incremental cost of including the function in the project, (2) no function should carry costs in excess of benefits or alternative justifiable expenditures, and (3) all functions of a project should share equitably in the joint savings of multiple-purpose development.

In order to illustrate the above procedures, two examples of power feasibility studies are summarized briefly in the following paragraphs.

Example A

The problem is to determine the initial and ultimate power installation for a run-of-river site where a dam and a navigation lock will be constructed to canalize the river and to develop the power head between two existing projects. Existing power sources in the area are interconnected and are predominately hydroelectric. The annual growth of load in the interconnected system is estimated to amount to about 750,000 kilowatts of capacity with a load factor of 70 per cent. The alternative source of power is assumed to be a steam electric plant, burning coal and with a heat rate of 10,000 b.t.u. per kilowatt-hour. The investment required for the alternative source is estimated to be $173 per kilowatt of capacity and is assumed to be on a non-Federal public financing basis. Taxes foregone is not a

/consideration because

consideration because of public financing. The Federal Power Commission computations show that this alternative power source would cost $15.46 per kilowatt for capacity and 3.32 mills per kilowatt-hour for energy at the load center. Losses in transmission from load center to the hydro site are estimated to be 4.5 per cent for capacity and 3.5 per cent for energy. Cost of transmission is computed to be $3.48 for kilowatt per year for full plant capability.

The project is to be located between two projects. The downstream project has a normal operating pool level at elevation 160 and the upstream project operating tailwater has a range from 249 to 260 in elevation for minimum to full load operation under natural conditions. Encroachment on the upstream project tailwater would be compensated for by the increase in pool level at the site under study up to a point where the effect on normal operating tailwater at the upper project shows a loss in head over that under existing conditions equal to that to be gained by the incremental raise. This is reached when the pool under study was at a 265 foot elevation. The hydraulic capacity of both initial power plants upstream and downstream of the site is about 200,000 c.f.s. and pondage at the three developments is not a major problem for initial conditions. The critical period stream flow occurs from September 15 to April 15 each year with the 1936-1937 occurrence being the most critical with the existing system storage. The critical flow and elevation 265 normal level of development would provide 745,000 kilowatts of prime power. Since the existing power supply for the market is predominately hydro, the installed capacity should be such that the critical period prime power would be firm on the load at system load factor. The installed capacity on this basis amounts to about 1,065,000 kilowatts which is the limiting amount for computation of capacity benefits for initial phase. The lowest unit cost of capacity is usually obtained from a unit that has the largest rating. Model data showed that an available turbine would be satisfactory and eight units would provide near capacity requirements. Eight units were selected based on savings that would

/accrue from

accrue from the low cost per unit of capacity and on the advantageous transmission arrangement for eight units as compared to that for other unit sizes and numbers. Additional studies were also made to determine the most economical unit installation to fit into the adopted unit space. The value of any added capacity installation was considered on the basis of revenue to be obtained in the initial system storage phase from the extra energy available. The added capacity provided initially would be firmed up in the near future by additional storage in projects to be constructed upstream but was not evaluated for the initial project in this case. The revenue from the incremental energy for the initial period was assumed as 2 mills per kilowatt-hour which is the present market value. The results of the study for unit rating are as follows:

Unit capability (kilowatts)	Annual cost (thousands of dollars)	Average energy increment (millions of kilowatts)	Value	B/C
125,000	960.0			
20,245 increment	127.0	85.0	170	1.34
145,245	1,087.0			
10,005 increment	86.0	43.0	86.0	1.00
155,250	1,173.0			

The annual cost consists of interest on the investment at 2 1/2 per cent, amortization at a 2 1/2 per cent rate for 50 years or 1.03 per cent operation, maintenance and replacement charges and annual cost of transmission. Eight units with a capability of 155,250 kilowatts were selected for the initial installation.

Studies for the ultimate installation were limited to the site characteristics and a shortened economic study to determine the time required when the cost of the last added unit on a present worth basis would equal the capacity value on a deferred basis. The site characteristics indicated that 20 units could be constructed in the space available for a power plant. The results of studies to determine the best method of making provisions showed that skeleton unit substructure

/would be

would be more economical than the Z type embankment provision if it was considered that a substantial portion of the units would be firm in the load before an 18 year period. The rate of growth of load and probable increasing rate of steam generating capacity indicated that the additional units would be loaded by the 18 year break-even point. Therefore, skeleton substructures were adopted as the best method to provide for future units. The time required for the last unit to be installed and to break-even on a cost benefit basis indicated about 30 years. Computations of the value of the power for the last added unit were based on capacity value only since the additional energy obtained would be during the annual flood season and would amount to operation for about one week only. The site conditions and the possible effect of the rate-of-change in tailwater levels during operation of the ultimate installation limited the proposed ultimate installation to 20 units. The computation is shown below.

20th unit installation

1. Investment (in thousands of dollars)
   a. Skeleton unit structure - 3,245
   b. Completion of unit - 9,509
2. Annual charges (in thousands of dollars)

	At indicated years after initial installation			
	0	30	35	40
a. Skeleton unit	115.0	115.0	115.0	115.0
b. Completion - present worth	9,509.0	4,540.0	4,010.0	3,540.0
1. Interest and amortization	335.0	160.0	142.0	125.0
2. Operation and maintenance	145.0	38.0	27.0	17.0
3. Replacements	38.0	5.0	0.0	0.0
4. Transmission	540.0	258.0	227.0	200.0
Sub-total completion	1,058.0	461.0	396.0	342.0
Total charges	1,173.0	576.0	511.0	457.0
3. Benefit (in thousands of dollars)	2,300.0	600.0	424.0	265.0
4. B/C ratio	1.96	1.04	0.83	0.58

/It was

It was determined that some flood control should be included in the project since it could be provided without detriment to navigation and power interests. It would be obtained by predrafting the pool at the beginning of the flood season to provide space for storage and by surcharging the pool. 500,000 acre-feet of flood control storage was provided on this basis. The cost allocation for the project is shown in table 2. The cost allocated to power of 14,900,000 dollars would require $14.00 per kilowatt of firm power per year to repay the cost.

Example B

The problem is to determine the power installation for a storage project where a reservoir will be created to develop storage for flood control, water supply, and power. The project is to be located upstream from two other storage projects that also provide flood control and power. The existing power sources in the marketing area are predominately steam plants. The annual load growth in the interconnected system is estimated to be about 300,000 kilowatts of capacity. The alternative source of power would be a steam electric plant which would have an investment cost of about $125 per kilowatt of capacity. The Federal Power Commission computed the cost of the alternative source of power on a privately financed basis and determined that capacity would cost $22.00 per kilowatt per year and energy 1.50 mills per kilowatt-hour at the site of the hydro project. Transmission costs and losses were accounted for in the value. The taxes foregone component in the capacity value amounts to $8.10 per kilowatt and represents an economic loss to Government bodies as a result of Federal rather than private development of the power. Various levels of development of the proposed site were studied to determine the most economic height as related to providing varying amounts of storage for each purpose. The increasing needs for water supply made it desirable to make the economic analysis on the basis of two periods in the assumed fifty-year economic life of the project. It was determined that flood control storage in the amount of 300,000 acre-feet would be provided in the space 10 feet above the top of power pool. This storage would be for

/exclusive flood

exclusive flood control use. Drawdown storage for power and water supply was based on detailed studies of the system critical low flow period and amounted to 925,000 acre-feet with a drawdown of 43 feet below maximum power pool level. However, the units were selected and set so as to take advantage of carry-over storage of 341,000 acre-feet in an additional 27 feet of drawdown in the event that firm energy is more critical than capacity requirements. The system critical flow period extended from 28 May 1953 to 30 September 1954. The existing hydro system output without the existing project would have an installed capacity of 626,000 kilowatts with seasonal dependable capacity of 612,000 kilowatts. The prime power would be about 67,000 kilowatts. With the proposed project added to the hydro system, installed capacity would be 738,000 kilowatts with seasonal dependable capacity amounting to 724,000 kilowatts. Annual prime energy for a critical flow period would be 94,000 kilowatts with initial water supply requirements. System prime energy including the proposed project would amount to 79,000 kilowatts for ultimate water supply requirements. The characteristics of the load to be served shows a high summer peak requirement so hydroelectric sources would be more economical than alternative sources in meeting peak loads. Capacity and energy generation from hydroelectric sources vary monthly but are utilized primarily in the peak of the monthly load. If a critical flow period recurs, the upstream project would be operated at an 8 to 9 per cent at-site load factor. The installed capacity at the proposed project was determined to be 112,000 kilowatts capacity and is to be provided in two units. The turbines selected would produce the 112,000 kilowatts of capacity with best efficiency at average head and at the point of drawdown corresponding to the time of system peak during the critical year would produce 112,000 kilowatts with full gate operation at the reduced head. Since the project develops substantially all of the energy available at the site, is a peaking project and has a relatively low load factor, the initial and ultimate installation are the same. The cost allocation analysis is shown in table 3.

/The cost

The cost allocation studies in examples A and B above show that some single purpose features of water resource development are not economically feasible when considered separately but are feasible when combined in a single development and share equitably in the joint savings. This demonstrates the advantages of the multiple use concept in resource development.

/Table 1

TABLE I

MULTIPLE-PURPOSE PROJECTS WITH POWER

PROJECT	RIVER	DRAINAGE AREA	DATE IN SERVICE	NAME PLATE RATING		AV. ANNUAL GENERATION	TOP OF POOL	GROSS HEAD(a)	STORAGE		RESERVOIR AREA
		Sq. Mi.		In Oper. MW	Ulti-mate MW	MWH (Init)	Usable Elev.	Ft.	Exclusive Fl.Control 1000 AF	Usable 1000 AF	At Usable Elevation 1000's Acres
OLUMBIA RIVER BASIN											
Bonneville	Columbia	240,000	1937	518.4	518.4	4,550,000	74.0	58	0	Pondage	20.5
Detroit (b)	N. Santiam	438	1953	118.0 (b)	118.0 (b)	465,000 (b)	1564.0	371	17	323 (c)	3.5
McNary	Columbia	215,000	1953	980.0	1400.0	6,140,000	340.0	75	0	Pondage	38.8
Lookout Point (b)	Willamette	991	1954	135.0 (b)	135.0 (b)	373,400 (b)	926.0	233	13	336 (c)	4.3
Albeni Falls	Pend Oreille	24,200	1955	42.6	42.6	219,000	2062.5	29	0	1,153 (c)	94.6
Chief Joseph	Columbia	75,000	1955	1024.0	1728.0	6,487,000	946.0	171	0	Pondage	7.8
The Dalles	Columbia	237,000	1957	963.0	1743.0	7,440,000	160.0	86	0	Pondage	11.2
Cougar	McKenzie	210	1962	-	60.0	146,900	1690.0	433	11	154 (c)	1.2
Hills Creek	Willamette	389	1961	-	30.0	166,580	1543.0	319	0	249 (c)	2.7
Ice Harbor	Snake	109,000	1961	-	540.0	1,840,000	440.0	100	0	Pondage	9.2
John Day	Columbia	226,000	1967	-	2700.0	8,000,000	265.0	105	150	Pondage (c)	52.0
TOTAL COLUMBIA BASIN				3781.0	9015.0	35,827,880			191	2,215	
ISSOURI RIVER											
Ft. Peck	Missouri	57,725	1943	85.0	165.0	979,000	2246.0	212	1,000	13,900 (c)	237.0
Ft. Randall	Missouri	262,150	1954	320.0	320.0	1,633,000	1365.0	128	900	3,800 (c)	102.0
Garrison	Missouri	180,900	1956	400.0	400.0	1,966,000	1850.0	170	1,600	18,000 (c)	390.0
Gavins Point	Missouri	279,480	1956	100.0	100.0	631,000	1208.0	41	64	321 (c)	31.1
Oahe	Missouri	243,490	1962	-	595.0	2,455,000	1617.0	190	1,100	17,000 (c)	358.1
Big Bend	Missouri	249,330	1964	-	468.0	985,000	1420.0	69	275	260 (c)	55.8
TOTAL MISSOURI RIVER				905.0	2048.0	8,649,000			4,839	53,281	
OUTHWESTERN											
Norfork	N. Fork	1,806	1944	70.0	140.0	195,000	552.0	174	732	707	22.0
Denison	Red	39,719	1944	70.0	175.0	267,000	617.0	108	2,694	1,730	93.1
Narrows	L. Missouri	237	1950	17.0	25.5	28,400	548.0	145	128	202	7.2
Bull Shoals	White	6,036	1952	160.0	340.0	647,000	654.0	198	2,360	2,084	45.4
Ft. Gibson	Grand	12,492	1953	45.0	67.5	190,500	554.0	61	922	Pondage	19.1
Whitney	Brazos	17,656	1953	30.0	30.0	82,141	520.0	89	1,630	132	15.8
Tenkiller Ferry	Illinois	1,610	1953	34.0	34.0	114,500	630.0	142	600	345	12.5
Blakely Mountain	Ouachita	1,105	1955	75.0	75.0	156,000	578.0	181	617	1,286	40.1
Table Rock	White	4,020	1959	100.0	200.0	493,000	915.0	204	760	1,932	43.1
Greers Ferry	Little Red	1,146	1963	-	96.0	189,000	461.0	184	934	716	31.5
Eufaula	Canadian	47,552	1964	-	90.0	317,000	585.0	81	1,470	1,481	102.0
Dardanelle	Arkansas	153,704	1964	-	124.0	644,000	338.0	48	0	Pondage	37.0
McGee Bend	Angelina	3,453	1965	-	52.0	118,400	164.0	69	1,149	1,383	114.5
Beaver	White	1,186	1965	-	112.0	170,000	1120.0	190	309	1,096	28.2
TOTAL SOUTHWESTERN				601.0	1561.0	3,611,941			14,305	13,094	
EASTERN											
Dale Hollow	Obey	935	1948	54.0	54.0	127,000	651.0	136	353	496	27.7
Allatoona	Etowah	1,110	1950	74.0	110.0	169,000	840.0	146	303	285	11.9
Center Hill	Caney Fork	2,195	1950	135.0	135.0	351,000	648.0	162	762	492	18.2
Wolf Creek	Cumberland	5,810	1951	270.0	270.0	867,000	723.0	162	2,094	2,142	50.2
John H. Kerr	Roanoke	7,800	1952	204.0	204.0	438,000	300.0	91	1,278	1,046	48.9
Clark Hill	Savannah	6,144	1953	280.0	280.0	698,000	330.0	139	390	1,340	71.1
Philpott	Smith	212	1953	14.0	14.0	25,400	974.0	158	34	111	2.9
Jim Woodruff	Chattahoochee	17,150	1957	30.0	30.0	220,000	77.0	25	0	Pondage	36.0
Old Hickory	Cumberland	11,620	1957	100.0	100.0	420,000	445.0	46	0	Pondage	22.5
Buford	Chattahoochee	1,040	1957	86.0	86.0	170,000	1070.0	148	637	1,049	38.0
Cheatham	Cumberland	14,070	1960	24.0	36.0	160,000	385.0	22	0	Pondage	7.5
Hartwell	Savannah	2,088	1962	-	330.0	453,000	660.0	180	295	1,427	56.4
Walter F. George	Chattahoochee	7,507	1962	-	130.0	436,000	190.0	75	0	Pondage (c)	46.0
Barkley	Cumberland	17,639	1964	-	130.0	600,000	359.0 (c)	46	1,273 (c)	282 (c)	62.0
TOTAL SOUTHEASTERN				1271.0	1909.0	5,134,400			7,419	8,670	
HER											
St. Marys, Mich.	St. Marys	80,900	1932	18.4	18.4	136,500	603.6	23	0	LAKE	SUPERIOR
GRAND TOTALS				6576.4	14551.4	53,359,721			26,754	77,260	

Gross Head - Difference between top of usable pool elevation and normal tailwater level.
Includes power data from reregulating dams. Other data for Detroit and Lookout Point only.
Flood Control provided by pre-drafting usable storage to provide necessary space.

Table 2

COST ALLOCATION: RUN-OF-RIVER PROJECT

(Thousands of dollars)

	Multiple purpose project	Alternative single purpose projects: Power	Navigation	Flood control
1. Summary of costs, charges and benefits				
a. First cost	400,000.0	384,000.0	280,000.0	250,000.0
b. Interest during construction	40,000.0	38,000.0	28,000.0	25,000.0
c. Investment	440,000.0	422,000.0	308,000.0	275,000.0
d. Annual charges				
1. Interest @ 2½%	11,000.0	10,550.0	7,700.0	6,870.0
2. Amortization 2½% - 50 years	4,500.0	4,350.0	3,160.0	2,830.0
3. Oper., maint., and replacements	3,100.0	2,600.0	440.0	400.0
4. Total annual charges	18,600.0	17,500.0	11,300.0	10,100.0
e. Annual benefits				
1. Power at site Capacity, 1,065,000 @ $11.25	11,980.0			
Energy - 9 billion kWh @ 3.2 mills	28,800.0	40,780.0		
2. Navigation	3,926.0		3,926.0	
3. Flood control	670.0			670.0
4. Total benfits	45,376.0			0
f. B/C ratio	2.44	2.33	0.35	0.07
2. Cost allocation - Annual				
a. Benefits	45,376.0	40,780.0	3,926.0	670.0
b. Alternate cost	38,900.0	17,500.0	11,300.0	10,100.0
c. Benefits limited by alternate cost	22,096.0	17,500.0	3,926.0	670.0
d. Separable cost	8,400.0	7,300.0	1,100.0	
e. Remaining benefits	13,696.0	10,200.0	2,826.0	670.0
f. Allocated joint costs	10,200.0	7,600.0	2,100.0	500.0
g. Allocation	18,600.0	14,900.0	3,200.0	500.0
h. B/C ratio	2.44	2.74	1.23	1.34

/Table 3

Table 3

COST ALLOCATION: STORAGE PROJECT

(Thousands of dollars)

	Multiple purpose project	Alternative single purpose projects		
		Water supply	Flood control	Power
1. Summary of costs, charges, and benefits				
a. First cost	49,621.3	8,752.6	13,500.0	46,127.5
b. Interest during construction	2,481.0	274.0	422.0	2,018.0
c. Investment	52,102.3	9,026.6	13,922.0	48,145.5
d. Annual charges				
1. Interest @ 2½%	1,303.0	226.0	348.0	1,204.0
2. Amortization 2½% - 50 years	534.0	93.0	143.0	494.0
3. Oper., maint., and replacements	274.0	20.0	35.0	241.0
4. Taxes foregone	907.0	0	0	907.0
5. Total	3,018.0	339.0	526.0	2,846.0
e. Annual benefits				
1. Power added to system				
Capacity - 112,000 @ 22.00	2,464.0			2,464.0
Energy - 172 million kWh @ 1.5 mills	258.0			258.0
2. Flood control	363.0		363.0	
3. Water supply	529.0	529.0		
4. Total	3,614.0	529.0	363.0	2,722.0
f. B/C ratio	1.16	1.56	0.69	0.95
2. Cost allocation - annual				
a. Benefits	3,614.0	529.0	363.0	2,722.0
b. Alternate cost	3,711.0	339.0	526.0	2,846.0
c. Benefits limited by alternate cost	3,424.0	339.0	363.0	2,722.0
d. Separable cost	2,597.0	48.0	113.0	2,436.0
e. Remaining benefits	827.0	291.0	250.0	286.0
f. Allocated joint costs	421.0	148.0	127.0	146.0
g. Total allocated costs	3,018.0	196.0	240.0	2,582.0
h. Taxes foregone	907.0	0	0	907.0
i. Total allocation, project cost	2,110.0	196.0	240.0	1,675.0
j. B/C ratio	1.16	2.70	1.51	1.05