US Army Corps of Engineers
Walla Walla District

Powerhouse Major Rehabilitation Program

Ice Harbor Lock & Dam
Snake River, WA

Prepared by
Walla Walla District
Portland District, Hydroelectric Design Center, and
North Pacific Division, Water Management

March 1997

DEPARTMENT OF THE ARMY
WALLA WALLA DISTRICT, CORPS OF ENGINEERS
201 NORTH THIRD AVENUE
WALLA WALLA, WASHINGTON 99362-1876

Reply To
Attention Of:

CENPW-PL-PF (1110)

MAR 31 1997

MEMORANDUM FOR CHIEF OF ENGINEERS, ATTN: CECW-AR, WASH DC 20314-1000

SUBJECT: Evaluation Report for Major Rehabilitation of Generating Units 1-6 at Ice Harbor Lock and Dam Powerhouse dated March 1997, Advance Copies

1. Reference is made to ER 1130-2-500 dated 27 December 1996, *Project Operations, Partners and Support (Work Management Policies)*, Chapter 3 - Major Rehabilitation Program. Enclosed are 15 advance copies of subject report for your information.

2. The report was formally submitted to Chief, CENPD-ET-OP by memorandum dated 31 March 1997, subject: Evaluation Report for Major Rehabilitation of Generating Units 1-6 at Ice Harbor Lock and Dam Powerhouse, Washington, dated March 1997 (Enclosure 2).

3. My staff would be pleased to meet with you and your review team to discuss any issues or concerns that you may have.

4. If I can be of further assistance, please contact me at 509-527-7700.

2 Encls
1. IH Rpt
2. NPW ltr to CENPD

/signed/
DONALD R. CURTIS, JR.
LTC, EN
Commanding

CF (w/encls):
CENPD-ET-OP(Rpt-5 cys)
CECW-AR (Craig Chapman)

DEPARTMENT OF THE ARMY
WALLA WALLA DISTRICT, CORPS OF ENGINEERS
201 NORTH THIRD AVENUE
WALLA WALLA, WASHINGTON 99362-1876

Reply To
Attention Of:

CENPW-PL-PF (1110)   31 March 1997

MEMORANDUM FOR Commander, North Pacific Division, ATTN: CENPD-ET-OP

SUBJECT: Evaluation Report for Major Rehabilitation of Generating Units 1-6 at Ice Harbor Lock and Dam, Washington, Powerhouse dated March 1997

1. References:

a. ER 1130-2-500, Partners and Support (Work Management Policies), dated 27 December 1996, Chapter 3 - Major Rehabilitation Program.

b. EP 1130-2-500, Partners and Support (Work Management Guidance and Procedures), dated 27 December 1996.

c. ER 1110-2-1150, Engineering and Design for Civil Works Projects, dated 31 March 1994.

d. ER 1110-2-1200, Plans and Specifications for Civil Works Projects, dated 30 October 1993.

2. In accordance with cited references and discussions with your staff, five copies of the subject report are forwarded for your review and approval. Fifteen copies are being sent directly to CECW-AR.

3. The report recommends new turbine blades for three units, rewinding of six generator units, six new solid state exciters, three new transformers, a new governor control system for three units, rehabilitate the tailrace gantry crane, modify the bridge crane controls, new unit protection relays, and improvements to the station service system.

4. The report documents that a marketability letter from the Bonneville Power Administration has not yet been obtained.

5. An Environmental Assessment (EA) on the recommended plan is not included in this report. The report recommends that the National Environmental Policy Act (NEPA) process be postponed until results are available on the Minimum Gap Runners that are being tested at Bonneville Dam. Test results will be available sometime in 1998. The National Marine Fisheries Service concurs with postponement of the NEPA process as stated in their letter dated 25 March 1997, referenced in Section 7, paragraph 7.3, of the report.

6. Please note the errata sheet that has been added to the front of the report to address cost changes from initial cost estimate to the baseline cost estimate of the National Economic Development recommended plan.

7. If additional information or assistance is needed, please contact Bill MacDonald at 509-527-7253.

FOR THE COMMANDER:

Encl

/signed/
DOUGLAS A. FREI, P.E.
Chief, Planning Division

CF (w/encl):
CECW-AR **(Steve Cone)**
CECW-AR (Craig Chapman)

ICE HARBOR LOCK AND DAM, WASHINGTON
POWERHOUSE MAJOR REHABILITATION PROGRAM

ERRATA SHEET

The purpose of this ERRATA sheet is to explain differences in costs used to identify the NED plan, as well as those in the baseline cost estimate.

In paragraph 9.2, it states that the NED plan is the same as the recommended plan. As a result of further analysis, a list of five work-items were later identified to be included as part of the NED plan. A list of these five added items is as follows:

a. Rehabilitation of the tailrace gantry crane

b. Modification of the bridge crane controls to decrease travel speed

c. New unit protection relays

d. Improvements to the station service system

e. An option to incorporate minimum gap runners (in lieu of new blades), if determined to be warranted

Items a. and b. were added in order to carry out the actual rehabilitation plan. Items c. and d. were added to maintain reliability of the overall powerhouse. Item e. was added to capture any advanced technological development on minimum gap runners. The following table is a comparison of items and costs included in the NED/recommended plan.

Comparison of Project Costs for NED Plan 1 October 1996 Price Level ($1,000)		
Item	**NED Plan (Alt 4c)[1]**	**NED Plan Adjusted Costs[2]**
Generation Units		
Turbine work, 1-3	10,886	11,227
Governor work, 1-3	625	643
Generators, 1-3	8,905	10,536
Generators, 4-6	9,330	9,540
Exciters, 1-6	3,750	2,135
Transformers, 1-3	6,887	5,668
Total Generation Units	**40, 383**	**39,749**
Support Equipment		
Hoisting equipment (items a and b, above)	0	806
Station Service and Unit Protection (items c and d, above)	0	698
Advanced Turbine Technology (item e above)	0	3,746
Government-furnished services (miscellaneous)	0	120
Total Support Equipment	**0**	**5,370**
Subtotal	**40,383**	**45,119**
Government Mark-Ups		
030 Account (E&D)	5,249	6,403
031 Account (S&A)	3,031	3,151
Total Government Mark-Ups	8,280	9,554
Total Project Cost	**48,663**	**54,673**
[1]Includes 25-percent contingencies [2]Includes 20-percent contingencies		

The inclusion of these added features resulted in a cost increase (at the 1 October 1996 price level), from $48,663,000 to $54,673,000, an increase of $6,010,000. The increase in costs does not affect the selection of the NED plan. While it is apparent that a decrease in net benefits has occurred, it is also apparent that the NED plan, as identified, remains the NED plan.

Costs associated with the hoisting equipment and station service protection are costs that will occur in all alternatives. In the base condition, as the various components of the powerhouse experience malfunctions, it will be necessary to perform this work and, therefore, this is not significant in determining the NED plan.

The increase in cost associated with engineering and design and supervision and administration are costs that will also apply to all alternatives. The rewinds for all six units are overwhelmingly justified and, therefore, particular attention has been paid to the incremental costs and benefits of the turbine and transformer work on units 1 through 3. The average annual incremental net benefits of the turbine and transformer work in the NED plan, relative to the generator rewinds alone, total $1.4 million. Net benefit is sufficient to support a $17 million increase in first costs, while maintaining justification. The runner replacement measure would also incur these additional costs. Inclusion of the minimum gap runners was not, and should not be, included in the economic analysis. This would distort the incremental last-added analysis.

In conclusion, although there has been some cost increase in the NED plan from its initial evaluation, these increases would apply to all alternatives. The relative ranking of alternatives would not change.

ICE HARBOR LOCK AND DAM, WA.
POWERHOUSE MAJOR REHABILITATION PROGRAM

EXECUTIVE SUMMARY

PROJECT DESCRIPTION

The Ice Harbor Lock and Dam Project is a run-of-river project located on the lower Snake River about 10 miles east of Pasco, Washington. The powerplant contains three 90,000-kilowatt (kW) generating units (units 1 through 3) and three 111,000-kW generating units (units 4 through 6), with a total rated generating capacity of 603,000 kW. The rated (overload) generating capacity is 693,000 kW. The Federal power marketing agency charged with marketing the power output of this project is Bonneville Power Administration (BPA). Project construction was initiated in December 1955, and the project began operation in January 1962. Units 1 through 3 and 4 through 6 came online in 1962 and 1975, respectively. The project accounts for about 5 percent of the total U.S. Army Corps of Engineers' output to hydroelectric power produced in the Pacific Northwest for the BPA system. In addition, BPA is responsible for managing the Federal portion of the Northwest power distribution system.

PURPOSE OF THE REPORT

This report evaluates a major rehabilitation of all six units in the powerhouse at the Ice Harbor Project. The primary purposes of the rehabilitation program are to correct generator and turbine reliability problems, as well as to restore the turbines' lost efficiency.

PROBLEM OVERVIEW

The Ice Harbor Powerhouse is experiencing an increasing number of turbine blade failures on units 1 through 3 (35 years old) and generator failures on units 4 through 6 (21 years old). The failures stem from a combination of age on units 1 through 3, frequent starting and stopping of the units required for power peaking, and a requirement to operate within 1 percent of the maximum efficiency to minimize juvenile fish mortality through the turbines.

At this moment, both units 2 and 5 are currently out of service, and are in different stages of diagnostic testing and/or repair. The unit 5 generator failure is currently under evaluation, and a recommended interim repair plan will be prepared in the very near future. Failures during two previous startup attempts have kept this unit out of service since May 1994. Units 4 and 6 have also had similar problems.

The availability of the Ice Harbor powerhouse has declined from 91.9 percent to 65.2 percent since 1989. The project has experienced six unplanned generator outages on units 4 through 6, and five unplanned turbine outages on units 1 through 3 over the past 5 years. Attempting to maintain availability in the face of decreasing reliability has required increases in repair efforts, thereby demanding a continual reprioritization of project resources.

The turbine blades on units 1 through 3 are subject to severe cracking. On two occasions, large pieces of the blades broke off, and had to be reattached. Additionally, the turbine efficiency on units 1 through 3 and 4 through 6 have deteriorated, on the average, about 2.4 and 1.1 percent, respectively. This reduces the total amount of energy the Ice Harbor Project can produce. Deterioration of turbine efficiency may also cause increased mortality in juvenile fish passing through the turbines.

On March 11, 1997, unit 2 experienced an unplanned outage due to a turbine blade crack. The evaluation of this failure is currently underway. Units 1 and 3 have had similar problems, as well.

Continued deterioration of Ice Harbor reliability and efficiency will have impacts on operation and maintenance costs, as well as on total western power system production costs. In the without-project condition, system production costs are estimated to be about $2 million more annually than if the recommended plan is implemented. In addition, turbine mortality of juvenile fish will continue to increase, as will spill, with a resultant increase of total dissolved gases. Rehabilitation to halt this trend of deterioration will take about 8½ years. Because of this, it is urgent that corrective action be taken as soon as possible.

ECONOMIC ANALYSIS

An economic analysis of multiple rehabilitation measures was performed as required. The analysis considered costs and benefits, and was based on National Economic Development (NED) criteria. These criteria included reductions in non-routine operation and maintenance costs, emergency repairs, restoration of lost efficiency, and total system energy production costs.

The analysis used a Monte Carlo (random sampling process) simulation based on the probability of breakdown of major powerhouse components. The analysis identified expected impact for the following measures:

- Base Condition: This is the "without-project" condition; requiring continued maintenance and repairs as necessitated by breakdowns.

- Rewind generators, with consideration for uprating when possible.

- New turbine blades, new standard runners, and new minimum gap runners (to reduce fish mortality) for units 1 through 6.

From the above identified measures, a group of 10 key alternative plans were defined and evaluated for the six generating units.

ENGINEERING CONSIDERATIONS

The engineering reliability analysis produced the breakdown probability distribution used in the economic analysis. The method is based on historical data for similar equipment. In addition, a measure of equipment condition (Condition Indicator) was assigned to each major component. The Condition Indicators were based on recent testing and inspections, and were used to modify breakdown probabilities stemming from the historical data, in order to better reflect current conditions.

ENVIRONMENTAL CONSIDERATIONS

The Portland and Walla Walla Districts have been actively engaged in investigations focused on improving juvenile fish passage through turbine environments. One such investigation will be conducted at the Bonneville powerhouse for minimum gap runners (MGR). The results from this test are expected in 1998. These results, coupled with the results of other regional investigations, hold great promise for the improvement of net power generation benefits, while also increasing endangered and threatened fish survival rates. For that reason, an optional item has been included in this report as an allowance to capture any outgrowth from future technological developments in this area. This option is supported by the National Marine Fisheries Service.

Congress has passed a number of environmental laws that address Federal responsibility for protecting and conserving special resources at and around this project. One of those laws, the Endangered Species Act (ESA), specifically applies to certain operations conducted at this project.

As a result of the ESA, several operational requirements were designated in the National Marine Fisheries Service's (NMFS) 1995 Biological Opinion for conservation of the endangered Snake River sockeye salmon and the threatened Snake River spring, summer, and fall chinook salmon stocks. Those restrictions include operational constraints on turbines during ESA fish migration seasons, flow mandates for spillway discharges during ESA fish migration seasons, 95-percent ESA fish passage survival by the project, 80-percent fish passage efficiencies, and gas abatement measures for total dissolved gas during high flow discharges over the spillways.

Along with the important Federal obligation to produce hydroelectric power at this project, there is also a vital need to respond to the ESA requirements as stated above. This report documents that the number of unplanned outages of this power generating equipment will only increase with age. However, the recommended rehabilitation plan given in this report will benefit both endangered and threatened salmon, through improved downstream survival rates, by increasing the efficiency of units 1 through 3 to better than their original state. Any delay in the implementation of this plan will impair passage and survivability opportunities for those species at this project.

The recommended action will benefit listed and petitioned endangered species through improved downstream survival rates, by increasing the efficiency of units 1 through 3, as well as by increasing the reliability of the units to reduce spill.

In addition to the above, hazardous or toxic wastes that may be encountered are expected to be minor, and will be handled in accordance with all state and Federal environmental regulations.

RECOMMENDED PLAN

The declining reliability and efficiency of units 1 through 6 justify an extensive rehabilitation program. The recommended plan for this rehabilitation is the same as the NED plan, and is summarized as follows:

Units 1 through 3

- Rewind Generators with 11-Percent Uprate
- New Solid State Exciters
- New Transformers
- New Turbine Blades
- New Governor Control System

Units 4 through 6

- Rewind Generators
- New Solid State Exciters

The benefits of the proposed rehabilitation program in terms of reductions in system power generation costs, operation and maintenance costs, and repair costs are $13,879,894 annually. With average annual costs of $3,043,273, the project provides net benefits of $10,836,621, with a benefit-to-cost ratio of 4.6.

A marketability letter was requested from Bonneville Power Administration (BPA), by letter, dated 31 January 1997. This letter has not yet been received from BPA.

COST ESTIMATE AND SCHEDULE

The recommended plan given in this report has a total construction cost of $54.7 million at the 1 October 1996 price level. The fully-funded cost estimate, including contingencies and inflation to mid-point of construction, is $67.0 million.

Planning and completing the major rehabilitation required to restore reliability is about an 8½-year process. Once onsite work begins, units would be rehabilitated at the rate of one unit per year, limited by working space within the powerhouse. The earliest date a generating unit can be rehabilitated and returned to service is the year 2001. The last unit would be returned to service in the year 2007. This report recommends starting this process now in order to minimize negative economic and environmental impacts.

ICE HARBOR LOCK AND DAM, WASHINGTON
POWERHOUSE MAJOR REHABILITATION PROGRAM

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POWERHOUSE MAJOR REHABILITATION PROGRAM

TEAM MEMBERS

NAME	TITLE	FUNCTION
WALLA WALLA DISTRICT		
Jack Allison	Electrical Engineer	Operations Representative
Teri Barila	Fishery Biologist	Technical Review
Jesus Barrios	Cost Engineer	Cost Estimates
Bob Berger	Civil Engineer	O&M History
Les Cunningham	Hydraulic Engineer	Technical Review
Dick Eilertson	Electrical Engineer	Technical Review
Gary Ellis	Economist	Economic Support
Richard Grubb	Cost Engineer	Technical Review
Randi Jeffrey	Program Analysis	Assistant Project Manager
Bill MacDonald	Wildlife Biologist	Technical Review
Lonnie Mettler	Wildlife Biologist	Technical Review
Chris Pinney	Fishery Biologist	Biological Analysis
Jerry Roediger	Civil Engineer	Technical Manager/Report Preparation
Scott Sutliff	Electrical Engineer	Project Representative
Sandy Simmons	Environmental Resources Specialist	Environmental Compliance
Brayton Willis	Project Engineer	Program Manager
NORTH PACIFIC DIVISION, WATER MANAGEMENT		
Jim Barton	Hydraulic Engineer	Power Studies
Mike Egge	Electrical Engineer	Power Studies
Kamau Sadiki	Hydraulic Engineer	Technical Review
PORTLAND DISTRICT, HYDROELECTRIC DESIGN CENTER		
Tam Bui	Electrical Engineer	Generator Analysis
Don Campbell	Electrical Engineer	Technical Review
Jim Kerr	Mechanical Engineer	Mechanical Peripheral Study
Brent Mayhan	Economist	Technical Review
April Patterson	Mechanical Engineer	Technical Review
Mark Pierce	Electrical Engineer	Generator Analysis
Varis Ratnieks	Engineering Technician	Product Coordinator
Dan Watson	Mechanical Engineer	Turbine Analysis
Rod Wittinger	Mechanical Engineer	Turbine Analysis
PORTLAND DISTRICT, PLANNING AND ENGINEERING DIVISION		
Brian Shenk	Economist	Economic Analysis/Write-Up
Joe Hise	Economist	Economic Write-Up

ICE HARBOR LOCK AND DAM, WA.
POWERHOUSE MAJOR REHABILITATION PROGRAM

LIST OF ACRONYMS/ABBREVIATIONS

BA	Biological Assessment
BI-OP	Biological Opinion
BCE	Baseline Cost Estimate
BOR	Bureau of Reclamation
BPA	Bonneville Power Administration
cfs	Cubic Feet Per Second
CNTG	Contingencies
Corps	U.S. Army Corps of Engineers
CRiSP	Columbia River Salmon Passage Model
CRSMA	Columbia River Salmon Mitigation Analysis
DACS	Data Acquisition and Control System
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FFDRWG	Fish Facility Design Review Work Group
FPDEP	Corps Fish Passage Development and Evaluation Program
FWCA	Fish and Wildlife Coordination Act
FY	Fiscal Year
HALLO	Hydropower Allocation
H	Height

hp	Horsepower
HYSSR	Hydro System Seasonal Regulation Model
k	Kilo (thousands)
kV	Kilovolts (thousand volts)
kW	Kilowatts (thousand watts)
kWh	Kilowatt Hours
lbs	Pounds
MCACES	Micro-Computer Aided Cost Estimating System
MGR	Minimum Gap Runners
MICAA	Machine Insulation Condition Assessment Advisor
mph	Miles Per Hour
msl	Mean Sea Level
MW	Megawatts (million watts)
MWh	Megawatt Hours
NED	National Economic Development
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NMFS	National Marine Fisheries Service
O&M	Operation and Maintenance
OMRR	Operation, Maintenance, Replacement, and Rehabilitation
PDA	Partial Discharge Analyzer
PMP	Project Management Plan
P&S	Plans and Specifications

REMR	Repair, Evaluation, Maintenance, and Rehabilitation
RM	River Mile
rpm	Revolutions Per Minute
SCAN	Survivor Curve Adjustment Number
SCRB	Separable Costs Remaining Benefits
SCT	System Configuration Team
SHPO	State Historic Preservation Office
TDG	Total Dissolved Gas
TVA	Tennessee Valley Authority
USFWS	U.S. Fish and Wildlife Service
W	Width
WRDA	Water Resource Development Act

ICE HARBOR LOCK AND DAM PROJECT, WASHINGTON
POWERHOUSE MAJOR REHABILITATION PROGRAM

PERTINENT DATA

1.	GENERAL:	
	Type of Project	Run-of-river
	Location	
	River	Snake
	River Mile	9.7
	State	Washington
	County	Franklin and Walla Walla
	Drainage Area above dam, Sq. miles	109,000
2.	AUTHORITY:	Public Law 14, 79th Congress, 1st Session approved 2 March 1945.
	Authorized Purposes	Slackwater Navigation, Irrigation, Power Generation, Fish/Wildlife, and Recreation
3.	RESERVOIR:	
	Name	Lake Sacajawea
	Elevation, maximum at dam for spillway design flood	446.4
	Normal operating range, elevation, feet msl	437-440
	Length (to Lower Monumental Dam), miles	31.9
	Surface Area at elevation 440, acres	8,375
	Storage between elevation 437 and 440, acre-feet	24,900
4.	EXISTING PROJECT:	
a.	General:	
	Project length, feet	
	Powerhouse, overall length	671
	Spillway, total length	590
	Navigation lock, overall width	173
	Concrete non-overflow sections, length	
	Navigation lock to spillway	154
	Spillway to powerhouse	40
	Powerhouse to south shore embankment	560
	Earth Embankment, north shore	624
	Total length of dam	2,822
	Deck elevation, feet above mean sea level (msl)	453

b. Spillway:

Type	Ogee, concrete, gravity, gate controlled
Number of bays	10
Crest elevation, feet msl	391
Top of gate in closed position, elevation	442
Deck elevation, feet msl	453
Gate lip elevation at maximum opening, feet msl	436
Control gate:	
Type	Tainter
Size	50' W X 52.9' H
Method of operation	Individual electric hoist
Spillway design flood:	
Peak discharge, cfs	850,000
Pool elevation, feet msl	446.4
Maximum discharge at normal pool elevation 440, cfs	685,000

c. Stilling Basin:

Type	Horizontal apron
Width, perpendicular to flow, feet	590
Length, parallel to flow, feet	168
Floor elevation, feet msl	304

d. Powerhouse:

General	
Number of units	6
In-Service Dates	
Unit 1	18 December 1961
Unit 2	27 February 1962
Unit 3	8 February 1962
Unit 4	28 November 1975
Unit 5	18 November 1975
Unit 6	7 January 1976
Number of stations service units	None
Spacing, feet	
Units 1-5	90
Unit 6	96
Erection and Service Bay length, feet	110

PERTINENT DATA (continued)

Generators	
Manufacturer, Units 1-6	General Electric
Rating (nameplate), kilowatts	
Units 1-3	90,000
Units 4-6	111,000
Rating (115-percent overload), kilowatts	
Units 1-3	103,500
Units 4-6	127,650
Plant capacity, nameplate , kilowatts	603,000
Plant capacity, rated (115-percent overload), kilowatts	693,000
Power factor	0.95
Kilovolt ampere rating	
Units 1-3	94, 737
Units 4-6	116,842
Voltage- Units 1-6, kV	13.8
Rotor Diameter/Height[1], Feet	
Units 1-3	33.75/6.8
Units 4-6	38.88/5.2
Rotor Weight[2], lbs	
Units 1-3	950,000
Units 4-6	851,000
Number of Rotor Poles	
Units 1-3	80
Units 4-6	84
Number of Stator Coils/Bars	
Units 1-3, coils	630
Units 4-6, bars	1440
Transformers- Units 1-6	
Low side winding, kV	13.2
High side winding, kV	
Line to line	115
Line to neutral	67

PERTINENT DATA (continued)

Turbines	
Type	Kaplan, 6-blade
Manufacturers	
Units 1-3	S. Morgan Smith
Units 4-6	Allis Chalmers
Rated Horsepower at 89 foot head	
Units 1-3	143,000
Units 4-6	174,000
Rated hydraulic capacity at 89 foot net head	
Units 1-3, cfs each unit	16,013
Units 4-6, cfs each unit	19,319
Total powerhouse, cfs	106,000
Runner Diameter, inches	
Units 1-3	280
Units 4-6	300
Shaft Diameter, inches	
Units 1-3	47
Units 4-6	50
Shaft Length, inches	
Units 1-3	303.0
Units 4-6	306.5
Revolutions per minute	
Units 1-3	90.0
Units 4-6	85.7
Weight of one blade, lbs.	
Units 1-3	25,000
Units 4-6	28,000
Crane Capabilities, tons	
Intake (joint use with spillway)	85
Bridge	500
Draft tube gantry	35

e. Navigation Lock and Channels:

Type	Single lift
Net clear length, lock chamber, feet	675
Net clear width, lock chamber, feet	86
Minimum water depth over lower sill, feet	16
Upstream gate	
Type	Radial
Height, feet	25

PERTINENT DATA (continued)

Downstream gate	
Type	Vertical lift
Height, feet	91.0
Maximum operating lock lift, feet	105
Normal fill time, minutes	11
Normal empty time, minutes	14
f. Fish Facilities:	
Number of adult fish ladders	2
Exit of ladders, invert elevation, feet msl	431
Entrance of ladders, invert elevation, feet msl	332
Normal fishway flow, forebay to each ladder	
North shore, cfs	74
South shore, cfs	142
Ladder clear width	
North shore, feet	16
South shore, feet	24
Pumps for fish attraction water, number	
North shore	3
South shore	8
Type	Turbine
Discharge, cfs	
North shore	250
South shore	300
Powerhouse collection system	
Number of orifices entrances	12
Length of channel, feet	661
Width of channel, feet	17.5
Downstream Migrants Bypass System	
Juvenile bypass system	1
Hydraulic capacity, cfs	300
Submerged traveling screens, number including one spare	19

[1]Height approximated by scaling.
[2]Includes weight of shaft.

ICE HARBOR LOCK AND DAM, WASHINGTON
POWERHOUSE MAJOR REHABILITATION PROGRAM

1.0. PROJECT AUTHORITY

1.1. Purpose and Scope

This major rehabilitation study was conducted to evaluate the reliability of the Ice Harbor powerhouse, and identify alternatives that will restore the reliability of the plant by returning the units to their original availability and efficiency. This report presents the technical, environmental, and economic analyses with supporting documentation for the purpose of demonstrating the need for major rehabilitation of the powerhouse. The report is submitted to higher authorities to be used as the basis for acquiring construction general funds for implementation. This document conforms to the provisions of Engineering Regulation (ER) 1110-2-1150, *Engineering and Design for Civil Works Projects*, dated 31 March 1994; and ER 1130-2-500, chapter 3, *Project Operations, PARTNERS AND SUPPORT (WORK MANAGEMENT POLICIES)*, dated 27 December 1996.

1.2. Authorization Documentation

The Ice Harbor Project was authorized by Public Law 79-14, 79th Congress, 1st Session; and was approved 2 March 1945. The applicable portion of this act reads as follows:

> "... Snake River, Oregon, Washington, and Idaho: The construction of such dams as are necessary, and open channel improvement for the purposes of providing slackwater navigation and irrigation in accordance with the plan submitted in House Document Numbered 704, Seventy-fifth Congress, with such modifications as do not change the requirement to provide slackwater navigation as the Secretary of War may find advisable after consultation with the Secretary of the Interior and such other agencies as may be concerned; Provided, that surplus electric energy generated at the dams authorized in this item shall be delivered to the Secretary of the Interior for disposition in accordance with existing laws relating to disposition of Power at Bonneville Dam: Provided further, That nothing in this paragraph shall be construed as conferring the power of condemnation of transmission lines;..."

ICE HARBOR LOCK AND DAM, WASHINGTON POWERHOUSE MAJOR REHABILITATION PROGRAM

2.0. PROJECT LOCATION AND DESCRIPTION

2.1. Location

The Ice Harbor Lock and Dam Project is a run-of-river project located on the lower Snake River at River Mile (RM) 9.7, about 10 miles east of Pasco, Washington, in both Walla Walla and Franklin Counties. The Ice Harbor Project is the most downstream project of a series of four projects located along the lower Snake River. The reservoir, designated as Lake Sacajawea, extends upstream approximately 31.9 miles to Lower Monumental Lock and Dam. The general location of the project is shown on figure 2-1.

2.2. Description

Ice Harbor Lock and Dam includes a concrete non-overflow section, powerhouse, spillway, navigation lock, fish ladders, and appurtenant facilities. The project provides for navigation, hydroelectric generation, recreation, and incidental irrigation. The layout of the project, including the powerhouse, is shown on figure 2-2. The reservoir has a normal operating range between elevations 437 and 440 feet above mean sea level (msl). The structure is about 2,822 feet long, and extends about 130 feet above the streambed. The powerplant contains three 90,000-kilowatt (kW) generating units (units 1 through 3) and three 111,000-kW generating units (units 4 through 6). An inside view of the powerhouse is shown in figure 2-3. The project includes two adult fish ladders (located on the north and south shores of the project), and a juvenile fish collection system for downstream migrants (located across the powerhouse, with submerged traveling screens). The spillway portion of the dam is 590 feet in length, with ten radial gates. The navigation lock is a single-lift type, with clear-span dimensions of 86 by 675 feet and a 14-foot minimum depth over the sills. The Ice Harbor Project is a multi-purpose project with authorized purposes of inland navigation, irrigation, power generation, recreation, and fish/ wildlife. One of the primary reasons for the project's construction was to provide a segment of slackwater navigation to the city of Lewiston, Idaho. Various recreation facilities are provided along the shores of Lake Sacajawea. Project construction was initiated in December 1955, and the project began operation in January 1962.

Figure 2-1. Location of Ice Harbor Project

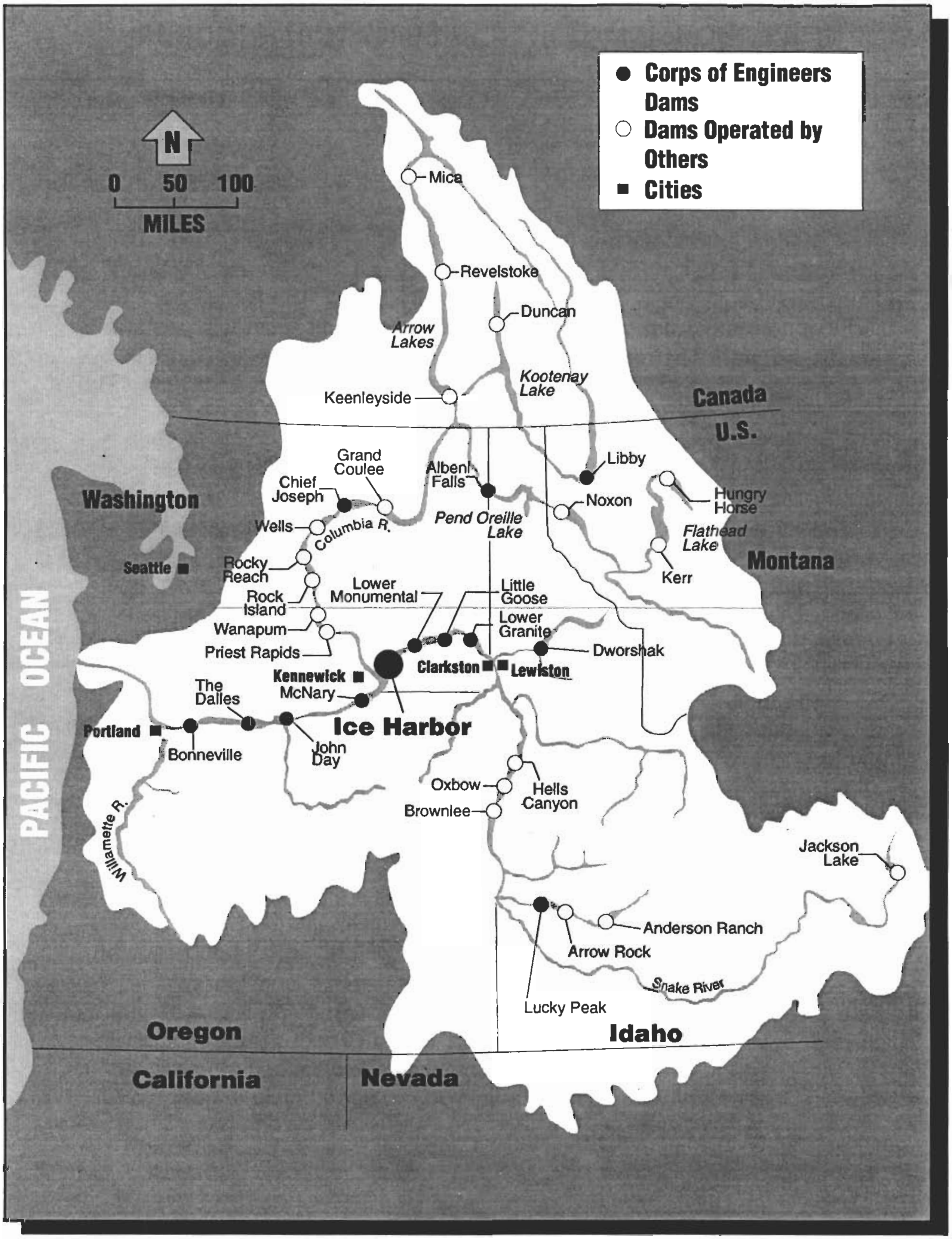
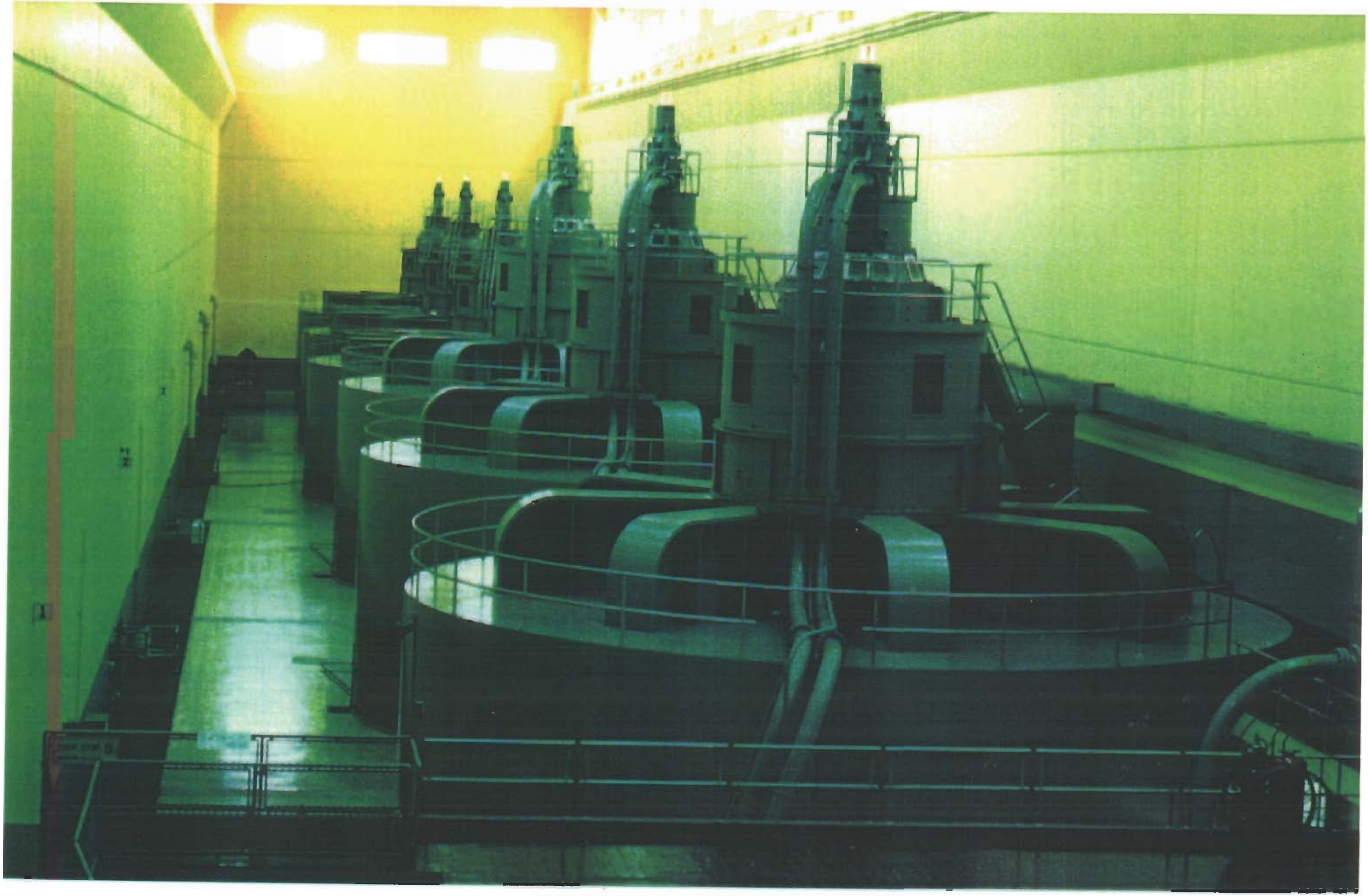


Figure 2-2. Ice Harbor Lock and Dam, WA

Figure 2-3. Ice Harbor Powerhouse Generators



The Ice Harbor powerhouse contributes 5 percent of the total Corps of Engineers output to the Bonneville Power Administrator's transmission system.

demands and stabilize system voltage, some generating units must be started, stopped, and regulated to produce varying amounts of power. This mode of operation is called peaking. The third mode of operation, intermediate load, refers to an operation in between the base load and peaking modes. In this type of operation, some units may be used on a fairly continuous basis to meet base loads while, at other times, additional units may be used for peaking operations.

Small natural gas-fired turbines and hydroturbine-powered generators can rapidly change load and can, therefore, operate in a peaking mode. Hydropower facilities are very effective for peaking operations, but can also be used in base load and intermediate modes of operation when water supplies are adequate and when allowed by other operational criteria. Gas turbines have the highest fuel cost and, therefore, usually operate only a few hours each day. Other energy sources, such as large thermal powerplants (fossil fuel and nuclear), provide primarily base load power. They can, however, also be used for intermediate loads. Hydropower facilities offer many benefits, including the flexibility to respond rapidly, provide more cost-effective load-following capabilities, and have no fuel costs.

The Ice Harbor powerhouse has been operating as a peaking plant for about 35 years, providing hydroelectric power for the Northwest Power Pool Grid. As a result of increasing limitations on water availability and operational flexibility at the project (due to environmental considerations), the peaking capability of the project has been constrained in recent years. However, power generation at the Ice Harbor powerhouse still contributes an average of 2 million megawatt-hours (MWh) annually to the power system in the western United States. The value of this power is about $40 million dollars per year, based on BPA's average wholesale rate of $20 per MWh.

According to the April 1995 *Northwest Regional Forecast of Power Loads and Resources*, sufficient capacity resources are currently available in the Northwest to meet forecasted peak power load requirements, but only through 1998 or 1999. Starting in 1999 to 2000, there will be a shortfall. Since these forecasts incorporate forecasts of expected imports of power from other regions, additional capacity will have to be constructed to offset the loss at Ice Harbor if a rehabilitation program is not implemented. An additional point to consider is that measures now implemented to improve conditions for the downstream migration of salmon may be revised before 2000. These revisions may further reduce the currently-restricted peaking capability of certain hydropower projects. In addition, there are indications that the current projected peaking capability at many hydropower projects, used in the April 1995 *Northwest Regional Forecast*

The Ice Harbor powerhouse is approximately 671 feet in length, and houses six units. The first three 90,000-kW units were installed during the initial project construction. The last three 111,000-kW units were installed at a later time in an effort to reduce spill at the project. The in-service dates for each of the units are shown in table 2-1. There are no station service units at the project, so most of the power used at the project is supplied by unit 1. The rated overload generating capacity of the powerhouse is 693,000 kW, which provides enough electrical energy to supply the needs of a city of approximately 65,000 people.

TABLE 2-1
ICE HARBOR POWERHOUSE UNIT IN-SERVICE DATES

UNIT NUMBER	IN-SERVICE DATE
1	18 December 1961
2	27 February 1962
3	8 February 1962
4	28 November 1975
5	18 November 1975
6	7 January 1976

The Northwest Power Pool Area of the Western Systems Coordinating Council is comprised of 126 public and private utilities and agencies, and markets and delivers 52,000 megawatts (MW) of capacity. The Corps operates and maintains the lower Snake River projects, while Bonneville Power Administration (BPA) transmits and markets the power from those projects. The BPA is responsible for managing the Federal portion of the Northwest power distribution system. Power produced at Ice Harbor is sold by BPA, and revenues repay the costs of the construction and operation of Federal power-generating facilities, as well as the cost of marketing and distributing the power.

2.3. Key Premises

This section presents key premises about the use and operation of the Ice Harbor powerhouse as a link in the Northwest Power Pool Transmission Grid. These premises are factored into models used to calculate the economic effects of deteriorating powerhouse reliability.

There are three different modes of powerhouse turbine-generator unit operation: base load, intermediate load, and peaking. Base load operation occurs when generating units run more or less continuously, under a relatively stable load. However, in all power systems, the demand for power varies from hour to hour, day to day, and season to season. To meet fluctuating power *of Power Loads and Resources,* may not be possible to attain due to the age and condition of some of the key equipment at these plants. It is, therefore, important that the Federal Government maintain capacity at the hydroelectric plants it owns and operates, and that those plants remain capable of responding to fluctuating long-term and short-term regional needs.

The Northwest Power Pool relies on the Corps to maximize its ability to support the power grid during voltage instability occurrences. This means ensuring that turbine-generator units are available for operation, and repair downtime is controlled to reduce impact on the overall power pool.

The risk of brownout or blackout from insufficient total capacity and voltage instability is increased when less reliable equipment is used. The system is most vulnerable to blackout or brownout risks during peak load periods, when all available generation is being used. This is when the consequences, impacts, and losses to power consumers are greatest; and conditions for restoring the system are at their worst. If the current maintenance philosophy of fixing units after they fail is continued, it could lead to a situation where units are unavailable at crucial times. This is counter to the goal of regional power grid stability. Unit availability is also critical to maintaining adequate units to pass water through the powerhouse during the fish migration period, rather than having to spill excessive amounts of water. Higher than necessary spill volumes, due to unit outages, can result in high dissolved gas levels in the river downstream of the powerhouse. This can, in turn, cause higher juvenile fish mortality.

Juvenile fish survival is also related to turbine efficiency. Snake River sockeye salmon have been listed as an endangered species under the Endangered Species Act (ESA), while Snake River spring/summer and fall chinook salmon have been listed as threatened. Snake River basin steelhead have been proposed for listing as threatened. In addition to the environmental impacts, survival of the Columbia and Snake River salmon runs has significant national and international impacts on trade and commerce. Billions of dollars are being spent to increase salmon survival. Higher fingerling survival rates occur when units operate at peak efficiency. The higher the efficiency level, the higher the fish survival rate. The efficiency of the Ice Harbor powerhouse turbines has deteriorated 2.4 percent in units 1 through 3 and 1.1 percent in units 4 through 6 since original installation. Turbine blade replacement would improve the original efficiency. Impacts to fish are considered separately in this report (see appendix D, *Environmental Documentation*), and non-monetary fishery benefits will occur in addition to the power benefits of the alternatives developed.

ICE HARBOR LOCK AND DAM, WASHINGTON
POWERHOUSE MAJOR REHABILITATION PROGRAM

3.0. IDENTIFICATION OF COMPONENTS AND PROBLEMS

3.1. Problem Summary

The Ice Harbor powerhouse has been operated as a peaking plant for nearly 35 years. The peaking operation results in an average of 180 start-stops per unit each year. A base loaded plant would average five to ten start-stops per unit each year. Additional starts-stops are required in the interest of fish survival, and this requires the units to operate within the highest 1-percent efficiency of the turbines in order to minimize fish mortality. On units 1 through 6, the cumulative effects of age and start-stop are showing up as a pattern of generator and turbine failures, thus indicating a declining reliability.

Turbine blade cracking has been the number one problem on units 1 through 3 since they were put into service in 1962. On two occasions, large pieces of turbine blades broke off and had to be reattached. The most recent occurrence was on unit 3 in 1995. Annual and bi-annual inspection programs have been in place to monitor and repair the blade cracking. Stator winding failures are the major problem on units 4 through 6. The generator on unit 4 failed in 1993, followed by a unit 5 failure in 1994. Unit 5 is still out of service at this time.

Problems can be expected to continue, and generating unit failures can be expected to increase, unless the powerhouse is rehabilitated. Increased outages will cause increased operation and maintenance costs, decreased system reliability, and increased energy production costs for the western United States power system. In addition, turbine efficiency has gradually declined with age, and reduced the total amount of energy the powerhouse is capable of producing.

Columbia and Snake River projects are being required to operate in a climate of increasing demands for energy and competing environmental concerns. Western Oregon and Washington, primarily in the Portland and Puget Sound areas, have experienced significant growth in the last decade. This growth, combined with limitations in the hydropower system caused by environmental concerns, has produced load balance problems during certain times of the year. The 1993 closure of the 1,100-MW Trojan nuclear power plant, located near Portland, Oregon, makes dependable power from Columbia and Snake River hydroelectric projects even more critical. Continued deterioration of powerhouse reliability and efficiency, combined with increasing power needs, could have an impact on the cost and reliability of power generated in the Pacific Northwest.

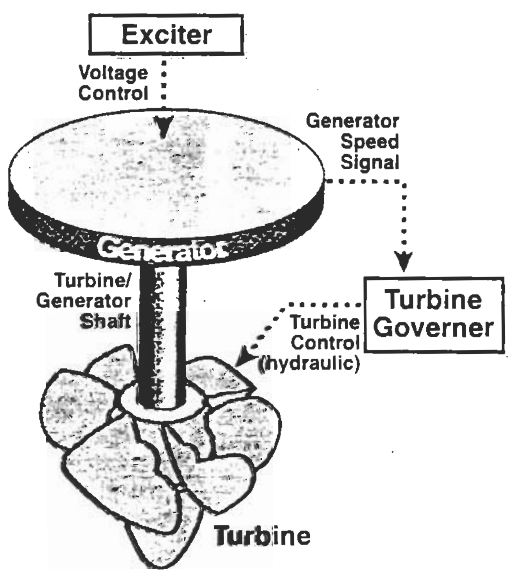
Declining turbine efficiency can also contribute to increased mortality in juvenile fish passing through the turbines, as discussed in appendix D, *Environmental Documentation*, paragraph 3.2. Declining fish populations is an on-going challenge in the Columbia River system. Already, programs to restore Columbia and Snake River fish runs have resulted in reduced energy production at the Ice Harbor Project , as well as other projects on the lower Snake and Columbia Rivers.

Initiating and completing the rehabilitation process required to restore powerhouse reliability may take about 8.5 years to accomplish. It is urgent that the Corps begin this process now.

3.2. Powerhouse Components

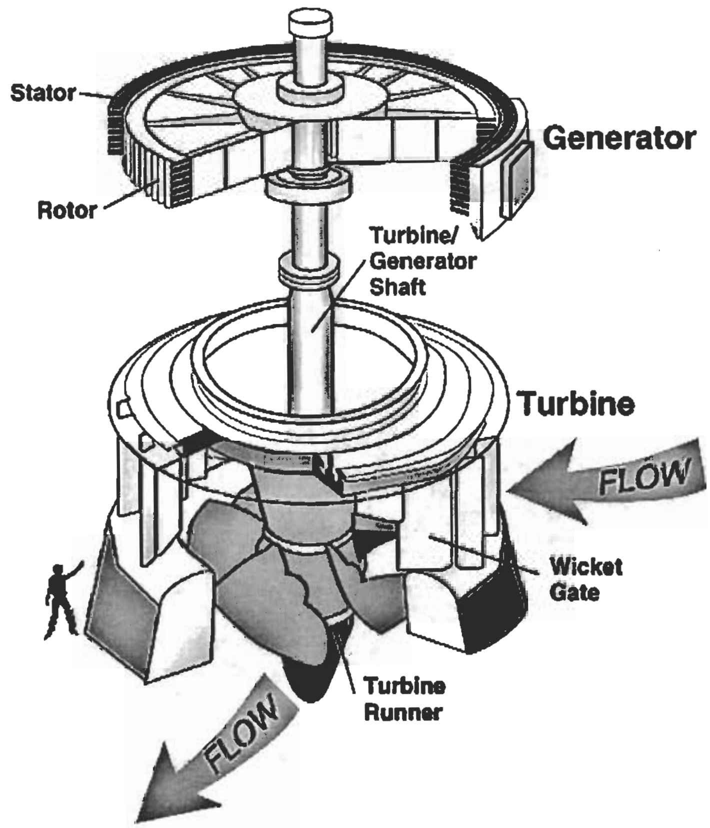
The Ice Harbor powerhouse has six main turbine-generator units. Each turbine-generator unit consists of the following major functional components, which will be addressed in this rehabilitation: the turbine, the governor, the generator, and the generator excitation system (see figure 3-1). The major rotating parts in each unit are the turbine runner, the generator rotor, and the shaft that connects them (see figure 3-2).

Figure 3-1
Major Functional Components



The major rotating parts in each unit are the turbine runner (blades, hub, and cone), the generator rotor, and the shaft that connects them.

Figure 3-2
Turbine, Shaft, and Generator



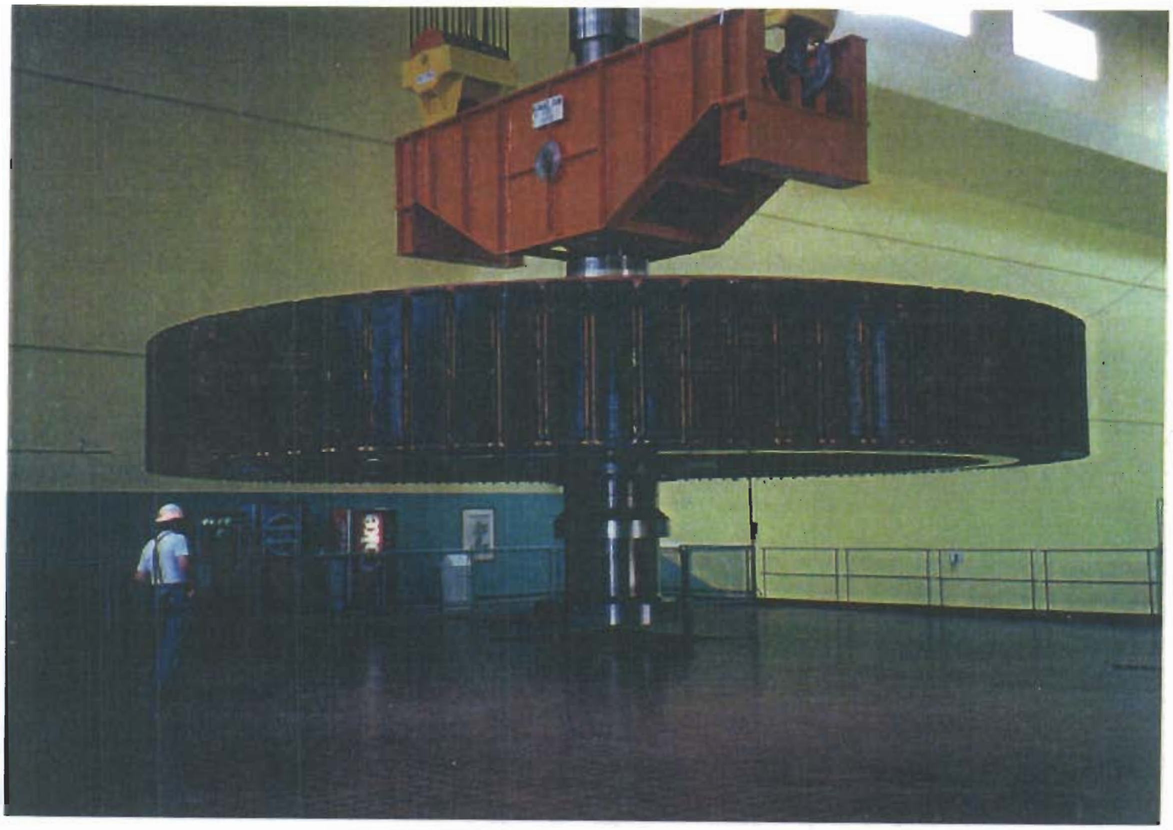
3.3. Generator and Exciter

The generators in the Ice Harbor powerhouse convert rotating mechanical power from the turbines into electrical power. Each generator has two main parts: a rotating part called the rotor and a stationary part called the stator (see figure 3-2).

Units 1 through 3 have a rotor that is a massive disk almost 7 feet high and about 34 feet in diameter. Around the edge of the rotor is a row of electromagnets, referred to as poles, that generate an intense magnetic field. The rotor is connected directly to the turbine by a shaft 47 inches in diameter and over 25 feet long. As the rotor is driven by the turbine and turns, at 90 revolutions per minute (rpm), the electromagnets (poles) on its outer edge move at about 109 miles per hour (mph).

The rotors in units 4 through 6 are almost 39 feet in diameter, about 5 feet high, and rotate at 85.7 rpm. The outer edge of the rotor travels at approximately 119 mph. A photograph of a rotor from unit 5 is shown in figure 3-3.

Figure 3-3
Generator Rotor From Unit 5



Generator rotor from unit 5 awaiting completion of repairs of the stator.

The stator surrounds the rotor with iron laminations, and is wound with a series of coils (called the "stator winding") made of heavy copper bars. The electromagnets (poles) on the outer edge of the turning rotor pass close to the stator coils, and the moving magnetic field generates high voltage electricity in the stator. The Ice Harbor generators produce power at 13,500 volts.

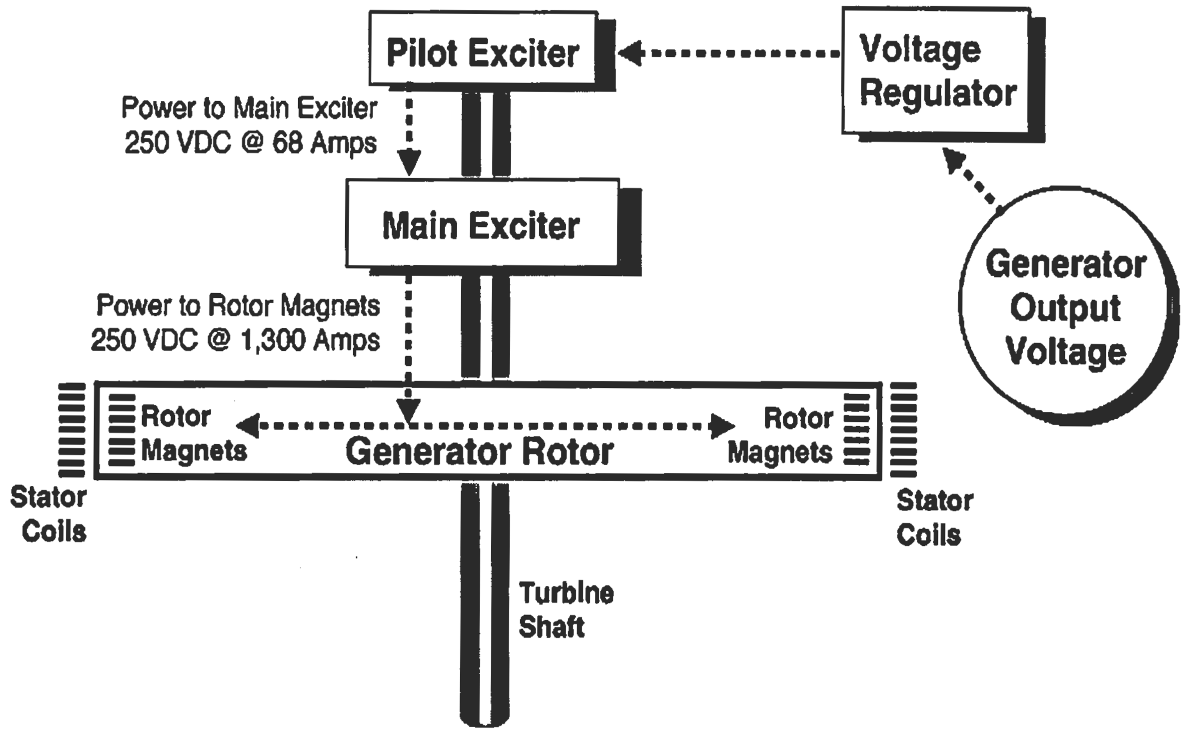
The generators in units 1 through 3 seem to be in average condition for their age. There has been only one stator winding failure in this group, and that failure was caused by mechanical damage from a loose object. Although the condition of these windings is average, their age (35 years) suggests that reliability will deteriorate in the near future, based on industry-wide statistical data of similar equipment.

The generators in units 4 through 6, while only about 21 years old, have had a more troubling failure history for their. A definitive reason for the premature failures has not yet been determined. In May 1993, unit 4 suffered an insulation failure, resulting in a forced unit shutdown. The failure was due to a breakdown of the winding insulation and shorting-out of the stator coils. Unit 5 experienced similar problems in May 1994. There were subsequent failures in May and December 1996, as part of the repair and testing process of unit 5. All three units of this family of generators have had some degree of stator bar abrasion from loose bar lashings and blocking, which may have caused the unit 5 failure. Although all lashing will be repaired, the extent of damage to stator bars is unknown. Section 4 contains more details of the failures and repairs.

All six generators are still operating with their original windings. Repair, Evaluation, Maintenance, and Rehabilitation (REMR) tests have been performed on the original windings. Data for these tests is shown in appendix F, *Generator Reliability Analysis*. Failures in units 4 through 6 have been occurring at an increasing rate, and it is expected that this will continue. The possible consequences of a generator failure include lost ability to generate power, higher cost of buying power elsewhere, and repairs that may take anywhere from 2 weeks to 3 years to complete, depending on the type and magnitude of the failure. An outage also reduces the hydraulic capacity of the powerplant, which can be critical during the months of March through August to control dissolved gases downstream of the project. The consequences for a planned rehabilitation are much less than for the failure of a unit.

The generator excitation system provides power to the electromagnets on the generator rotor. By controlling the strength of the rotor's magnetic field, the excitation system regulates the output voltage of the generator. The exciter is composed of a small generator, mounted at the top of the main generator shaft, and a voltage regulator. The voltage regulator maintains proper generator output voltage by controlling exciter operations (see figure 3-4). The exciter generates power for the electromagnets on the main generator rotor.

Figure 3-4
Generator Excitation System



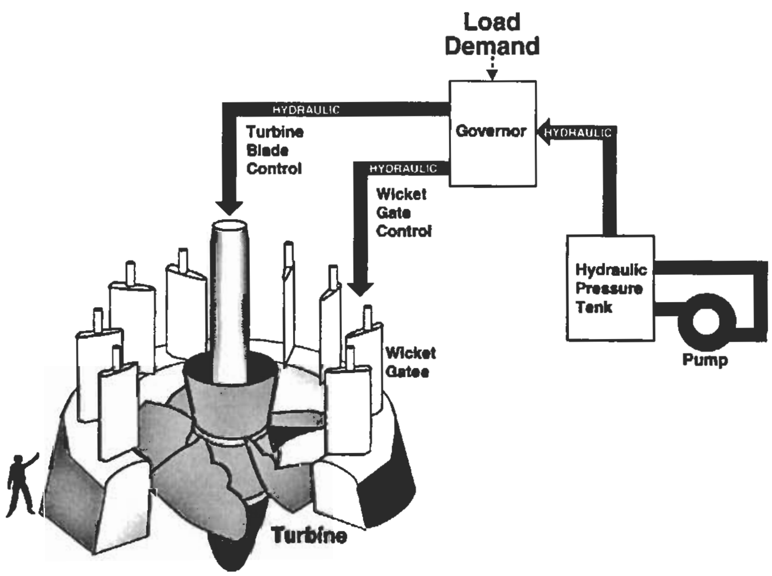
The excitation system controls generator output.

Ice Harbor units 1 through 6 have the old rotating-type exciters typical of most large hydroelectric generators installed prior to 1975. Units 1 through 3 have had no major failures. However, the exciters are 35 years old, and they are showing the increase in routine maintenance typical of aging equipment. Since 1980, there have been four failures of the Ice Harbor unit 4 through 6 exciters due to commutator winding failures. Unit 6 failed in 1980, units 4 and 6 failed in 1992, and unit 5 failed in 1996. Each repair of a failure has had an average cost of $20,000. A typical exciter winding failure puts a unit out of service from 4 to 8 weeks. Repair necessitates disassembling the exciter, shipping it offsite for repair, and reassembling the exciter.

3.4. Turbine and Governor

The hydraulic turbines at Ice Harbor are a standard design known as the Kaplan type. They look like huge six-bladed fans. Each cast-steel blade weighs about 25,000 pounds (lbs) for units 1 through 3, and about 28,000 lbs for units 4 through 6. The turbines on units 1 through 3 turn at a speed of 90 rpm, and are designed to deliver 143,000 horsepower (hp) when operating at a head of 89 feet. Turbines on units 4 through 6 operate at 85.7 rpm, and deliver 174,000 hp at a head of 89 feet. The turbine blades are set into a central hub. The angle of the blades can be changed while the turbine is running. Each turbine has its own governor control system, which responds to system load demand changes (see figure 3-5).

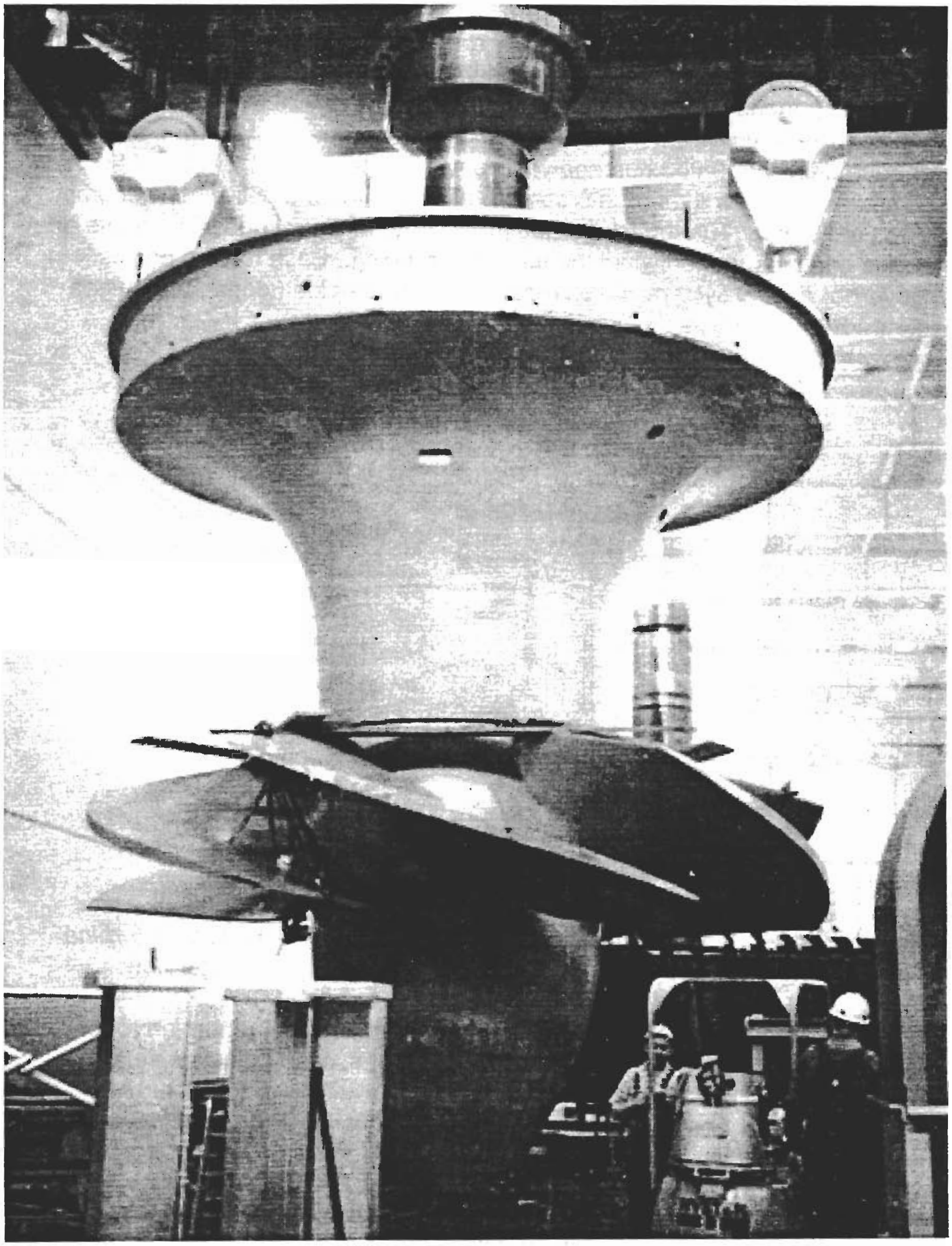
Figure 3-5. Hydraulic Governor Functions



When the system power demands change, the governor adjusts both turbine blade angle and the opening of wicket gates that control water flow.

The governor controls a hydraulic system that adjusts the turbine to most efficiently provide the required power. The governor system adjusts a set of guide vanes (called wicket gates) that control the flow of water to the turbine and, therefore, power output. The governor also adjusts the turbine blade angle for maximum efficiency. Each turbine is connected directly to a generator through a vertical shaft. As water moves past the turbine blades, it forces the turbine to turn, thus providing the power the generator converts into electricity. Figure 3-6 shows a turbine runner from units 1 through 3.

Figure 3-6. Turbine Runner Assembly



The turbine has six variable-angle blades, each weighing approximately 25,000 pounds. The photo shows a turbine runner for units 1-3 during initial assembly prior to installation.

The turbine efficiencies of units 1 through 3 and units 4 through 6 have deteriorated by about 2.4 and 1.1 percent, respectively, since they were first put into service. The primary cause of reduced turbine efficiency is wear and tear and roughened wetted surfaces. Smoother wetted surfaces will increase efficiency, and will also enhance fish survival.

Figures 3-7 and 3-8 illustrate and compare the test results representative of units 1 through 3 and units 4 through 6, respectively. Note that figures 3-7 and 3-8 depict overall unit efficiency, and reflect both turbine and generator losses. However, efficiency deterioration between 1962 and 1994 is essentially attributable to the turbines.

Figure 3-7

Comparison of 1962 (Unit 2) and 1994 (Unit 3) Turbine Index Tests at 98 Feet Net Head

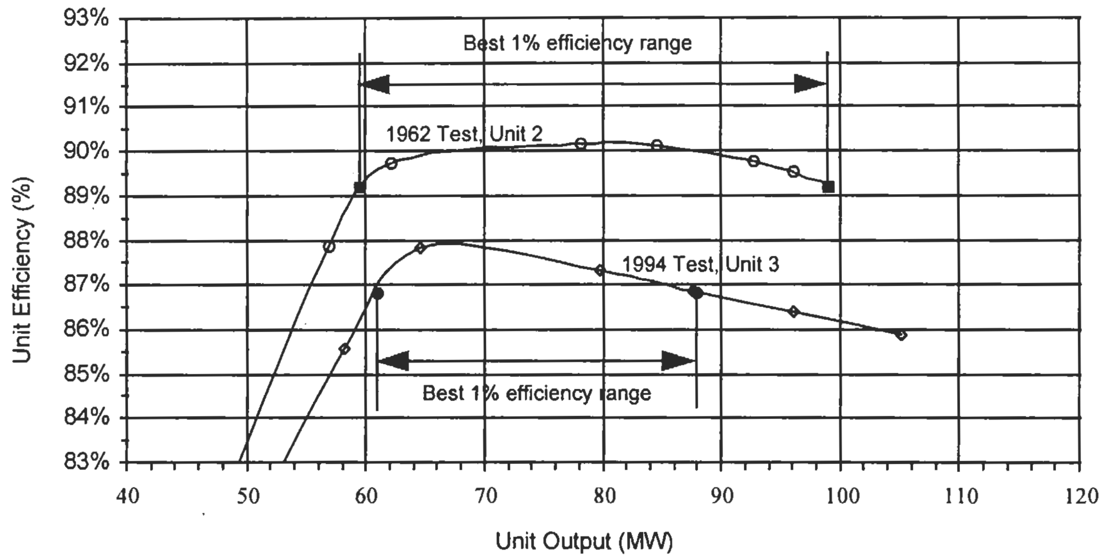
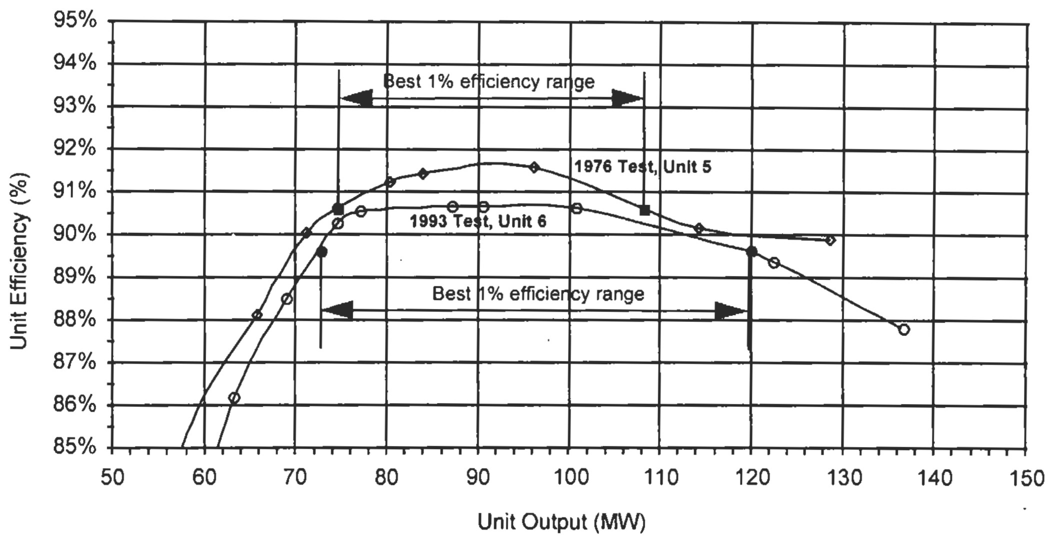


Figure 3-8.
Comparison of 1976 (Unit 5) and 1993 (Unit 6) Turbine Index Tests at 98 Feet Net Head



As shown in figure 3-7, the upper curve (1962 Index test on unit 2) shows a maximum unit efficiency of about 90.2 percent. Because of concerns about endangered fish, the units must be operated to within 1 percent of maximum efficiency during the fish passage period. (There is a general consensus among the fishery community that the requirement to operate within the maximum 1-percent efficiency was arbitrary and not based on scientific-based data.) The operating band for the 1962 curve allows generating between 59.5 MW and 99.0 MW, a fairly broad range that allows considerable flexibility in adjusting to system load changes.

The lower curve (1994 test on unit 3) shows that maximum unit efficiency has dropped to approximately 87.9 percent. Also, the shape of the performance curve is more peaked and, therefore, the allowable operating range is narrowed (61.0 MW to 88.0 MW). With this narrower range, the amount of generation capacity available has been reduced from 99.0 MW to 88 MW per unit, a total reduction of 33 MW for units 1 through 3 at the rated head.

The narrower operating range for units 1 through 3 also necessitates starting and stopping units more often to meet fluctuating system load changes. These frequent start-stops cause additional wear and tear on the equipment. Repeated heating and cooling (thermal cycling) of the generator stator shortens service life. It results in the breakdown of generator insulation, and increases the chance of coil failures. These are the types of failures occurring at Ice Harbor.

Blade cracking on units 1 through 3 has been a major concern to date. One blade was lost from unit 2 in 1974, and 2/3 of a blade was lost from unit 3 in 1995. Unit 2 has required yearly maintenance, by project personnel, to repair the blade cracks. The main reason for the cracking is the constant starting and stopping of the units, and the inferior fatigue and fracture material properties, when compared to the modern materials used today. The maintenance of unit 3 for blade cracks will most likely have to be increased since the loss of its blade. Oil leaks past the blade packing have been a continuous problem, even after replacement of the blade packing.

The turbines on units 4 through 6 have been maintained in fair condition overall. Full cavitation repair was performed in Fiscal Year 1991/1992. Oil leaks have occurred in the past, but reducing the oil leakage by replacement of the blade packing has been successful.

The governors of units 1 through 3 have had no major rework, only normal operation and maintenance. They contain many precision moving parts, are badly worn, and are about 35 years old. The many linkage joints and other wearing parts are loose and worn, which causes a lack of precision in unit operation. The governors on units 4 through 6 are about 21 years old, and have had no major failures.

3.5. Transformers

There is one transformer per unit (units 1 through 6) at the Ice Harbor powerhouse. Transformers step-up the voltage generated at 13.8 kilovolts (kV) to the line voltage of 115 kV.

A transformer transfers power by electromagnetic induction between circuits at the same frequency, but at changed values of voltage and current, thus serving a step-up function. The transformer has no functional moving parts, but works based on the motion between a magnetic field and the electrical conductors.

A power transformer consists of three essential parts: the core, the primary winding, and the secondary winding. The core, a stack of steel laminations with a clamping structure, is the part of the transformer where a magnetic field oscillates. The primary and secondary windings include clamping arrangements. The two separated windings are insulated from each other, and are wound on the core.

To date, no transformer failures have occurred at Ice Harbor. However, a transformer winding's normal life is about 40 years, with some lasting 50 years and sometimes longer. The transformers for units 1 through 3 have been in operation for about 35 years, and are fast approaching the end of their normal service life.

4.0. PROJECT HISTORY AND SUMMARY OF CORRECTIVE MEASURES

This section summarizes the current condition and major repair history of the turbine-generator units, including episodes of service disruption and emergency repairs. It lists repair costs and other consequences of outages. Corrective measures considered for each component are summarized, as are the powerhouse operation and maintenance (O&M) repair costs and system service levels. The appendices contain supporting data for this section.

4.1. Generator and Exciter

Generator stator coils fail either from external causes or when the insulation on the windings deteriorates. External causes include voltage spikes from the transmission system and damage from foreign objects in the generator. Insulation deteriorates because of unavoidable factors: heat, vibration, age, and expansion and contraction caused by thermal cycling. All of the stator coil failures at Ice Harbor have been due to insulation deterioration, except for the latest failure on unit 5 (in December 1996), which was caused by a foreign object in the unit. When a stator coil fails, the high voltage generated in the stator coil arcs either to the surrounding framework or internally between turns of the coil, thus causing damage to the coils. The generating unit is shut down by protective relays, and must be repaired before it can be restarted.

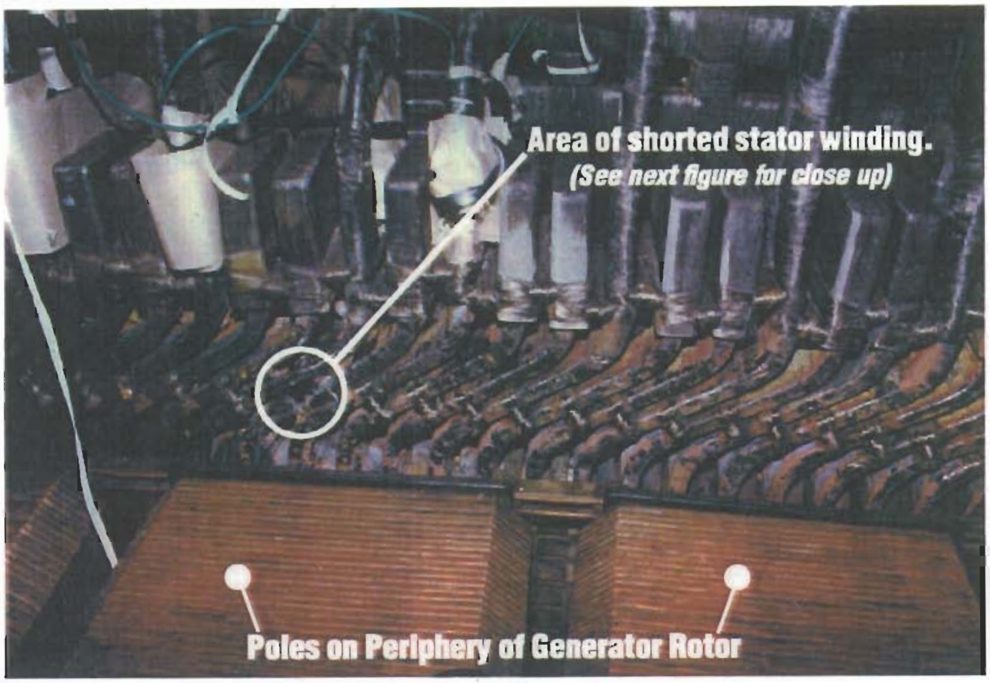
Generator failure in units 4 through 6 has developed into a major problem in the last 3 years. The units' non-routine repair history, since 1993, is tabulated in table 4-1 (through September 1996). Substantial costs in Fiscal Year 1997 were not available at the time the data was compiled. Stator winding failures are becoming more frequent and severe. Unit 5 has been out of service since May 1994. Two subsequent attempts were made to return the unit to service, but with no success. A stator rewind is required when coil damage is so extensive that repair is not possible or economically viable. For a more detailed explanation of cost breakdowns, as well as the specific work done on each unit, see appendix E, *Operation and Maintenance History*, and appendix F, *Generator Reliability Analysis.*

Table 4-1 Generator Failure and Repair Records Units 4 through 6[1]				
Unit	**Date of Outage**	**Date Returned to Service**	**Remarks**	**1996 Costs**
4	25 June 1993	18 October 1993	Stator Winding Ground	$52,703
	26 October 1995	31 October 1995	Water on Stator	$837
	16 January 1996	22 February 1996	PDA Couplers	$15,701
	16 January 1996	21 February 1996	Stator Rewinding Reinforcement	$64,885
5	15 May 1994	Present	Two Stator Failures, 1 Rotor Failure	$1,377,133
6	10 January 1995	10 February 1995	Thrust Bearing	$86,103
	4 September 1996	30 September 1996	Stator Winding Reinforcement	$65,000

[1]Includes cost through September 1996. Does not include problems with governors, exciters, turbines, and miscellaneous problems under 8 hours.

Figure 4-1 shows a stator winding failure on unit 5, which is typical for units 4 through 6. A close-up view of the shorted stator winding is shown on figure 4-2. Note the blown-out section of the stator coil, which must be replaced. Figure 4-3 shows the typical worn-through area of the stator insulation prior to shorting and failure. Also note the white powder on the coils, which is the result of abrasion from movement between loose lashings (ties that connect coils together for stability purposes as pointed out in figure 4-3) and insulated coils as a result of vibration and thermal cycling.

Figure 4-1. Stator Winding Failure, Unit 5 (November 1995)



In May 1994, a stator coil on unit 5 shorted out and failed.
A close-up view of the circled area is shown on the following figure.

Figure 4-2. Stator Winding Failure Close-Up , Unit 5 (November 1995)

Close-up view of the failed stator coil as shown on the previous figure.

Figure 4-3
Exposed Stator Winding, Unit 5 (January 1996)

*Typical worn-through stator insulation exposing the coil.
Note the white powder resulting from abrasion of epoxy insulation.*

Under the Without-Project Condition, also referred to as the base condition, when an individual stator coil fails, a number of courses can be taken depending on the extent of damage determined by diagnostic testing. Current practice is to leave the rotor in place when possible, and repair the damaged coil(s). This can be accomplished only if the damage to the iron lamination is at, or near, the surface. Access to the coils can be gained by the removal of strategic rotor poles opposite the shorted coil. This practice, however, provides only limited access. If numerous coils must be replaced, or if damage to the iron lamination is much below the surface, removal of the rotor is required in order to allow unstacking of the iron laminations for repair and replacement.

Repair of the coils is based on diagnostic testing. This testing can identify immediate problems, but cannot evaluate the condition or expected life of the coils that were not repaired or replaced. The unrepaired coils would likely be the most susceptible for future failures.

Shutting down a unit, finding failed coil(s), and making necessary repairs can range up to 1200 manhours. The average downtime is 120 days, with a maximum of 150 days. A drawback to waiting for a failure is that an unexpected major failure may disrupt power grid capacity at a peak load time, block other maintenance activities, prevent the ability to meet power generation needs, and cause damage to additional equipment (in good working condition), such as damage to rotor parts or bearings. It takes anywhere from 24 to 36 months to justify, specify, procure, and install a new winding under normal procedures.

Possible courses of action for dealing with the stator windings as they approach the end of their operating life include total stator winding replacement after failure (continue with present practice as in base condition), or total stator winding replacement during a scheduled outage (planned rehabilitation). Enhanced maintenance was considered, but was determined not to be a feasible option for generators because it is not effective in extending the life of the remaining coils.

- Spare Winding: One measure consists of having a spare winding at the site to use when it is not reasonable to repair a unit after a major stator failure. Holding a spare winding in reserve would reduce the long downtime associated with a major failure and, when evaluated relative to the base condition, this measure shows significant benefits. The Ice Harbor Project does not have a spares program because of limited O&M funds.

- Total Stator Winding Replacement During Scheduled Outage: Another measure would be total stator winding replacement during a scheduled outage. Replacing deteriorating stator windings on a planned schedule allows appropriate time for detailed design, orderly funding, and installation, with the least impact on power generation. In addition, if rewinding is performed in conjunction with turbine repairs, some of the unit disassembly and reassembly expenses and outage times can be shared between the activities. Planned, scheduled rewinds will generally provide the most cost-effective means to maintain the reliability of old generators. The downtime for rewinding a generator only, and/or a combination generator and turbine, is about 4 months and 11 months, respectively. The scheduled downtime will have less negative impact. Rewinding will result in more reliable units with less likelihood of unpredictable future failures.

The winding failure problem would best be addressed by scheduled rewinds on the unit 4 through 6 generators. Without rehabilitation, stator reliability will continue to deteriorate, causing more unplanned outages and repairs.

The exciters on units 1 through 6 are the old rotating type, with electro-mechanical voltage regulators. This technology has since been replaced by solid-state equipment, because of high maintenance, slow and inconsistent performance, and high energy losses. Similar exciters at The Dalles, Bonneville, and Lookout Point projects (in the Portland District) have experienced multiple failures. The Ice Harbor exciters are showing the same failure pattern, and will need to be replaced soon.

4.2. Turbine and Governor

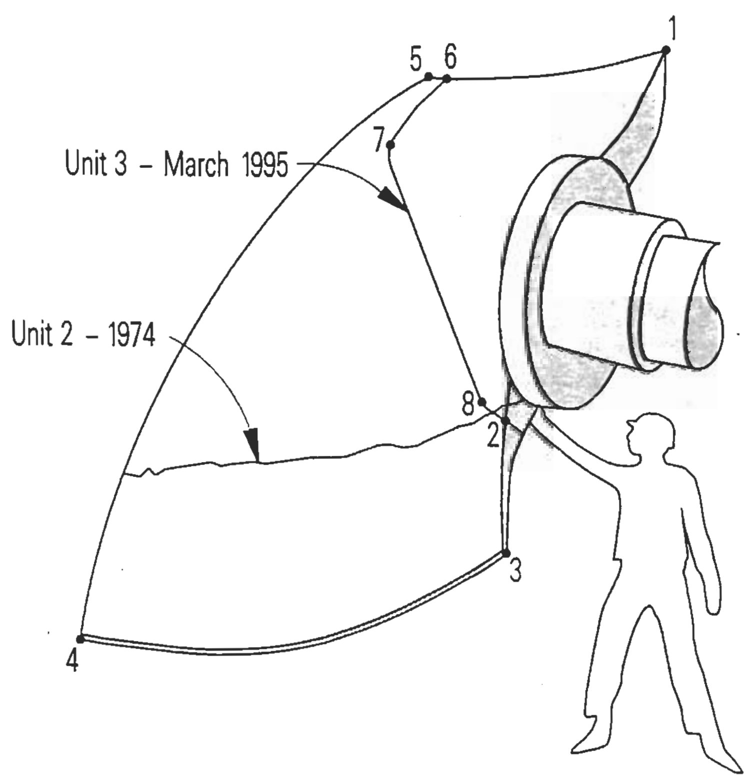
The main turbine-related problems at the Ice Harbor Project are associated with blade cracking and breakage on units 2 and 3, and a significant decrease in turbine efficiency on units 1 through 3. Although there have been minor problems with blade cracking on units 4 through 6, project personnel have been able to repair and control cracking under the routine O&M program. The following paragraphs contain a more in-depth discussion of the turbine and governor problems.

The turbines on units 1 through 3 have been in operation for about 35 years. As a result of cyclic loading on the turbine blades, resulting from starts and stops imposed by both fish and power-related requirements, the turbine blades on units 2 and 3 have reached the material endurance limit. This has resulted in fatigue failure of the blade material, and has caused cracking. The frequency of cyclic loading has increased significantly over the last decade, which promotes and accelerates blade failure. Since unit 1 is adjacent to the fish facility on the south shore, it is normally kept in constant operation to assure attraction water for the fish ladder. Consequently, the turbine blades on unit 1 are not subjected to starting and stopping cycles, and blade cracking has not yet become a significant problem.

In 1974, a crack on one blade of unit 2 propagated to the point that a large portion of one turbine blade broke off and fell into the draft tube. The piece was reattached between November 1974 and January 1975. In early 1995, unit 3 lost about two-thirds of one blade, causing the unit to be out of service from April to December 1995. Since the unit 2 blade break, project personnel have had to dewater unit 2 on a regular basis to inspect and, invariably, to repair the blades. Generally, the unit has been down for 2 to 7 months, depending on the inspection and severity of the damage. The cracks are ground out and filled with weld metal. However, the repair of the cracks does not restore the areas to the original undamaged condition. The weld repair of the cracks results in residual stresses that unfavorably change the material characteristics. Cracks often reoccur in, or near, the weld repair areas. The welding required for crack repair also creates new problems. The welding forms brittle areas in the blade that are susceptible to further cracking. In addition, welding changes the blade contour. These contour changes make the turbine less efficient, decreasing energy generation at the project. The decrease in turbine efficiency also increases juvenile fish mortality (see appendix D, *Environmental Documentation*). The units at Rocky Reach Dam (Chelan County, Washington) are virtually identical (except for the direction of rotation) to Ice Harbor units 1 through 3. They are currently being replaced, in large part because of the same blade cracking problems found at Ice Harbor.

Figure 4-4 shows the approximate location of the turbine blade breaks on units 2 and 3. The edges of the blades, defined by numbers 1, 5, 4, and 3 are typically lined with stainless steel to resist cavitation.

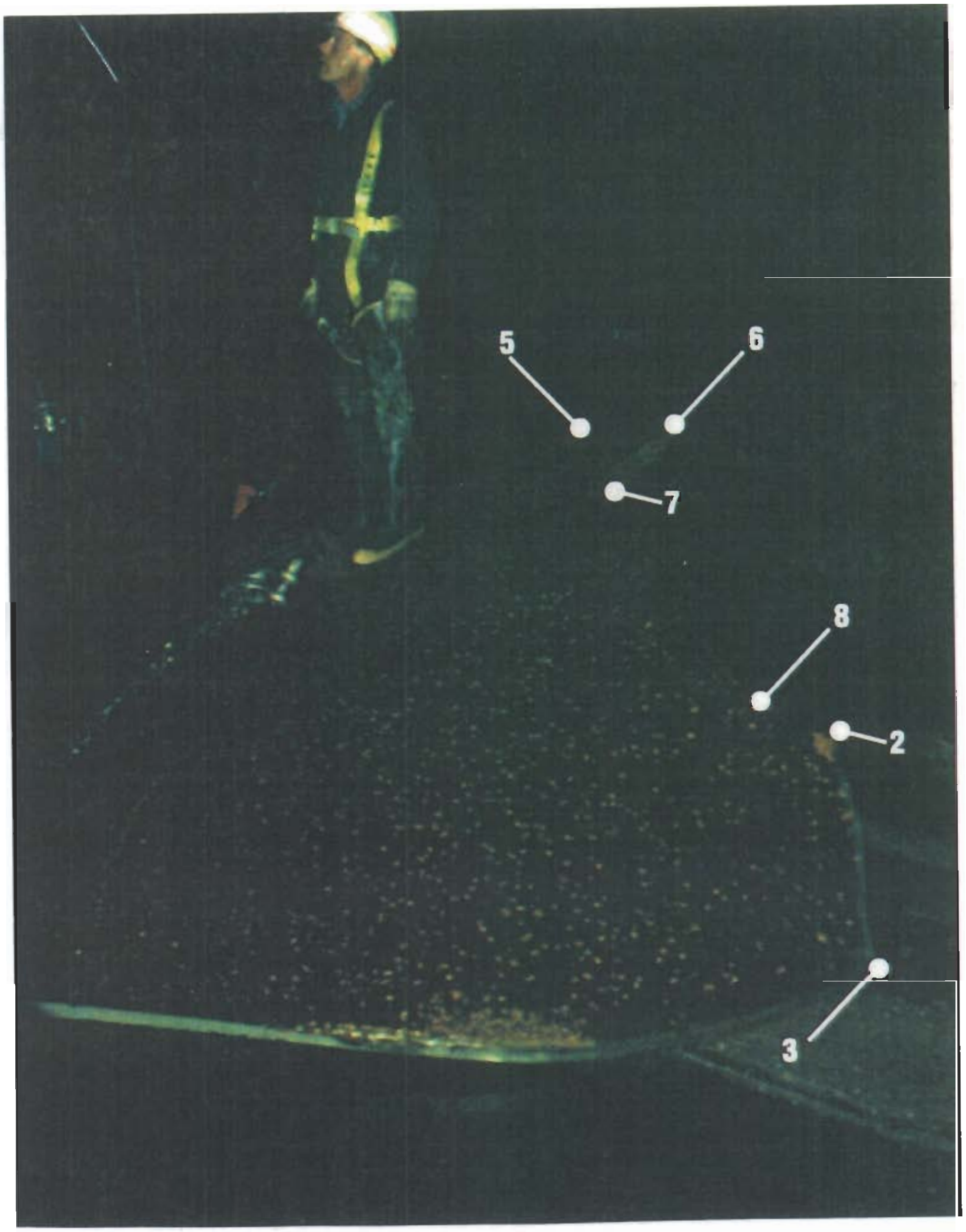
Figure 4-4
Location Of Turbine Blade Breaks



Turbine blade segments have broken off on two different occasions. The numbers (1 through 8) are used for orientation purposes in figures 4-5 and 4-6, relative to unit 3.

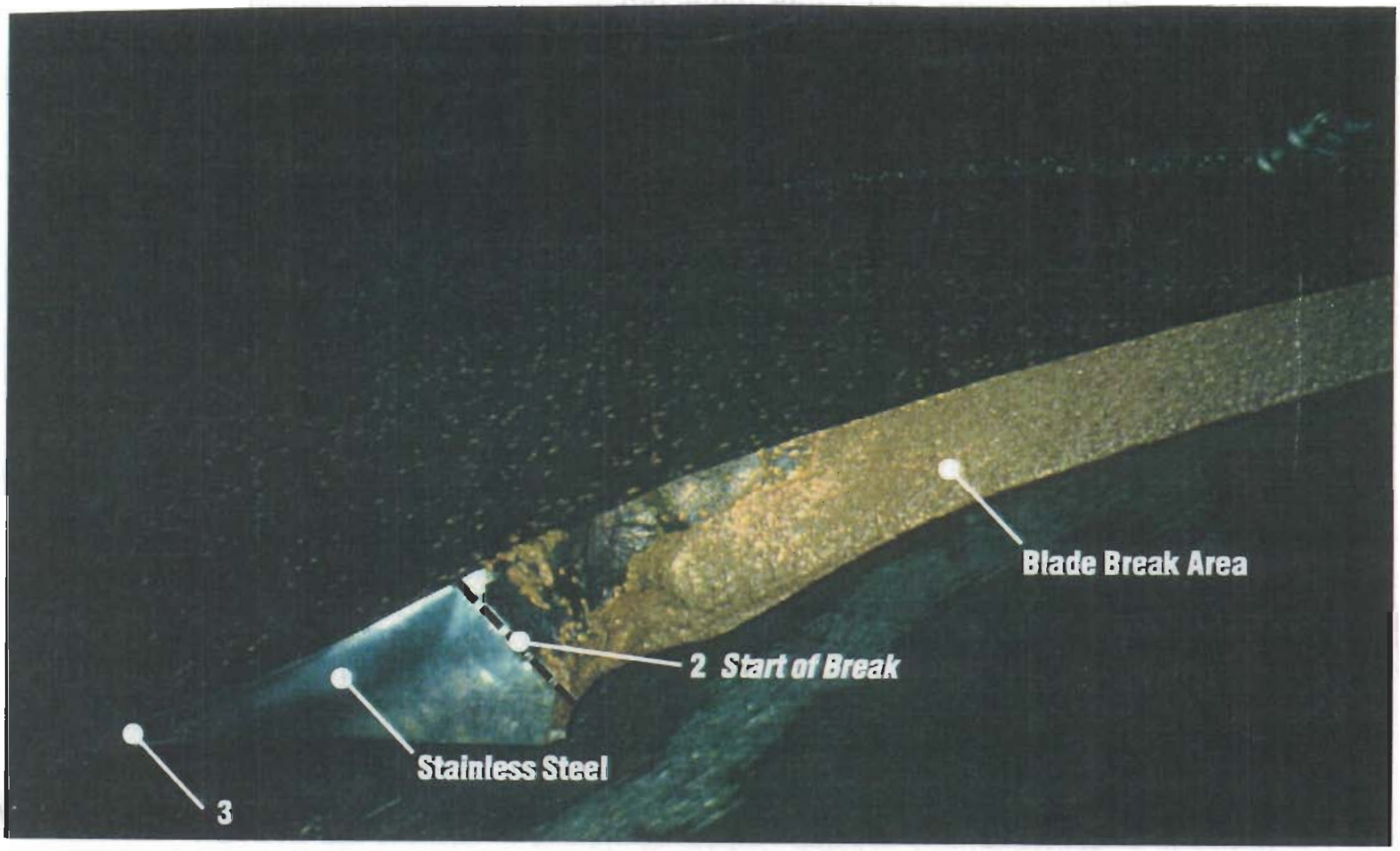
A photograph of the broken piece of blade from unit 3 is shown in figure 4-5 in the process of being prepared for reattachment. Figure 4-6 is a partial view of the broken edge of the blade, viewed as shown, from figure 4-5.

Figure 4-5
Broken Blade From Unit 3, July 1995



View of broken piece of blade. For orientation, refer to numbers 1 through 8 on figure 4-4. Figure 4-6 is a partial view of the broken section of blade, represented by the line defined by numbers 2, 8, 7, and 6.

Figure 4-6. View of Broken Edge of Blade From Unit 3, July 1995



View looking into the broken edge of the blade, as shown on figure 4-5. The broken edge of the blade is the brown area. The bright portion in the lower left is the stainless steel edge between numbers 2 and 3. The dark areas along the break (to the immediate right of the stainless steel) are a previously welded area that has failed.

A more in-depth discussion of blade breakage and causes is included in appendix H, *Governor Sensitivity Analysis, and Turbine Engineering and Reliability Analysis.*

An aggressive, labor-intensive program of blade inspections and crack repairs is now in place since the recent blade breakage. Turbines on units 1 through 3 are scheduled to be dewatered and inspected annually during the months of September through November. However, due to a growing workload and lack of resources, it may be impossible to meet this schedule. Realistically, the inspections will probably be held every 2 years. During bi-annual inspections, new fatigue cracks have been found on five of the six blades in both units 2 and 3.

The turbines are clearly showing the effects of usage, and this trend can be expected to continue. The crack repair program is an interim solution that will be difficult to sustain. The inspections and repair are accomplished inside the dark turbine water passage under difficult conditions, as can be seen on figure 4-5. Grinding out and welding the cracks in the blade sections (which can be up to 8 inches thick) is time-consuming and labor-intensive. The intensified turbine blade inspection and repair effort subtracts directly from maintenance on other critical powerhouse components, and the resulting deferral of scheduled maintenance is contributing to the deterioration of other project equipment. Examples include deferred overhauls of all six units, including cavitation repair, turbine blade packing replacement (to reduce oil leakage), delays or cancellation of annual inspections and repairs of units, and completing only about 50 percent of regularly-scheduled preventive maintenance on all other project equipment.

Units 1 through 3 have experienced a significant decrease in overall unit efficiency (includes both turbine and generator efficiency) and unit output. Unit efficiency is a measure of how well a given flow of water is converted to electrical energy. Index tests performed in 1994 on Ice Harbor's unit 3 documented a loss of efficiency that ranged from about 2.1 to 3.2 percent, depending on the generator output (as shown in table 4-2). Results of testing on unit 3 were compared to initial testing on unit 2 just after the unit was put into service. Although the 1994 and 1962 index tests were based on two different units, it is considered to be representative of units 1-3.

**TABLE 4-2.
COMPARISON OF INDEX TEST RESULTS
REPRESENTATIVE OF UNITS 1 THROUGH 3
UNIT EFFICIENCY (%)**

GENERATOR OUTPUT (MW)	1962 INDEX TEST	1994 INDEX TEST	DECREASE
50	83.4	-	-
55	86.7	84.0	2.7
60	89.4	86.5	2.9
65	89.9	87.8	2.1
70	90.1	87.9	2.2
75	90.1	87.6	2.5
80	90.2	87.4	2.8
85	90.1	87.0	3.1
90	89.9	86.7	3.2
95	89.6	86.4	3.2
100	89.2	86.1	3.1

During the 31 years that elapsed between the two tests, no major non-routine repair work was done on the turbine, and no events occurred that would have changed generator efficiency to any significant degree. Unit 2 was inspected in June 1993. The turbine runner and discharge ring were in fair condition. There was moderate cavitation on the discharge ring and runner blades. The wetted surfaces of the distributor and runner showed an accumulation of rust scale. The unit 1 and unit 3 turbines display cavitation, corrosion, and surface roughness similar to those found in unit 2. A study of industry experience, performed for *The Dalles Powerhouse Rehabilitation Report,* is included here to show the reasonableness of the efficiency loss determined from the Index tests of 1962 and 1994. Units 1 through 14 at The Dalles are equal in diameter to units 1 through 3 at Ice Harbor. The following section is taken from The Dalles Report, and shows the thoughts of technical experts on the effects of surface roughness on turbine performance degradation. The report reads:

> "Based on the numerical modeling of turbine units for Bonneville First Powerhouse, Bill Colwill of American Hydro determined that as much as 3% could be lost at The Dalles due to surface roughness alone. Voest-Alpine M.C.E. provided the Corps with a report prepared by R. Grenier and T.C. Vu of GE Hydro for the XVII IAHR Symposium in Beijing, China in 1994. This paper presents efficiency losses of up to 3.7% due to surface roughness in the turbine passage of which 2.7% is from the wicket gates alone. Utilizing extensive field experience, John Kirkland of Tennessee Valley Authority and Don Sachs of Omaha District also determined that a 2% loss in efficiency due to surface roughness was acceptable in Kaplan turbines."

It should also be noted that the error in efficiency determined from the Index testing is generally accepted as approximately 1 percent. This, in conjunction with the range in values gathered from technical experts for efficiency loss due to surface roughness, suggests that the Index test findings are credible. Therefore, the efficiency degradation of 2.4 percent determined from field testing was utilized in the rehabilitation analysis of units 1 through 3 at Ice Harbor. The loss of efficiency is attributed to the rough surface, and it has been determined that all turbines have a similar loss of output.

The loss of unit efficiency indicates that the project is not capable of producing as much energy now, with the same amount of water flow, as it could when it was first commissioned, about 35 years ago. The average annual output of units 1 through 3 is 0.9 million MWh. Based on an estimated 2.4-percent deterioration in unit efficiency, this equates to a loss of about 21.6 million kWh of energy per year.

The primary factor in efficiency decline is turbine surface finish changes resulting from erosion, corrosion, and, to a lesser extent, cavitation damage. (Cavitation occurs when small bubbles of water vapor implode. The implosion creates a pressure pulse that induces stresses in the surface of nearby steel surfaces.) Figure 4-5 shows the rough surface on a blade in unit 3, which is representative of units 1 through 3 .

Fish screens at Ice Harbor reduce efficiency of turbines even further: an estimated additional 1.25 percent, based on recent model tests of the McNary turbines. While all turbines are subject to a loss of efficiency because of fish screens, evidence suggests that the survival of fish passing through turbines decreases with a decrease in efficiency, as discussed in appendix D, *Environmental Documentation*, paragraph 3.2. Fish screens have the same effect on all rehabilitation alternatives in this report.

Units 1 through 3 have had continuous problems with oil leakage. Efforts have been made to replace the blade packing, but oil leakage continues to be a problem. Most of the leakage appears to be coming from the area between the top of the turbine hub and the turbine shaft. Table 4-3 shows the extent of the oil leakage problem in these units.

TABLE 4-3
OIL LEAKAGE FOR UNITS 1 THROUGH 3

GALLONS OF OIL USED				
	1975-1989 (15 YEARS)		1990-1995 (6 YEARS)	
UNIT NUMBER	OVER PERIOD	AVERAGE PER YEAR	OVER PERIOD	AVERAGE PER YEAR
1	4,645	310	875	146
2	26,975	1,798	7,630	1,526[1, 2]
3	9,975	665	3,540	590

[1]Unit 2 did not operate in 1994. This represents a 5-year average.
[2]Unit 2 blades were repacked in 1994. Oil usage in 1995 was 1,415 gallons, showing little improvement.

Under the base condition, the turbines and governors would continue to be maintained and repaired on a routine basis, or as they fail under non-routine repairs. Time and cost of inspection and repair are expected to increase over time as the overall condition of the turbine blades deteriorates further. In addition, turbine efficiency will continue to decrease, resulting in increased energy losses and fish mortality.

A number of measures were evaluated for the unit 1 through 3 turbines, which included new blades, new standard runners, and new minimum gap runners. Blade replacement would address the identified problems in the most economical manner. A summary of the best measure is described below:

- Rehabilitation with Blade Replacement: Replace existing turbine blades with new ones; including replacement of blade bushings, packing, installation of greaseless bushings in the gate mechanism; and reconfigure and refurbish the water passageway. This measure would increase turbine efficiency 3.5 percent above the existing condition (1.1 percent above original turbine efficiency).

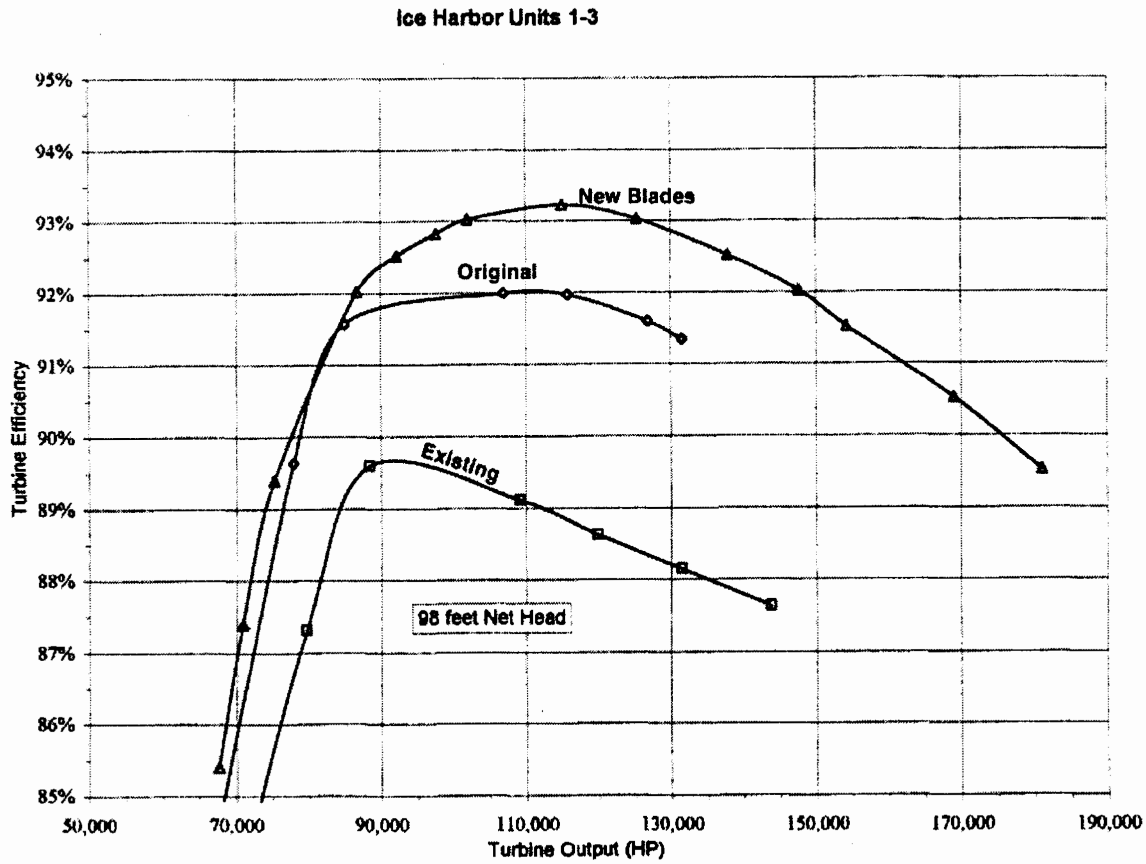
For blade replacement, the performance changes achievable due to modifying the stay vane angles, the shape of the runner nose cone, the scroll case shape, and wicket gate shapes will be evaluated. This will occur because model testing would be done under this measure. It is unlikely that changing the stay vane angle would be performed because of the difficulty in performing the work without the undue risk of future cracking problems in the welds. The execution of any of these measures would be dependent upon the payback (efficiency gain) achievable and the degree of risk of future maintenance problems.

Other measures were considered, but were found more costly. For example, the installation of a new standard runner assembly was eliminated from further consideration. It would be more expensive, and would not result in a sufficient efficiency increase to justify a complete runner replacement. Also, new minimum-gap runners were considered in the interest of fish survival. The minimum-gap runners would provide the highest efficiency of all alternatives considered, but the range of operation is much more restricted when operating within the highest 1-percent operating efficiency, as required by the Biological Opinion discussed in paragraph 3.4. Because of the limited effectiveness of increasing fish survival (less than 1 percent), and the infancy of minimum gap runner technology, further consideration at this time was dropped. Fixed-blade (propeller-type) turbines were also considered, but were not evaluated. They were extensively considered for the rehabilitation of the Bonneville plant on the lower Columbia River, but fishery agencies and tribes prefer only all-Kaplan alternatives for environmental reasons. Moreover, because of design considerations, fixed blade turbines cannot have an efficiency peak as broad as do adjustable-blade (Kaplan) turbines. (See appendix H, *Governor Sensitivity Analysis, and Turbine Engineering and Reliability Analysis*, for further information.)

No measures involving spare turbine blades were evaluated. If a spares program for turbine blades is considered, the most reasonable approach would be to link it to planned generator rewinding. Whenever a generator was rewound, the spare set of turbine blades would also be installed. This would take advantage of shared disassembly and reassembly costs, improved performance of a newer design turbine blade, and reduction in the effective age of the turbine. Under such a program, new spare blades would be procured as soon as existing ones were used. This is not practical for turbines. Performance of the turbines is totally dependent on the hydraulic shape of the waterway passages and primarily dependent on blade shape. The design and actual shape is proprietary. This leaves the Corps with three options: purchase the replacement blades from a sole source, pay for re-design and performance of new model tests for every set purchased, or reverse engineer (measure the blade shape of the new design) and duplicate the blades. Also, it is much more economical to spread the cost of a model test for the new blades over three units, rather than over a single unit (as required with a spares program). In addition, blade design would be limited to the available technology at the time when the spare blades were fabricated, and could not take advantage of the most recent technology.

The action to fully restore lost turbine reliability and efficiency with minimum expense is replacement of the existing turbine blades. Refurbishment of the blades was not considered as a viable measure, because of the blade breakage problem. Figure 4-7 compares turbine efficiency of the current and original turbine blades on units 1 through 3 to that which would be achieved by replacing the blades. More detailed information is included in appendix H, *Governor Sensitivity Analysis, and Turbine Engineering and Reliability Analysis.*

Figure 4-7
Comparison of Performance on Units 1 through 3



The new blades curve is based upon an existing model from a turbine manufacturer. No special emphasis was placed upon its flatness. A "flatter" curve is achievable, and emphasis will be placed on such a characteristic in the procurement contract.

The existing hydraulic governor system on units 1 through 3 has actuator-type mechanical governors. These mechanical hydraulic governors have been in service for approximately 35 years. Electronic three-dimensional cams were later installed, and were designed to adjust the turbine blade angle automatically in response to inputs of net head and gate opening.

The many linkage joints and other wearing parts on units 1 through 3 are loose and worn, which causes a lack of precision in unit operation. When the units are started, the speed often drifts well above and below the operating speed, and the autosynchronizer has been unable to close the main unit breaker for as long as 12 minutes. In an emergency, either the BPA generation requirements are not served, or the operator must synchronize the unit manually.

Few replacement parts are available for the governor oil pumps. Most essential parts are fabricated onsite, and worn parts continue to be used until a failure occurs. This practice further reduces governor reliability.

The existing hydraulic governor system on units 4 through 6 consists of Woodward analog electrical-type governors, which have been in service for about 21 years. Electronic three-dimensional cams were later installed. Consideration was given to rebuilding the existing governors, or to replace the existing governors with the digital governor system.

4.3. Peripheral Mechanical and Auxiliary Electrical Equipment

Peripheral mechanical equipment is defined as equipment that is necessary to support power production and is critical for the maintenance of the powerplant. As part of the rehabilitation study, an investigation was conducted of all major peripheral mechanical equipment to determine its condition (see appendix I, *Mechanical Peripheral Study*). As a result, the following two items have been identified for consideration as part of the rehabilitation plan:

- Rehabilitate tailrace gantry crane; and
- Modify bridge crane controls to decrease travel speed (trucks).

Auxiliary electrical equipment is defined as equipment that is essential for operation of the unit, but is not part of the power train. Auxiliary electrical equipment includes items such as electrical supplies, back-up batteries, protective relays, and station lighting. As part of this rehabilitation study, an investigation was conducted of all major auxiliary electrical equipment to determine its existing conditions, as well as to make recommendations (see appendix G, *Generator Step-Up Transformers and Auxiliary Electrical Equipment Analysis*. As a result, the following two items have been recognized for consideration as part of the rehabilitation program:

- New unit protection relays; and
- Improvement to the station service system.

4.4. Project Maintenance Costs

This section summarizes the historical maintenance costs that can be attributed to the Ice Harbor powerhouse turbine and generating unit failures. Costs are listed in 1996 dollars. Appendix E, *Operation and Maintenance*

History, presents an analysis of outage and labor hours related to specific components of which each powerhouse unit is comprised: the turbine, generator, exciter, and governor.

This section details only direct powerhouse repair costs. It does not address loss of power revenues. The replacement cost to purchase energy when Corps powerhouses are unable to meet peak loads is dramatic. For example, the Corps produces energy at a cost of approximately $2.00 per MWh. If this energy is purchased from other sources, the replacement cost can run as high as $40.00 per MWh, depending upon the time of year, availability, *etc.*

Maintenance cost can be divided into two major categories: routine and non-routine. Routine maintenance costs, due to normal periodic maintenance, remain relatively constant whether or not rehabilitation is performed. However, the non-routine costs go up significantly as components fail. Historical total maintenance costs for the Ice Harbor powerhouse are displayed in table 4-4. Also included in table 4-4 are the non-routine in-house maintenance costs, as well as non-routine contracted maintenance costs. The difference between the total maintenance cost and non-routine cost is the routine costs, which are not shown. The average total annual maintenance cost, price adjusted to 1996 dollars, is $1.724 million. Of that, an annual cost of approximately $53,100 was used to repair failed turbines on units 1 through 3; $593,000 was used for failed turbines on units 4 through 6; and $274,300 was used for failed generators on units 4 through 6. Repairs to turbines on units 1 through 3, 4 through 6, and generators on units 4 through 6 have averaged 3.1 percent, 34.4 percent, and 15.9 percent, respectively, of the total powerhouse maintenance budget.

Table 4-4 Annual Maintenance Costs, Ice Harbor Powerhouse

Fiscal Year	1996 Cost Adjustment	Total In-House Maintenance Costs	Non-Routine In-House Maintenance Costs	Non-Routine Contracted Maintenance Costs	Total Maintenance Costs In-House and Contract	Adjusted Maintenance Costs
89	1.199	$649,525	$25,607	$0	$649,525	$778,777
90	1.164	$745,534	$100,840	$0	$745,534	$867,983
91	1.132	$889,509	$49,681	$2,957,569	$3,847,078	$4,353,092
92	1.111	$809,378	$86,052	$0	$809,378	$898,918
93	1.085	$830,898	$47,719	$0	$830,898	$901,658
94	1.061	$723,750	$36,003	$0	$723,750	$767,707
95	1.030	$1,098,961	$221,894	$430,425	$1,529,386	$1,575,269
96	1.000	$998,462	$390,377	$928,207	$1,926,669	$1,926,669
97	0.974	$1,799,742[1]	$1,167,213[1]	$1,116,872[2]	$2,916,614	$2,839,934

[1] 1st quarter numbers multiplied by 4
[2] Estimated cost

Summary of table 4-4:

Average Annual Maintenance Costs (Fiscal Years 1989 - 1996):	$1,724,296

Non-Routine Maintenance Costs (Fiscal Years 1991 - 1996)

Average Annual Generator Repairs, units 4 through 6:	$274,274 (15.9% of total)
Average Annual Turbine Repairs, units 4 through 6:	$592,973 (34.4% of total)
Average Annual Turbine Repairs, units 1 through 3:	$53,079 (03.1% of total)

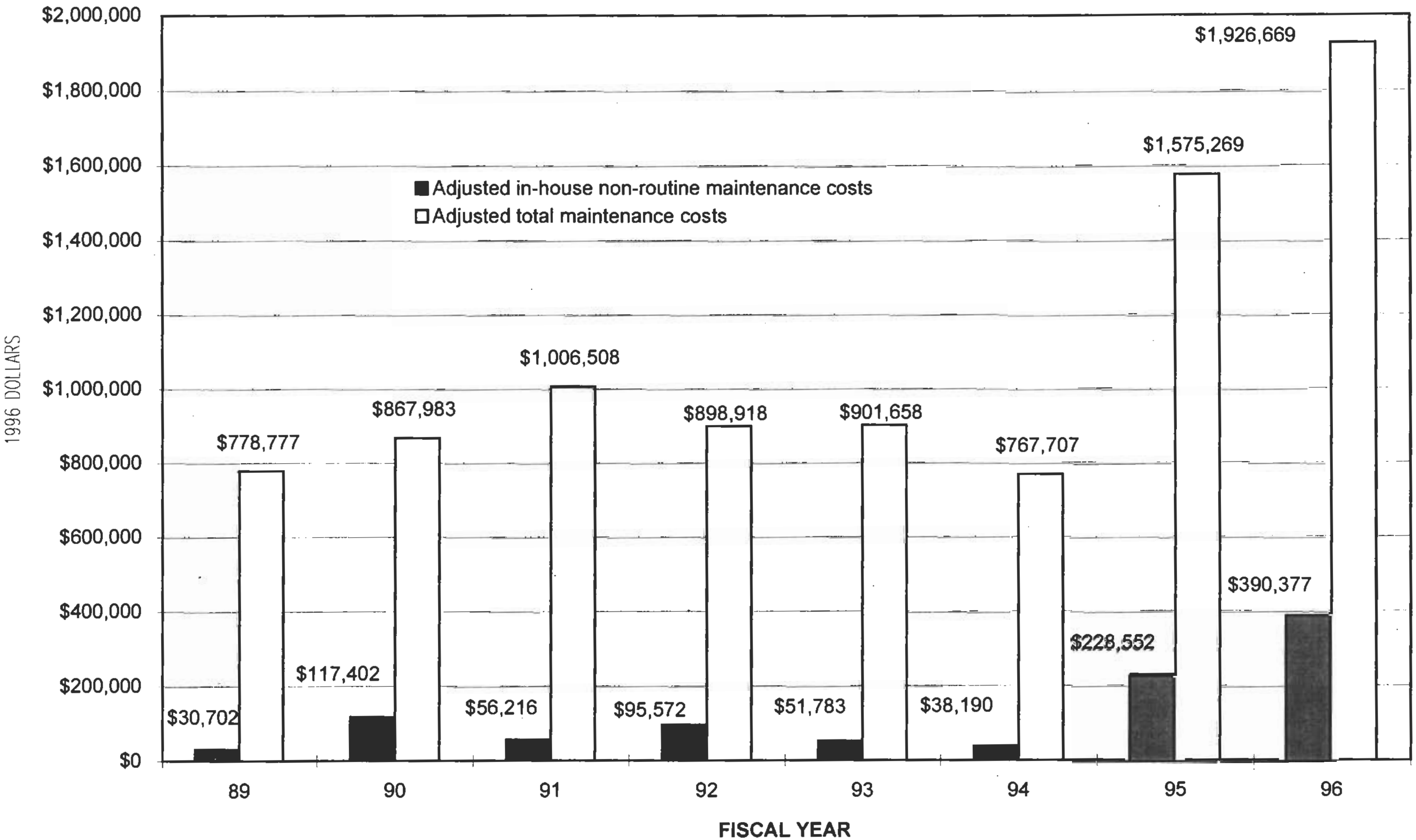
The 1991 contract to repair cavitation damage in the discharge rings for units 4 through 6 (see table 4-4) skewed the adjusted maintenance costs and diminished other problems , such as cracked turbine blades for units 1 through 3.

Cumulative outages to date total approximately 3 outage years for turbine repair, and approximately 5 outage years for generator repairs. Outage hours, like repair costs, have increased in the short run because of deferred maintenance, and will continue to rise over the long run due to unit fatigue and deterioration reducing the units' reliability. Outages due to deferred maintenance consumes plant assets, and creates a downward spiral of plant condition.

The base condition in this report discusses future increases in non-routine maintenance costs and the decline of unit reliability. Future costs are difficult to predict since some maintenance has been deferred due to a lack of funds and manpower. The available historical maintenance data does not indicate a significant annual rise in maintenance costs, except for the multiple failures of unit 5 and the cavitation repair of turbine units 4 through 6 (see Fiscal Years 1991, 1995, and 1996). However, the costs projected for non-routine maintenance for these generators and turbines is expected to rise in the ensuing years. It is very difficult to project the costs over the next 5 years, let alone the next 30 years, because of the unknown quantities of catastrophic failures, such as those that have occurred on unit 5.

The adjusted powerhouse maintenance costs for in-house non-routine maintenance and adjusted total maintenance cost, including total in-house and contract costs, are indicated in figure 4-8 (note the increased costs for 1995 and 1996 as a result of generator failures). Future repair costs are not shown on this figure. The contract costs for cavitation repair of units 4 through 6, in the amount of $2.958 million, were ignored in calculating the adjusted maintenance cost shown in this figure for Fiscal Year 1991. As can be seen, the data for adjusted maintenance costs from 1989 to 1994 shows a slight increase from 1989 to 1991 and a slight decrease from 1991 to 1994. In 1995, a contract to repair unit 5 was awarded, and the job was completed in 1996. During start-up of unit 5, on 1 May 1996, a second failure occurred due to the grounding of two or more of the unit's rotor poles. The next phase of repair work on unit 5 was completed in December 1996, using in-house crews and hired labor from Tennessee Valley

FIGURE 4-8 POWERHOUSE MAINTENANCE COSTS ADJUSTED TO 1996 DOLLARS



Authority (TVA). In the first quarter of Fiscal Year 1997, approximately $300,000 was spent on non-routine maintenance for the powerhouse, and most of that was for completing repairs on unit 5. On 16 December 1996, unit 5 failed for the third time due to a stator winding failure that was caused by foreign object damage. The total cost for repairing unit 5, from 15 May 1994 until 31 September 1996, was $1.377 million (1996 cost level). Since 16 December 1996, another $44,000 has been spent on outside labor hired to investigate this third failure. Costs estimated to repair unit 5 are approximately $1.8 million, which is being direct funded by BPA. Funds for all other repairs came from Walla Walla District's Operations and Maintenance budget.

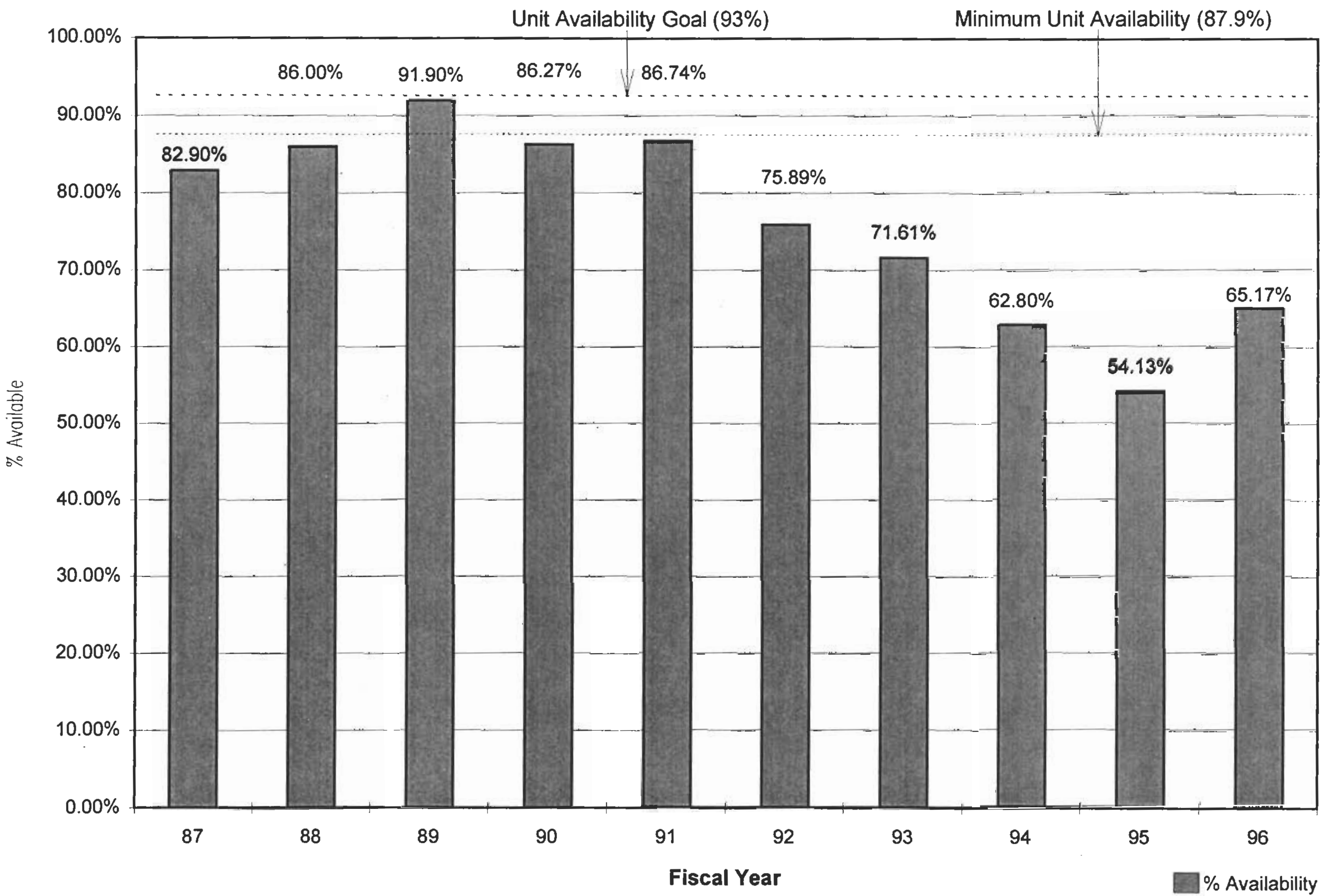
It is expected that the cost to inspect turbine blades and weld cracks will increase. Currently, only units 2 and 3 are inspected routinely. It has been estimated that 1300 hours of labor will be necessary to inspect and weld cracks on each unit every other year, for a total (in 1996 dollars) of $68,000 per unit. These costs are for non-routine maintenance. In Fiscal Year 1996, generator units 4 through 6 had their stator windings reinforced at a cost of approximately $75,000 per unit. These cost are also non-routine maintenance, and reinforcement could be required every 2 years. Because of initial manpower and maintenance dollars, the additional turbine and generator maintenance work could be performed in alternating years. These costs will escalate by an estimated 2.7 percent per year over the next 5 years according to Office of Management and Budget projections. It is difficult to predict mechanical problems and the related cost that might be associated with a catastrophic failure or multiple failures, such as what has happened to unit 5, during the next 5 years.

4.5. Below Goal Service Levels

The North American power industry has a unit availability goal of 95 percent. This is the availability needed to dependably supply power to the system when unscheduled outages and transmission system failures occur. The Corps participates with a goal of 93-percent availability. Figure 4-9 reproduced from appendix E, *Operation and Maintenance History,* shows the Ice Harbor power plant availability over the past 10 years (1987 through 1996). As can be seen, the highest availability occurred in 1989.

The declines in power plant availability noted on the graph are the results of unit failures due to deferred maintenance on generator and turbine components caused by insufficient funding and manpower. The unit availability goal of 93 percent has not been met since sometime before 1985. The data shows a steadily-declining trend, with 1991 values around 86 percent, to a low of 54 percent in 1995.

FIGURE 4-9 ICE HARBOR HISTORICAL POWERHOUSE UNIT AVAILABILITY



Unless the generator windings and turbine blades are replaced, availability will continue to drop. The impact on the system grid is dependent on the time and length of each outage. In general, the impact could include the necessity to purchase power at premium costs, increased risk of system voltage instability during peak loads, and an inability to meet customer demand for energy during peak load times. In the extreme case, voltage instability and inability to meet customer demand can lead to brownouts or blackouts similar to what happened on 3 July 1996 and 10 August 1996 throughout the western states.

ICE HARBOR LOCK AND DAM, WASHINGTON
POWERHOUSE MAJOR REHABILITATION PROGRAM

5.0 ECONOMIC CONSIDERATIONS

This section summarizes the analytical procedures used to test the economic feasibility of alternative plans for rehabilitating the generating units at Ice Harbor. Details of the economic analysis methodology, data, and results are located in appendix B, *Plan Formulation and Economic Analysis*. Reliability data are contained in appendix F, *Generator Reliability Analysis*, and appendix H (c), *Turbine Reliability Analysis*.

5.1. Federal Interest

The U.S. Congress mandated the development and operation of Federal hydroelectric power projects, including Ice Harbor. There is Federal interest in the ongoing maintenance and operation of this project. The operational reliability of Ice Harbor has an impact on the total cost of electrical power generation in the Pacific Northwest. It is in the Federal interest to minimize these costs. Rehabilitation of Ice Harbor hydro-generating units to improve their reliability will contribute toward this objective.

5.2. Problems and Opportunities

There are two immediate problems associated with the Ice Harbor hydro-generating facilities. First, the generators on units 4 through 6 are in poor condition, and failure of these units appears to be imminent. Second, the turbines on units 1 through 3 have begun to experience blade cracking and breakage. Addressing these problems serves as the basis for formulating alternative plans.

In addition to the mechanical reliability problems of turbines on units 1 through 3, a reduction in average overall generating efficiency, compared to the original installation, has been documented. There has been a decline on units 1 through 3 of about 2.4 percent. New turbine blades can be designed to not only restore lost efficiency, but to raise efficiency above the original output by about 1.1 percent.

Economic evaluation of alternative plans will be based on benefits associated with the generators, turbines, and transformers. However, other considerations (*i.e.,* operational flexibility, peaking capability and survival rates for juvenile fish) will be addressed in later chapters in a non-economic analysis.

5.3. Without-Project (Base) Condition

Under the base condition, equipment that fails to perform satisfactorily will be repaired or replaced as quickly as resources allow, so that plant availability is maintained to the greatest extent possible. To establish the base condition, generator, turbine, and transformer performance were modeled to establish future levels of reliability.

For the evaluation, an initial malfunction of generator stator coils was assumed to be repairable only through a rewind of the unit. The cost of rewind is approximately $5.5 million, and repair downtime is 36 months.

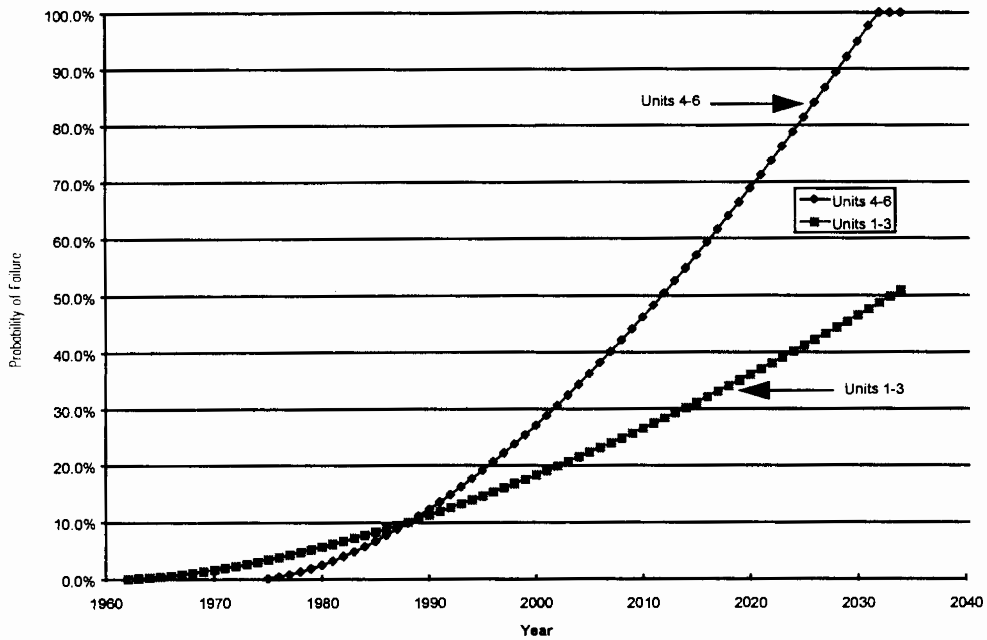
It is projected that the turbines for units 1 through 3 will continue to experience blade failures over the period of analysis. Each blade failure will cost $200,000 to fix, and repair time is about 6 months. It is also assumed that there is potential for a greater failure of these units, costing around $1 million and requiring a 15-month repair time. The reliability for turbines on units 1 through 3 has been modeled but, based on their age and condition, the probability of a failure is quite low. If a failure does occur, it is assumed to cost $1 million to fix, and repair downtime is 15 months.

Transformer reliability is also simulated in the evaluation model. When a transformer fails, it is assumed to be replaced at a cost of $2.8 million, and repair downtime is 16 months.

5.4. Evaluation Method

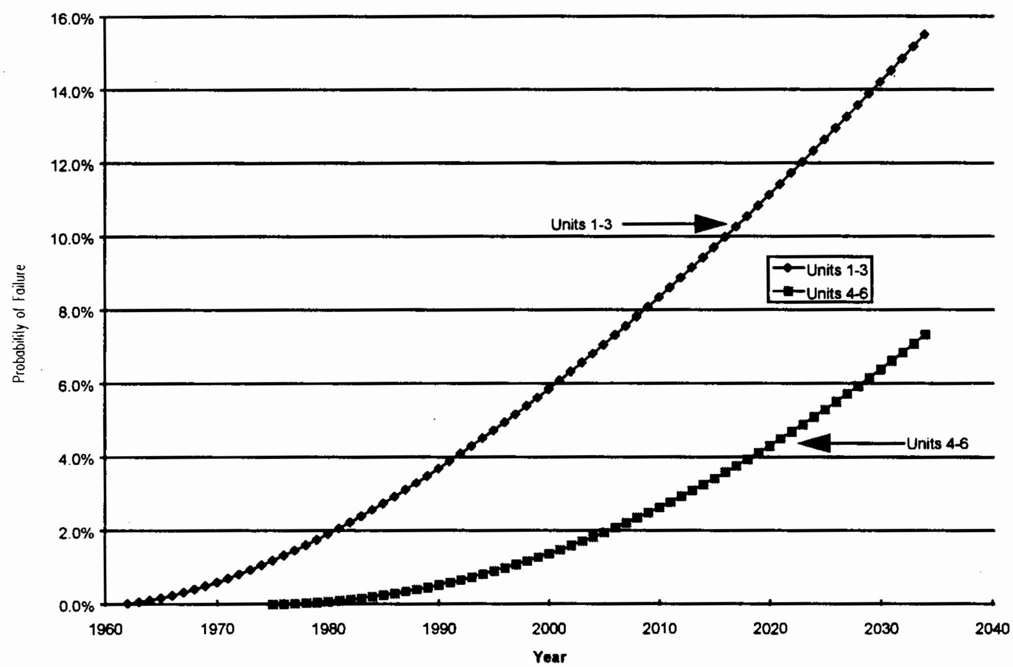
The economic evaluation of generators, turbines, and transformers at this project was made using a computer model that employs Microsoft Visual Basic software to measure the economic impacts of unsatisfactory equipment performance over successive future time periods. Both the without project condition and various alternative measures were modeled in this way. Monte Carlo (random sampling process) simulation was applied to reliability factors to project the timing and frequency of unsatisfactory performance of the respective components. Reliability factors were developed based on the age of the generators, transformers, and turbines, and are displayed in figures 5-1, 5-2, and 5-3.

Figure 5-1 Probability of Generator Failure, Ice Harbor



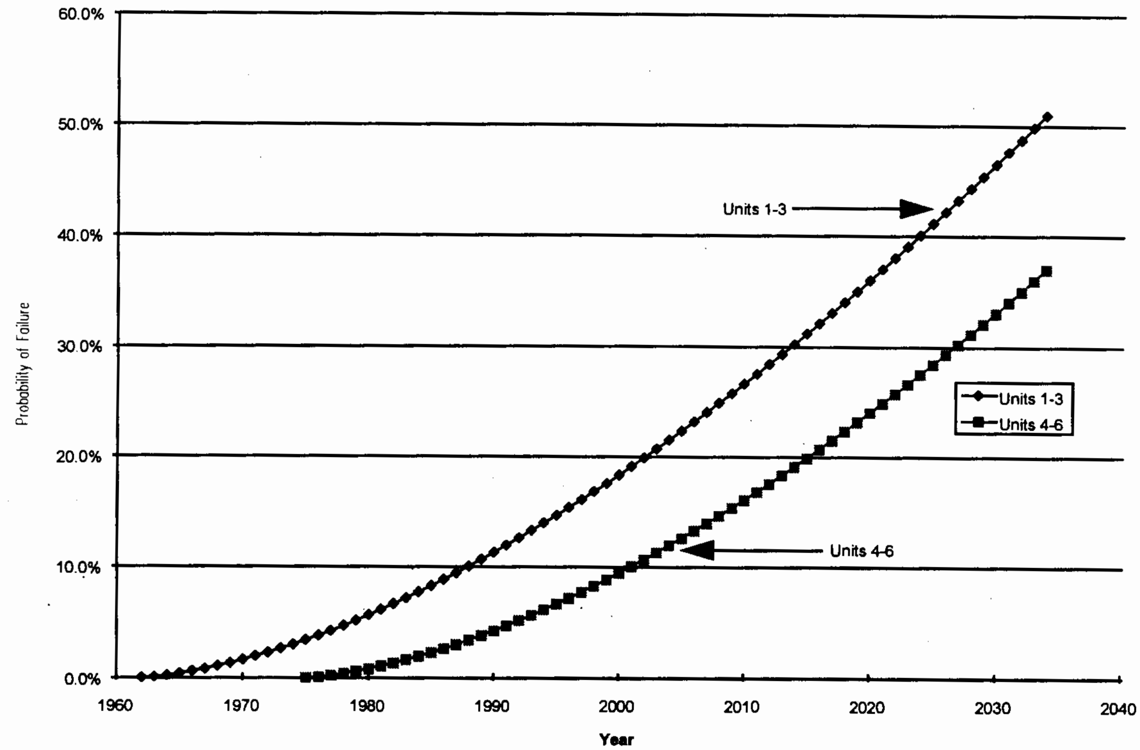
Source: Corps, Portland District, Hydroelectric Design Center

Figure 5-2 Probability of Turbine Failure, Ice Harbor



Source: Corps, Portland District, Hydroelectric Design Center

Figure 5-3 Probability of Transformer Failure, Ice Harbor



Source: Corps, Portland District, Hydroelectric Design Center

Based on reliability indicators, the model used random number generation to establish the most probable timing of a component malfunction, given the relevant probabilities. This process involves the selection of a random number between zero and one for each successive year over the period of analysis. If the number selected at random is greater than the stated probability of unsatisfactory performance, no service disruption is indicated. If the number selected is less than the probability of unsatisfactory performance, an equipment malfunction is indicated. The model then sums the results of multiple iterations, and produces expected values and variance. By incorporating probability distributions that reflect the range of possible outcomes, the analysis addresses the uncertainty inherent in forecasting mechanical reliability.

The model is also designed to relate the probability of unit outage to the economic consequences of each event. Economic consequences are expressed as the energy production costs to meet projected loads, the alternative costs of providing dependable system capacity, and the costs to repair or replace damaged components. Potential economic benefits resulting from both restoration and enhancement of generating efficiency, as well as increased unit reliability, were identified and compiled for each event. Simulations were conducted for the base condition and each alternative measure.

Costs and benefits associated with alternative plans are adjusted to a common point in time, in this case, the year 2000. The summed benefits and costs are amortized over a 35-year economic life at the Federal interest rate of 7.375 percent, and are expressed as average annual amounts.

5.5. Corrective Measures Evaluated

Various measures were considered to improve generator, turbine, and transformer reliability. For the generators, increasing the level of maintenance was initially considered as a strategy. However, because only limited levels of maintenance can be performed on the windings, increased or enhanced maintenance does not adequately address reliability concerns. In some cases, damaged stator coils can be replaced but, if insulation is disturbed in the process, an increased risk of failure in adjacent coils is introduced. Prior attempts to utilize this technique at other projects have proven only minimally successful.

Three measures that address generator reliability were analyzed. The first is a planned replacement of windings on 1 to 6 units, depending on economic justification for each additional winding and net benefits that could be achieved. A planned rewind program would be initiated in 1999 and completed by 2005, with the initial rewind completed by 2000. Costs associated with this alternative are presented in appendix B, *Plan Formulation and Economic Analysis*.

The second measure is one in which spare windings would be purchased as early as possible, and subsequently used to replace the first windings to experience a malfunction. Following a winding malfunction in any unit, the spare winding would be installed, and procurement of another spare stator winding would be initiated.[1] Unit outage time for this option is 15 months, reduced from the 36 months that would occur in the without-project condition.

A third measure for addressing generator reliability is one in which an open-ended contract is established for generator rewinds. In this case, a contractor would be available on short notice to perform a rewind. Unit outage time for this option is 22 months.

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[1] Note that the spare program will be discontinued after the third unit of each family has been rewound.

For the turbines, both blade replacement and runner replacement were analyzed. An estimated 3.5 percent gain in unit efficiency above existing levels would be achieved with this blade replacement of units 1 through 3. Runner replacement achieves higher efficiency than the blade replacement option, but it does not provide significant reliability improvements over blade replacement.

For the transformers, two measures were considered.[2] The first is a planned replacement of the transformers in an immediate fashion. The second involves purchasing a spare transformer for use when a transformer fails. A spare transformer on hand would reduce forced outage time to 3 months, from the 16 months required in the without-project condition.

5.6. Alternatives Evaluated

Corrective measures considered in the rehabilitation study were discussed in section 4 of this report. From the corrective measures, a list of alternatives was identified for consideration and evaluation. Each alternative included a combination of the various corrective measures for units 1 through 3 and units 4 through 6. Through a process of screening and preliminary evaluations, the long-list of alternatives was reduced down to ten key alternatives (including the base condition) for more detailed evaluation. In some cases, other alternatives were evlauated in somewhat more detail to answer specific questions, however those alternatives are not included. A list of the ten key alternatives is presented in table 5-1.

TABLE 5-1
ALTERNATIVES EVALUATED IN MORE DETAIL

	Units 1 through 3 Measures		Units 4 through 6 Measures		
Alternative	**Turbines**	**Generators**	**Turbines**	**Generators**	**Comments**
1a	Existing	Existing	Existing	Existing	Base Condition
3f	Original	Original	Existing	Existing	Theoretical[1]
4a	New Blades	Existing	Existing	Rewind	
4c	New Blades	Rewind	Existing	Rewind	
4h	New Blades	Existing	Existing	Existing	
5b	New Standard Runners	Rewind	New Standard Runners	Rewind	
5h	New Standard Runners	Rewind	Existing	Rewind	
6h	New Minimum Gap Runners	Rewind	Existing	Rewind	
6j	New Minimum Gap Runners	Existing	New Minimum Gap Runners	Rewind	
7a	Existing	Existing	Existing	Rewind	

[1]Used to distinguish between costs to restore to original efficiency (reliability) and costs to increase efficiency above the original level.

[2] These measures have only been considered for units 1 through 3. The younger transformers on units 4 through 6 have shown no signs of impending failure, and are considered to have substantial remaining life.

ICE HARBOR LOCK AND DAM, WASHINGTON
POWERHOUSE MAJOR REHABILITATION PROGRAM

6.0. ENGINEERING CONSIDERATIONS

This section summarizes the methodology and results of the engineering reliability analysis of powerhouse turbines and generators. Reliability analysis details are located in appendices F, *Generator Reliability Analysis*, G, *Generator Step-Up Transformers*, and H, *Governor Sensitivity Analysis, and Turbine Engineering and Reliability Analysis*.

6.1. General

The reliability analysis methodology used for this report predicts the probability of unsatisfactory performance in units currently in service. This section used the standard survivor curve reliability methodology for the turbines and generator stator windings. Since a retirement database does not exist for transformers, an alternate methodology was used for that equipment. The resulting probabilities of failure required for the economic analysis are discussed in section 5, *Economic Considerations*.

6.2. Survivor Curve Methodology

The reliability of equipment is commonly determined using a methodology known as "survivor curves." Survivor curve analysis has been used for well over 200 years by insurance companies to determine human life expectancy. Adaptation of this methodology for physical properties began in the early 1900's, with a substantial amount of development work done in the 1930's through the 1950's. The driving force behind the adaptation was the need to determine equipment service life for taxable depreciation purposes, as well as for rate base development in various utilities. These methods are adaptable to forecast the probable serviceability and failure rates of generators and turbines.

A survivor curve shows the percentage of equipment that survives in service at any given age from zero years to 100-percent retirement. These curves are based on historical data for similar equipment. The raw data is plotted, and a smooth curve is fitted and extrapolated. At any given age, the probability that a piece of equipment will be retired within the year is equal to the slope of the smooth curve at that point.

In applying survivor curve methodology to specific equipment, three smooth curves are drawn over the raw historical data. The middle curve represents the most likely probability of failure. The other two curves represent higher and lower probabilities, which can be used in a sensitivity analysis.

The survivor curve, based on historical data, can be applied directly to project service life or can be used to determine the probability of unsatisfactory performance. Since the curve is based on a sample of turbines and generators with wide variations, it can be assumed to represent a "typical" turbine or generator if there is nothing to distinguish a specific piece of equipment. Where there is data available on a given piece of equipment, it is reasonable to make adjustments to the curve that reflect known conditions.

A formalized testing and inspection process produces a condition indicator for each piece of equipment. The factor adjusts the slope of the "typical" survivor curve to match it to the known condition of an individual piece of equipment. In the case of Ice Harbor, the curve was modified due to condition indicators. There is significant turbine reliability decrease for units 1 through 3 due to past failure histories and testing.

6.3. Application to Ice Harbor Turbines

In applying survivor curves to Ice Harbor turbines, a Weibull Probability Distribution Curve was fitted to the raw historical data. This curve represents the best mathematical fit of the raw data and, as such, may be manipulated mathematically to show the reliability of a turbine that has less than or better than expected performance when compared with the baseline or "best fit" historical data. The manipulation of data is done using condition indicators, and is discussed in more detail in appendix H, *Governor Sensitivity Analysis, and Turbine Engineering and Reliability Analysis.*

The baseline Weibull curve was used for units 4 through 6 since they were considered to be average units with normal wear after 21 years of use. However, since units 1 through 3 are exhibiting signs of premature or accelerated deterioration, an appropriate modifier, based on the condition indicators, was used to lower the overall reliability of the baseline curve.

These curves were used in the economic analysis to model unit outage costs for the planned and unplanned rehabilitation scenarios. The actual age of the turbines was used in this analysis, unless the condition of the turbine changed. If the turbine was replaced or refurbished, the reliability of the turbine was improved. In this report, several different situations were considered. Under the best-case condition (*e.g.,* if a turbine is replaced with a new runner), the unit is considered to be new and at age zero. The "effective age" of a machine that has had a blade replacement is considered to be 10 years. If basic repair (*e.g.*, repair of a broken blade) is undertaken, it does not change the age of a unit, but merely allows the unit to be returned to service. The probability of future unsatisfactory performance in this latter case is not improved, and the unit continues along its path of degradation.

6.4. Application to Ice Harbor Generators

Standard Corps practice has used historical winding failure data to adjust the life expectancy for generators. This data is modified using a winding condition index developed from REMR data. In order to apply REMR data to survivor reliability, a modified number was established using weighting factors for each inspection or test. This weighted number is designated as the Survivor Curve Adjustment Number (SCAN). Failure history, existing condition, and the method used to determine the SCAN's for the unit 1 through 6 generators is described in more detail in appendix F, *Generator Reliability Analysis*.

The condition of the winding, as indicated by tests and visual inspections, varies depending on the unit. Units 1 through 3 seem to be in average condition for their age. Units 4 through 6, while only 21 years old, appear to be in poor condition. Units 4 and 5 have both suffered coil failures.

In past studies, these SCAN's would be used in much the same way as that which occurred in the economic analysis. However, there is an additional tool that can be used in this case. Fairly complete condition surveys of units 1, 3, 4, and 6 have been performed using the Machine Insulation Condition Assessment Advisor (MICAA) program, developed by Iris Engineering. The MICAA results for units 2 and 5 were not included due to a lack of data. This program is being evaluated as a replacement for the REMR condition indicator procedure for generator windings.

The MICAA is an expert program which, like the REMR condition indicators, assesses winding condition based on tests and inspections. It goes further than REMR condition indicators, in that it takes the operating conditions of the units into account. Unlike REMR condition indicators, MICAA is design-specific, taking into account industry experience with various winding types produced by major manufacturers active in the North American market. The MICAA program also provides an estimate of the probability of a winding failure.

6.5. Generator Step-Up Transformer Reliability

Work is underway to develop a historical transformer retirement database similar for that used for generators. When it is completed, transformer reliability will be handled in the same manner as generator stator windings.

Since this information is not yet available for use, transformer failure probabilities in this report have been estimated based on general industry and Corps experience. For the average transformer, reliability is expected to be very high for the first 35 years, but declining thereafter. By age 50, two out of three transformers are expected to have been replaced. A failure probability distribution based on these end points was developed and used in analysis of those cases that included replacement of transformers operated at nameplate load. Insufficient condition and operating data was available to make a judgment that other than "average transformer" failure probabilities should be used. More detailed information is included in appendix G, *Generator Step-Up Transformers and Auxiliary Electrical Equipment Analysis.*

Generator uprating increases transformer operating temperature and can reduce transformer life. Maximum uprate levels in the study are 11 percent for units 1 through 3 and 5 percent for units 4 through 6. For transformers associated with units 4 through 6, there appears to be enough temperature rise margin in the design that there should be little, if any, life reduction at 5-percent uprate. Given the age of units 1 through 3 transformers at the beginning of the study period (38 years old in the year 2000) and the life reduction expected from the relatively large uprate proposed, it is estimated that failures of these transformers will happen very early in the study period. Accordingly, all 11-percent uprate options include purchase of new step-up transformers for units 1 through 3.

ICE HARBOR LOCK AND DAM, WASHINGTON
POWERHOUSE MAJOR REHABILITATION STUDY

7.0. ENVIRONMENTAL CONSIDERATIONS

This section presents a brief summary of project environmental effects. It also summarizes environmentally-related coordination required. Supporting data are located in appendix D, *Environmental Documentation*.

7.1. Environmental Effects

The Snake River is a vital passageway for anadromous fish species. Adults migrate upstream to their spawning grounds, and juveniles migrate downstream to the ocean. Both adult and juvenile fish must pass through Ice Harbor Lock and Dam. Anadromous fish species include sockeye and chinook salmon, steelhead, lamprey, and American shad. The Snake River sockeye salmon was listed as endangered, under the Endangered Species Act (ESA), on November 20, 1991. Snake River spring/summer and fall chinook salmon were listed as threatened under the ESA on April 22, 1992. Snake River basin steelhead were proposed for listing as threatened on August 9, 1996. The Snake River was designated as critical habitat for Snake River ESA-listed species on December 28, 1993.

Overall, the proposed action of rehabilitating the 6 units of the powerhouse would benefit these species. These benefits would arise through increased turbine efficiencies and restoration of reliability and availability of the units. Increased turbine efficiency is believed to improve the survival rate of downstream migrating juvenile fish that pass through the turbines. Restoration of the reliability and availability of the units would mean that during high flow conditions, more water could be run through the powerhouse instead of through the spillway, decreasing the amount of total dissolved gas (TDG) produced by the dam. During high flows, Ice Harbor Dam has produced TDG concentrations that are damaging or lethal to aquatic organisms, including fish species listed under ESA. To help minimize the impacts on migrating fish, rehabilitation of the initial unit will begin after the fish migration season.

To help determine which of the alternatives would have the greatest benefit for migrating fish, the Corps conducted two model analyses - a spreadsheet model and a juvenile passage survival model, Columbia River Salmon Passage (CRiSP). A summary of biological effectiveness for anadromous salmonids is provided below. The Corps will revisit these model analyses in 1998 following the minimum gap runner (MGR) testing at Bonneville Dam.

7.1.1. Spreadsheet Model Analysis

Peak turbine efficiency improvements of about 1 to 4 percent above the existing efficiency resulted in 0- to 2-percent turbine survival adjustments for all alternative plans examined. The recommended plan (described in Section 9) would increase turbine efficiency for units 1 through 3 to about 3.5 percent above the existing peak efficiency and about 1.1 percent above the original peak efficiency, which would result in a less than 1-percent increase in smolt survival from the Lower Granite reservoir to the Ice Harbor tailrace.

Increased turbine reliability (from restoring reliability to the original condition) could result in a greater than 10-percent increase in smolt survival to the tailrace of Ice Harbor Dam during high flow years (flows greater than 120,000 to 140,000 cfs in the lower Snake River).

The analysis of MGR's, with or without spill, was conducted for two operational scenarios. A highly probable operational scenario, with MGR's on all six turbines, was assumed based on prototype testing results at Rocky Reach Dam and physically-scaled turbine model evaluations. Total Ice Harbor turbine passage survival for this scenario was assumed to increased from 89 percent to 92 percent (3-percent increase), which resulted in a less than 1-percent increase in smolt survival to the tailrace of Ice Harbor Dam. A theoretical best case operation scenario, with MGR's on all six turbines, was assumed based on regional expectations of MGR performance prior to prototype testing. Total Ice Harbor turbine passage survival for this scenario was assumed to increase from 89 percent to 96 percent (7-percent increase), which resulted in a 1- to 3-percent increase in smolt survival to the dam tailrace.

7.1.2. The CRiSP Juvenile Passage Survival Model Analysis

Spreadsheet models are incapable of simulating the dynamics of total dissolved gas production related to spill volume and rate. The CRiSP juvenile passage model has been recently recalibrated and tested to account for spill-produced effects on dissolved gas production and subsequent gas bubble mortality effects on juvenile salmon. As anticipated due to the minor operational differences incorporated through the Hydro-System Seasonal Regulation (HYSSR) simulation at a single dam, CRiSP results indicate that the operation of any one of the rehabilitation alternative plans would have nearly the same effect on Columbia/Snake River system-wide juvenile survival for all index stocks modeled. Compared to the base condition, all alternative plans could increase juvenile survival by less than 1 percent. Installing minimum-gap runners in all six turbines could increase system-wide juvenile survival by about 1 percent.

7.1.3. Conclusion

The alternative that would have the highest benefit for migrating fish would be the one that ensures that all the units are reliable and available to pass the maximum amount of annual runoff at the widest range of flow passage capacity within the best operating range of turbine efficiency. However, the methods used to meet the criteria, whether through blade replacement, changing the type of runner, rewinding generators, *etc.*, is of less importance to fish survival than ensuring that the turbines are operating at peak efficiency and are available to pass flows when needed.

The alternative that best meets the above criteria is 5b, the alternative calling for new standard runners on all six units. New standard runners would be expected to be reliable, and would be more efficient than the existing runners. Standard runners are also able to operate within 1-percent peak efficiency over a wider range of flows.

The MGR's on units 1 through 6 could increase juvenile passage survival, but by less than 1 percent, which is insignificant. The MGR testing at Rocky Reach Dam during 1996 indicated that the technology may still be too young in its development to provide positive net benefits for fish. The MGR runners are not as beneficial to fish as standard runners because MGR runners operate within 1-percent peak efficiency over a narrow range of flows. If MGR and related turbine design technology can broaden the peak efficiency range of flows prior to implementation of the Ice Harbor rehabilitation scheduled for the year 2000, then MGR-equipped units should receive further consideration during consultation with NMFS prior to construction contract award.

7.2. Environmental Compliance

Rehabilitation of the powerhouse requires coordination with appropriate agencies as well as compliance with applicable environmental laws and regulations. These requirements include compliance with the National Environmental Policy Act (NEPA), the Clean Water Act, the Fish and Wildlife Coordination Act (FWCA), the ESA, and various cultural resources and water quality laws.

7.2.1. National Environmental Policy Act

The Corps will be preparing an Environmental Assessment for this project in 1998 when results from MGR testing at Bonneville Dam will be available. Insufficient data is available at this time to conduct a meaningful analysis of the economic and environmental effects of MGR's. By waiting until results of the testing at Bonneville Dam are available, the Corps and the region will be able to make an informed decision regarding the best rehabilitation efforts to take at Ice Harbor Dam. In their letter, dated March 25, 1997, NMFS concurred with this response. A copy of the NMFS letter is in appendix D, *Environmental Documentation*.

7.2.2. Clean Water Act

The entire rehabilitation project would take place within the Ice Harbor Dam powerhouse, and would not be subject to Section 404 requirements of the Clean Water Act. The power units, particularly units 1 through 3, have been leaking oil for many years. Although this leakage is of concern, the environmental effects are believed to be negligible because of the large volume of water involved. The Washington Department of Ecology is aware of the leakage, and has recommended that the Corps obtain a National Pollution Discharge Elimination System (NPDES) permit. In the State of Washington, the Environmental Protection Agency (EPA) issues NPDES permits to Federal agencies. The District has previously discussed the need for an NPDES permit with EPA, and was informed that EPA does not have sufficient resources to issue NPDES permits to Federal agencies at this time. Rehabilitation of the power units will reduce the leakage. The District is pursuing replacing the petroleum-based lubricants at Ice Harbor Dam with a vegetable-based food grade lubricant. Use of this vegetable-based lubricant would eliminate the need for regulatory permits and would greatly reduce the environmental concerns associated with potential leakage in the future.

During the rehabilitation of each of the power units, petroleum products and other chemicals (*i.e.*, paint and asbestos) may be released. These releases would be expected to be routine and minor, and would be handled in accordance with established protocols according to applicable environmental laws and regulations. None of these materials would enter the water, as flows to the affected power unit would be shut off and appropriate mechanisms and containers would be used to capture any of these materials.

7.2.3. Fish and Wildlife Coordination Act

The Moses Lake Office of the U.S. Fish and Wildlife Service (USFWS) indicated, in a telephone conversation on March 20, 1997, that they will need to prepare a Coordination Act Report for this project. The USFWS plans to prepare this report in 1998 in conjunction with the Environmental Assessment being prepared by the Corps.

7.2.4. Endangered Species Act

7.2.4.1. Bald Eagles and Peregrine Falcon

Federal agencies are required to consult with USFWS for actions they intend to implement that may jeopardize the existence of listed species. The Corps has identified two species, the wintering bald eagle and the migrating peregrine falcon, which may utilize the habitat in the vicinity of Ice Harbor Dam. The Corps contacted the Moses Lake Office of the USFWS on January 28, 1997, to discuss project effects on these species. The USFWS indicated the project is not likely to adversely affect bald eagles or peregrine falcons. In a follow-up telephone conversation on March 20, 1997, USFWS indicated that the Corps will need to request a species list in 1998, and complete ESA coordination at that time. The Corps will also need to coordinate with USFWS again just prior to starting the rehabilitation work.

7.2.4.2. Endangered Salmon Stocks

Federal agencies are also required to consult with NMFS for actions they intend to implement that may jeopardize the existence of ESA-listed saltwater and anadromous fish stocks. Snake River sockeye and Snake River spring/summer and fall chinook salmon are listed stocks that pass Ice Harbor Dam during their downstream outmigration as juveniles and upstream migration as adults. Snake River basin steelhead, which have been proposed for listing as threatened, also pass Ice Harbor Dam. Consultation is being conducted with NMFS for the impact of powerhouse rehabilitation actions on individuals of the listed salmon stocks. The Corps has also prepared a Biological Assessment addressing these impacts and has sent this to the NMFS as part of the consultation process. A copy of this is in Appendix D, *Environmental Documentation*. However, it is unlikely that the consultation process will be completed prior to 1999. This is because a new Biological Opinion for the Operation of the Federal Columbia River Power System will likely go into effect at that time and criteria for operating the dams may change. By that time, turbine technology may have advanced enough to provide a minimum-gap runner that provides a higher survival and turbine efficiency range in addition to being economically justifiable. Also, the NMFS will need detailed and specific information on the project and construction timing, and this information would not be available until near the completion of plans and specifications. The NMFS is also awaiting the results of minimum gap runner testing being conducted at Bonneville Dam. These results will not be available until 1998. The consultation process will be completed prior to awarding the contract.

In the meantime, rehabilitation actions are being coordinated with NMFS and the regional fisheries agencies and Indian tribes. This coordination is being accomplished through the System Configuration Team (SCT), a regional coordination group co-chaired by NMFS and the Northwest Power Planning Council, as discussed in paragraph 7.3. The primary coordination issues are what type of runner should be considered, and the timing of unit outages to minimize effects on upstream adult salmon migrants.

7.2.5. Cultural Resources

Coordination for cultural and historical properties must be in compliance with Sections 106 and 110 of the National Historic Preservation Act (NHPA). The Corps has consulted with the Washington State Historic Preservation Office (SHPO) and determined the affected structures are not eligible for inclusion in the National Register of Historic Places. A memorandum documenting this determination is included in Appendix D, *Environmental Documentation*.

7.3. Coordination with Regional Fish Managers

This project has been coordinated with regional fish management groups. One of these is the Fish Facility Design Review Work Group (FFDRWG), which is part of the Corps' Anadromous Fish Evaluation Program (AFEP). The District has made presentations to FFDRWG at several of their meetings.

A format has been developed to coordinate the NMFS programs for at-risk Snake River salmon stocks with other programs for fish and wildlife throughout the Columbia Basin. As part of this effort, the Implementation Team, which is chaired by NMFS, serves as the primary point of coordination among the participants. The Implementation Team is comprised of representatives from NMFS, USFWS, BPA, the Corps, and the Bureau of Reclamation. The four states and thirteen Federally-recognized Indian tribes of the Columbia Basin also participate.

As part of the Implementation Team, there are several Technical Teams that coordinate the implementation at the technical level. One of those teams is the SCT. The SCT develops proposals, plans, and budget priorities for physical improvements to structures, including monitoring and evaluation. The SCT is co-chaired by NMFS and the Northwest Power Planning Council. Members of the SCT are shown in table 7-1. Letters, dated 21 February 1997, were sent to each SCT member, forwarding copies of a draft rehabilitation report and requesting comments. By letter, dated 25 March 1997, NMFS indicated that they support submitting the report this year to get the project included in the

Fiscal Year 1999 budget. The NMFS also supports reevaluating any decision regarding the use of MGR's after results of the testing at Bonneville Dam in 1998, and information from other projects, are available. A copy of the 25 March 1997 letter is included in appendix D, *Environmental Documentation*.

TABLE 7-1
SYSTEM CONFIGURATION TEAM MEMBERS

Witt Anderson	North Pacific Division
John Kranda	Portland District
Mike Mason	Walla Walla District
Bill Hevlin	National Marine Fisheries Service
Ron Boyce	Oregon Department of Fish and Game
Bob Heinith	Columbia River Inter-Tribal Fish Commission
Keith Kutchins	Shoshone-Bannock Tribes of Fort Hall
Steve Petit	Idaho Department of Fish and Game
Rod Woodin	Washington Department of Fish and Wildlife
Marv Yoshinaka	U.S. Fish and Wildlife Service
Richard Prang	Bureau of Reclamation
John Rowan	Bonneville Power Administration
Jim Ruff	Northwest Power Planning Council

7.4. Government to Government Consultation

On 28 October 1996, letters describing the process for the rehabilitation study and soliciting formal consultation on the proposed rehabilitation project were sent to the Nez Perce Tribal Executive Committee, Shoshone-Bannock Tribes of the Fort Hall Reservation, Confederated Tribes of the Umatilla Indian Reservation, and the Yakama Tribal Council. Only the Yakama Tribal Council responded. On 5 January 1997, after discussion on the rehabilitation work to be completed inside the powerhouse, Mr. Johnson Mow stated that the Tribe was in agreement with the project.

8.0. ASSESSMENT OF ALTERNATIVES

8.1. Critical Assumptions

The following paragraphs discuss the most critical assumptions applied in this analysis. A fundamental assumption regarding the base condition is that the generating units will be kept in operating condition and available for service. Standard maintenance will continue, and breakdowns will be repaired as they occur.

Generators, turbines, and transformers have been simulated over the period of analysis. While it is likely that generator windings will experience minor failures during the period of analysis, for the purposes of this analysis, only major malfunctions (requiring a rewind) have been simulated. It is assumed that the turbines on units 1 through 3 will experience blade cracking and blade failure over the period of analysis. For units 4 through 6, there has been no evidence that blade cracking will be a problem and, therefore, only major malfunctions have been simulated. Transformers are also expected to reach the end of their useful life during the period of analysis, experiencing major malfunctions that will result in the need for replacement.

No additional decline in turbine efficiency has been projected in this analysis. Although the units will deteriorate with continued use over the next 35 years, no method has been established by which to accurately project ongoing rates of deterioration. Therefore, for the base condition, the present level of generating efficiency has been assumed to remain constant throughout the period of analysis.

Operating restrictions to accommodate juvenile fish migration (*i.e.*, mandatory spill and other measures) are detailed in appendix D, *Environmental Documentation*, subsection 2.4.

8.2. Key Variables

The most significant variables in the evaluation process are reliability factors. The probability of unsatisfactory performance is derived from engineering factors that are indicators of the present and future reliability of mechanical and/or electrical components. These factors are based on the age and present condition of the components. The expected timing of future equipment malfunctions has been statistically determined by applying these factors in a Monte Carlo simulation, where 500 iterations per simulation were run for all conditions tested. The results were averaged for all iterations, and these averages represent estimates of the expected values. This determines the frequency of forced outage events throughout the period of analysis. As such, reliability data represent the most significant element of risk with respect to the conclusions reached in this study. This variable has been addressed as a sensitivity issue in appendix B, *Plan Formulation and Economic Analysis*.

8.3. Results of Analysis

Table 8-1 displays alternative plans that produce the highest net benefits. Impacts are described in appendix D, *Environmental Documentation*.

TABLE 8-1
SUMMARY OF AVERAGE ANNUAL COSTS AND BENEFITS

TURBINES	GENERATORS	TRANSFORMERS	COSTS ($)	BENEFITS ($)	NET BENEFITS ($)
	Six New		1,687,210	11,109,092	9,421,882
New Blades 1-3	Six New		2,606,071	12,333,764	9,727,693
New Blades 1-3	Six New	Spares 1-3	3,121,684	13,650,272	10,528,588
New Runners 1-3	Six New	New 1-3	3,153,236	13,987,233	10,833,997
New Blades 1-3	Six New	New 1-3	3,043,273	13,879,894	10,836,621

More detailed cost information is included in appendix B, *Plan Formulation and Economic Analysis.*

8.4. National Economic Development Plan

The plan that contributes most significantly to national economic development, in terms of providing maximum net economic benefits to the nation, is defined as the National Economic Development (NED) Plan. A couple of the plans evaluated to address the existing deficiencies of the six units at Ice Harbor produce similar levels of output in terms of net benefits. The least costly plan that provides relatively similar levels of outputs includes the following elements: 1) rewind generators (including new exciters) on all six units; 2) replace blades on units 1 through 3; and 3) replace transformers on units 1 through 3. This plan has been identified as the NED Plan.

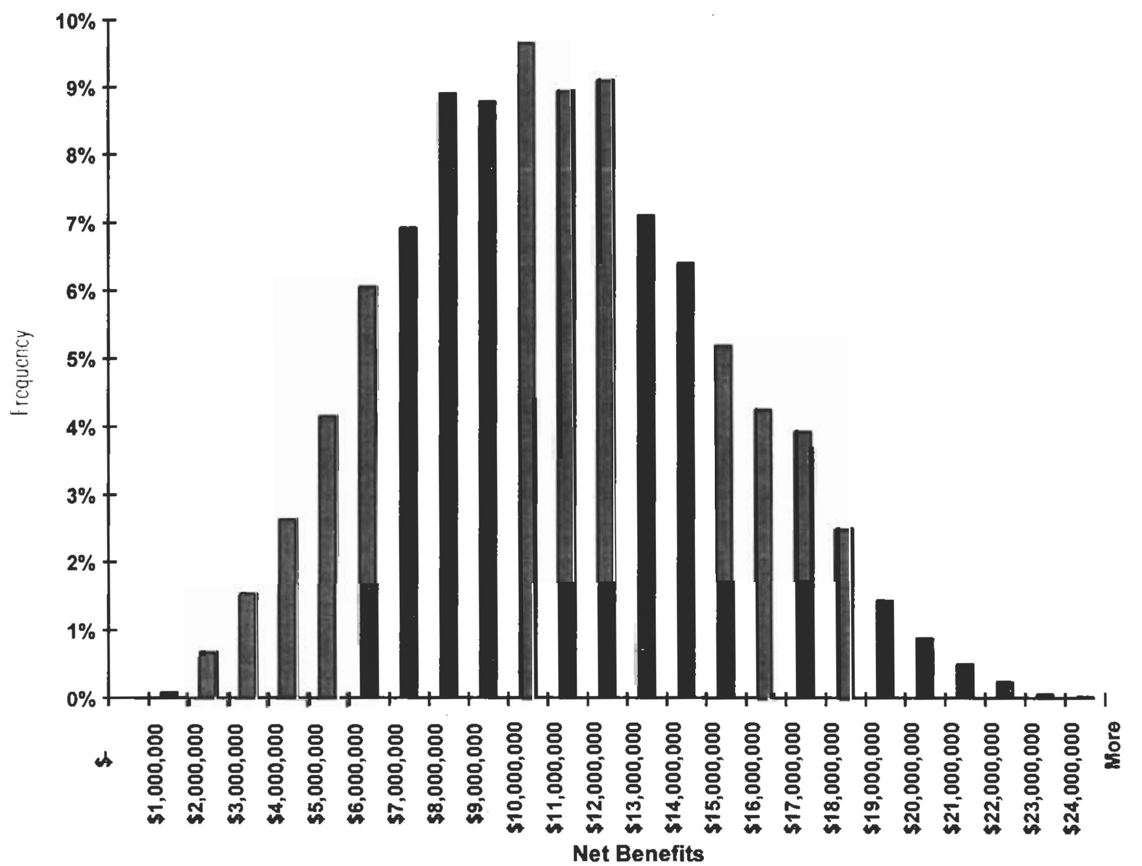
The NED plan addresses the reliability issues of each major component. Fish survival rates would also be improved due to greater turbine efficiency. The annualized costs of this plan are $3.04 million, the annual benefits amount to $13.9 million, and annual net benefits total $10.8 million.

8.5. Statistical Results

Table 8-2 displays the descriptive statistics for the net benefits of the NED plan. Figure 8-1 displays a histogram of the net benefits for the NED plan.

TABLE 8-2 DESCRIPTIVE STATISTICS FOR NET BENEFITS OF NED PLAN	
Mean	$10,836,621
Standard Error	$56,913
Standard Deviation	$4,024,386
Kurtosis	(0.44)
Skewness	0.22
Range	$23,025,031
Minimum	$251,307
Maximum	$23,276,338

Figure 8-1. Histogram of Net Benefits for NED Plan



For further data on the benefits of the alternatives, see appendix B, *Plan Formulation and Economic Analysis*, section 8.

9.0. RECOMMENDED PLAN

9.1. Discussion

The NED plan discussed in section 8 includes generator rewinds and new exciters on units 1 through 6, and new turbine blades and transformers on units 1 through 3. Because of concerns about the endangered Snake River sockeye and threatened and endangered chinook salmon, the reduction of fish mortality past the project was given consideration. Although fish screens are in place on all six units to intercept downstream migrating juvenile fish prior to entering the turbine, somewhat less than half of the fish unavoidably pass through the turbine. New state-of-the-art minimum gap runners (MGR) were evaluated, because of their high efficiency, in an effort to reduce overall fish mortality. This is based on the generally-accepted concept that the higher the turbine efficiency, the higher the fish survival through the turbines.

An analysis was conducted to compare fish survival for new turbine blades, as included in the NED plan, versus new MGR. The study used the base condition as the basis for the evaluation. The analysis took into consideration the impacts of spill requirements for fish passage and the resulting increase in dissolved gases with its impact on fish survival, as discussed in appendix D, *Environmental Documentation*.

As a result of the Biological Opinion, the units are required to operate within 1 percent of their best efficiency. (There is a general consensus among the fishery community that the requirement to operate within the maximum 1-percent efficiency was arbitrary, and not based on scientific-based data.) The concept of the best 1-percent efficiency limits for the standard runner is discussed in paragraph 3.4 and figure 3-7. Because of the more "peaked" shape of the performance curve of an MGR, compared to a conventional turbine, the operating range of the units is more limited if the best 1-percent limits are imposed. This results in reduced operating capacity (see appendix H, *Governor Sensitivity Analysis, and Turbine Engineering and Reliability Analysis,* figure HB-7) and, consequently, reduced energy generation.

Table 9-1 is a summary of economic and environmental study results comparing the NED plan including new turbine blades on units 1 through 3, with new MGR on units 1 through 3 and new MGR on all six units. The percentages for fish survival represent spring chinook. More detailed information is presented in appendix D, *Environmental Documentation*. As shown in table 9-1, fish survival at the Ice Harbor Project for new turbine blades versus new MGR for units 1 through 3 are 75 and 76 percent, respectively, a difference of about 1 percent. Because of a decrease in benefits and higher cost, net benefits for the minimum gap runners are lower than the NED plan.

Table 9-1 Comparison of New Blades Versus Minimum Gap Runners (Includes 11-Percent Uprate of Generators 1 through 3, and Rewinding of Generators 4 through 6) Compared to Base Condition				
	Base Condition	**New Blades Units 1-3 Only (NED Plan)**	**Minimum Gap Runners**	
			Units 1- 3 Only	**Units 1- 6**
Alternative	**1a**	**4c**	**6h**	**6j**[2]
Average Annual Benefits				
Reduced O&M		$ 1,807,398	$ 1, 807,398	$1,847,285
Energy Benefit		$ 7,053,125	$ 6,897,930	$6,826,128
Capacity Benefit		$ 5,019,372	$ 5,019,372	$5,572,856
Total Benefits		$ 13,879,894	$ 13,724,699	$14,246,269
Average Annual Costs		$ 3,043,273	$ 3,246,589	$4,541,755
Net Benefits		$ 10,836,621	$ 10,478,110	$9,704,514
Fish Survival (50 year average)[1]				
At Ice Harbor Dam	75%	75%	76%	76%
Total System	54%	54%	54%	54%

[1]Rounded to nearest percent. More detailed information is presented in appendix D (IHR = at Ice Harbor Dam; BONN = total system), *Environmental Documentation*, table D-8 (spring chinook).
[2]For fish survival purposes, alternative 6J was used in the evaluation. Although alternative 6J does not include a rewind on units 1 through 3, the fish survival would be essentially the same.

It is presently estimated that MGR's could increase passage survival by less than 1 percent. This estimate reflects projected improvements to the MGR beyond the current state-of-the-art design. Prototype tests of minimum gap blades (an early prototype to investigate turbine design for fish survival) were conducted at Rocky Reach Dam near Wenatchee, Washington, during the spring of 1996. The tests indicated that the technology is still in a development stage too early to warrant a significant positive biological effect. Further tests are required of prototype MGR's that include a broader range of identified potential improvements. The hydraulic condition across the turbine unit structure through the range of high efficiency operations is felt to be more critical to gaining larger or significant increments in turbine fish survival.

If the state of MGR and related turbine design technology can improve on the flow capacity-related, high-efficiency range of operation for MGR units prior to implementation of the Ice Harbor rehabilitation, MGR-equipped units should receive further consideration during the NMFS consultation performed prior to the initial phase of implementation.

9.2. Recommended Plan

The declining reliability and efficiency of units 1 through 6 justify an extensive rehabilitation program. The recommended plan for this rehabilitation is the same as the NED plan, and is summarized in table 9-2.

TABLE 9-2
RECOMMENDED PLAN

UNITS 1 THROUGH 3	UNITS 4 THROUGH 6
Rewind generators with 11-percent uprate New solid-state exciters New transformers New turbine blades New governor control system	Rewind generators New solid-state exciters

New transformers are required on units 1 through 3 in order to meet the design capacity of the 11-percent uprate of the generators. Rewind of generator units 4 through 6 potentially could result in about a 5-percent increase in capacity as a result of new state-of-the-art technology. However, testing of the generator for actual output after the rewind would be required for verification. Operating the units at the higher rating could shorten the life of existing transformers. Consequently, benefits for the recommended plan were based on existing unit capability and existing transformers on units 4 through 6. Upon transformer failure on units 4 through 6, new higher-rated transformers could be installed to take advantage of the 5-percent increase in capacity if determined available and warranted.

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10.0. MAJOR REHABILITATION CLASSIFICATION

Studies to address problems at the Ice Harbor powerplant focus on two major objectives: equipment reliability and operating efficiency. Rehabilitation guidance treats the increase in operating reliability and the restoration of lost operating efficiency as reliability issues, and classifies them accordingly. Any measures that increase project outputs beyond the original project design are categorized as efficiency improvements. Based on these designations, measures analyzed in this report to correct problems at Ice Harbor fall within the respective categories, as described below.

All measures that address generator problems at the Ice Harbor powerplant focus on the restoration of unit reliability. Measures involving turbine blade or turbine runner replacement both restore mechanical reliability and operating efficiency lost over time, and also raise operating efficiency to levels beyond the original project design. As such, these measures provide both reliability and efficiency improvements. It should be noted that both turbine runner replacement and the replacement of blades also extend the useful operating lives of the turbines. Measures involving spare transformers or transformer replacement are also reliability based[1].

For the recommended plan, annual incremental costs to restore original efficiency (reliability) are $3,000,000, and incremental costs attributable to efficiency improvements are $40,000. Comparable annual incremental benefits amount to $13,680,000 and $200,000, respectively. A detailed discussion of costs and benefits attributable to both reliability and efficiency improvements is presented in section 11 of appendix B, *Plan Formulation and Economic Analysis*.

[1] Note that, if all three components are replaced and uprated, a minor uprate benefit is achieved.

11.0. PROJECT COST ESTIMATE

A project cost estimate for the recommended plan was prepared using the Microcomputer Aided Cost Estimating System (MCACES) software. The NED/recommended plan given in this report has a total construction cost of $54.7 million at the 1 October 1996 price level. The fully-funded cost estimate, including contingencies and inflation to mid-point of construction, is $67.0 million. Details of this estimate is included in appendix A, *Cost Estimate* (Recommended Plan), and is summarized in table 11-1.

TABLE 11-1
SUMMARY OF TOTAL PROJECT COST

	Current *MCACES* Estimate Effective Pricing Level: 1 Oct 96				Authorize./Budget Year: 1999 Effect. Pricing Level: 1 Oct 98			FULLY FUNDED ESTIMATE			
Item Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	COST ($K)	CNTG ($K)	TOTAL ($K)	SPENT COST ($K)	COST ($K)	CNTG ($K)	FULL ($K)
Powerplant	37,600	7,519	20%	45,119	39,668	7,934	47,602		45,325	9,067	54,392
Feasibility Studies								1,300			1,300
Planning & Engineering	5,336	1,067	20%	6,403	5,631	1,129	6,760		6,188	1,240	7,428
Construction Management	2,626	525	20%	3,151	2,770	553	3,323		3,214	641	3,855
Total Project Cost	45,562	9,111	20%	**54,673**	48,069	9,616	57,685	1,300	54,727	10,948	**66,975**

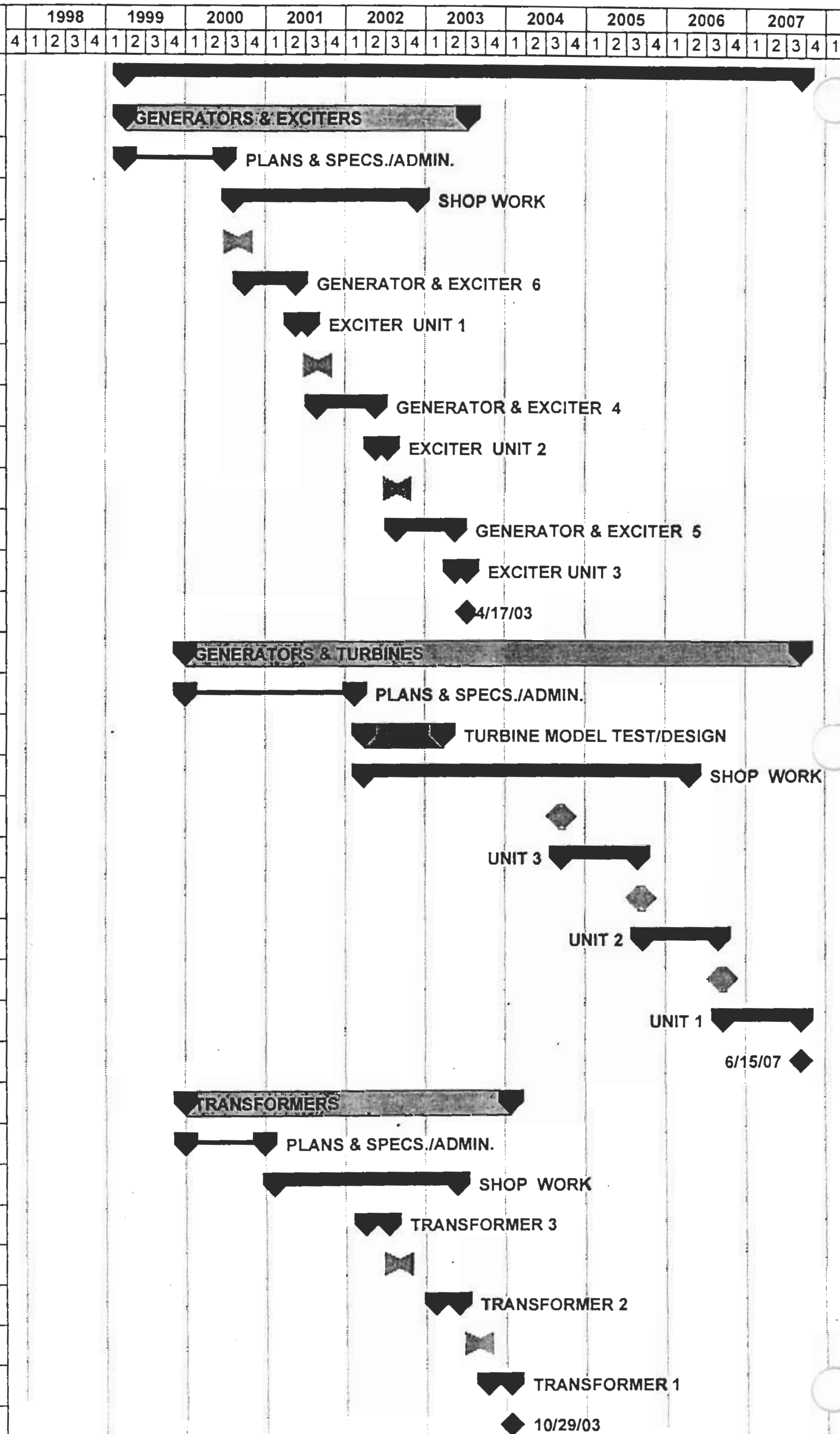
An estimated schedule of fund requirements by fiscal year is presented in table 11-2. The estimates are based on the projected construction schedule as shown in figure 11-1.

TABLE 11-2
FUNDING SCHEDULE

Account Number	Description of Item	FY 1997 ($K)	FY 1998 ($K)	FY 1999 ($K)	FY 2000 ($K)	FY 2001 ($K)	FY 2002 ($K)	FY 2003 ($K)	FY 2004 ($K)	FY 2005 ($K)	FY 2006 ($K)	FY 2007 ($K)	PROJECT TOTAL
07	Power Plant				2,313	7,011	11,775	10,985	6,172	5,970	5,948	4,218	54,382
22	Feasibility Studies	1,300											1,300
30	Planning & Engineering			655	1,783	1,289	979	823	521	510	508	360	7,428
31	Construction Management				161	489	830	778	442	427	426	302	3,855
	FY TOTAL	1,300		655	4,257	8,789	13,584	12,586	7,135	6,907	6,882	4,880	66,975

FIGURE 11-1. IMPLEMENTATION SCHEDULE
ICE HARBOR DAM POWERHOUSE REHAB. (FISCAL YEARS)

ID	Task Name
1	POWERHOUSE REHABILITATION
2	GENERATORS & EXCITERS
3	PLANS & SPECS./ADMIN.
11	SHOP WORK
21	FISH WINDOW
22	GENERATOR & EXCITER 6
30	EXCITER UNIT 1
34	FISH WINDOW
35	GENERATOR & EXCITER 4
43	EXCITER UNIT 2
47	FISH WINDOW
48	GENERATOR & EXCITER 5
56	EXCITER UNIT 3
60	FINISH PROJECT
61	GENERATORS & TURBINES
62	PLANS & SPECS./ADMIN.
72	TURBINE MODEL TEST/DESIGN
73	SHOP WORK
80	FISH WINDOW
81	UNIT 3
91	FISH WINDOW
92	UNIT 2
102	FISH WINDOW
103	UNIT 1
114	FINISH PROJECT
115	TRANSFORMERS
116	PLANS & SPECS./ADMIN.
124	SHOP WORK
128	TRANSFORMER 3
133	FISH WINDOW
134	TRANSFORMER 2
139	FISH WINDOW
140	TRANSFORMER 1
145	FINISH PROJECT



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12.0. OTHER CONSIDERATIONS

12.1. Cost Sharing

In multiple-purpose reservoirs under the jurisdiction of the Corps, the Chief of Engineers is responsible for determining the costs allocated to the hydroelectric power function, except where otherwise required by law. It is Corps policy that all purposes in a multiple-purpose project should share equitably in the benefits of multiple-purpose development, and that no purpose should be subsidized by other project purposes to enable the sale of services at lower rates. By the interagency agreement of 12 March 1954, Federal agencies, Department of the Interior, Department of the Army, and the Federal Power Commission [now the Federal Energy Regulatory Commission (FERC)] have accepted the Separable Costs Remaining Benefits (SCRB) method of cost allocation as a preferred method of distributing project costs. This method permits equitable allocations of project costs to power for use as a basis in establishing power rates. All costs related to the major rehabilitation of power facilities are allocated as specific power costs. Costs (including operation, maintenance, replacement, and rehabilitation) allocated to power are fully repaid to the U.S. Treasury by revenues collected by the marketing agency. This is in accordance with existing law, as referenced in subsection 103(c)(1) of the Water Resource Development Act (WRDA) of 1986. A local cost-sharing agreement is not required.

12.2. Marketing of Power Produced by the Corps

Under the provisions of Section 5 of the Flood Control Act of 1944 (Public Law 534, 78th Congress) and other acts, power developed at projects under the jurisdiction of the Chief of Engineers that is surplus to project needs, is turned over to the Secretary of Energy for marketing. Law requires that the Secretary will transmit and dispose of power and energy so as to encourage the most wide-spread use at the lowest possible rates to consumers, consistent with sound business principles. It also provides that, in the sale of power, preference is given to public bodies and cooperatives. Agencies of the Department of Energy that market the power include Bonneville Power Administration, Southwestern Power Administration, Southeastern Power Administration, Western Area Power Administration, and Alaska Power Administration. Rates for the sale of power to recover allocated costs are established by the marketing agency of the

Department of Energy, and are approved by the FERC. The marketing agency is required to establish rates to recover the cost of producing and transmitting the power, including repayment of the Federal investment, over a period of 50 years (as established by the Secretary).

Coordination has been maintained with BPA throughout the study. The BPA representatives provided input to the power analysis, attended all major planning meetings, and participated in discussions of possible measures and alternative plans. A copy of BPA's comments, presented at the 30-percent In-Progress Review Meeting held on 29 October 1996, is included in appendix J, *Coordination with Bonneville Power Administration*. A common agreement could not be made that met the objectives of both the Corps and BPA. In a letter to BPA, dated 31 January 1997, the Corps requested a marketability letter for the powerhouse rehabilitation plan. By letter, dated 3 March 1997, BPA indicated that they cannot support the recommended plan, and will be unable at this time to provide a marketability letter. The BPA also provided a list of outstanding issues, dated 3 March 1997. Copies of these documents, as well as preliminary responses to BPA outstanding issues, are included in appendix J, *Coordination with Bonneville Power Administration*.