8.0 CONSTRUCTION COSTS AND SCHEDULES

8.1 Estimates of Cost

Estimates of construction costs have been prepared for the following alternatives for project development:

Alternative A - 400 MW McArthur tunnel development

Alternative B - 330 MW McArthur tunnel development

Alternative C & D - 300 MW Chakachatna tunnel development

Alternative E - 330 MW McArthur tunnel development

The estimates are based on schedules of quantities of materials and equipment needed for the major features of each alternative to the extent permitted by the drawings for Section 3.0 of this report. In some cases, quantities were proportioned from the construction records of other projects bearing significant similarity of structures and conditions expected to be encountered during construction of the Chakachamna Hydroelectric Project. Unit prices developed for this and other projects involving similar types of construction and from analyses of bids received for the construction of similar types of projects in Alaska, adjusted as necessary to reflect January 1982 price levels, were then applied to the schedules of quantities to arrive at the estimated costs set forth in the Conceptual Estimate Summaries, sheets 1 of 2 and 2 of 2. The summaries show the

CHAKACHAMNA HYDROELECTRIC PROJECT
CONCEPTUAL ESTIMATE SUMMARIES – SHEET 1 OF 2

ALTERNATIVES	ESTIMATED COSTS IN THOUSANDS OF DOLLARS									
	A		B		C		D		E	
LAND AND LAND RIGHTS	Not included	0	Not included	0	Not included	0	Not included	0	Not included	
POWER PLANT STRUCTURE AND IMPROVEMENTS										
Valve Chamber	5,600		5,500		5,600		5,600		5,500	
Underground Power House	26,200		25,200		26,200		26,200		25,200	
Bus Galleries	200		200		200		200		200	
Transformer Gallery	4,600		4,300		4,300		4,300		4,300	
Valve Chamber and Transformer Gallery – Access Tunnel	400		400		400		400		400	
P. H. Access Tunnel	13,500		13,500		13,500		13,500		13,500	
Cable Way	800		800		800		800		800	
		51,300		49,900		51,000		51,000		49,900
RESERVOIR, DAM AND WATERWAYS										
Reservoir	100		100		100		100		100	
Intake Structure	10,400		9,300		10,400		10,400		9,300	
Intake Gate Shaft	13,200		12,400		13,200		13,200		17,600	
Fish Facilities	–		–		–		–		85,400	
Dike & Spillway	–		–		–		–		9,100	
Access Tunnel										
– At Intake	21,600		19,100		21,600		21,600		0	
– At Surge Chamber, No. 3	6,600		5,900		8,900		8,900		5,900	
– At Mile 3, 5, No. 1	0		0		20,800		20,800		0	
– At Mile 7, 5, No. 2	0		0		14,500		14,500		0	
Power Tunnel	626,800		580,400		712,500		712,500		447,800	
Surge Chamber – Upper	12,900		11,000		12,900		12,900		18,900	
Penstock – Inclined Section	18,000		16,500		15,400		15,400		0	
– Horizontal Section and Elbow	6,700		6,000		6,700		6,700		6,000	
– Wye Branches to Valve Chamber	13,200		11,900		12,100		12,100		11,900	
– Between Valve Chamber & Power House	800		600		800		800		600	
Draft Tube Tunnels	1,900		1,700		1,900		1,900		1,700	
Surge Chamber – Tailrace	2,400		2,400		2,400		2,400		2,400	
Tailrace Tunnel and Structure	10,300		9,600		10,300		10,300		9,600	
Tailrace Channel	900		700		900		900		700	
River Training Works	500		500		500		500		500	
Miscellaneous Mechanical and Electrical	7,100		6,100		5,700		5,700		6,100	
		753,400		694,200		871,600		871,600		633,600

A, B – McArthur development, high level tunnel excavated by drilling and blasting
C, D – Chacackatna valley development excavated by drilling and blasting
E – Mc Arthur development, low level tunnel excavated by boring machine

CHAKACHAMNA HYDROELECTRIC PROJECT
CONCEPTUAL ESTIMATE SUMMARIES – SHEET 2 OF 2

ALTERNATIVES	ESTIMATED COSTS IN THOUSANDS OF DOLLARS				
	A	B	C	D	E
TURBINES AND GENERATORS	67,900	57,900	54,500	54,500	57,900
ACCESSORY ELECTRICAL EQUIPMENT	11,200	9,500	9,000	9,000	9,500
MISCELLANEOUS POWER PLANT EQUIPMENT	8,600	7,300	6,900	6,900	7,300
SWITCHYARD STRUCTURES	3,600	3,600	3,600	3,600	3,600
SWITCHYARD EQUIPMENT	13,800	12,500	12,100	12,100	12,500
COMM. SUPV. CONTROL EQUIPMENT	1,600	1,600	1,600	1,600	1,600
TRANSPORTATION FACILITIES					
Port	4,600	4,600	4,600	4,600	4,600
Airport	2,000	2,000	2,000	2,000	2,000
Access and Construction Roads	59,600	59,600	44,100	44,100	59,600
	66,200	66,200	50,700	50,700	66,200
TRANSMISSION LINE & CABLE CROSSING	63,200	63,200	56,500	56,500	63,200
TOTAL SPECIFIC CONSTRUCTION COST AT JANUARY 1982 PRICE LEVELS	1,040,800	965,900	1,117,500	1,117,500	905,300
ENGINEERING & CONSTRUCTION MANAGEMENT	124,900	115,900	134,100	134,100	108,700
SUBTOTAL	1,165,700	1,081,800	1,251,600	1,251,600	1,014,000
CONTINGENCY @ 20%	233,100	216,400	250,300	250,300	203,000
ESCALATION	Not Incl.	Not Incl.	Not Incl.	Not Incl.	Not Incl.
INTEREST DURING CONST. @ 3% PER ANNUM	111,900	104,100	101,400	101,400	97,400
OWNER'S COSTS	Not Incl.	Not Incl.	Not Incl.	Not Incl.	Not Incl.
ALLOWANCE FOR FISH PASSAGE FACILITIES	–	50,000	–	50,000	Under Reservoir Item
TOTAL PROJECT COST AT JANUARY, 1982 PRICE LEVELS	1,510,700	1,452,300	1,603,300	1,653,300	1,314,400
USE	1,500,000	1,450,000	1,600,000	1,650,000	1,314,000

A, B – McArthur development, high level tunnel excavated by drilling and blasting
C, D – Chacackatna valley development excavated by drilling and blasting
E – Mc Arthur development, low level tunnel excavated by boring machine

following estimated project costs excluding owner's costs and escalation:

Alternative A	$1.5 billion
Alternative B	$1.45 billion
Alternative C	$1.6 billion
Alternative D	$1.65 billion
Alternative E	$1.32 billion

The above costs include a 20% contingency added to the specific construction cost plus engineering and construction management, and interest during construction. The costs for Alternatives B and D additionally include a provisional allowance of $50 million for fish passage facilities at the lake outlet. Costs for Alternative E include a constant grade tunnel from powerhouse level at the McArthur River to the base of the intake gate shaft at Chakachamna Lake, and pending the completion of geological studies of the tunnel alignment, the assumption is made that this tunnel will be driven by a boring machine. Included also in Alternative E is the estimated cost of proposed fish facilities at the Chakachamna Lake outlet as described elsewhere in this report and shown on drawings. The estimated project costs are considered to be conservative because of the conservative assumptions made regarding the amount of rock support required in the underground excavations.

For all of the alternatives, the principal structures consist of the following:

- Intake structure at Chakachamna Lake with underwater lake tapping, and control gate shaft.

- Concrete lined power tunnel with construction access adits.

- Surge chamber and except for Alternative E, emergency closure gates at the downstream end of the power tunnel.

- Underground concrete lined pressure penstock and manifold.

- Concrete and steel lined penstock branches leading to a valve chamber and the turbines.

- Four unit underground powerhouse with exploratory adit (to become the ventilation tunnel) and main access tunnel.

- Underground transformer vaults and high voltage cable gallery.

- Tailrace tunnel and surge chamber.

- Tailrace outlet channel and river protection works.

- High voltage cable terminals and switchyard.

- Transmission lines to northerly shore of Knik Arm.

- High Voltage submarine cable crossing of Knik Arm.

In addition, for Alternative E the following principal structures are included:

- Concrete lined surge shaft connecting surge chamber and downstream end of power tunnel.

- Rockfill dike at Chakachamna Lake outlet.

- Spillway at lake outlet.

- Fish passage facilities at lake outlet for both upstream and downstream migrants.

8.1.1 Power Tunnel

The cost of constructing the power tunnel is the dominant feature, representing more than half the estimated cost of constructing each alternative. Detailed evaluations were made of all operations and the direct costs considered necessary to construct the 25-foot diameter concrete lined power tunnel for Alternatives A, C and D, using both rubber tired and rail haulage equipment. The difference in cost between the two was found to be small. Thus, the choice of haulage equipment will probably be determined by other considerations such as for example, whether excavation and concrete placement would be scheduled by a Contractor to take place concurrently in a given tunnel heading. This can be accomplished if necessary in a 25-foot diameter tunnel with either rail haulage or rubber tired equipment.

The estimated cost of constructing the 23-foot diameter tunnel required for Alternative B was first proportioned from the estimated unit costs per lineal foot for constructing the 25-foot diameter tunnels for Alternatives A, C and D using the same construction

methods of drilling and blasting. These costs are indicated in the summary schedule for Alternative B at the end of this chapter as $580,400,000.

For Alternative E, an alternative method of driving the tunnel by a boring machine was considered as well as a modification of the profile of the tunnel using uniform grade from near the base of the intake shaft to the powerhouse. Two surface samples of rock collected from the general vicinity of the power intake site at Chakachamna Lake and one sample collected from the surface in the vicinity of the powerhouse site near the McArthur River were tested for compressive strength, indentation, point load, quartz content and cutter penetration rate at The Robbins Company laboratory in Kent, Washington. Although test data obtained from surface samples can sometimes be misleading when compared to comparable data obtained from fresh rock samples taken at depth, the data were used with appropriate conservatism to estimate the rate of penetration of a tunnel boring machine working in this rock. The use of a boring machine for excavating showed a saving in costs of $126,700,000. Changing the grade of the tunnel showed an additional saving of $5,000,000. The total cost of constructing the tunnel was thus reduced from $580,400,000 to $448,700,000. This cost was used in the summary schedule for Alternative E, the recommended alternative.

The estimated tunnel construction costs are based on the following items:

- Excavation for Alternatives A, B, C and D would be by conventional drilling and blasting generally with full face excavation, drilling 12-foot depth rounds. Allowance is included for a nominal length of tunnel where the depth of rounds might have to be reduced, or where top heading and bench techniques might have to be used temporarily, if less favorable ground conditions are encountered.

- Excavation for Alternative E would be by a boring machine to 27-foot boring diameter which after lining would be hydraulically equivalent to the 23-foot diameter horseshoe for Alternative B driven by conventional methods. The rate of advance was estimated at 50 feet per day calculated on the basis of a similar project in similar rock formation. Assumptions for support were conservatively left the same as for the conventionally driven tunnel, although it is realized that some savings would probably result in actual operation. Also, sections of the tunnel may be left unlined because the boring machine provides a smoother excavated surface than conventional methods, thus reducing tunnel friction losses.

- The assumptions are made that 25% of the tunnel length would require steel rib support, 25% would be supported by patterned rock bolts and 50% would be unsupported.

- Chain link mesh for the protection of workmen from rock falls is provided above the spring line over the full tunnel length.

- Estimated excavation costs include provision for handling and removing 2000 gallons per minute of groundwater inflow in each tunnel heading.

- Excavation and concrete lining would proceed on a 3-shift basis, 6 days per week.

- Construction access adits would be located near the upstream and downstream ends of each tunnel alternative. In addition two intermediate adits would be provided for Alternatives C and D.

8.1.2 Underground Powerhouse and Associated Structures

For purposes of the current estimates, the powerhouse has been taken as an underground installation for each alternative, with a high pressure penstock shaft and low pressure tailrace tunnel. The estimates of cost are based on the following conditions:

- All excavation and concrete work would proceed on a 3-shift, 6 days per week basis.

- The powerhouse cavern, valve chamber and tailrace tunnel would be excavated by top heading and bench.

- The penstock and surge shafts would be excavated first by pilot raise, then by downward slashing to full diameter.

- Excavation for the horizontal penstock and manifold, access tunnel, cable gallery and draft tubes would be full face.

- Chain link mesh is provided for protection of workmen over the upper perimeter of all excavations exceeding 12 feet in height.

- All permanent excavations would be supported as determined necessary by patterned rock bolts.

- Allowance is included for lining the upper perimeters of all caverns, chambers and galleries required for permanent access and those housing vulnerable generating or accessory equipment with wire mesh reinforced shotcrete (this may only be needed locally according to rock conditions exposed during construction).

- Excavation of an exploratory adit, and a program of core drilling and rock testing will precede and confirm the suitability of the site for the underground powerhouse complex during the design phase and the costs thereof are included in the estimates.

- The costs included for the major items of mechanical and electrical equipment are based on current data with added allowance for delivery and transportation to the powerhouse site. Installation costs are also included.

- Costs of mechanical and electrical auxiliary equipment and systems, control and protective equipment are included.

8.1.3 Tailrace Channel

The estimates include a monetary allowance for the construction of an outlet channel and river training

works to protect it from damage during floods in the river. Details of such requirements are not well defined at the present stage but it is contemplated that extensive use would be made of rock spoil from excavation of the powerhouse complex for these purposes.

River gravels excavated from the tailrace channel would be processed and used to the maximum extent possible for concrete aggregate.

8.1.4 Switchyard

In each alternative, due to space limitations, the switchyard would be located outside the mouth of the canyon on gently sloping land and an appropriate allowance is included in the estimates for their cost.

8.1.5 Transmission Line and Cable Crossing

Field data acquisition has not been performed and information regarding construction conditions is limited to aerial observation of the proposed transmission line alignment and cable crossing. The cost allowed in the estimate for the transmission line is based on experience and includes the estimated cost of the submarine cable crossing to a dead end structure on the Anchorage Shore of Knik Arm.

8.1.6 Site Access and Development

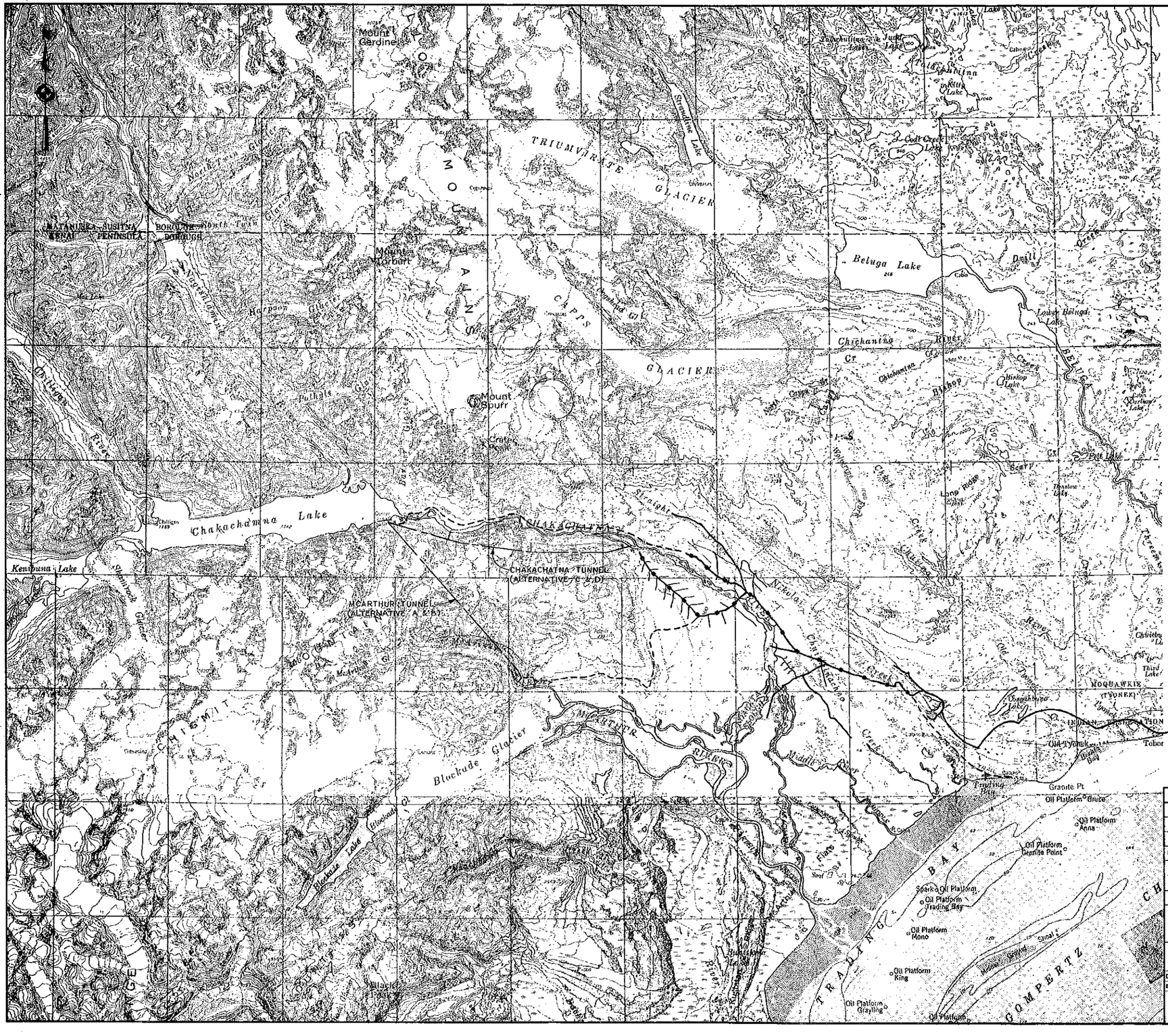
The estimates include costs of constructing access and support facilities needed for construction of the permanent works. These would consist basically of the following installations:

- Unloading facility on tidewater at Trading Bay, complete with receiving and warehousing provisions, bulk cement and petroleum fuels storage plus a small camp for operating staff.

- Gravel surfaced all-weather access roads to construction sites (Figure 8-1). It has been assumed that where existing roads are suitably located, permission to use them could be negotiated with their owners in exchange for improvements that would include widening them to full two-way traffic roads. Bridges and culverts would be provided at all streams and water courses and where needed for drainage. Year-round maintenance costs are included throughout the construction period.

- An aircraft landing facility with a runway of sufficient length to handle aircraft up to DC-9 and 737 types, and ground support facilities.

- For Alternatives A, B and E, major construction camps would be located outside but close to the mouth of the McArthur Canyon to accommodate workers employed on the downstream heading of the power tunnel, the powerhouse and associated structures. A second camp for workmen employed on the upstream heading of the power tunnel and intake works would be provided just east of the Barrier Glacier on the northerly side of the river. This camp will also be used for construction of the lake outlet works and fish facilities for Alternative E.



NOTES:

1.) TOPOGRAPHY IS FROM USGS QUADRANGLE MAPS

2.) HORIZONTAL GRID IS UNIVERSAL TRANSVERSE MECATOR PROJECTION, 1927 NORTH AMERICAN DATUM.

3.) VERTICAL DATUM IS MEAN LOWER LOW WATER.

LEGEND:

- EXISTING ROAD TO BE IMPROVED
- EXISTING ROAD
- NEW ACCESS ROAD

2 0 2 4 MILES

SCALE: 1"=2 MILES

No.	DATE	REVISION	BY	CHKD	ENGR SUPV	PROJ ENGR	PROJ MGR

ALASKA POWER AUTHORITY
ANCHORAGE, ALASKA

CHAKACHAMNA HYDROELECTRIC PROJECT

ACCESS ROAD

BECHTEL CIVIL & MINERALS, INC.
SAN FRANCISCO

DESIGNED	DRAWN PRITCHARD	CHECKED
ENGR SUPV	PROJ ENGR	APP'D

JOB No.	DRAWING No.	REV.
14879	FIGURE 8-1	B

- For Alternatives C and D the main construction camp would be located outside the mouth of the Chakachatna Canyon for workers employed on the downstream heading of the power tunnel, the powerhouse and associated structures and also for the second intermediate access adit to the power tunnel. A second camp for workers employed on the upstream heading of the power tunnel, intake works and headings driven from the first intermediate access adit to the power tunnel would be located east of the Barrier Glacier.

- The construction camps would be self-contained with all needed support facilities which would include water supply sewage treatment, solid waste disposal, catering and medical services.

- Electrical power during construction is provided for on the assumption that diesel driven equipment would be used.

- Major compressed air facilities would be required for the excavation work and their cost is provided for in the estimates.

- Camps needed to accommodate transmission line workers would be light weight "fly camps". Much of the line work would be undertaken in winter and would be avoided during waterfowl nesting periods.

As construction work approaches completion, all temporary facilities will be dismantled and removed from the site, which will be restored insofar as is

possible to its original condition, and the cost of such demobilization and site restoration is included in the estimates.

8.2 Exclusions from Estimates

The estimates of construction costs do not include provision for the costs of the following items:

- Owner's administrative costs.
- Financing charges.
- Escalation (Estimated costs are "overnight costs" at January 1982 price levels.
- Land and Land Rights.
- Water Rights.
- Permits, licenses and fees.
- Switchyard at the Anchorage transmission line terminal.

8.3 Construction Schedules

Typical construction schedules are shown on Figure 8-2 for Alternatives A and B, on Figure 8-3 for Alternatives C and D, and on Figure 8-4 for Alternative E. These schedules have as their beginnings the existing schedule for completion of the project feasibility study and preparation of the application to the Federal Energy Regulatory Commission (FERC) for a license to construct the project.

CHAKACHAMNA HYDROELECTRIC PROJECT
PROJECT SCHEDULE
ALTERNATIVES A AND B

DESCRIPTION	
ENGINEERING	
Feasibility Study	
FERC License	
Exploration Program – Pioneer Road	
Intake Exploration Program	
Engineering Design	
PROCUREMENT – TURBINE/GENERATOR	
CONSTRUCTION	
Mobilization and Water/Sewage Plant	
Trading Bay Port and Facilities	
Airstrip	
Access Roads & Camps – Intake	
Access Roads & Camps – Downstream Tunnel	
Access Roads & Camps – Powerhouse	
Access Tunnels – Intake	
Access Tunnels – Downstream	
Access Tunnels – Powerhouse	
Power Tunnel – Excavation	
Power Tunnel – Concrete	
Upper Surge Chamber	
Intake Gate Shaft	
Intake Tunnel and Lake Tap	
Powerhouse Complex	
Lower Surge Chamber	
Penstock and Manifold	
Tailrace Tunnel Top Heading & Bench	
Tailrace Canal	
River Training Works	
Switchyard	
Transmission Line	
Demobilization and Site Restoration	

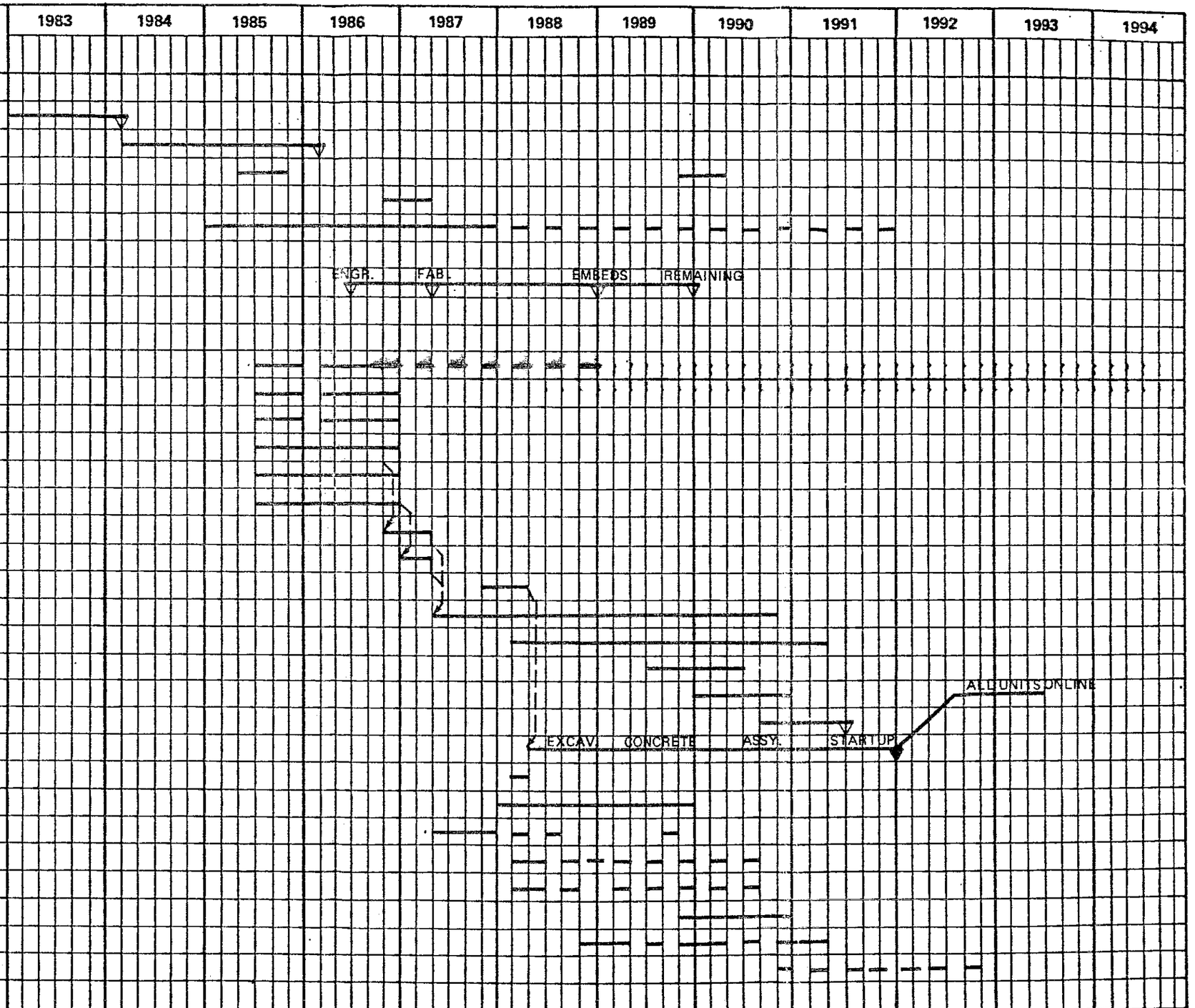


FIGURE 8-2

CHAKACHAMNA HYDROELECTRIC PROJECT
PROJECT SCHEDULE
ALTERNATIVES C AND D

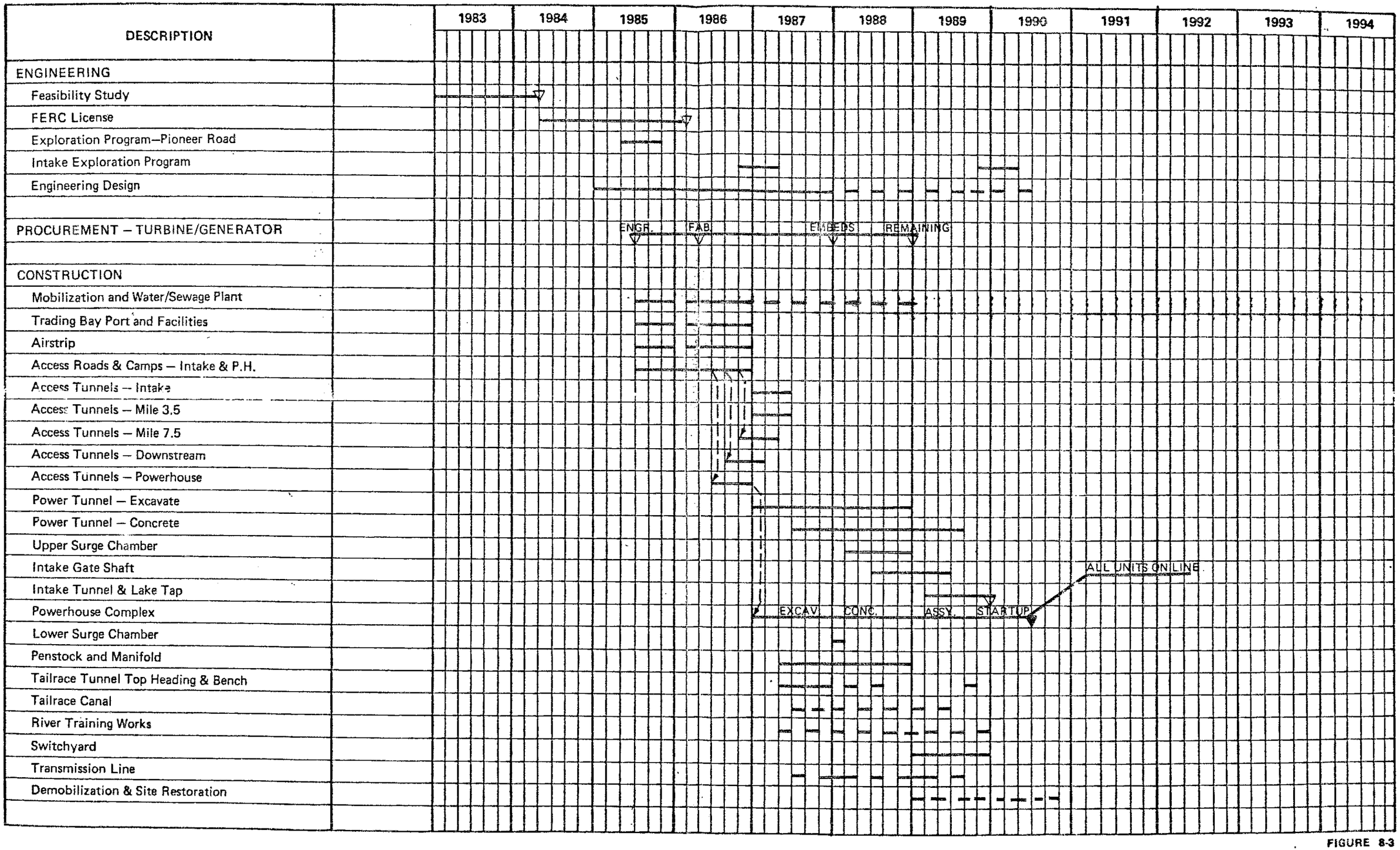


FIGURE 8-3

CHAKACHAMNA HYDROELECTRIC PROJECT
PROJECT SCHEDULE
ALTERNATIVE E

DESCRIPTION	
ENGINEERING	
Feasibility Study	
FERC License	
Exploration Program – Pioneer Road	
Intake Exploration Program	
Engineering Design	
PROCUREMENT – TURBINE/GENERATOR	
CONSTRUCTION	
Mobilization and Water/Sewage Plant	
Trading Bay Port and Facilities	
Airstrip	
Access Roads & Camps – Intake	
Access Roads & Camps – Downstream Tunnel	
Access Roads & Camps – Powerhouse	
Access Tunnels – Intake	
Access Tunnels – Downstream	
Access Tunnels – Powerhouse	
Fish Facilities	
Chakachatna Dike and Spillway	
Power Tunnel – Excavation	
Power Tunnel – Concrete	
Upper Surge Chamber	
Intake Gate Shaft	
Intake Tunnel and Lake Tap	
Powerhouse Complex	
Lower Surge Chamber	
Penstock and Manifold	
Tailrace Tunnel Top Heading & Bench	
Tailrace Canal	
River Training Works	
Switchyard	
Transmission Line	
Demobilization and Site Restoration	

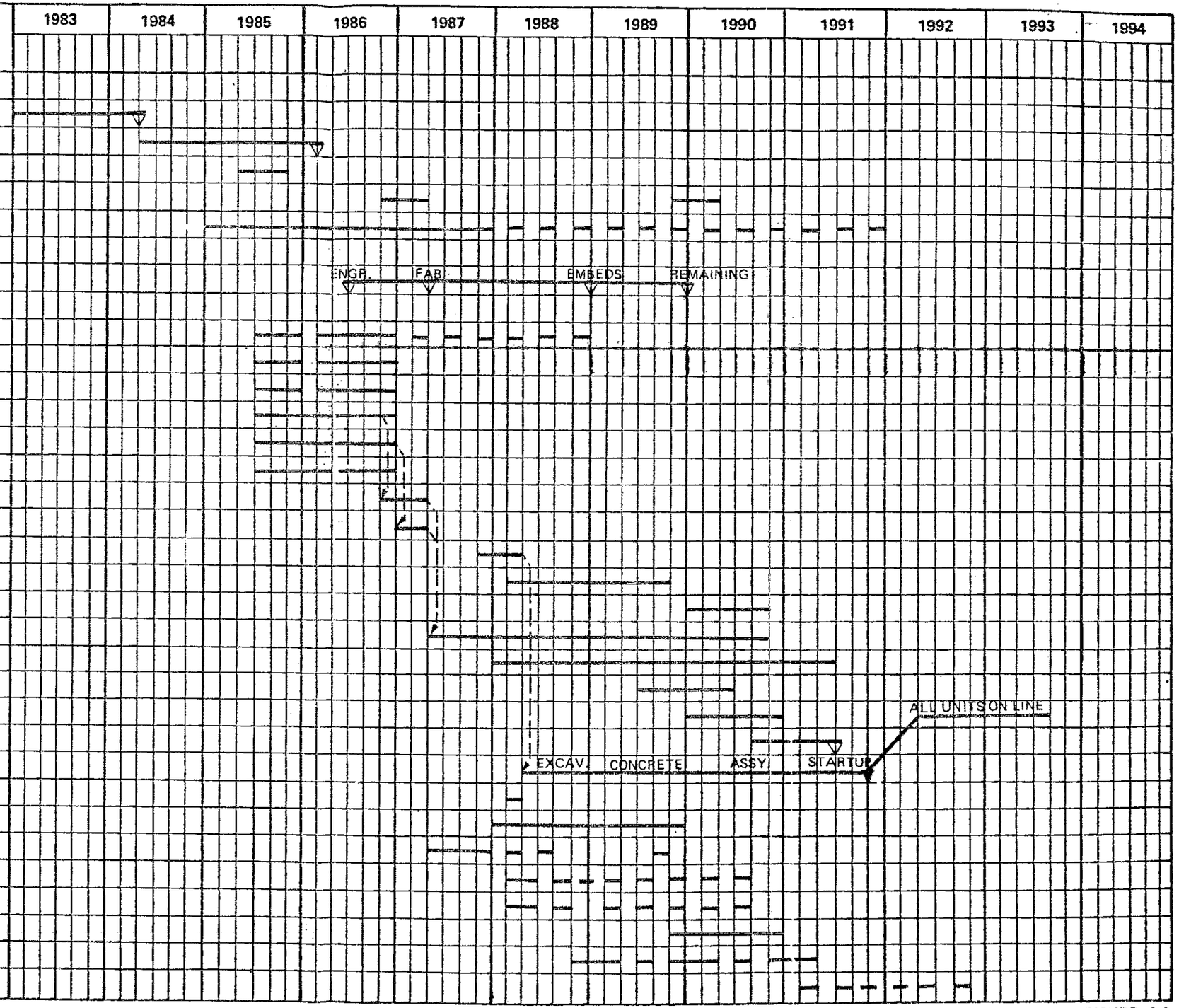


FIGURE 8-4

The assumption has been made that the license application would be submitted to FERC March 1, 1984. Assuming also that the FERC licensing process continues in much the same manner as it does at the present time, an early step will be the preparation of an environmental assessment of the project by FERC staff. This generally takes about 12 months following which is a 60-day period for review and comment by interested agencies. Thus, by the end of April, 1985, it should have become clear whether there are any outstanding unresolved issues. If there are not, then it would be possible to forecast with reasonable certainty that the FERC license would be issued in early 1986, in which event there would not appear to be any reason why the construction of access facilities and camp installations could not commence by June 1, 1985. In order to provide adequate lead time to commence design and prepare plans and specifications for the construction of access facilities, design engineering of the project would need to commence at the beginning of 1985.

Noting that there is a possibility that FERC might also require completion of an exploratory adit and rock testing program at the powerhouse site before issuing the project license, June 1, 1984 would appear to be a logical time to commence that program. Making an early start in the manner described above would permit the plant to commence commercial operation a year earlier than if the design of the project and construction of infrastructure did not commence until after the FERC license had been issued.

Construction of the power tunnel lies on the critical path for completion of development via the McArthur River in Alternatives A, B, and E. For conventional excavation methods assumed for Alternatives A and B the schedule was based on tunnel excavation advancement at an average rate of 26 feet per day in each heading. At that rate, excavation would be completed in approximately 3-1/2 years.

For excavation by boring machine assumed for Alternative E the schedule was based on net advancement of 50 feet per day from one heading at which rate the excavation would be completed in approximately the same time.

Placement of the concrete lining would proceed generally concurrently with the excavation. Total construction time for the tunnel is thus 50 months and the first unit in the powerhouse could be started up by August 1, 1991.

As discussed above a saving in time might be effected if any sections of the tunnel can be left unlined as a result of smoother boring machine excavation and reduction of rock shattering.

For development via the Chakachatna River in Alternatives C and D, the ability to provide two intermediate construction access adits enables the tunnel construction to be completed within 32 months, or 18 months less than for the McArthur tunnel. Timely delivery of the turbines and generators, and construction of the powerhouse complex becomes more critical. Assuming an early start on site access and

development as described above for Alternatives A and B, the first unit in Alternatives C and D could be started up by February 1, 1990, or 18 months earlier than would be the case with Alternatives A, B and E.