DESIGN CRITERIA

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Project: Tyee Lake Hydroelectric Project

Section: 1. CIVIL
Subject: 1.2 HYDROLOGY AND RESERVOIR OPERATION

Submitted,
Design Manager [signature]
Approved,
Chief Engineer [signature]

CONTENTS

1. PURPOSE

The purpose of these criteria is to provide the hydrologic data necessary for the design of the basic elements at the project.

2. TYEE LAKE INFLOW

The drainage area of 14.2 square miles contributing to Tyee Lake is shown on the map, Exhibit 1.2-1. Also indicated is the location of two gaging stations where the U.S. Geological Survey has collected streamflow records close to the project site:

1. Station 0201: Tyee Creek at mouth, near Wrangell
   Location: 37 miles southeast of Wrangell
   Drainage Area: 16.1 square miles
   Period of Record: November 1922 to September 1927 (fragmentary), August 1963 to September 1969

2. Station 0220: Harding River near Wrangell
   Location: 34 miles southeast of Wrangell, and 5 miles west of the mouth of Tyee Creek
   Drainage Area: 67.4 square miles
   Period of Record: August 1951 to present

In July and August 1979 two more gaging stations were installed near the project site: one on Tyee Creek at the outlet from Tyee Lake and one on the East Fork, Bradfield River.

The runoff pattern for Tyee Creek is characterized by prolonged, fairly high flows from snowmelt runoff in June and July. The magnitude and duration of the flows depend on the depth of snow on the basin, the temperature pattern during the melting season, and the occurrence of rain. Extremely high flows result from heavy rainstorms and glacier melt during September and October. About 70 percent of the runoff in Tyee Creek occurs in the five-month period from June through October.

Monthly inflows to Tyee Lake were estimated by graphical correlation of streamflow records from gaging stations at Tyee Creek at mouth and Harding River near Wrangell. The concurrent records available for monthly graphical correlations covered water years 1963 through 1969. Through correlation, records for flow at mouth of Tyee Creek were expanded to cover 27 years (water years 1952 through 1978). From this extended set of monthly flows at Tyee Creek mouth, the inflow to Tyee Lake at the upper portion of the basin was synthesized by drainage area proportioning, and further adjusted for elevation and runoff characteristic differences between the upper and lower portions of the watershed.

Because of the large snowpack at higher elevations, melting during the summer months, a greater portion of summer runoff would occur at the outlet of Tyee Lake than that represented by a linear relationship between the drainage areas of Tyee Creek at the mouth (16.1 sq. mi.) and the outlet of Tyee Lake (14.2 sq. mi.). The snowpack in the portion of the drainage basin below Tyee Lake is less than that at higher elevations, where temperatures are lower. Much of the winter flow is represented by the melting snowpack below Tyee Lake. The flows were further adjusted to represent the above described conditions, with higher runoff coefficients for May through September. The monthly inflows to Tyee Lake are shown in Exhibit 1.2-5. This synthesized set of monthly inflows to Tyee Lake is considered to be representative of the inflow conditions, although it was based on correlation with the streamflows at Harding River near Wrangell and Tyee Creek at mouth. The latter gage reflects the historic lake regulation and storage effects to a certain extent.

3. PROBABLE MAXIMUM FLOOD

The probable maximum flood (PMF) for the Tyee Lake Hydroelectric Project was developed by the following procedure:

- The heaviest precipitation in the project catchment area comes from large storms in fall or winter. The probability of an intense 24-hour storm is greatest in October; therefore was assumed to occur during that month. Snowmelt was considered in the event of a rain-on-snow flood.

- The probable maximum precipitation (PMP) was synthesized from information contained in Technical Paper No. 47, Probable Maximum Precipitation and Rainfall Frequency Data for Alaska, U.S. Department of Commerce (Weather Bureau), 1963. A total rainfall of 22.5 inches in a 24-hour period was calculated for the project area. Snowmelt contribution was determined from criteria developed by the U.S. Army Corps of Engineers and was calculated to be 2.6 inches during the 24-hour PMP storm period. The snowmelt was prorated to the hourly incremental PMP. The total precipitation, which included snowmelt, was distributed according to intensity-duration relationships published by the U.S. Bureau of Reclamation.

- Infiltration was assumed to be 2 inches over the first 4 hours of the storm. This was based on estimated characteristics of the catchment area.

- The hydrograph for the PMF was derived according to the Soil Conservation Service (SCS) method as outlined by the U.S. Bureau of Reclamation in "Design of Small Dams". This is an approximate method involving the derivation of a synthetic triangular unit hydrograph. For the unit hydrograph, the time to the peak was 1.26 hours and the base time was 3.36 hours. The PMF hydrograph was derived by computing individual triangular hydrographs for each increment of PMP excess and then graphically adding the ordinates of these hydrographs to obtain the total runoff. The computed peak inflow into Tyee Lake was 28,500 cfs. The inflow hydrograph for the PMF is shown on Exhibit 1.2-2.

- The flood was routed through the reservoir. During October, when the PMF is most likely to occur, the lake will usually be close to its normal maximum level. The flood would pass through the reservoir and out of the natural lake outlet, unaffected in any way by the construction of the project. As shown on Exhibit 1.2-2, the maximum routed outflow through the lake outlet is 20,500 cfs at a lake elevation of 1414.14.

4. RESERVOIR EVAPORATION

The climatic conditions, with high humidity and extensive cloudiness, are such that the amount of evaporation is likely to be small. Specific information on lake evaporation at Tyee Lake is not available; however, some pan evaporation data are available near Juneau. Based on temperature and elevation differences between Juneau and Tyee Lake, and adjustments from pan evaporation to lake evaporation, a maximum lake evaporation rate of 3 inches for July was assumed for Tyee Lake. The estimated monthly evaporation amounts are:

Month	Average Lake Evaporation (inches)
October	1.0
November through March	0
April	0.6
May	1.8
June	2.7
July	3.0
August	2.8
September	2.2
Annual	14.1

5. RESERVOIR SEDIMENTATION

Field inspection of Tyee Creek both at the inlet to Tyee Lake and the lower portion of Tyee Creek show the creek to transport a very light sediment load. Transported sediment loads for streams with similar characteristics were analyzed to estimate the total weight of transported material over the period of record.

This value was then used to estimate the probable sedimentation at Tyee Lake. It was estimated that over a period of 50 years the sedimentation in Tyee Lake would amount to about 100 ac-ft, a negligible amount compared to the available dead storage of 62,600 ac-ft.

6. OPERATION OF TYEE LAKE

The Tyee Lake Hydroelectric Project will be operated so as to generate all the energy requirements of the combined systems of Petersburg and Wrangell. Existing capacity will be maintained to provide potential standby emergency capacity only.

The Tyee Lake Reservoir will not be operated for flood control, irrigation, municipal, or domestic water supply.

Tyee Lake Reservoir will have a potential operating range from Elevation 1396 to Elevation 1250, which will provide an active storage of 52,400 ac-ft. The area and capacity curves are shown on Exhibit 1.2-3. Most of the precipitation in the catchment area falls as snow in the winter months. The major part of the runoff, principally from snowmelt, occurs between May and October; streamflows during the winters are low due to the prevailing freezing temperature. Tyee Lake will be operated so as to store as much as possible of the runoff during the summer months, and to release regulated flows for power generation throughout the year. In years of normal or high flow, the reservoir will fill to Elevation 1396 and some flow through the natural lake outlet will occur during the summer months. Greatest drawdown will occur during April or May, immediately before the snowmelt commences. Drawdown is greatest following years of low precipitation.

7. RESERVOIR OPERATING RULE

The project will have the capacity to provide 130,000 MWh of firm energy per annum, which is more than the projected requirements of both communities beyond the year 2000. The powerhouse will therefore be operated so as to supply all the consumers' requirements for both base and peak power. At some time in the next century when consumer demand may exceed the project capacity of 130,000 MWh per annum, it might become advisable to devise a more elaborate operating rule in order to maximize the energy output.

In summer, from mid-May to October, the runoff will fill the lake until it reaches El 1396, approximately when flow will commence through the natural lake outlet, and will continue until October. Then the lake will be drawn down gradually during the winter months when runoff is low, reaching a minimum level in mid-May, when the cycle starts again. The level to which the lake is drawn down will increase over the years as the demand for power grows. It will also be lower in a year following a year of low precipitation.

Drawdown for power development will not reach the lowest estimated level of Elevation 1250 until the demand for power reaches 130,000 MWh per annum, and then only following years of exceptionally low precipitation. However, in the first year following construction of the project it will be desirable to draw the lake down as close to Elevation 1230 as possible (the invert elevation of the lake tap) in order to inspect the zone of the breakthrough, make possible modifications, and to install trashrack.

8. RESERVOIR OPERATION STUDIES

Reservoir operation studies were made by using the 27-year period of synthesized flows at Tyee Lake outlet. The computer program, "HEC-3, Reservoir System Analysis", developed by the U.S. Army Corps of Engineers, was employed. This program was modified to facilitate the computation of turbine flows and spills.

It was assumed that no leakage would occur out of the reservoir. This assumption is justified by the excellent geological conditions at the reservoir.

Head loss coefficients for minor losses were based on U.S. Bureau of Reclamation recommended data. Friction losses were based on values of Manning's "n" of 0.030 in the unlined tunnel sections, 0.013 in the concrete-lined tunnel sections, and 0.011 in the steel-lined tunnel and manifold. The estimated head losses were minor compared to the total gross head available. At turbine discharge of 200 cfs, head losses were about 4 to 6 feet. In the study, the losses were assumed to be constant at 5 feet.

The program, by a series of iterations, computes the firm capacity, which is the minimum reliable power that can be generated on a continuous basis during the critical period used in the analysis. Next, the program computes the generation for each year, and the average annual generation over the period. The computer printout of the operation study for the recommended project is shown in Table 1-2 of the Amended Application for License, Volume I, December 1979.

The analysis was run using the Mean Lower Low Water elevation datum in accordance with Alaskan practice. (The analysis in the operation study included in the original application was based on Mean Sea Level datum.) The maximum lake storage level was Elevation 1396, and the specified minimum lake level was elevation 1250. The total installed capacity is 20 MW, consisting of two 10 MW units. Since the units are impulse turbines, the effective tailwater elevation is constant at the average elevation of the turbine jets. Under the hypothetical conditions of energy generation over the period 1952 to 1978, the minimum lake level would have been Elevation 1256, and would have occurred in 1967.

For the recommended project, with an installed capacity of 20 MW, the power and energy which can be generated are computed to be as follows:

Firm capacity	14.8 MW
Annual firm generation	130,000 MWh
Average annual secondary generation	3,000 MWh
Average annual total generation	133,000 MWh

Provision has been made for the future installation of a third 10 MW turbo-generator set in the powerhouse. This would provide additional peaking capacity to the Petersburg/Wrangell system, but would not increase energy production significantly. The timing of the installation of this unit would depend on the growth of the demand in the system, and it is not included in the present application.

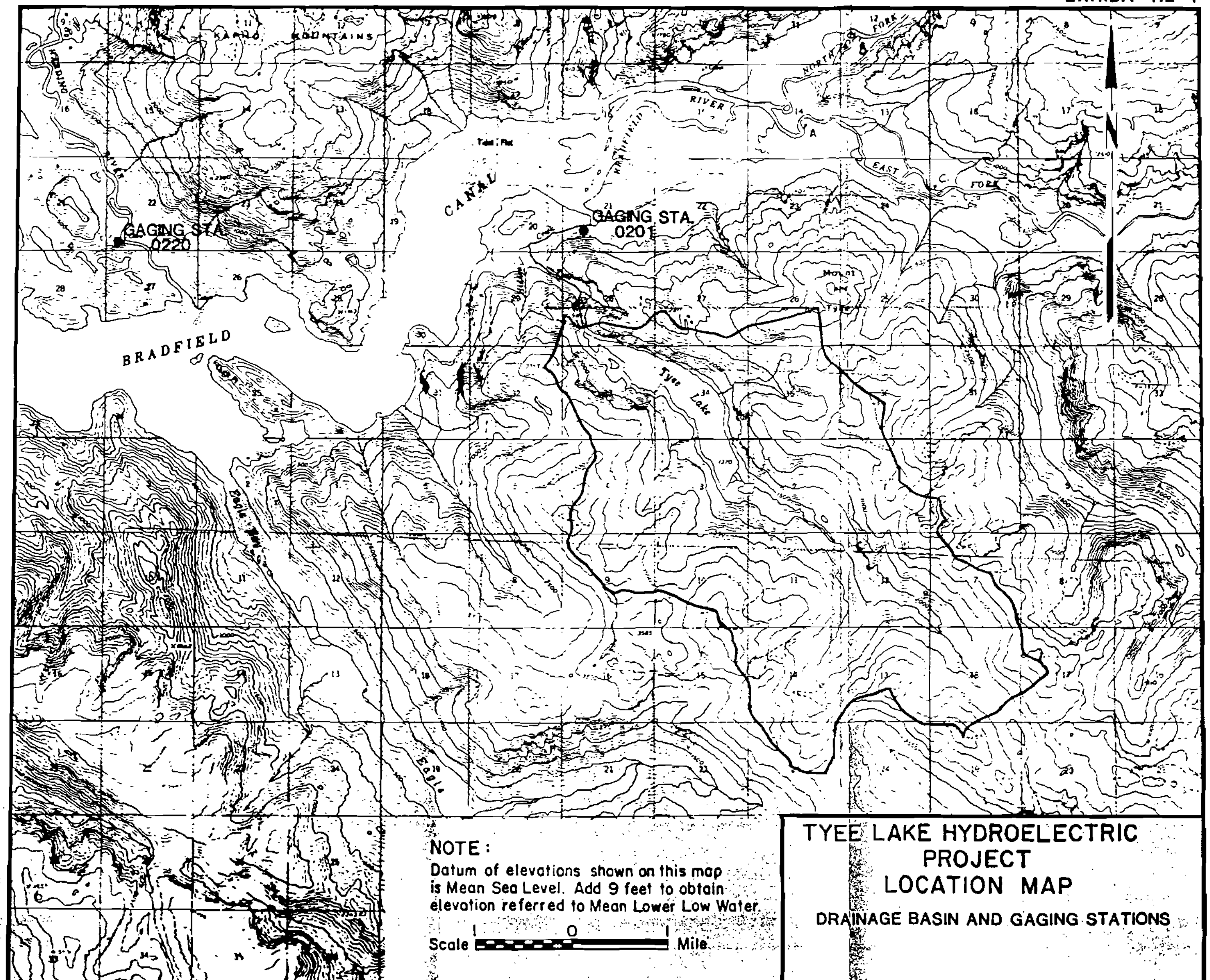
9. TAILWATER AT TYEE LAKE POWERHOUSE

Discharge from the powerhouse tailrace will flow in a channel about 1,100 feet long, which will be excavated in the soil materials of the valley floor until it joins a small natural creek. Flow will continue down to the sea at Bradfield Canal about half a mile downstream. The tailwater rating curve for the draft tube weir is shown on Exhibit 1.2-4.

Estimates were made of the PMF and 100-year flood in the Bradfield River. The highest flood flow would pass over the low divide into Airport Slough and flow past the powerhouse. The elevation at the tailrace would depend on the tide elevation at the time of occurrence of the flood. The results of the study were:

Flood Magnitude	Tide Magnitude	Tide Elevation	Flow at Powerhouse	Water Surface Elevation at Powerhouse
PMF	Highest Tide	22.0	39,000 cfs	25.2
PMF	Mean Higher High	16.5	38,000 cfs	25.0
100-yr	Highest Tide	22.0	10,500 cfs	22.3
100-yr	Mean Higher High	16.5	11,000 cfs	19.1

EXHIBIT 1.2-1

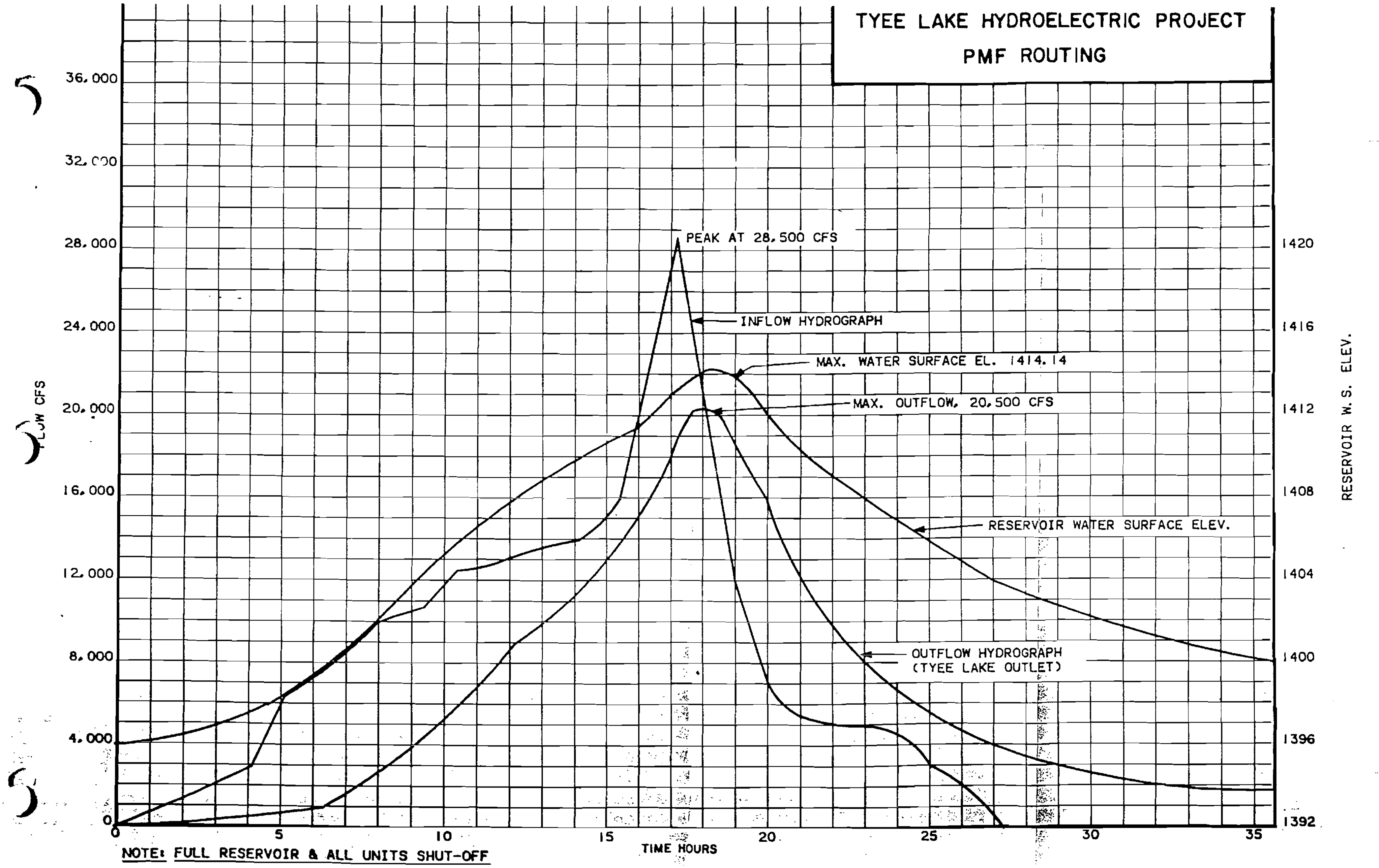


NOTE: Datum of elevations shown on this map is Mean Sea Level. Add 9 feet to obtain elevation referred to Mean Lower Low Water.

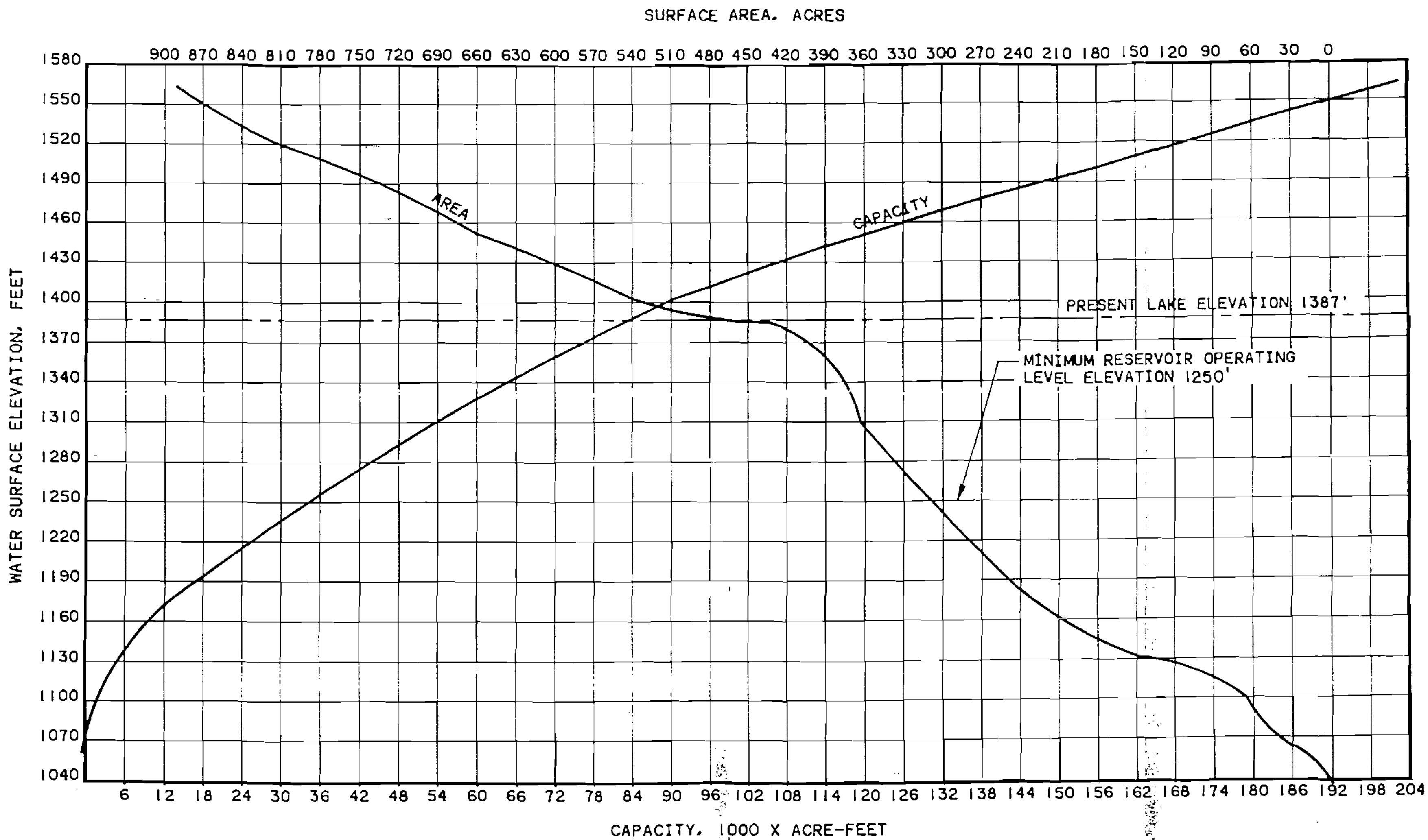
Scale 1 0 1 Mile

TYEE LAKE HYDROELECTRIC PROJECT LOCATION MAP

DRAINAGE BASIN AND GAGING STATIONS

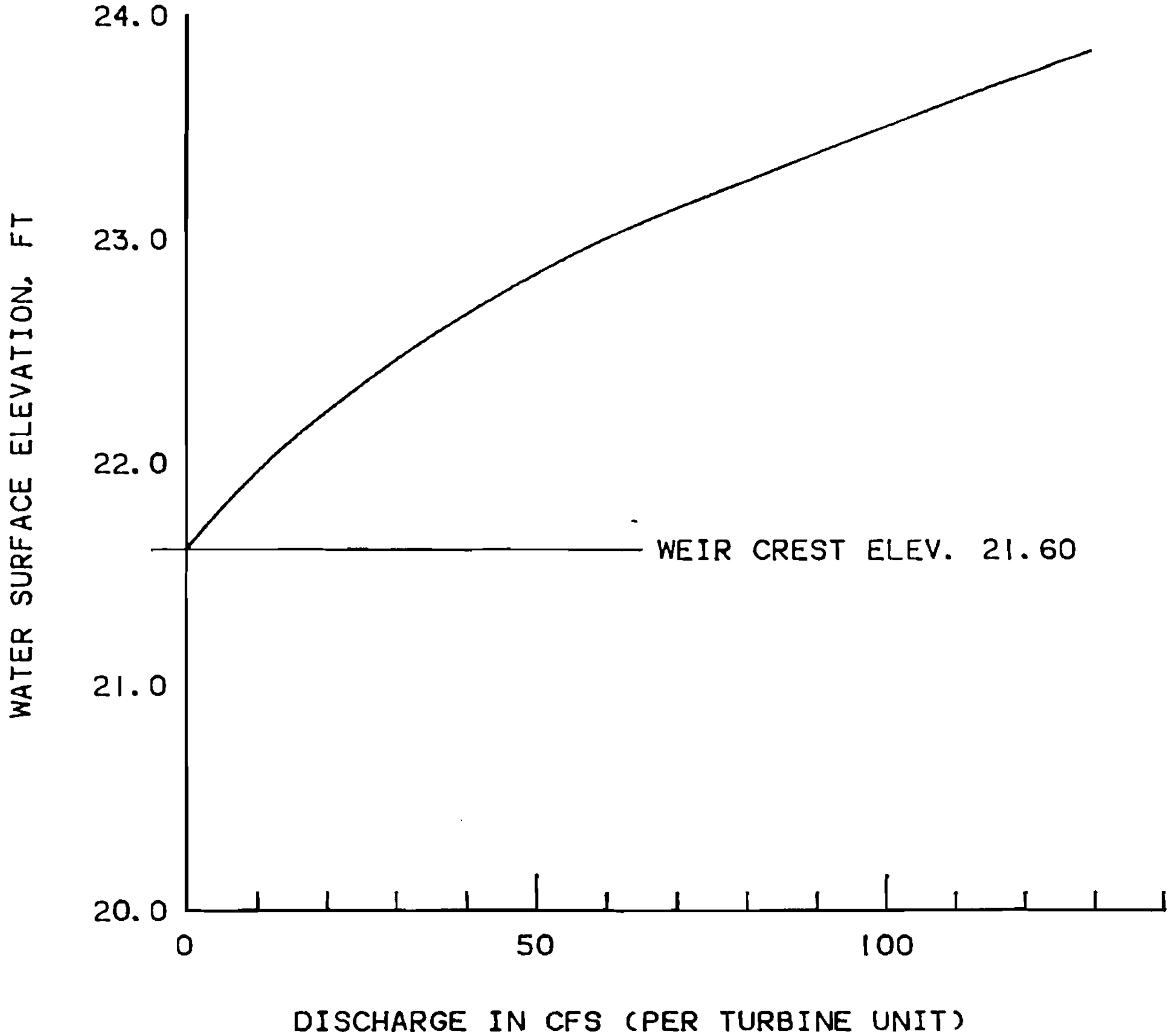


NOTE: FULL RESERVOIR & ALL UNITS SHUT-OFF



TYEE LAKE HYDROELECTRIC PROJECT

AREA-CAPACITY CURVES



TYEE LAKE HYDROELECTRIC PROJECT

TAILWATER RATING CURVE

INTERNATIONAL ENGINEERING COMPANY, INC.

INTERNATIONAL ENGINEERING COMPANY, INC.

TYEE LAKE HYDROELECTRIC PROJECT
MONTHLY DISCHARGE (IN CFS) AT TYEE LAKE OUTLET

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Average
1952	150	71	55	22	14	15	58	215	321	338	260	279	151
1953	325	114	44	25	16	21	53	303	338	244	170	230	158
1954	361	101	66	28	122	16	14	138	329	261	156	167	147
1955	242	198	111	51	30	21	39	129	328	301	345	231	170
1956	198	94	29	18	11	11	48	338	277	273	350	150	151
1957	192	132	133	31	14	13	42	236	371	268	158	198	150
1958	176	155	55	87	22	24	77	249	327	207	256	124	147
1959	475	113	84	34	20	25	55	214	376	395	225	177	184
1960	348	112	186	56	33	34	88	205	324	338	276	214	186
1961	453	111	104	62	53	37	87	196	371	276	285	209	188
1962	598	98	39	168	43	49	85	178	365	301	240	266	204
1963	251	157	218	127	101	30	49	181	306	245	96	256	168
1964	293	56	96	54	40	22	45	134	420	320	287	177	163
1965	295	91	66	74	37	34	64	138	340	294	148	97	141
1966	383	52	42	21	15	38	63	188	352	289	244	281	165
1967	195	110	42	30	21	16	19	240	464	287	221	363	168
1968	239	133	46	26	41	81	36	218	298	273	166	392	163
1969	196	108	32	11	10	9	60	253	400	268	224	140	143
1970	148	322	102	28	47	36	41	156	414	282	276	270	177
1971	229	138	51	34	13	13	33	162	362	263	269	176	146
1972	179	83	39	24	41	54	22	227	385	414	328	218	169
1973	151	73	31	48	20	19	45	198	327	282	277	234	143
1974	167	41	92	25	49	23	64	157	293	320	258	257	146
1975	510	101	42	31	15	18	26	113	291	414	235	192	167
1976	158	55	97	71	39	36	58	201	339	367	294	290	168
1977	242	162	126	43	87	28	86	126	451	195	175	159	157
1978	277	75	34	29	28	26	62	123	268	188	215	133	122
Average	275	113	76	47	36	28	53	193	350	293	238	218	161
Maximum	598	322	218	168	122	81	88	338	464	414	350	392	204
Minimum	148	41	29	11	10	9	14	113	268	188	96	97	122

EXHIBIT 1.2-5