ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DESIGN TRANSMITTAL

SUBTASKS 6.02, 6.03, 6.06 - PRELIMINARY DESIGN CONSIDERATIONS

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Alaska Power Authority
Susitna Hydroelectric Project
Task 6 - Design Development
Subtasks - 6.02, 6.03, 6.06 - Design Transmittal
Preliminary Design Considerations
Associated with Project Definition Studies

TABLE OF CONTENTS

1 - INTRODUCTION

The objective of documenting the following design considerations is to facilitate a standardized approach to the engineering layout work being done as part of Subtasks 6.02 "Investigate Tunnel Alternative", 6.03 "Evaluate Alternative Susitna Developments" and 6.06 "Staged Development". The material presented is very preliminary and detailed enough only for the project definition studies. The numbers presented are very often based on judgement and should not be confused with the more definitive "design criteria" which will be produced next year

Throughout the execution of Subtasks 6.02, 6.03 and 6.06 the design considerations were modified and several draft copies of this document were issued for internal use. This final document outlines the final version of the design considerations.

2 - APPROACH TO PROJECT DEFINITION STUDIES

The general approach to the project definition studies involves three steps:

(i) Single Site Developments:

All sites are treated as single projects.

(ii) Multisite Developments:

Two or three sites are developed in a series. This means that the downstream sites may have installed capacities, spillway and diversion capacities, and drawdown levels which differ considerably from the single site development.

(iii) Staged Developments:

Development at a site may be staged, i.e. the dam crest level may be increased and the powerhouse capacity expanded.

Although the steps follow consecutively, there is considerable overlap, and work could be progressing on all three steps at the same time.

This document essentially addresses the step (i) type studies. Careful interpretation of the information is required when applying it to stage (ii) and (iii) studies. If modifications are required to the basic data presented here the appropriate departmental coordinator should be contacted.

3 - ELECTRICAL SYSTEM CONSIDERATIONS

The current total system load factor is reported to be of the order to 50% to 55%. The WCC projections indicate that this may go up between 56 and 63% in future years.

Initially, all projects should be sized for a 45 to 55% capacity factor and should incorporate daily peaking to satisfy this requirement. As a later step, some of the proposed developments could be reanalized for higher or lower capacity factors.

All projects should be capable of meeting a seasonally varying power demand. Table 1 was developed from data contained in the WCC Subtask 1.02 report and lists the monthly variation in power and energy demand that should be used.

The installed capacity and reservoir level regulating rules should be established so that the firm energy output of the project is maximized.

Listed below are the power/energy definitions to be used for this study. The list is limited to terms used in the project definition studies. The definitions are preliminary and may be modified during the subsequent steps of the feasibility studies.

Average Monthly or Annual Energy - The average monthly annual energy produced by a hydro project over a 30 year period of operation.

Firm Monthly or Annual Energy - The minimum amount of monthly or annual energy that can be guaranteed even during low flow periods. For purposes of this preliminary study this should correspond to the energy produced during the second lowest energy producing year on record. This corresponds roughly to an annual level of assurance of 95%.

Secondary Energy - Electric energy having limited availability. In good water years a hydro plant can generate energy in excess of its firm energy capability. This excess energy is classified as secondary energy because it is not available every year, and varies in magnitude in those years when it is available.

Installed Capacity - The rating of generators at design head and best gate available for production of saleable power.

4 - GEOTECHNICAL CONSIDERATIONS

4.1 - Main and Saddle Dams

The geotechnical considerations are summarized in Table 2.

4.2 - Temporary Cofferdams

It will be assumed that all cofferdams are of a fill-type. Since much of the original river bed material under the main dam shell may have to be excavated, all cofferdams should be located outside the upstream and downstream limits of the main dam.

5 - HYDROLOGIC AND HYDRAULIC CONSIDERATIONS

Tables 3, 3A, 4 and 5 list the provisional hydrologic and hydraulic parameters to be used. Table 6 details preliminary freeboard requirements while an example is worked out in Table 6A to calculate freeboard requirements.

5.1 - General

Figures 1-8 illustrate the storage capacity at each dam site for different water levels.

5.2 - Sizing of Hydraulic Components

(a) Power Conduits - For dam schemes the sizes should be based on the maximum velocities listed in Table 5. For long tunnel schemes the diameter should be determined such that the cost of energy is minimized.

(b) Diversion System - The cofferdam-diversion tunnel system is to be sized as follows:

1. Size diversion tunnel for maximum velocity (Table 5) for the design diversion flow. Calculate head loss in the tunnel and fix top of upstream cofferdam (allow 10' freeboard).

2. Calculate height of downstream cofferdam from approximate stage-discharge relationship.

(c) Spillway - Size spillway to accommodate the Project Design Flood shown in Table 3/3A. Utilize supplementary emergency spillway if necessary. All service spillways should be fitted with downstream stilling basins. The capacity of the structure should be checked for the PMF with a reduction up to 9' in freeboard (Table 6). The energy to be dissipated should not exceed 45,000 hp per foot width under PMF conditions.

6 - ENGINEERING LAYOUT CONSIDERATIONS

Table 7 lists the components that should be incorporated in the engineering layouts and describes the types of components to be used. This table should be used as a guide for all layouts.

7 - MECHANICAL

7.1 - Powerhouse

(a) Number of Units

In general, a decrease in the number of units will result in a reduction in powerplant cost. For preliminary studies assume:

- unit capacities 100MW to 250MW;
- minimum number of units = 2;
- maximum number of units = 4.

(b) Turbines

Assume rated net head approximately equal to:

minimum net head + 0.75 (maximum net head - minimum net head).

For rated heads above 130 ft. units will be vertical Francis type with steel spiral cases. For lower heads assume vertical Kaplan units.

The turbines will be directly connected to vertical synchronous generators.

7.2 - Overflow Spillway

The spillway gates will be fixed wheel vertical lift gates operated by double drum with rope hoists located in an enclosed tower and bridge structure. Maximum gate size for preliminary design should be:

- width ---------- 50 ft.
- height --------- 60 ft.

Provide 3 ft. freeboard for gates over maximum operating water level. The gates will be heated for winter operation.

7.3 - Miscellaneous Mechanical Equipment

Cost estimates should provide for a full range of power station equipment including cranes, gates, valves, etc.

8 - ELECTRICAL CONSIDERATIONS

8.1 - Powerhouse

Generators will be of the vertical synchronous type. Separate transformer galleries will be provided for main and station transformers. Provision will be made in the cost estimates for a full range of miscellaneous operating and control equipment including where necessary allowance for remote station operations.

8.2 - Switchyard and Transmission Lines

Switchyard should be located on the surface and as close to the powerhouse as possible. The size of the yards should be approximately 900 x 500 ft. Cost estimates should allow for transmission lines and substations (see Table 7).

9 - ENVIRONMENTAL CONSIDERATIONS

For this step, environmental considerations will be limited to the effect on fisheries. In order to avoid a severe detrimental impact on the fisheries habitat tentative water level fluctuations and downstream flow release constraints have been developed and should be adhered to.

9.1 - Flow Constraints

Table 8 lists preliminary values of minimum flows required downstream of any development at all times. The lower flows are based on preliminary assessment of requirement of resident fish while the higher flows are estimated anadromous fish needs.

9.2 - Water Level Constraints

Daily reservoir level fluctuations should be kept below 5 ft. while seasonal drawdown should be limited to 100 to 150 ft.

TABLE 1 - Monthly Variation of Energy and Peak Power Demand

1. Monthly energy variation as a fraction of the total firm energy:

OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
.086	.101	.109	.100	.094	.086	.076	.069	.067	.066	.070	.076

2. Monthly variation of peak demand as a fraction of the installed capacity:

OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
.80	0.92	1.00	0.92	0.87	0.78	0.70	0.64	0.62	0.61	0.64	0.70

TABLE 2

GEOTECHNICAL DESIGN CONSIDERATIONS

GENERAL CONDITIONS	DENALI	MACLAREN	VEE
1. Dam Type	Earth-Rockfill	Earth-Rockfill	Earth-Rockfill
2. U/S Slope	4:1 (H/V)	4:1	2.25:1
3. D/S Slope	4:1	4:1	2:1
4. General Foundation Conditions	All structures would have soil foundations. Depth to bedrock is believed to be 200'+. Interstratified till and alluvium foundation material, local liquefaction potential. 40'+ alluvium in valley.	Assume soil foundations. Depth to bedrock estimated at 200'. Compressible, permeable and liquefiable zones probably exist.	River alluvium 125', drift or talus on abutments is 10-40' thick. Saddle dam located on deep permafrost alluvium.
5. Required Foundation Excavation (in addition to overburden)	Total Excavation Depth: Core / Shell Abutment 30' / 10' Channel 70' / 50'	Unknown. Assume same as for Denali.	Assume: Core - Remove average of 50' of rock Shell - Remove top 10' of rock
6. Required Foundation Treatment & Grouting	Assume core-grout in five rows of holes to 70% of head up to a maximum of 300'. Probable drain curtain or drain blanket under downstream shell. Foundation surface - no special treatment.	Assume same as for Denali.	Assume grouting same as for Watana. No special treatment under shell. Assume extensive sand drains in saddle dam permafrost area.
7. Seismic Considerations (MCE = Maximum Credible Earthquake)	High exposure, no known site faults. MCE = Richter 8.5 @ 40 miles.	High exposure, no known site faults. MCE = 8.5 @ 40 miles.	High exposure, no known site faults. MCE = 8.5 @ 40 miles.
8. Powerhouse Location	Underground powerhouse unsuitable.	Underground powerhouse unsuitable	Unknown. Assume suitable for underground with substantial rock support.
9. Permafrost	> 100' deep in abutments, probable lenses under river.	Probably > 100'.	> 60' in saddle area, sporadic in abutments.
10. Construction Material Availability	No borrow areas identified. Assume suitable materials are available within a five-mile radius. Processing of impervious material will be required.	Assume same as for Denali.	Assume available 0.5 to 5 mile radius. Impervious will require processing.
11. Remarks	Based on Kachadoorian, 1959.	No report on site. Parameters based on regional geology.	Based on USBR studies.

NOTE: 1) Actual estimates on Watana & Devil Canyon have been taken from overburden contour maps.

2) Data compiled prior to January 1, 1981. Estimates made after this date have used updated excavation criteria.

TABLE 2 (cont'd)

GEOTECHNICAL DESIGN CONSIDERATIONS

GENERAL CONDITIONS	SUSITNA III	WATANA	HIGH DEVIL CANYON
1. Dam Type	Earth-Rockfill	Earth-Rockfill or concrete arch	Earth-Rockfill
2. U/S Slope	2.25:1	2.25:1 (for earth)	2.25:1
3. D/S Slope	2:1	2:1	2.1
4. General Foundation Conditions	Unknown but rock probably over 50' in depth. Possible permeable compressible and liquefiable strata.	Abutments - assume 15' overburden(OB) Valley bottom - 48-78' alluvium. Assume 70'. Right bank upstream - approximately 475' deep relict channel on right bank, upstream of dam site.	Assume 30-60' overburden and alluvium.
5. Required Foundation Excavation (in addition to overburden)	Assume same as for Watana.	Core: Remove top 40' of rock Shell: Remove top 10' of rock	Core: Remove top 40' of rock Shell: Remove top 15' of rock
6. Required Foundation Treatment & Grouting	Assume grout and drain system full width of dam, dependent on foundation quality. Drain gallery & drain holes.	Extensive grouting to depth = 70% of head but not to exceed 300'. Drain gallery & drain holes.	Assume same as for Watana.
7. Seismic Considerations (MCE = Maximum Credible Earthquake)	High exposure. MCE = 8.5 @ 40 miles. Also near zone of intense shearing.	MCE = Richter 8.5 @ 40 miles <u>or</u> 7.0 @ 10 miles.	Same as for Watana.
8. Powerhouse Location	Unknown. Assume suitable for underground with substantial rock support.	Underground favorable, extensive support may be required.	Probably favorable for underground but assume support needed.
9. Permafrost	Probably sporadic and deep.	> 100 feet on left abutment. More prevalent and deeper on north facing slopes.	Sporadic, possibly 100' ±.
10. Construction Material Availability	Assume available within five miles. Processing similar to that at Watana.	Available within 0-5 miles. Processing required.	No borrow areas defined. Assume available within 5 miles.
11. Remarks	No reports available. Parameters based on regional geology of the area.	Based on Corps studies and 1980 Acres exploration.	No geotechnical data available. Parameters based on regional geology.

TABLE 2 (cont'd)

GEOTECHNICAL DESIGN CONSIDERATIONS

GENERAL CONDITIONS	DEVIL CANYON	DEVIL CANYON	PORTAGE CREEK
1. Dam Type	Concrete arch or gravity	Rockfill	Concrete gravity
2. U/S Slope	---	2.25:1	---
3. D/S Slope	---	2:1	---
4. General Foundation Conditions	Assume 35' alluvium in river bottom. Shears and fault zones in both abutments, 35-50' of weathered rock. Saddle dam overburden up to 90' deep. Assume excavation for spillway totals 30' to sound rock on valley walls.		Unknown - assume same as for Devil Canyon.
5. Required Foundation Excavation (in addition to overburden)	Remove 50' of rock. Extensive dental work and shear zone over-excavation will be required. Saddle dam: Excavate 15' into rock.	Core: Excavate 40' into rock Shell: Excavate 15' into rock Allow for surface treatment. Saddle dam: Excavate 15' into rock.	Rock type is similar to Devil Canyon, so assume foundation conditions are similar.
6. Required Foundation Treatment & Grouting	Extensive grouting to 70% of head, limited to 300'. Allow for long anchors into rock for thrust blocks. Extensive dental treatment. Deep cutoff under saddle dam, 15' into rock.	Extensive grouting to 70% of head, limited to 300'. Extensive dental treatment under core. Deep cutoff under saddle dam, 15' into rock.	Assume same as Devil Canyon.
7. Seismic Considerations (MCE = Maximum Credible Earthquake)	Same as for Watana.	Same as for Watana.	MCE = Richter 8.5 @ 40 miles <u>or</u> 7.0 at 10 miles.
8. Powerhouse Location	Favorable for underground powerhouse, assume moderate support.	Favorable for underground powerhouse, assume moderate support.	Probably favorable for underground powerhouse, assume moderate support.
9. Permafrost	None expected, but possibly sporadic.	None expected, but possibly sporadic.	None expected, may be local areas on north exposures or in overburden.
10. Construction Material Availability	Concrete aggregate within 0.5 miles, embankment material - assume within 3 miles.	Concrete aggregate within 0.5 miles, embankment material - assume within 3 miles.	Unknown - expect adequate sources 2-5 miles downstream.
11. Remarks.	Based on USBR, Corps and 1980 Acres exploration.	Based on USBR, Corps and 1980 Acres exploration.	No previous investigations are available on this site.

Table 3: HYDROLOGIC DESIGN CONSIDERATIONS

Parameter	Denali	Maclaren	Vee	Susitna III	Watana	High Devil Canyon	Devil Canyon	Portage Creek	Tunnel Alternative	Remarks
Catchment area-sq.mi.:	1,260	2,320	4,140	4,225	5,180	5,760	5,810	5,840	--	--
Mean annual flow-cfs:	3,290	4,360	6,190	6,350	8,140	9,140	9,230	9,230	--	--
Spillway design flood-cfs:	89,800	106,000	133,000	137,000	175,000	198,000	200,000	200,000	175,000	1:10,000 year flood peak without routing
Construction diversion flood cfs:	42,500	50,000	63,000	64,600	82,600	93,500	94,400	20,000*	20,000*	1:50 year flood peak
50 year sediment accumulation Acre-ft:	290,000	243,000	162,000	165,000	204,000	248,000	252,000	--	--	assumes no upstream development

*Considered only as second developments after upstream dam(s) is built

Addendum

TABLE 3A - Revised Design Flood Flows for Combined Development

Parameters	Scheme 1 (Watana	& Devil Canyon)	Scheme 2 (High Devil Canyon	& Portage Creek	& Vee)	Remarks
Spillway design flood-cfs	115,000	135,000	145,000	150,000	105,000	1:10,000 yr flood routed through the reservoir at FSL as in Table 4
Construction diversion	89,100	20,000	99,100	20,000	71,200	Subsequent developments enjoy regulation by upstream reservoir(s).
PMF for checking design-cfs	235,000	270,000	262,000	270,000	189,000	

Note: This table is based on Acres Flood Frequency Analyses and supercedes Table 3 for Watana and High Devil Canyon first developments.

Table 4: SITE SPECIFIC HYDRAULIC DESIGN CONSIDERATIONS

Parameter	Denali	Maclaren	Vee	Susitna III	Watana	High Devil Canyon	Devil Canyon	Portage* Creek	Tunnel* Alternative	Remarks Tunnel Alternative Only
Reservoir Full Supply Level - ft	2,540	2,395	2,330	2,340	2,220/ 2,000	1,750	1,445	1,020	2,200/ 1,475	Tunnel alternative consists of Watana and re-regulation dams
Dam Crest Level - ft	2,555	2,405	2,350	2,360	2,225/ 2,060	1,775	1,465 (rock fill) 1,459 (concrete)**	1,030	2,225/ 1,490	See above remarks
Average Tail Water Level - ft	2,405	2,320	1,925	1,810	1,465	1,030	880	850	1,465/ 1,260/ 900	Watana/Re-regulation dam/Devil Canyon, respectively
Installed Capacity - MW	50	10	230	330	800/400	800	400	150	--	--
Maximum Power Flow - cfs	5,400	2,000	8,300	9,000	18,000/ 11,000	18,000	10,000	15,000	8,400	In Tunnel between re-regulation and Devil Canyon Power House
Minimum Compensation Flow - cfs	600	1,200	1,500	1,500	2,000	2,000	2,000	2,000	1,000	In reach between tunnel outfall at Devil Canyon
Low Level Outlet Capacity - cfs***	,900	4,700	8,300	10,000	20,800	15,600	10,600	9,300	20,800 (Watana)	

*Considered only as second developments after u/s dam(s) is built.
**Includes 4' high wave wall on top of dam.
***Empties reservoir to 1[illegible] percent capacity in 12 months.

TABLE 5 - General Hydraulic Design Considerations

Water Passage

Maximum velocities-fps:			
	Steel penstocks:	20	
	Power tunnels - lined:	15	For tunnels less than 5 miles long.
	Tailrace - lined:	15	
	unlined:	10	
	Diversion tunnels - lined:	50	

For the tunnel-alternative scheme (tunnel length greater than 5 miles) optimize velocity with respect to cost of tunneling and energy loss in friction.

TABLE 6 - Preliminary Freeboard Requirement

Parameter	Rockfill/ Earthfill Dam	Concrete Dam
1. Design Conditions		
Dry freeboard - ft.	3	3
Wave run up & wind set up - ft.	6	6
Flood surcharge over full supply level (FSL) - ft.	5	5
Allowance for post-construction settlement	1% dam height	nil
Total Freeboard - Ft.	14'	14'
Dam Crest Level - Ft.	FSL + 14' + 1% dam height	FSL + 14'
2. Extreme Conditions for Checking Design		
a) Seismic slump	1½% of dam height	nil
b) PMF surcharge over FSL allowable	14'	14'

If seismic slump $\leq$ 14' design conditions fix dam crest level.

If seismic slump > 14' dam crest level = FSL + seismic slump $\pm$ 1% allowance for post-construction settlement.

TABLE 6A - Calculation of Freeboard Requirement at Devil Canyon

F S L = 1445' Dam height = 600'

Design Conditions	Rockfill Dam	Concrete Dam
Dry freeboard	3'	3'
Wave run up, etc.	6'	6'
Flood surcharge	5'	5'
Height of dam	600'	600'
1% of height for post-construction settlement	6	nil
Dam Crest Level	1445 + 14 + 6 = 1465'	1445 + 14 = 1459'

Extreme Conditions	Rockfill Dam	Concrete Dam
a) Seismic slump (1½%)	9'	nil
Seismic slump < 14'		
Thus, dam crest level remains the same as calculated above.		
b) PMF condition		
Maximum allowable water level	1445 + 14 = 1459'	1445 + 14 = 1459'

TABLE 7 - Engineering Layout Considerations as Single Developments

Components	Denali	Maclaren	Vee	Susitna III	Watana	High Devil Canyon	Devil Canyon	Tunnel Alternatives
Dam	← Conventional earth/rockfill →						Concrete	Earth/rockfill
Spillway	← Service: Gated, open chute with downstream stilling basin →							
	← Emergency: (if required) as above with downstream flip bucket →							
Power Facilities								
Intake:	← Single level →	← Multilevel →						
Power Tunnel:	← Single concrete lined →	← Minimum of two, concrete lined →						Two partially lined tunnels (1/3 conc. lined, 1/3 shotcreted, 1/3 unlined)
Penstocks:	← Steel lining where necessary (near U.G. Powerhouse)(length=1/5 turbine head) →							
Powerhouse:	← Underground if feasible →							
Tailrace Tunnel:	← One lined/unlined →	← Two lined/unlined →						
	← (Lined or unlined - based on cost/energy loss optimization →							
Low Level Outlet Works Intake and Tunnel:	← One or two with gates - use diversion tunnel(s) if possible →							
Construction Facilities U/S & D/S Cofferdams:	← Earth or rockfill →						← Fill or cellular →	← Fill →
Diversion Tunnels:	← Minimum of two →							
Access								
Road Access:	← To Denali Highway →	← to Gold Creek →						
Transmission Line	← To Cantwell along Denali Highway →	← to Gold Creek →						
Local	← Roads/tunnels and bridges as required →							

TABLE 7 (cont'd)

Components	Denali	Maclaren	Vee	Susitna III	Watana	High Devil Canyon	Devil Canyon	Tunnel Alternatives
Compensation Flow Outlet	← Independant intake with control valve discharging through low level outlet works or independent conduit →							
Surge Chamber	← Upstream surge tank required if net head on machines < 1/6 of distance between reservoir and machine →							
	← Downstream surge tank is required if tailrace is pressurized →							
	← Size differential surge chambers for all locations where required →							

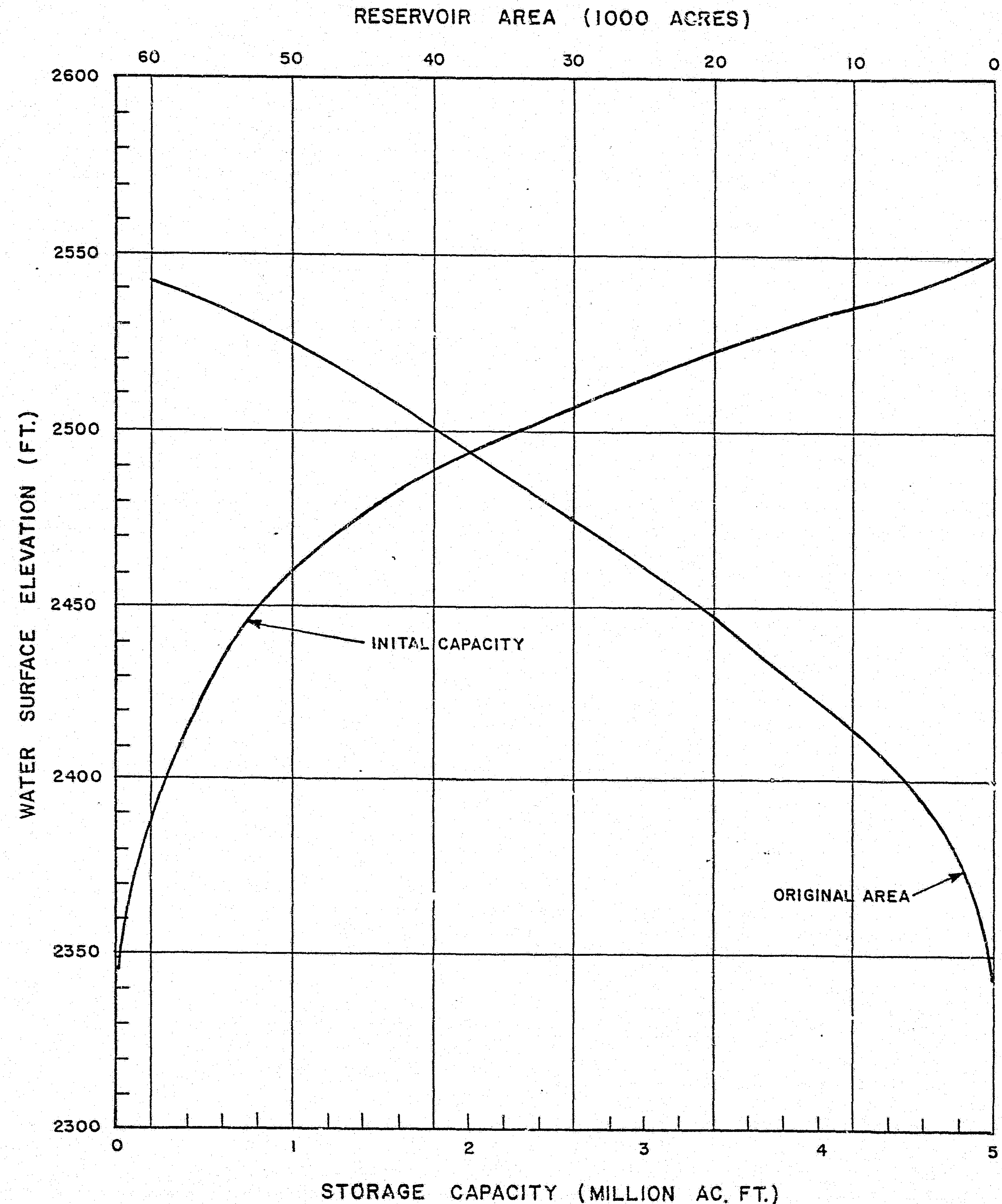
NOTE: Portage Creek development will be similar to Maclaren except that access roads and transmission lines will be to Gold Creek.

TABLE 8: Tentative Environmental Flow Constraints

Site	Required Minimum Flow Release-cfs: With Project Located Downstream *	Required Minimum Flow Release-cfs: Without Project Located Downstream*	Maximum Allowable Flow for Daily Peaking Operations CFS **	Remarks
Denali	300	600	5,000	
Maclaren	600	1,200	6,500	
Vee	800	1,500	9,500	
Susitna III	800	1,500	9,500	
Watana	1,000	2,000	12,000	
High Devil Canyon	1,000	2,000	13,500	
Devil Canyon	1,000	2,000	14,000	
Alternative Tunnel Scheme	1,000		14,000	In the reach between re-reg. dam and tailrace outfall at Devil Canyon.

Note: * Does not apply if downstream dam backs up to tailwater level of dam above.

** Would not necessarily apply if scheme considered did not include a substantial amount of seasonal regulation.



AREA AND CAPACITY CURVES
DENALI RESERVOIR

FIGURE 1

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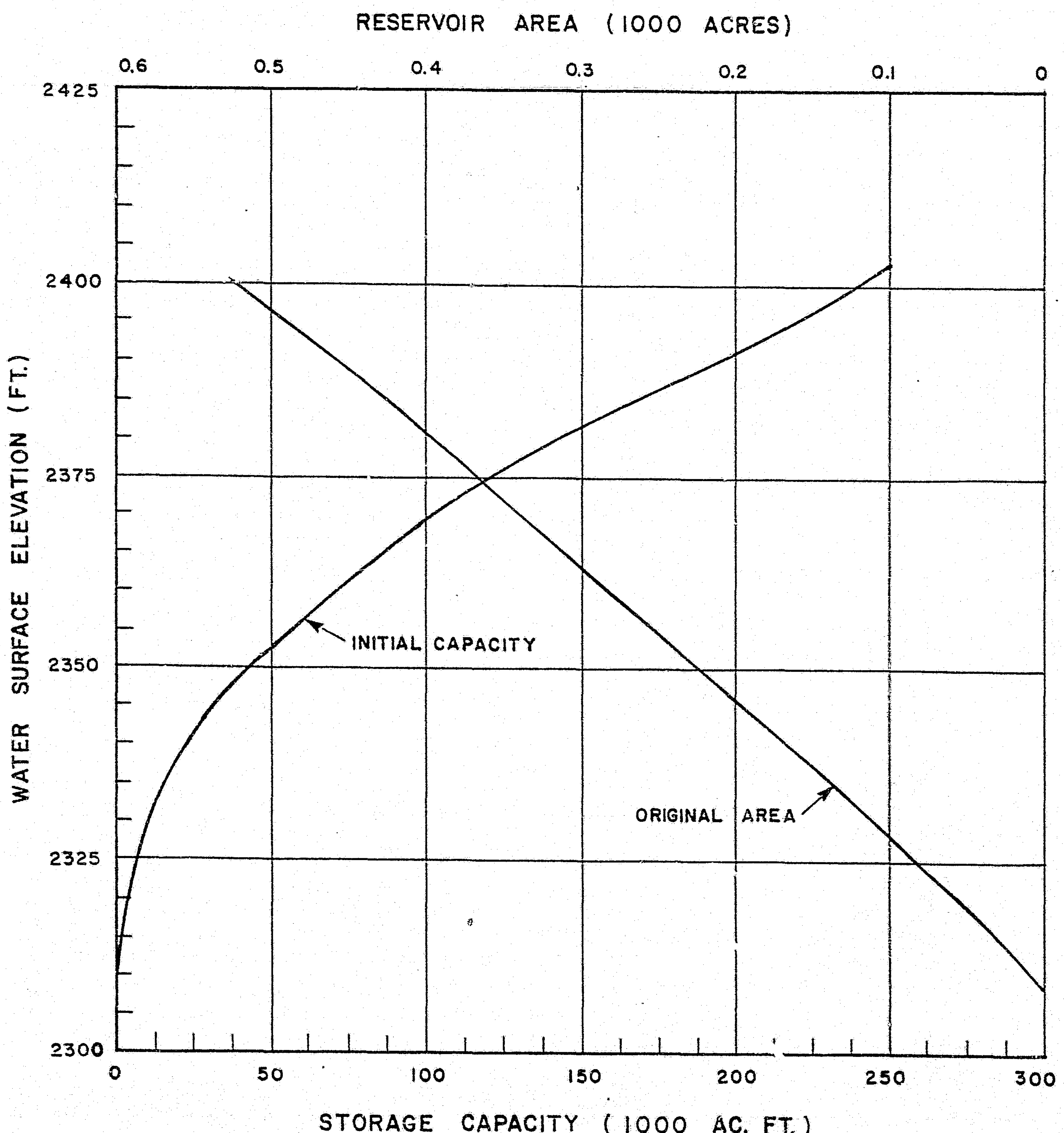
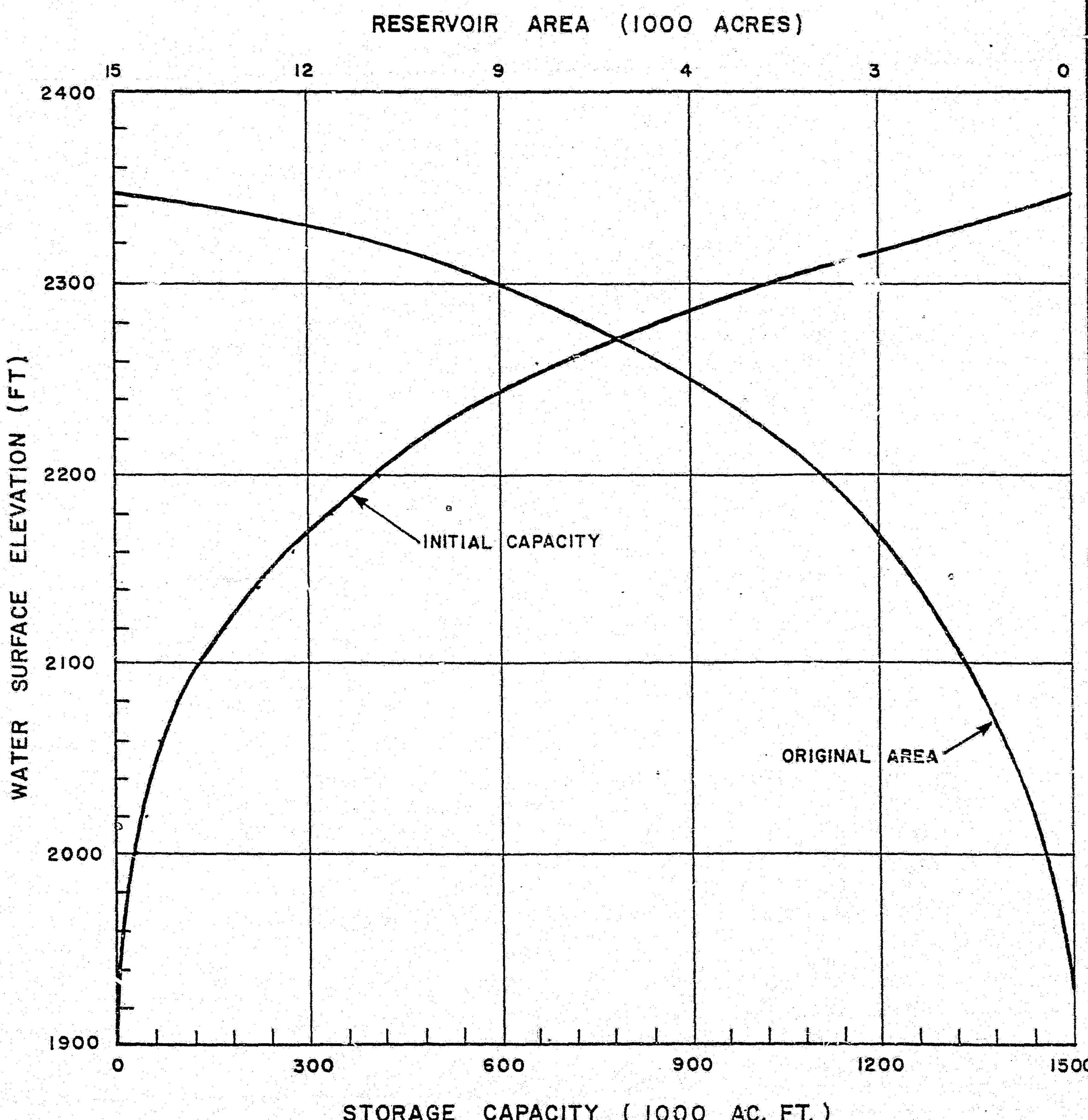


AREA AND CAPACITY CURVES
MACLAREN RESERVOIR

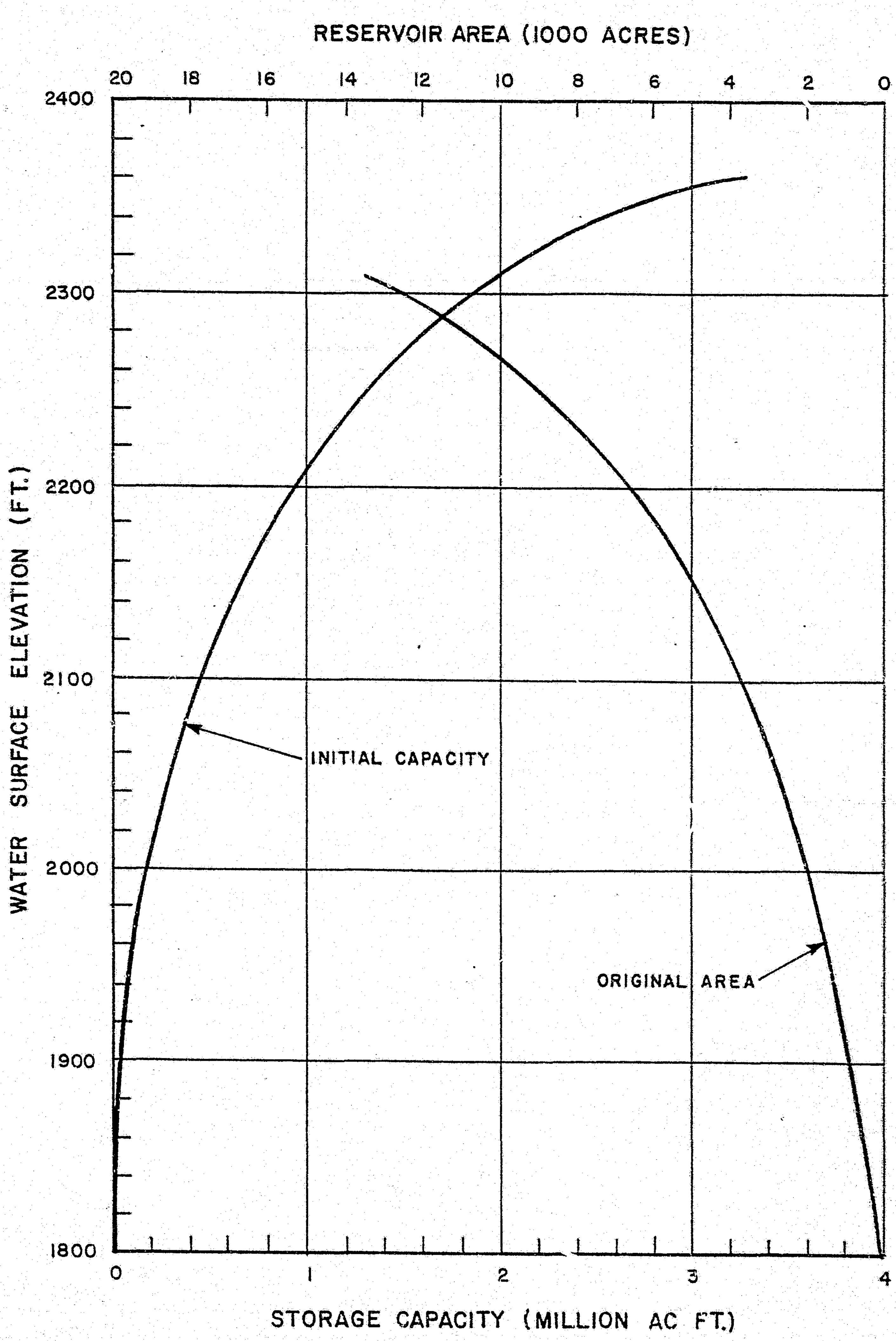
ACRES

FIGURE 2



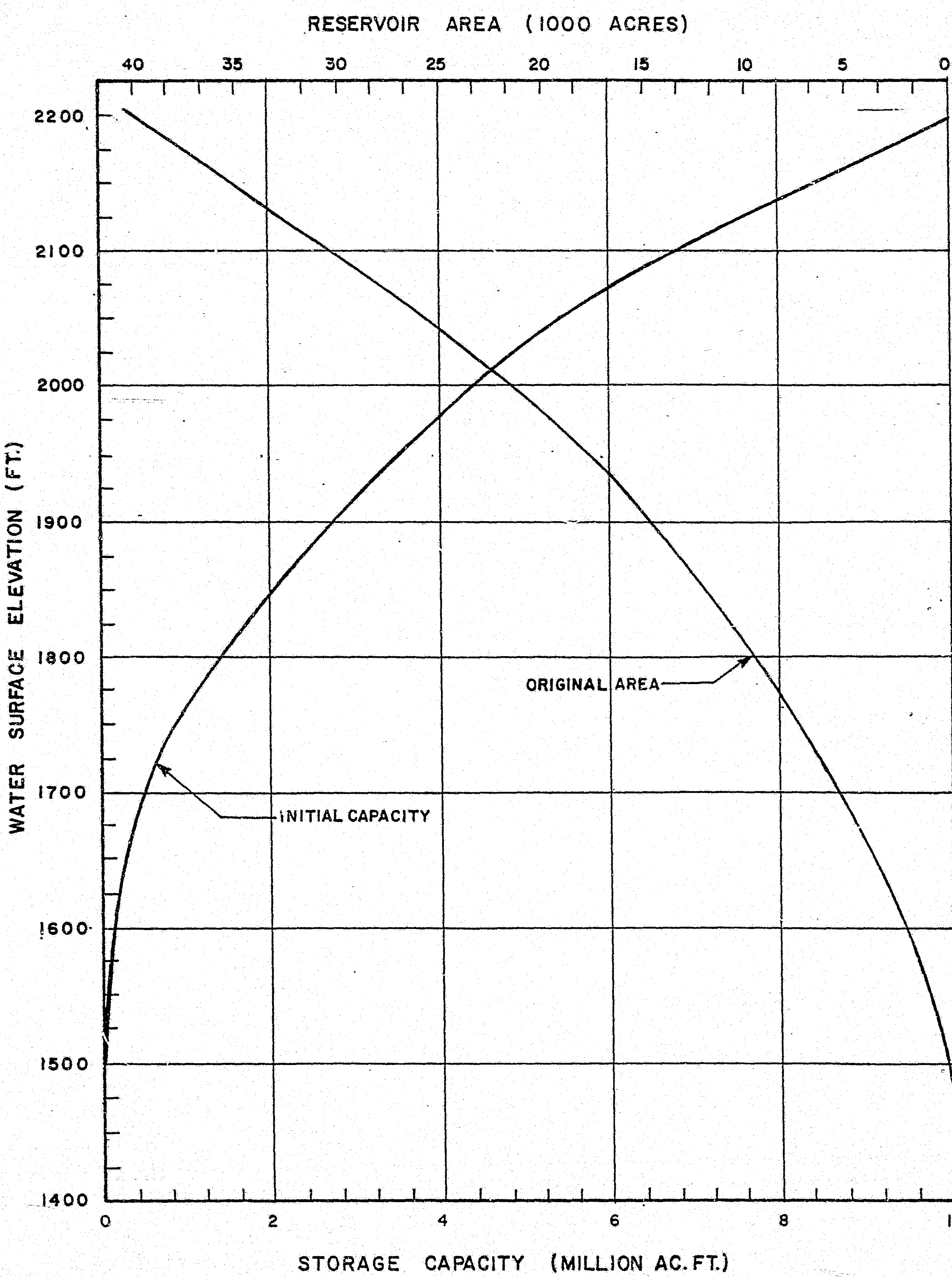
AREA AND CAPACITY CURVES
VEE RESERVOIR

FIGURE 3



AREA AND STORAGE CAPACITY CURVE
SUSITNA III

FIGURE 4



AREA AND CAPACITY CURVES
WATANA RESERVOIR

FIGURE 5

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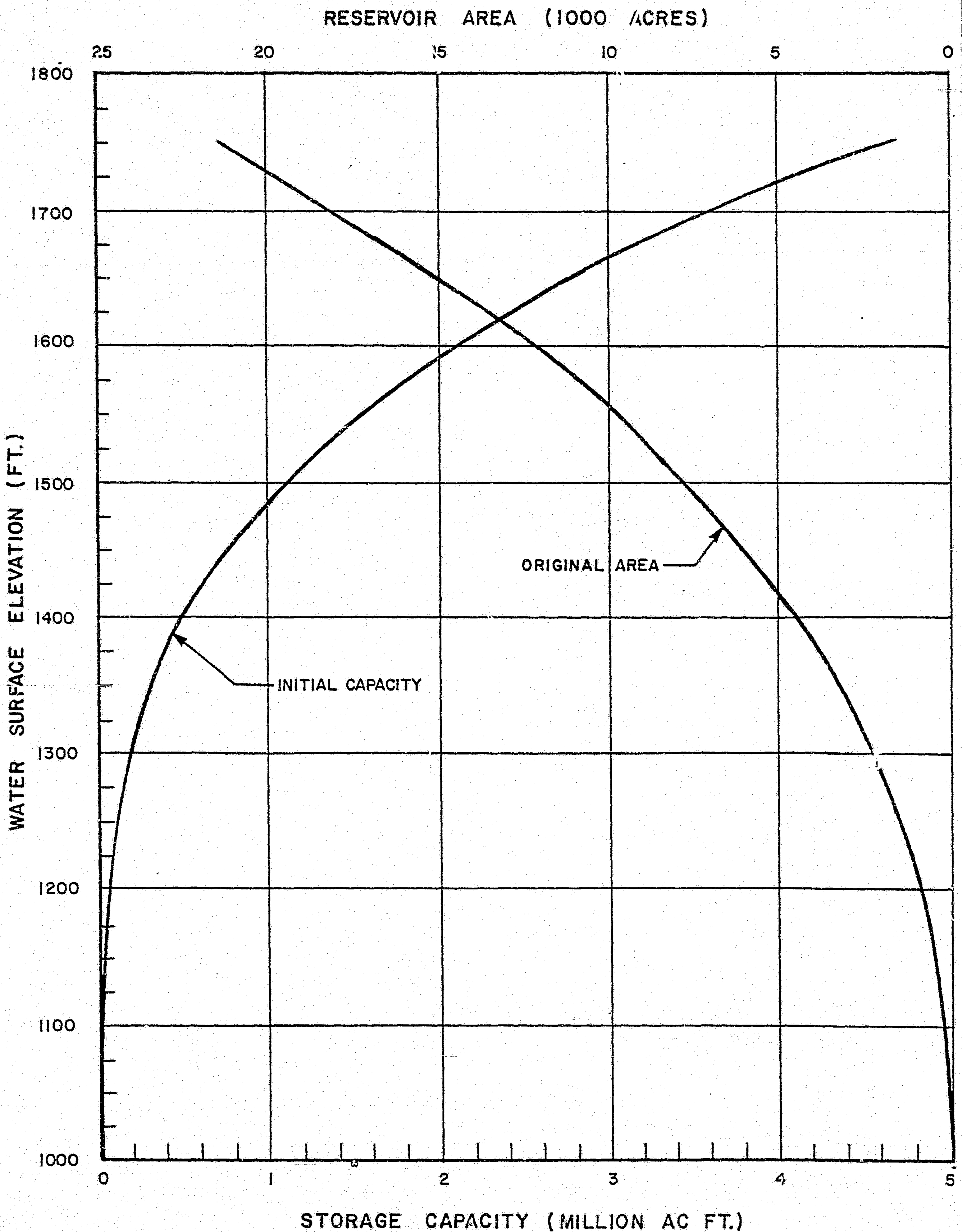

AREA AND CAPACITY CURVES
HIGH D.C. RESERVOIR

FIGURE 6

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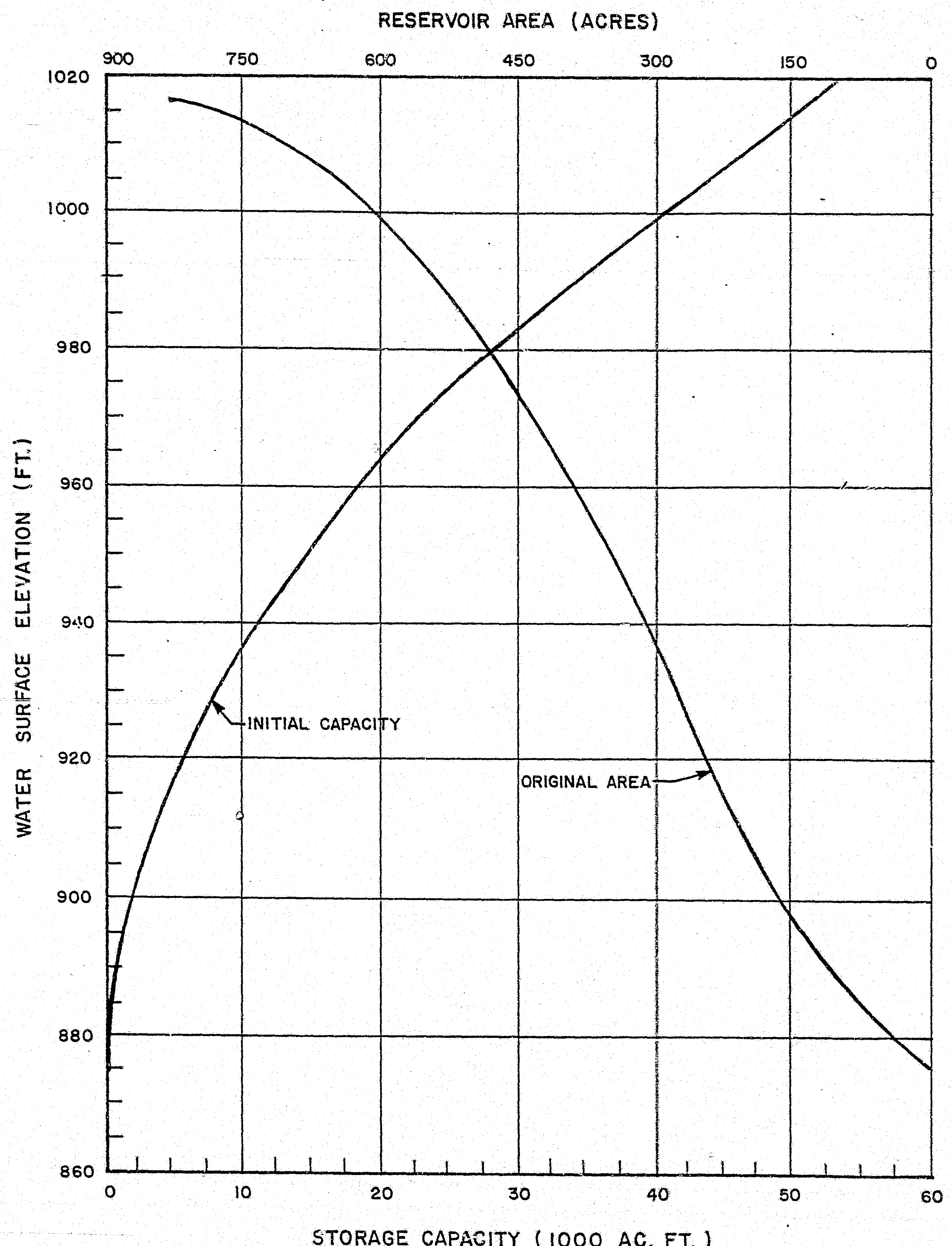

AREA AND CAPACITY CURVES
PORTAGE CREEK RESERVOIR

ACRES

FIGURE 8