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AN EVALUATION OF THE COST AND SCHEDULE ESTIMATE OF THE SEABROOK NUCLEAR PROJECT

Prepared for

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EXECUTIVE SUMMARY

The Public Service Company of New Hampshire (PSNH) is a major owner and managing utility of the Seabrook Nuclear Generating Station (Seabrook). PSNH employed Yankee Atomic Electric Company (YAEC) to directly oversee the design and construction of Seabrook and to provide start-up services. United Engineers and Constructors (UE&C) was contracted to design the plant and to serve as construction manager. Construction began in 1976 and the plant was then estimated to cost $2 billion. The project schedule has been delayed, partly due to intervention in the licensing process, and costs have risen. In the spring of 1982, PSNH directed YAEC and UE&C to perform a complete evaluation of the Seabrook cost and schedule estimate. The result of that study was an estimated cost of $5.12 billion based on commercial operation dates of December 1984 and March 1987 for Units 1 and 2, respectively - a ten-month delay from the previously announced schedule.

As a result of the schedule delay and large cost increase, PSNH selected Management Analysis Company (MAC) to conduct an independent review of the estimated cost and schedule for Seabrook. MAC performed that review with personnel experienced in nuclear power plant project management, estimating and costs, planning and scheduling, and project control systems. The study included a review of the estimating process, the cost and schedule data and the assumptions used in developing the estimated cost and schedule to complete Seabrook. But MAC did not prepare an independent re-estimate of the project. This document reports on the work done by the MAC team.

Since the start of construction in July 1976, the Seabrook project has progressed toward completion on a time line statistically equivalent to the top 5% of the industry for projects in this time period. This good performance reflects the many things on the project that have been done well. The opportunity to continue this trend exists and success in this effort can result in a completion date significantly better than the industry average. Therefore, this report does not dwell on the good record of the past, but focuses on the latest cost and schedule estimate, the areas of concern that MAC has, and some areas for improvement that can be achieved for continuing good performance.

A review of the November 1982 cost and schedule estimate for the Seabrook project performed by MAC has led to several conclusions concerning the currently stated cost

and schedule. The basis for the Seabrook project estimate is the projected completion dates of December 1984 and March 1987 for Units 1 and 2, respectively. These dates are a result of the development of a "study schedule" for the estimate. The cost estimate developed in accordance with these projected completion dates was thorough, detailed and well founded, though it was not developed following a documented procedure or plan. The cost estimate was found to be complete and reasonable with minor exceptions. However, based upon an analysis of the present project status and the remaining work to go, MAC has concluded that it will require a minimum of 12 additional months to complete the Unit 1 portion of the project. The range of extension of the completion date is indeterminate at this time due to lack of necessary detailed data. The development of a detailed schedule with achieveable production, resource and density levels should be accomplished to determine an achieveable completion date for Unit 1 and common to which the project can be managed.

In summary, this project has exceeded most industry performance in construction progress and, if our minimum projected extension is met, will still exceed industry "average" construction experience. All elements are included in the cost estimate and it can be reasonably utilized for management decisions if an achievable schedule is developed and the project is managed to it.

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1.0 INTRODUCTION

1.1 BACKGROUND

The Public Service Company of New Hampshire (PSNH) is an electric utility serving residential and commercial customers throughout the state of New Hampshire. The company's principal mission is to maintain an adequate and reliable supply of power at minimum possible cost to serve the needs of its customers. Fulfillment of this mission requires the company to project future demands for power and to plan its power generating and distribution system accordingly. Based on its projections of future demand, PSHN announced its plans in 1973 to construct the Seabrook Nuclear Generating Station (Seabrook).

Seabrook is comprised of two 1,150 MWe generating units using pressurized water reactors (PWRs). Ownership of the plant is shared by 16 utilities. PSNH owns a 35.5% share and is the managing utility responsible for design, construction, start-up and operation of the plant.

PSNH employed the services of Yankee Atomic Electric Company (YAEC) to directly oversee the design and construction of Seabrook and to provide start-up services. YAEC was established by a number of New England utilities to serve as their agent in managing the construction and operation of planned nuclear power facilities. YAEC is not the architect/engineer (A/E) nor is it the constructor of Seabrook. United Engineers and Constructors (UE&C) was contracted to design the plant and to serve as construction manager. Thus, YAEC oversees the efforts of UE&C.

Construction of Seabrook began in July 1976. The plant was then estimated to cost approximately $2 billion. Commercial operation was targeted for November 1981 and November 1983 for Unit No. 1 and Unit No. 2, respectively. That schedule was not achieved, partly due to work stoppages caused by intervention in the licensing process. In April 1981 the estimated cost of Seabrook was placed at $3.65 billion and commercial operation targets became February 1984 and May 1986.

In the spring of 1982, PSNH directed YAEC and UE&C to perform a complete reevaluation of the Seabrook cost and schedule estimate. The results of that

extensive effort were announced in November 1982. The estimated total cost of Seabrook rose to $5.12 billion, which is an increase of 44% over the 1981 estimate. The completion date of both units was estimated to slip ten months to December 1984 and March 1987, respectively.

A chronological listing of the estimates at Seabrook is included in Table 1.

TABLE 1

PSNH SEABROOK STATION -
UNITS 1 AND 2

DATE OF ESTIMATE	COMMERCIAL OPERATION DATE		UE&C AMOUNT (MILLIONS)	TOTAL (MILLIONS)
	UNIT 1	UNIT 2		
7/73	11/79	09/81	$ 710	$ 1,175
5/74	11/79	09/81	798	1,300
10/75	11/80	11/82	895	1,545
10/76	11/81	11/83	1,150	2,015
7/77	07/82	07/84	1,150	2,150
12/77	12/82	12/84	1,335	2,355
12/78	04/83	02/85	1,448	2,610
12/79	04/83	02/85	1,672	3,162
4/81	02/84	05/86	1,950	3,560
11/82	12/84	03/87	2,846	5,120

ITEMS NOT INCLUDED IN UE&C AMOUNT:

Nuclear Steam Supply System

Owners' Cost

Allowance for Funds Used During Construction (AFUDC)

Turbine Generator (7/73 only)

Boiler Feed Pump Turbine Drives (7/73 only)

1.2 INDEPENDENT ASSESSMENT

As a result of the large increase in estimated costs, PSNH and the other owners raised concerns as to the completeness of the new cost estimate. PSNH decided to seek an independent review of the estimated cost and schedule for Seabrook. Shortly after public announcement of the revised estimate, Management Analysis Company (MAC) was selected to act as a third party in this evaluation by supplying consulting personnel experienced in nuclear power plant project management, estimating and cost, planning and scheduling, and project control systems.

This is an independent evaluation since MAC has not previously performed services such as these for PSNH, YAEC or UE&C, nor for any regulatory body or agency associated with the Seabrook project. Though we had to rely on information from Seabrook project sources, we critically examined it in light of MAC's nuclear industry experience and data. Conclusions stated herein are our own.

1.3 SCOPE AND OBJECTIVES

The scope of this study was to perform an independent review and evaluation of the November 1982 cost and schedule estimate for the Seabrook nuclear project. The study includes a review of the estimating process, the cost and schedule data, and the assumptions used in developing the estimated cost and schedule to complete Seabrook. The specific objectives of this study were to:

- Review and evaluate the estimating process to determine the adequacy of the process and data used to produce a realistic estimated total cost of Seabrook.
- Identify major cost and schedule elements that are high exposure areas and quantify the levels of uncertainty in those areas.
- Identify the key forces, factors and events that could affect the targeted commercial operation dates.

- Provide a probabilistic schedule identifying the uncertainty ranges of remaining key schedule elements and targeted commercial operation dates.*
- Determine where the $5.12 billion cost estimate falls with regard to the range of costs based on the probable schedule of Seabrook.*
- Identify opportunities for improvement in schedule and cost or reduction in risk of further delay and cost increases.*

1.4 METHODOLOGY

The evaluation was conducted by a MAC team experienced in cost and schedule evaluation, construction, construction management and project management. The team used a combination of interview techniques, observations, data and document reviews and comparative analysis to perform the evaluation.

1.5 REPORT ORGANIZATION

This report represents the findings, evaluations and resultant recommendations of the evaluation and is intended as a framework for discussions between MAC and YAEC/PSNH and between YAEC/PSNH and UE&C. Section 2 of the report provides a summary of the evaluation. Sections 3 through 6 present the details of the evaluation and include findings, background information for evaluation, assessment and recommendations.

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* After review of the study schedule evaluation findings and recommendations by MAC, YAEC and PSNH determined that the project would be best served by conducting an evaluation of the then current Unit 1 project schedule in lieu of doing the probabilistic risk analysis. (See Section 6.2.)

2.0 MANAGEMENT SUMMARY

2.1 ASSESSMENT SUMMARY

2.1.1 Estimate Process

The first step in evaluating an estimate of this type is to review the procedures for preparation and documentation of the estimate, the estimate bases, the assumptions, and the review and approval process. No documented procedure existed on the project for the preparation of such an estimate nor was the actual process documented until months after the fact. Most of the assumptions were made "as required" during development of the estimate and were not documented. No known qualifications or exclusions were documented for inclusion in the estimate package. The overall process, however, was good and appears to be basically consistent with standard estimating practices. The estimating process at Seabrook was found to be thorough.

2.1.2 Estimate

The Seabrook project estimate includes all the major elements expected in an estimate of this type, with the exception of a management reserve, normally provided by the owner. There are some "highs" and "lows" but overall the estimate is considered a reasonable assessment of costs based on the then-current scope and schedule.

2.1.3 Study Schedule

During review of the study schedule and other related schedule data, it became clear that current events were impacting the study schedule and that elements of the study schedule were no longer applicable. At that point, MAC identified a number of serious concerns with the study schedule and it was determined that all current events were reflected in the then-current project schedule. Therefore, MAC's efforts were redirected towards that document.

2.1.4 Project Schedule

Analysis was made of the Critical Path Method (CPM) activities. One of the key points brought out by this analysis is that currently 23% of all the activities to go are projected to occur later than scheduled. Another, and more important consideration, is that more start-up activities are critical than

construction activities. This is an indication that the available float is being consumed at a rate that could leave start-up in a position where everything is critical and, therefore, there is no time to recover from unexpected events.

UE&C indicates that it plans to use multiple shifts to achieve the scheduled completion date; however, no specific plans for shift work utilization were identified for activities in the schedule. Critical areas affecting the schedule were not prioritized for the application of multiple shift work nor were activities identified to be worked. In addition, consideration has not been given to changes in productivity or production due to multiple shift work, high resource levels or interferences.

The commodity installation rates were evaluated and compared to industry data. The comparison indicates that, while peak installation rates do not appear to be unachievable, the periods of peak installation are being sustained much later in the schedule than industry experience indicates is practical. This "later" installation of piping and electrical commodities will have a deleterious effect on the schedule, as it does not consider the impact on the start-up schedule requirements. Resource requirements have been raised to an extremely high level, with little regard for density limitations within the buildings or work areas, or consideration of the effect high resource levels will have on the progress of the work.

During construction of nuclear power plants, revising a summary schedule to reflect major changes and add significantly more detail is a normal process but generally occurs much earlier in the project. At this point in time, the schedule process should be in more of a month-to-month statusing mode, with detail changes being made to deal with specific problem areas. At Seabrook this is not the case. The schedule is still in a major "state of flux", precluding making a definitive schedule projection. However, while a definitive projection is not possible, a definite conclusion can be drawn from the available data.

The Seabrook project has made significant progress toward achieving a shorter schedule than industry average and has an opportunity to continue that trend. However, the currently scheduled Unit 1 commercial operation date targeted

by UE&C does not appear to be feasible. Based on analysis of project status and the amount of work remaining, MAC estimates that the schedule will require a minimum of 12 additional months. The maximum range of the project completion date is indeterminate at this time because insufficient detailed data exist on which to base analyses. Until a detailed integrated project schedule reflecting reasonable production, resource and density levels is produced and made available, the most likely completion date for Unit 1 and common cannot be projected with any degree of certainty.

2.1.5 Cost Impact

The concerns addressed in the schedule area and the resultant potential for schedule extension place the estimate in danger of being overrun. Determining accurate estimated costs that may be expected due to a delay in the Unit No. 1 schedule is somewhat difficult and highly subjective at best, especially since detailed plans and schedules with appropriate guidelines and parameters are not available at this time.

MAC did, however, estimate a range of costs for a delay in the Unit 1 schedule, assuming that the current schedule targets are utilized. Depending on the accounting methods used, the estimated cost per month of delay is $27 million to $44 million, ± $10 million, excluding AFUDC. AFUDC adds an additional $26 million per month, ± $1 million for fluctuations of cash flow. However, by revising resource loadings to new and more realistic targets, it may be possible to minimize the cost exposure noted here.

2.2 RECOMMENDATIONS

Prior to performing a major estimate or forecast, procedures must be developed and implemented covering the estimating and review processes. In addition, a detailed "basis of estimate" should be issued to each of the responsible participants and should address, as a minimum, the major elements of the estimate.

A management reserve should be established for the project. The management reserve would include considerations for items such as:

- Unresolved safety and generic concerns
- Schedule uncertainty
- Productivity
- Availability of manpower
- Environmental qualification
- Cash flow limitations
- Other project specific items

UE&C has been developing a detailed schedule for the piping/mechanical area since January 1983. The incorporation of these new data into the data base is expected to occur during the April 1983 update (in progress). In addition to the major piping scheduling effort, it is recommended that a complete and detailed integrated plan incorporating the other major commodities (i.e., electrical, instrumentation and control, heating, ventilating and air conditioning) be developed. Integration of all the construction activities should improve the existing interface between the piping/mechanical area and the start-up schedule.

A highly visible schedule must consist of detailed logic with applicable discipline to discipline and area restraints. The schedule must reflect reasonable resources, personnel density limits within an area/zone/building, and specific shift work/overtime plan.

A task of this magnitude will take a concentrated effort. We recommend that a separate team of planning personnel, relieved of day-to-day responsibilities, be assigned in order to expedite the schedule development. Many of the personnel, with the levels of ability required, are available at the job site. The Incomplete Items List identifies all remaining work for those Boundary Identification Packages (BIPs) which have been conditionally accepted by the start-up organization. All items reflected on the Incomplete Items List must be scheduled and controlled as should all "punch list" items.

3.0 ESTIMATING PROCESS EVALUATION

3.1 BACKGROUND

The most essential ingredient in a useful cost planning and control system is a good definitive estimate, particularly with regard to the manpower component which is the most controllable. A cost estimate by definition is a documented evaluation or appraisal of the approximate anticipated costs for all resource components of a task (project) which is defined by an agreed upon work scope. This estimate normally includes escalation and contingencies to cover additional resources (labor and material costs) anticipated to be required to complete the work scope even though these items are not explicitly shown or described in the work scope details.

A definitive cost estimate is usually the last type of major estimate performed on a project and becomes the detailed base for a project's cost control system and schedule. Detailed quantities and unit rates are established in the estimate and are used to control field operations and in manloading schedules. The accuracy of a definitive estimate is greatly dependent upon the amount of engineering completed, detailed information available, time available for preparation and the level of expertise of the estimators. As a minimum, the estimate should take into account:

- Defined project work scope/detailed project description
- Completed and conceptual design
- Issued engineering drawings
- Constructability reviews and construction methods
- Engineering, procurement and construction schedules
- Quantity take-offs, layout and flow diagrams
- Applicable labor agreements, work week, wage rates (current and future)
- Plant layout and complexity
- Previous and future purchased material and equipment information, including specifications and pricing
- Productivity information/experience on similar jobs, current industry standards and productivity in the area

- Required plant conditions and probable working conditions
- Project specific information
- Inflation, escalation, de-escalation
- Owners' costs including AFUDC/Interest During Construction (IDC)
- Estimate bases and assumptions

The estimate bases, assumptions, process and results should be properly documented.

In addition, the total project cost estimate requires a determination of owners' risk (management reserve).

3.2 GENERAL

The preparation of the revised cost estimate began in May 1982 with the reimbursable contractors preparing quantity and productivity data, as necessary, to support the estimate process. Quantity take-offs were made from the design drawings with each contractor responsible for estimating the installation unit rates for quantities included in its scope of work. Since Unit 2 is for the most part a replica of Unit 1, actual installed quantities were used for much of the Unit 2 estimate. The estimate-to-complete was concentrated on and actuals-to-date were added to arrive at a total estimate at completion. UE&C reviewed the major purchase orders required to complete the project, met with each contractor supplying an estimate and discussed questionable items. As a result of these meetings, UE&C made revisions to the estimate. After final review by UE&C and YAEC management, the estimate was presented to PSNH on November 23, 1982.

3.3 ESTIMATING PROCESS

3.3.1 UE&C Estimating Process

UE&C developed a "bottom-up" estimate of "to-complete" costs. The estimate is comprised of approximately 15,000 account numbers. Contained within each account is a breakdown of material quantities, productivity unit rates, man-hours, labor dollars, permanent material dollars and the cost of field purchased material. There are approximately 75 contractors and 500 permanent material

suppliers. This represents approximately 125,000 elements with an assessment of the "cost-to-complete" being made for each element.

Each reimbursable contractor prepared "to-complete" unit rates for its portion of the project. UE&C reviewed the contractors' estimates with them and made adjustments to contractor estimate data as a result of these reviews. The lump sum contracts were reviewed for known change orders and potential change orders to complete the project. Each change order was escalated to May 1982 dollars. For lump sum contracts not yet awarded, a conceptual estimate was developed by UE&C based on May 1982 dollars. Each major purchase order for materials or permanent equipment was re-estimated with consideration given for pending design modifications and changes in scope of supply.

A study schedule was developed to determine scheduled completion dates for Units 1 and 2 for purposes of the estimate.

Bulk material was estimated using the current quantity take-off data from design drawings and allowances where design was considered incomplete. May 1982 "per unit" pricing data was used.

Indirect costs were developed using historical data and future projections for each line item of indirect cost. Site non-manual costs were comprised of expended-to-date costs plus a forecast to completion of expected non-manual requirements.

Allowances for special anticipated changes were made using a combination of judgment factors and historical data. Included were allowances for:

- Overtime work
- Growth in quantities
- Growth in various material contracts
- Permanent plant equipment warranties which may have to be extended due to schedule change
- Rework
- Additional engineering

"Learning curve" credits were taken into account for Unit 2.

Escalation was applied at 9.0% compounded monthly based on a UE&C-developed cash forecast, and contingency was calculated at 3% of the "to-complete" dollars from January 1, 1983 to the end of the project.

Estimated "cost-to-complete" were added to "expended-to-date" to determine the total estimate at completion.

3.3.2 YAEC Estimating Process

The YAEC portion of the estimate included both YAEC and owners' costs. The YAEC non-manual estimate was developed using historical data and forecast of future requirements. This category covered site non-manual, quality assurance (QA), home office support and YAEC start-up. The current non-manual manpower level was carried to completion of Unit No. 1 then reduced a proportional amount. This reduced amount was continued for Unit No. 2. A current standard rate was multiplied by the man-hours to convert manpower to dollars.

3.3.3 Estimate Review and Approval Process

Various levels of the estimate were reviewed by appropriate UE&C personnel including an upper level review and sign-off by engineering and construction vice presidents and finally the president of UE&C.

3.3.4 Estimating Process Documentation

No documented procedure existed on the project for the preparation of such an estimate nor was the actual process documented until months after the fact. Most of the assumptions were made "as required" during development of the estimate and were not documented. No known qualifications or exclusions were documented for inclusion in the estimate package. Only one copy of the estimate was made. This copy resides in the cost engineering group at the job site.

3.4 ESTIMATING PROCESS ASSESSMENT

The overall process was good and appeared to be basically consistent with standard estimating practices. The estimating process at Seabrook was thorough; however, there were unilateral cuts made by UE&C in the contractors' estimates with no apparent sound foundation for these cuts other than optimism. The "learning curve" credit in unit performance rates applied to Unit 2 is questionable in some areas.

3.5 ESTIMATING PROCESS RECOMMENDATIONS

MAC recommends that prior to performing a major estimate or forecast, procedures be developed and implemented covering the estimating and review processes. In addition, a detailed "basis of estimate" should be issued to each of the responsible participants and, as a minimum, should address:

- Estimate scope and project scope
- Applicable guidelines and parameters
- Schedule, project milestone dates
- Classification of accounts structure
- Direct costs
  - Quantities
  - Unit rates
  - Material
  - Labor contracts and subcontracts
  - Labor man-hours
  - Wage rates
- Distributable costs
- Indirect costs
- Escalation
- Contingencies
- Estimate analysis, review and presentation
- Documentation
- Assignment of responsibilities

4.0 ESTIMATING EVALUATION

4.1 EVALUATION PROCESS

Interviews were conducted with cognizant site and home office personnel who were involved in the preparation and/or review and approval of the estimate. Estimate data were gathered in order that comparisons of estimates of other nuclear units could be made. MAC did not re-estimate the project but did review the estimate process and resultant output for reasonableness. Estimated quantities were compared to industry data compiled on 45 nuclear power plants. Estimated man-hour unit rates (unit rates) were compared to unit rate histograms compiled from a similar data base. Higher unit rates are experienced in the Northeast than in other parts of the country, and this was taken into account in making industry data comparisons at Seabrook.

4.2 KEY BASES AND ASSUMPTIONS

Following are the key bases and assumptions used in producing the estimate.

4.2.1 Productivity

- Increased productivity and lower rework costs were included in Unit 2.
- Unit rates were developed from historical Seabrook cost data.

4.2.2 Allowances

- Allowances in the estimate were included to provide for:
  - Overtime
  - Growth in quantities
  - Growth in various material contracts
  - Permanent plant equipment warranties
  - Rework
  - Additional engineering
- "Rework" in the allowance category is defined as resulting from design revisions (changes) not field errors (contractor error, i.e., bad welds).

4.2.3 Contingency

- The UE&C contingency is provided in a one-line entry and is based on a calculation of 3.0% of the total estimated cost-to-complete as of January 1, 1983.

4.2.4 Escalation

- The escalation rate applied is 9.0% per year and is compounded monthly, resulting in an effective rate of 9.38% per annum.

4.2.5 Owners' Cost

- AFUDC was applied at 10.5% compounded semiannually net of federal taxes.
- Contingency was applied at 3.8% of the to-complete costs, excluding a "power generated" credit of $35 million per unit.
- The escalation rate applied is 9.0% per year and is compounded annually.

4.2.6 Schedule

As a result of the Unit No. 1 study schedule, commercial operation dates were extended ten months on each unit to:

Unit 1 - December 31, 1984

Unit 2 - March 31, 1987

4.2.7 Other

- Estimate quantities are based on a combination of actual installed quantities to date; drawing take-off from the design drawings; estimates of quantities still in the conceptual design phase; and allowances.
- The cut-off date for the estimate data was the end of May 1982 (engineering drawings, unit rates, etc.).
- Future manpower needs, by craft, would be available at reasonable levels.
- Unlimited availability of required resources (other than manpower).

4.3 ESTIMATE DATA ASSESSMENT

In reviewing and evaluating the data, it was necessary to divide the estimate into manageable elements in order to avoid duplication of effort and to make certain that all the major areas of the estimate were considered. These elements are:

- Wage rates
- Quantities and unit rates
- Permanent material pricing
- Contracts and subcontracts
- Indirect costs
  - Non-productive time (show up, weather, etc.)
  - Indirect manual labor
  - Site non-manual
  - Materials and supplies
  - Temporary facilities and construction services
  - Construction equipment
- Engineering and home office
- Allowances
- Owners' costs:
  - Non-manual
  - NSSS
  - AFUDC
  - Contingency
- Contingency
- Escalation
- Management reserve

An evaluation of each major element follows.

4.3.1 Wage Rates

The composite wage rates used for the Seabrook estimate are based on UE&C's determining the craft mix associated with each construction activity and then applying current labor rates (5/82) to the crew mix to arrive at the composite rate. The composite craft rate for the project in May 1982 was $16.30/man-hour. This approach is considered an acceptable method.

4.3.2 Quantities and Unit Rates

Concrete Quantities and Unit Rates

- Structural design was approximately 92% complete for both units, with construction at 96% and 42% respectively for Units 1 and 2. The estimated quantities for Units 1 and 2 are within the range of industry data. The unit rate for Unit 1 is at the high end of the range of industry data. The unit rate for Unit 2 is above the range.

- Unit rate performance to date, when compared to unit rate histograms, indicates that there is a good chance of achieving the Unit 1 rate at completion and an opportunity for improvement of the Unit 2 rate at completion.

Large Bore Pipe Quantities and Unit Rates

- Mechanical design was approximately 89% complete for both units with construction reported at 55% and 4.0% respectively, for Units 1 and 2.

- Quantities for Units 1 and 2, when compared to industry averages, are on the low end of the range but considering that the site is compact and that 90% of the quantity was from drawing takeoffs, this estimate appears to be adequate.

- The unit rate for Unit 1 is at the mean of industry averages and should be attainable based on comparisons of unit rates to date with the piping histograms.

- The unit rate for Unit 2 at completion is significantly lower than Unit 1. There is not enough quantity installed to date (4%) to make a valid comparison to piping histograms for Unit 2. Should Unit 1 performance carry over to Unit 2, there is potential for an overrun in Unit 2.

Large Bore Field Welds Quantities and Unit Rates

- The quantity of field welds when compared to industry data is considered within the acceptable range.

- For Unit 1 the estimated unit rate for welding is significantly higher than industry averages for similar work. The unit rate performance to date is approximately 23% higher than the estimate at completion. Based on past job performance and histograms for this type work, there is no reason to believe that the unit rate will be achieved. We feel there is exposure to an overrun on this item. Histogram comparisons indicate that Unit 1 could result in an average of 50 man-hour/weld compared to the 38.4 man-hour/weld in the estimate with a potential 240,000-man-hour increase.

- The Unit 2 estimated unit rate at completion is approximately 8.0% higher than Unit 1. With only 2.0% of the welds complete, insufficient data exists to make valid histogram comparison. Should the performance on Unit 1 to date carry over to Unit 2, an overrun of approximately 120,000 man-hours can be expected.

Large Bore Hangers

- The quantity of large bore hangers when compared to industry data is lower but is considered acceptable when plant layout and size are taken into account. The estimated unit rate for Unit 1 is in the very high end of the industry range. The Unit 2 estimated rate is lower than Unit 1. Actual unit rate performance compared to unit rate histograms indicates that unless performance is improved, there is a potential for a 200,000-man-hour overrun for Unit 1 and a 200,000-man-hour overrun for Unit 2.

Small Bore Pipe Quantities and Unit Rates

- The estimated quantity of small bore piping for Units 1 and 2 is based on 90% drawing take-off and is significantly lower than that of other plants. Some explanations are that the site is compact and that some borderline small bore pipe has been increased in size and is now considered large bore piping. It should be noted that the large bore piping compared to the industry is also on the low side. Although the estimated unit rates at completion are significantly higher than industry data, histogram comparisons of performance to date indicate a potential for a 100,000-man-hour overrun on Unit 1 and a 77,000-man-hour overrun on Unit 2.

Cable Tray Quantities and Unit Rates

- Cable tray quantities for Units 1 and 2 are within the averages of the industry data.

- The Unit 1 estimated unit rate at completion is near the mean as compared to industry. However, when performance to date is compared to the histograms for 80% complete, the Seabrook project is currently 0.5 man-hour over what would be expected now in order to meet the estimated unit

rate at completion. Unless improvement in performance is made there is a potential for overrun amounting to some 43,000 man-hours.

- The estimated unit rate at completion for Unit 2 is lower than Unit 1 because of "learning curve" credit. We have no reason to believe that this "learning curve" credit is justified. There is a potential of a 65,000-man-hour overrun.

Conduit Quantities and Unit Rates

- Quantities for Units 1 and 2 are lower than industry data but can be attributed to the compactness of the site, the use of multiplex instrumentation and the more extensive utilization of cable trays.

- The estimated unit rate for Unit 1 is outside the range (higher than) of industry data. Performance to date on Unit 1 compared to histograms at 67% complete is worse than one would expect at this point in time and will probably result in an overrun of 16,000 man-hours unless performance is improved.

- The estimated unit rate for Unit 1 is 20% higher than Unit 2. With only 5.0% of conduit installed to date for Unit 2, histogram comparisons are not valid; however, if anticipated performance for Unit 1 carries over to Unit 2, some savings in man-hours could be expected and offset the increase in Unit 1.

Cable Quantities and Unit Rates

- Quantities for Units 1 and 2 compared to industry data are approximately 1.5 million linear feet less but may be justified when consideration is given to physical plant size and the use of shorter cable runs, mutliplexing and the use of decentralized control centers.

- The estimated unit rates at completion for Units 1 and 2 are within industry average range but on the high side. Actual performance to date when compared to histograms indicates slightly better performance to date than one might normally expect at this point in the project. Should this better-than-expected performance continue on Unit 1 and carry over to Unit 2, there is a potential man-hour savings of approximately 45,000 for Unit 1 and 30,000 on Unit 2.

Terminations Quantities and Unit Rates

- The estimated quantities for Units 1 and 2 appear to be approximately 5.0% higher than the industry standard but are considered within reason.

- The estimated unit rates for terminations are within the industry averages but on the high side. Actual performance to date based on 28% complete, compared to histograms, is better than one would expect at this stage of completion. Should this better-than-expected performance to date continue for Unit 1 and carry over to Unit 2 expected savings could be approximately 18,000 man-hours on Unit 1 and 14,000 man-hours on Unit 2.

4.3.3 Permanent Material Pricing

- All major purchase orders were escalated to May 1982 dollar values. For "items to complete", specific consideration was given to individual contract terms and agreements to arrive at a current unit price for estimate purposes. These unit prices, plus an allowance for scrap material, where applicable, were multiplied times the same quantity information used in determining direct labor costs to get the material cost. This is considered to be an accepted practice.

4.3.4 Contracts and Subcontracts

- Awarded contracts were escalated to May 1982 dollars based on the contract escalation provisions and the resulting rates applied to the remaining work. Anticipated or possible changes were included, as appropriate, and reviewed with the contractors to avoid possible omissions or duplications. This is considered to be an acceptable approach.

- Contracts not yet let were scoped, and a conceptual estimate prepared for each, using a May 1982 base date for pricing. Upon completion of these conceptual estimates, reviews by the appropriate UE&C organizations were conducted. This is an acceptable approach.

4.3.5 Indirect Costs

Elements of the indirect cost are addressed as follows:

Non-Productive Time

An allowance was included in the estimate for non-productive time that may result due to weather, show-up time, etc., and is based on project experience to date.

Indirect Manual Labor

Indirect manual labor was developed using historical data and current project experience. More specifically, each indirect work activity was analyzed and estimated using one or more of the following as a basis:

- Time-related activity
- Direct-labor-related activity
- Limited scope activity
- Combination of time-related and direct-labor-related activities

Site Non-Manual

The non-manual estimate is comprised of expended non-manual costs to date combined with a forecast to complete. The forecast to complete considered the current non-manual work force of UE&C, the contractors and the non-manual requirements to support the project to completion. These requirements were reviewed and approved by project management and then priced according to UE&C's standard developed rates.

Materials and Supplies

Materials and supplies were separated into two basic categories: force-related and limited-scope-type items. A forecast to complete of force-related items was developed based on historical data. Limited scope activities were estimated individually.

Temporary Facilities/Construction Services

These estimated costs were developed based on force-related and time-related activities according to project historical data except for one-time occurrences that were estimated on an individual basis. Salvage was taken into account for temporary facilities where it was deemed appropriate.

Construction Equipment

The construction equipment portion of the estimate was developed by taking into account equipment utilization, purchase price and a projection of the necessary equipment to complete the project. Further consideration was given as to whether the particular equipment is related to force, time or one-time occurrence. Equipment salvage was included as part of the estimate and took into consideration both depreciation and appreciation.

The approach used in estimating the indirect costs is acceptable. While the estimated indirect costs are somewhat higher than current industry experience, they are reflective of the current management philosophy for completion of this project.

4.3.6 Engineering and Home Office

Historical expenditures were considered and coupled with a detailed projection of future requirements. Considerations were made as to the amount of detailed engineering left to complete on the project and the amount of engineering man-hours needed to support construction. The known scope of the project was considered as well as specific allowances for additional man-hours. To these costs, expenses were added to produce the total engineering and home office estimate. The composite rate used was $30.66/man-hour and is lower than might be expected, especially when compared to those currently being used in the industry. This is considered a reasonable approach.

4.3.7 Owners' Cost

Elements of the owners' cost are addressed as follows.

Non-Manual

Each responsible manager supplied estimated manpower requirements necessary to support the current schedule. These man-hours were multiplied by a standard YAEC rate to arrive at a non-manual cost. This is considered reasonable.

Nuclear Steam Supply System (NSSS)

The estimate for the NSSS is based on the Westinghouse purchase order. The purchase order base date for escalation is 1972. An allowance of $4,500,000 was made in the estimate for extended warranty. Future options were estimated at $2,500,000.

It should be noted that the extended warranty amount is just an allowance and is not based on any current ongoing negotiations. Based on recent Westinghouse warranty extension negotiations on other projects, there appears to be a potential for cost impact in this area.

AFUDC

An average rate of 10.5% compounded semiannually was used for the project since the owners have varying percentages and ways of computing AFUDC. This is a reasonable approach.

Contingency

Contingency was included in the owners' cost as an allowance of 3.8% of the to-go scope, excluding the $70,000,000 credit for revenues anticipated during the power generation test and ascension period. Based on the current scope and schedule, the owner's contingency dollars may be adequate. However, an evaluation process to determine contingency is a more acceptable industry practice.

4.3.8 Contingency

Since estimating the costs of a nuclear power plant is not an exact science, it is an accepted practice to include contingency as part of the estimate to protect against in-scope changes (i.e., quantities, errors and omissions, unit rates, etc.). The contingency included in the estimate by UE&C is based on a calculation of 3.0% of the to-complete dollars as of January 1983. While the approach of establishing contingency based on a percentage of to-go costs is not uncommon, a more accepted approach would be to:

- First, define the contingency parameters to determine which items in the project scope are to be covered by contingency and which are not.
- Second, assess each element of the estimate to determine its level of uncertainty.
- Third, determine the contingency required based on varying degrees of uncertainty and the estimated cost of the element.

It is possible, but remote, that both methods could produce the same total dollars to be applied as contingency. The UE&C approach does not specifically address the varying degrees of uncertainty associated with each estimate element as is necessary to improve confidence in the total estimate.

4.3.9 Allowances

Allowances were included in the estimate for specific anticipated changes based on historical data, current experience and engineering and construction judgment. Allowances were included for overtime, growth in quantities, growth in material contracts, warranties, rework and additional engineering. While this is considered an acceptable approach, certain of these allowances are more commonly included as part of contingency.

4.3.10 Escalation

The escalation in the estimate was calculated based on a cash flow extended at 9.0% compounded monthly to the completion of the project, resulting in a 9.38 annual percentage rate. Changes in the cash flow used as a basis for the escalation, calculation and actual escalation/inflation may result in a cost impact to the project. The 9.0% rate used, however, is within the range currently being used by the industry.

4.3.11 Management Reserve

There is no allowance in this estimate for management reserve. Management reserve is an allowance that is usually included by the owners to cover potential out-of-scope changes that may occur based on their view of current and projected regulatory and economic conditions.

4.4 ESTIMATE ASSESSMENT

The estimate includes all the major elements that one might expect in an estimate of this type. There are some "highs" and "lows", but overall the estimate is considered a reasonable assessment of costs based on the current scope and schedule.

4.5 ESTIMATE RECOMMENDATIONS

MAC recommends that a management reserve be established for the project. It is further recommended that the management reserve would include considerations for items such as:

- Unresolved safety and generic concerns
- Schedule uncertainty

- Productivity
- Availability of manpower (density)
- Environmental qualifications
- Cash flow limitation
- Other project specific items

5.0 STUDY SCHEDULE EVALUATION

5.1 STUDY SCHEDULE PROCESS

In August 1982, the Philadelphia scheduling group of UE&C began preparation of a schedule to study the impact of the re-estimate and determine new scheduled completion dates for the Seabrook Units 1 and 2. The basis of the study schedule was the August 23, 1982 computerized integrated project schedule. Approximately 6.9 million man-hours were added into the study schedule to reflect increases determined by approved changes since the previous estimate and by the re-estimate. This was done via a resource multiplier computer program on an individual building basis. Durations were adjusted as required to reflect increases in scope or additional work.

Resource density studies were performed with the aid of site management personnel to determine maximum manpower levels possible for each building. These levels were then loaded against the schedule. UE&C produced a computer run with these data worked into the schedule and provided both unleveled and leveled manpower histograms for analysis.

The original schedule logic required 100% of the piping and hanger activities to be complete prior to the turnover date of the associated BIP. This philosophy was changed for the study schedule in some areas because of the impact of increased man-hours on the Unit No. 1 completion date. UE&C analysis determined that 40% of the to-go pipe hanger activities could be moved downstream and completed in parallel with testing activities.

A computer run was made with what was thought to be 40% of the to-go large bore hanger man-hours and 10% of the large bore piping man-hours backed out of the study schedule. The man-hours were extracted on a formula basis and totalled a 646,000-man-hour reduction. This number appears to be based on total, not to-go effort, and therefore, MAC considers this reduction to be greater than what should have been removed.

Schedule logic was not developed to accommodate this philosophy as it was just a study schedule and time did not permit development of a revised logic.

5.2 STUDY SCHEDULE PROCESS ASSESSMENT

While the concept and methodology of doing this study schedule was acceptable, certain assumptions used in making the increased estimated man-hours "fit" into the schedule were overly optimistic:

- Forty percent of large bore hanger and 10% of large bore piping installation to be accomplished subsequent to system (BIP) turnover
- Two shifts would be utilized in critical areas (reactor containment building, reactor auxiliary building, waste processing building)
- Work activities and resources for each shift would be the same
- Production and productivity for each shift would be equal

Additionally, the man-hours extracted from the installation activities were not loaded back into the computerized schedule to test the "plan" or to determine the potential impact on other construction work or start-up activities.

5.3 STUDY SCHEDULE ASSESSMENT

During review of the study schedule and other related schedule data, it became clear that current events were impacting the schedule and that elements of the study schedule were no longer applicable. At that point, MAC identified a number of serious concerns with the study schedule and it was determined that all current events were reflected in the then-current project schedule. Therefore, MAC's efforts were redirected towards that document. The study schedule findings and concerns are addressed as part of the project schedule evaluation in Section 6.0.

6.0 PROJECT SCHEDULE EVALUATION

6.1 GENERAL

The preparation of the UE&C project schedule is an ongoing, iterative process with input and resultant information updated and reviewed on a monthly basis.

The project schedule dated March 8, 1983 with status (data date) as of February 22, 1983 was selected for the MAC schedule evaluation.

The data supplied to MAC were from both manual and computerized sources and were both unleveled and leveled. The manual data were not directly supported by or generated from the computerized data.

During the total evaluation, UE&C was supportive in providing all of the required documentation; however, MAC feels that the accuracy and timeliness of information provided for management decisions needs improvement.

6.2 SCHEDULE ELEMENTS

6.2.1 CPM Schedule

The Unit No. 1 project schedule is a CPM summary level schedule (typically level 2-2 1/2) consisting of some 16,000 engineering, construction and start-up activities, of which approximately one-half have been completed. Development of a more detailed schedule had begun but was not implemented at the time of this review.

The schedule reports are run in both the leveled and unleveled mode. Unleveled is interpreted as being without resource (manloading) restriction and leveled as being resource limited.

Findings

The unleveled report indicates that the critical path through the piping activities has a negative float of 73 days, and through the electrical activities, it has a negative float of 64 days.

The leveled report indicates that negative float has increased to 84 days on the piping and to 170 days on the electrical. The unleveled electrical path is considered to be of little concern as sufficient additional resources could be applied to maintain the unleveled status while maintaining a reasonable resource level.

Assessment

Analysis was made of the remaining open CPM activities to determine the number of critical and near critical activities. (See Table 2 below.) Critical activities are defined as those having zero or negative float. Near critical is defined as those activities with less than 25 days positive float. The "near critical" definition stems from the fact that scheduling is not an exact science; therefore, any activity within one month of critical which suffers the slightest aberration could quickly be on a negative path, especially on projects of long duration.

TABLE 2

CRITICAL AND NEAR CRITICAL ACTIVITIES

Type Activity	Total Activities	Critical (C)		Near Critical (NC)		Total C&NC	
Engineering	2545	280	(11%)	400	(16%)	680	(26%)
Construction	3120	720	(23%)	240	(8%)	960	(31%)
Start-Up	2665	920	(35%)	320	(12%)	1240	(47%)
	8330	1920	(23%)	960	(12%)	2880	(35%)

One of the key points brought out by this analysis is that currently 23% of all the activities to go are projected to occur later than scheduled. Another, and more important consideration, is that more start-up activities are critical than construction ones. This is an indication that the available float is being consumed at a rate that could leave start-up in a position where everything is critical.

Analysis was made of the schedule, for turnover to start-up, of 886 BIPs which are prerequisite to system turnovers. According to the February 22 schedule,

only 85 partial and 150 complete BIPs have been turned over to start-up. Of the balance, 175 complete packages and the 85 partial BIPs are either currently behind or are projected to be completed later than scheduled. This represents approximately 29% of the total BIPs.

6.2.2 Start-up Schedule

Assessment

The start-up portion of the Unit No. 1 schedule consists of some 2,665 activities integrated with construction through the BIPs.

Analysis of the stand-alone schedule indicates that it is shorter than current industry experience (see Table 3).

TABLE 3

ANALYSIS OF SCHEDULE
(Months)

	Seabrook	Industry
Schedule (stand alone)	21	22-30
Cold Hydro - Fuel Load	5	9-12
Fuel Load - Commercial Operation	3	3- 6

As stated earlier, BIP turnovers and related start-up CPM activities continue to fall further behind schedule. MAC is not aware of any attempt to determine the impact of this delay on the start-up organization resources.

6.2.3 Assumptions

Assessment

While UE&C continually indicated that it plans to use multiple shift work to achieve the scheduled completion date, no specific plans for multiple shift work utilization were identified for activities in the schedule. Critical areas affecting the schedule were not prioritized for the application of multiple shift work nor were activities identified to be worked.

In addition, UE&C has assumed equal performance on any given shift with no loss or gain in productivity or production due to multiple shift work, high resource levels, or interferences with start-up test activities.

6.2.4 Commodity Installation Data

Background

Power plants are designed by system, constructed by bulk/area methods and tested by start-up system. Typically, the interface between construction and start-up is very difficult due to the bulk-to-system transition. Completing construction in a sequence necessary to support the start-up activities is not necessarily conducive to rapid bulk installation. If construction were to maximize only the scheduled bulk installation rates, the system turnover schedule required by start-up is almost always impacted. Conversely, if the emphasis is placed on completing work for systems turnover, the bulk installation rates usually cannot be achieved.

Findings

The Unit No. 1 commodity installation schedule data for wire and cable, large and small bore piping and large bore hangers were not produced by the CPM schedule. Instead, UE&C manually developed installation curves which were published in the monthly project performance report. Therefore, the installation rates do not necessarily reflect the sequencing or the magnitudes of rates required to the support CPM schedule. Table 4 indicates the percent complete, peak installation rate per month and the number of months the peak installation rate would be sustained for these four critical or near critical commodities.

TABLE 4

% COMPLETE, PEAK INSTALLATION RATE
AND MONTHS SUSTAINED

Commodity	% Complete	Peak Rate Per Month	Months Sustained
Large Bore Pipe	65	6000 feet	6
Large Bore Hangers	53	500 each	6
Small Bore Pipe	35	7500 feet	7
Wire and Cable	65	150,000 feet	12

Assessment

The commodity installation rates were compared to industry data. In order to normalize the data to account for differences in plant size and quantity, the comparison was made on a percent of total like quantity per month basis.

The comparison indicates that, while peak installation rates do not appear to be unachievable, the periods of peak installation are being sustained much later in the schedule than industry experience. This "later" installation of piping and electrical commodities will have a deleterious effect on the schedule, as it does not consider the impact on the start-up schedule requirements.

In addition, the commodity schedules appear to underestimate the difficulty of completing the last 15 to 20% of the tasks.

6.2.5 Resource Density Limits

The resource density limits established in the study schedule were set at a level that would preclude efficient use of manpower in the three main buildings (waste processing building, reactor containment building, reactor auxiliary building). In the project schedule, most of the resource density limits were revised upward and, in fact, were no longer restricted by building. (See Table 5).

TABLE 5

RESOURCE DENSITY LIMITS

Resource	Study Schedule		Project Schedule	
	Direct Labor Required at Peak	Density Limit	Direct Labor Required at Peak	Density Limit
Johnson Controls, Inc.	400	by total	310	by building
Fischback-Boulos-Manzi	500	by total	384	by total
Pullman-Higgins	1095	by building	1326	by total
Other	not identified		1380	none

Assessment

The above data show that the Pullman-Higgins (piping contractor) peak resource requirements in the project schedule have been raised by 30% and the associated building density limitations removed. MAC must therefore question the project schedule durations where Pullman-Higgins work is concerned. MAC believes that the impact of such changes on the Pullman-Higgins work will also adversely impact the schedule performance of the other reimbursable contractors.

6.3 SCHEDULE ASSESSMENT

Findings

- In March, the actual levels of key craft (pipefitters and electricians) were significantly below the scheduled level.
- A stop work order on the piping installation initiated during November 1982 was still partially in effect during this evaluation.
- Progress for December 1982 and January, February and March 1983 did not meet schedule requirements.
- The CPM indicates that the project is four to five months behind schedule with 19 months to fuel load.
- Engineering has not been sufficiently ahead on the hanger and support program to support the forecasted bulk installation rates.
- Twenty-nine percent of the BIP turnovers are behind schedule.

- Forty-seven percent of the start-up activities are behind schedule.
- There are no building or area density limits established for the piping and electrical contractors.
- Forecasted manpower requirements are extremely high (2000+ pipefitters).
- Schedule duration between the cold hydro and commercial operation milestones is extremely short (eight months).
- No specific plans for shift work have been developed.
- No allowance for loss of production/productivity due to shift work or high resource density requirements has been made.
- Bulk commodity installation schedules are not produced by the CPM schedule.
- Bulk commodities are not being installed per the manual or CPM schedule.
- Bulk installation rates sustain peaks later than industry experience.
- Bulk installation unit rates do not consider varying difficulties during different stages of construction.
- The difficulty in installing the last 15 to 20% of the commodities is apparently not recognized.
- No detail plan; the schedule is in a state of flux.
- There is no punch list control system.

Conclusions

During construction of nuclear power plants, revising a summary schedule to reflect major changes and add significantly more detail is a normal process but generally occurs much earlier in the project. At this point in time the schedule process would normally be in more of a month-to-month statusing mode, with detail changes being made to deal with specific problem areas.

At Seabrook this is not the case. The schedule is still in a major "state of flux". This condition precludes making a definitive schedule projection. However, while a definitive projection is not possible, a definite conclusion can be drawn from the available data.

The Seabrook project has made significant progress toward achieving a shorter schedule than industry average and has an opportunity to continue that trend. However, it does not appear that the currently scheduled Unit 1 commercial operation date can be met. Based on analysis of the project status and the amount of work remaining, MAC forecasts that it will take a minimum of 12 additional months. The maximum range of where the project completion date could extend to is unknown at this time. Until a detailed integrated project schedule reflecting reasonable production, resource and density levels is produced and made available, the expected completion date for Unit 1 and common cannot be determined.

6.4 COST IMPACT

The current estimated cost at completion was assessed by MAC as being "a reasonable assessment of costs, based on the current scope and schedule". The concerns addressed in the schedule area and the resultant potential for schedule extension place the estimate in danger of being overrun.

Determining accurate estimated costs that may be expected for a delay in the Unit No. 1 schedule is somewhat difficult and highly subjective at best, especially since detailed plans and schedules, with appropriate guidelines and parameters, are not available at this time.

Factors which must be considered in developing this type of estimate are:

- Determination of when the actual delay occurs (not possible at this time)
- The status of Unit No. 1 and the level of effort at the time of delay
- The status and the level of effort in Unit No. 2 at the time of delay
- The length of the delay
- The method of accounting for the indirect cost of both units

Since the majority of this data is indeterminant, we have developed the estimated detailed costs per month, based on the following assumptions:

- Continue current method of accounting, i.e., facilities, construction non-manual, indirects, engineering and owners' costs are all allocated to Unit No. 1 with only direct costs for Unit No. 2 being charged to Unit No. 2. (See column A below.)

- Project to continue at same level of activity (manpower and costs) as forecasted and delay would be added at the end of 1983, as this is the time that construction is forecasted to "tail off".

- Costs estimated using May 1982 current day cost and adding escalation to the point in time of expenditure. Escalation was also added for forecasted expenditures occurring after January 1, 1984 to allow for the slippage. Escalation was calculated at 9.0% per year compounded monthly at an effective rate of 9.38%.

Total estimated costs per month included estimates for:

	Amount x $1,000 A	B
• Construction non-manual for UE&C and contractors	6,100	3,400
• Additional fees for contractor or subcontractors	2,000	1,100
• Indirect craft labor and materials	6,700	3,700
• Engineering and home office support from UE&C	3,300	1,800
• Direct costs	9,200	9,200
• Off-site storage and rental commitments	100	100
• Owner costs	6,000	3,300
• Escalation	10,100	3,700
TOTAL	43,500	26,300
AFUDC	26,000	26,000

The estimates were determined by applying average costs of the last quarter of 1983 for the categories listed above. Data source was the November 1982 estimate.

The cost per month is a highly subjective estimate, especially when applied to a one-year delay; therefore, we established an estimate of ± $10 million to bracket the expected monthly delay costs of $44 million.

Were you to allocate the indirect costs for Unit No. 2 to that unit instead of to Unit No. 1, the monthly delay costs for Unit No. 1 would be $27 million. (See column B above.)

The $26 million AFUDC is based on 10.5% compounded semiannually using the last month before scheduled commercial operation as a guide.

We established an estimated ± 1 million per month bracket for fluctuation in cash flow prior to the delay date and for the extended one-year period of the delay.

6.5 SCHEDULE RECOMMENDATIONS

UE&C has been developing a detailed schedule for the piping/mechanical area since January 1983. The incorporation of this new data into the data base is expected to occur during the April 1983 update (in progress). In addition to the major piping effort we recommend that a complete detailed integrated plan incorporating the other major commodities (i.e., electrical, instrument and control, heating, ventilating and air conditioning) be developed.

A highly visible schedule must consist of detailed logic with applicable discipline to discipline and area restraints. The schedule must reflect reasonable resources, recognizing the types of work activities being performed by both construction and start-up in the same areas.

Personnel density limits within an area/zone/building must be kept within reasonable limits if efficiency and performance factors are to be achieved. Without this consideration, the density of personnel will adversely affect project productivity.

A specific shiftwork/overtime plan must be identified for the remaining to-go work. A well coordinated plan for the types of work to be accomplished on shiftwork and overtime will eliminate duplication of effort and interference problems with craft, scaffolding, material laydown, testing and radiography.

A task of this magnitude will take a concentrated effort. We recommend that a separate team of planning personnel, relieved of day-to-day responsibilities, be assigned in order to expedite the schedule development. Many of the personnel, with the levels of ability required, are available at the job site.

The Incomplete Items List identifies all remaining work for those BIPs which have been conditionally accepted by the start-up organization. All items reflected on the Incomplete Items List must be scheduled and controlled as should all "punch list" items.