MANAGEMENT AND CONTROL OF A HIGH TENSION TRANSMISSION LINE PROJECT

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ABSTRACT

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HIGH TENSION TRANSMISSION LINE PROJECT

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The engineering and construction activities, and their management, to build a high tension transmission line are investigated on the basis of their practice in the Province of Quebec. The major components of a high tension transmission line are described. The three phases of a transmission line project are analysed with a focus on the necessary environmental studies, the required government authorizations and the presentation of the project to the affected public. The project control tools are also given appropriate attention, and possible improvement to them are proposed.

Finally, the construction methods of the different transmission line components are analysed; and the environmental restoration measures, once construction is completed, are described.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION AND BACKGROUND SCENARIO

1.1 Preliminaries

Through time the engineer has made electricity of continually greater use to mankind. Before the invention of the transformer, the scope of electric energy was limited to relatively short distances from the power generating stations because of the low voltage of the transmission lines. The invention of the transformer made high voltage and long distance transmission possible. The first generating transmission system using transformers in North America was put in operation in the state of Massachusetts in 1886 at the tension of 500 volts. From that time on, electric load and transmission tension have continued to grow.

In Canada, the electric energy sector has grown at a very fast rate. At the end of the seventies, Canada had more than 70 000 Megawatts of installed capacity available in the electric grid of its ten provinces. Whereas in the United States the electricity sector is 80 percent privately owned and 20 percent government owned only, in Canada, as well as in most other countries, electric supply is now essentially an agency of central government. The two largest electricity producers in Canada are the provinces of Ontario and Quebec, which produce and distribute 30% and 25%, respectively, of the electric energy produced by the ten Canadian provinces.

Production of electricity in Canada is 70% of hydraulic origin, 20% of thermal origin (coal, oil or gaz) and 10% of nuclear origin. The provinces where energy is mainly of hydraulic origin have many long distance transmission lines with high voltage because the hydraulic dams are generally far from the consumption centers. At the turn of the century the highest tension for transmission in Canada was 69 000 volts, and all transmission lines were built using wood poles. In the fifties the first 315 000 volts transmission line was built in the province of Quebec to transport the 1500 Megawatts of the Bersimis Hydro-Electric power station. In the sixties Hydro-Quebec was the first public utility in the world to commercialize the 735 000 volts transmission lines. This was done to transport the 10 000 Megawatts of the Manic-Outarde and the Churchill falls Complexes. Later, tensions of up to 1300 000 volts were explored for the James Bay Complex in the north of Quebec, but for reasons of grid reliability, it was decided to use the tension of 735 000 volts. Today, Quebec has more than 6000 kilometers of 735 000 volts transmission lines.

Quebec is the only province in Canada that uses 735 kilovolt transmission lines. It is also the province that has the longest transmission lines grid due to the fact that most of its energy is produced from hydraulic sources in the far north of the province. However, In Ontario a 500 kilovolt line transports the power produced in the north of the province to Metropolitan Toronto, a distance of 700 kilometers. In Manitoba, two lines of 450 kilovolt link the Nelson hydro-electric project to Winnipeg, a distance of 900 kilometers. And in British Columbia, a 500 kilovolt line links the Peace River Generating Station to the south of the province, a distance of 924 kilometers.

The gradual increase in transmission tension since the beginning of this century from 69 kilovolt to 735 kilovolt required the use of conductors of higher caliber and bigger clearance from the ground. Consequently, wood poles could not always be used, and different types of steel towers had to be designed. Research and studies are still underway in many countries directed at experimenting with the use of even higher tension in transmission lines and at the optimization of the design of the line supporting structure and other components.

The construction of a high tension transmission line today is considered to be not only a major project from the technical design and financial implication points of view, but also because it attracts the attention of the public and raises criticism because of its impact on the environment. Consequently, special permits have to be obtained from the government and specific requirements and recommendations have to be respected in the course of the design and construction of the new line.

1.2 Scope of the Present Investigation

In this study, the stages and methods necessary to complete a transmission line project from conceptual planning to commissioning of the line are investigated, based on Hydro-Quebec practices.

In this chapter, the organization of the enterprise, Hydro-Quebec, is presented. The transmission line and its major components are described, and the different phases of a transmission line project are outlined.

In Chapter 2, the feasibility phase of the project is studied from the initiation of the project to the preparation of the feasibility study report which contains the project cost estimate, schedule and description of construction work. The environmental studies and presentation of the project to the public are analyzed. The steps that lead to the choice of the line corridor from mapping, properties investigation, to the preliminary design are described. The strengths and weaknesses of the management control tools in this phase are also investigated.

In Chapter 3, the engineering phase of the project is studied. The authorizations required before any contract is awarded are identified. The design of the line, the preparation of tender documents and the procedures to award design or soil investigation contracts to external consulting firms are studied in this chapter. The strengths and weaknesses of the management control tools in the engineering phase are also investigated.

In Chapter 4, the construction phase of a transmission line project is investigated. The procurement of material and fabrication quality control are described. The organization of the construction site is explained. The tree removal contract, one of the essential contracts in transmission line projects is analyzed and the control and problems of construction work is investigated.

Finally, a discussion on major findings and conclusions is presented in Chapter 5.

1.3 Description of the Enterprise

Hydro-Quebec is a public utility enterprise which produces and distributes electric energy in the province of Quebec. It was founded in 1944 from the acquisition of the electric utility companies serving the Montreal region. The size of Hydro-Quebec almost doubled in 1963 when the other private utility companies operating in Quebec were also acquired. Consequently, today most of the electric power distributed in Quebec is furnished by Hydro-Quebec.

Because the province of Quebec possesses abundant water resources which offer distinct advantages for system operation and reliability of supply, electricity plays an increasingly important role in the economy of Quebec. The gross revenues of Hydro-Quebec exceed two and a half billion dollars per year. The sources of its revenues are: residential and farm customers: 35 percent, industrial customers: 24 percent, municipal distribution and neighboring systems 15 percent, general revenues (commercial customers, schools, hospitals, hotels and office buildings): 22 percent, and other revenues (public lighting and public transportation): 4 percent. The chart of Fig. 1.3.1 shows the enterprise sources of revenue.

Hydro-Quebec revenues are applied as follows: operating, maintenance, administration and other expenses: 32 percent, interest charged to operation: 30 percent, power purchased (from neighboring systems): 5 percent, provision for renewal (depreciation): 7 percent, provincial levy and municipal taxes: 4 percent. The net earning of the enterprise is in the order of 20 percent of its total revenue dollars. The chart in Fig. 1.3.2 shows the application of Hydro-Quebec revenue dollars.

1.4 Organization of the Enterprise

1.4.1 Global Organization of the Enterprise

Hydro-Quebec is administered by a board of directors composed of eleven members nominated by the government of Quebec. This board of directors includes the president and chief executive officer of Hydro-Quebec. The enterprise is managed by seven Vice-Presidents and a Secretary General. Their responsibilities are briefly described below.

The Secretary General is responsible for the Environment and Legal Affairs departments. The Environment department performs studies on all of Hydro-Quebec's major projects whether they are transmission lines projects, thermal power stations or new substations. At the end of each study, they prepare a report describing all the impacts that the project may have during construction and after completion. The environment department is also responsible for requesting the different government authorizations required for each project. (See Chapter 3)

The Public Affairs Vice-presidency is responsible for all public relations aspects. It is also responsible for preparing and performing

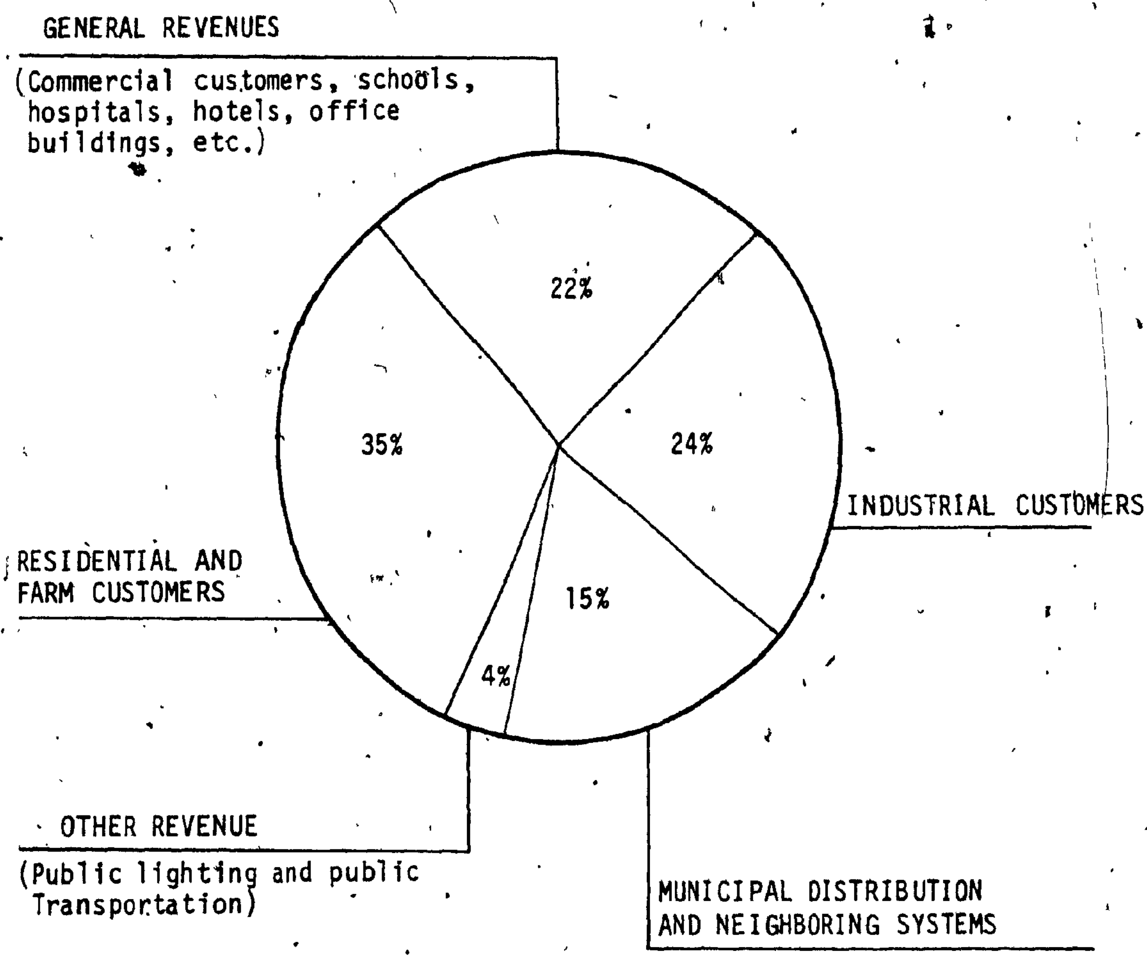


FIGURE 1.3.1: Hydro-Quebec Sources of Revenue Dollars

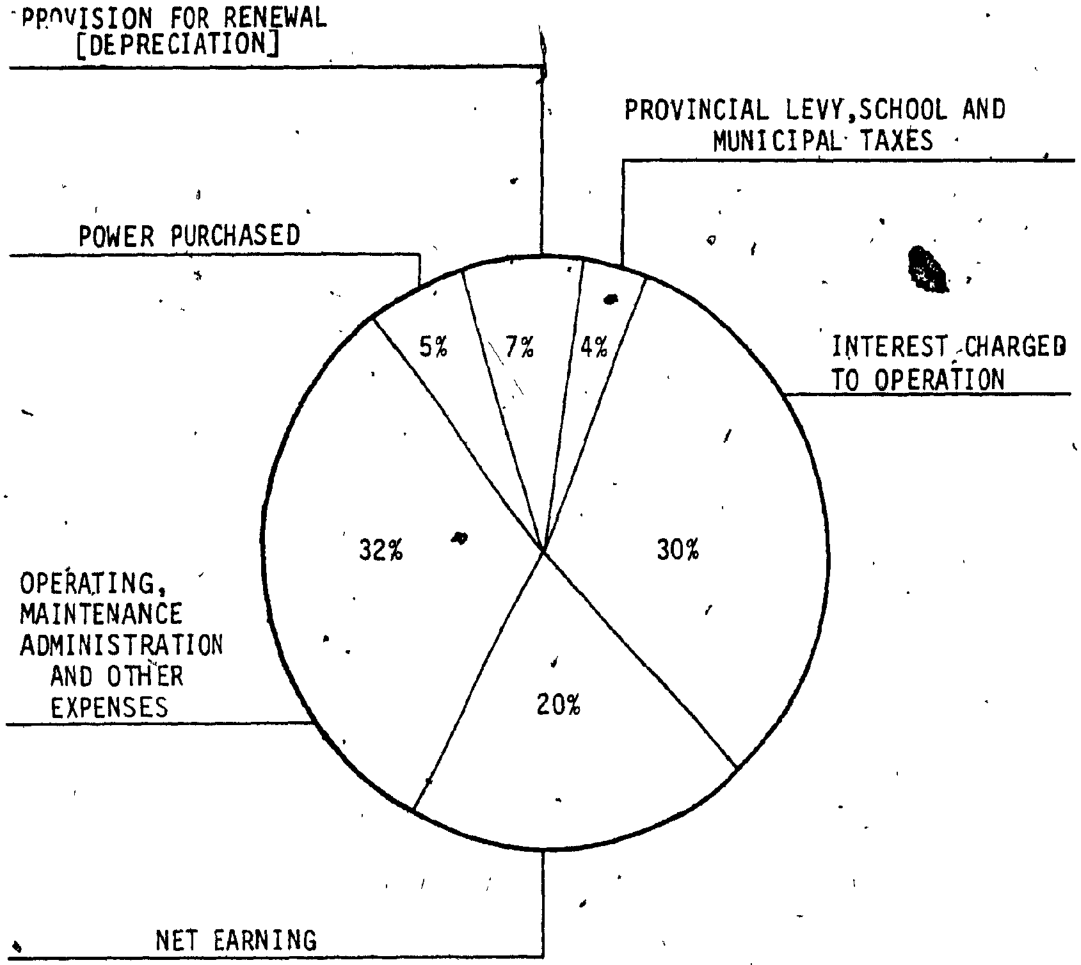


FIGURE 1.3.2: Hydro-Quebec application of revenue dollars

a program of communications before any project is approved for construction. This communication program is directed at the segment of the public likely to be affected by the proposed facility. A major goal of such a program is the collection of negative and positive reactions of the public to all aspects of the project. The communication program is discussed in more detail in Chapter 3.

The Finance and Resources Vice-Presidency is responsible for the management of funds, financial planning, the management of the organization's long term borrowings and all economic research regarding future inflation and interest rates. This Vice-presidency is also responsible for the management of human resources which includes the assessment of future personnel needs, recruiting new personnel, development of the organization, training of personnel, salaries and fringe benefits, labour relations, and all aspects of security and safety of Hydro-Quebec personnel.

The Technology and International Affairs Vice-presidency is responsible for technical research and for the recently formed Hydro-Quebec International . Research is carried-out through Institut de recherche Hydro-Quebec or, as commonly named IREQ . IREQ is responsible for performing and exchanging technical knowledge with other national and international organizations in the fields of Power Generation, Power Transmission and Power Storage. It also looks into the possible non-conventional use of electric power like the electric car or the preparation of liquid hydrogen by electrolysis process. "Hydro-Quebec International" was formed in 1978 and has as a mission the export of Hydro's know-how in production, transmission and distribution of electricity, Hydro-Quebec International personnel are loaned from Hydro-Quebec's permanent staff.

The Production and Operation Vice-Presidency is responsible for the maintenance and operation of the whole power system and the setting of electricity tarrifs. It is also responsible for the eleven production regions into which the province is divided. All power generation and transmission facilities fall under the responsibility of this Vice-Presidency directly after the commissioning of each specific facility is completed. The Vice-Presidency has divisions for the maintenance of the power generation and distribution facilities from the structural, mechanical and electrical aspects. It also has divisions to coordinate the movement of energy. This coordination starts at the level of the power generating station as to the amount of energy transmitted to the sub-station served by this station. This depends mainly on the variable energy demand of each area.

The Production and Operation Vice-Presidency, is also responsible for system automation and communication, and for the measurement and recording of energy demand at all times at the generating stations and at the transmission sub-stations.

Finally, there is the Planning, Engineering and Construction Vice-Presidency which is repsonsible for the planning, design, procurement, construction and commissioning of power stations, sub-stations and transmission lines. Depending on the forecast rate of increase in electricity demand for the whole province and for each region of the province, this Vice-Presidency is responsible for the projects planning, engineering and for obtaining government approval in order to construct on time the necessary facilities to respond to the forecasted demand. The responsibility of this Vice-Presidency ends with the commissioning phase of the project, at which time the completed facility is transferred to the responsibility of the Production and Operation Vice-Presidency.

Twice a year the General Planning department, which is under the authority of the Finances and Resources Vice-President, sets the forecast increase in electricity demand and advises the Planning, Engineering and Construction Vice-Presidency of the expected demand increase over the next 15 year period. Based on this forecast the projects construction program is adjusted. The General planning department is also responsible for initiating the start of projects. Since it has an overview of the whole system it sets the commissioning date of specific power stations depending on the number of Megawatts required to be added to the system and the date they are required. After setting the commissioning date of a specific power station it sets the commissioning date of the required sub-stations and transmission lines to service this power station.

Also under the responsibility of the Planning, Engineering and Construction Vice-President is the Societe d'energie de la Baie James, known as S.E.B.J. S.E.B.J. was originally formed as a separate society reporting directly to the Minister of Energy of Quebec. It was formed to develop the Hydro Electric potential in the James Bay region. Recently S.E.B.J. was integrated into the organization of Hydro-Quebec. Its new mandate is to engineer and construct Hydro-Quebec's extra large projects in the north of the province. Fig. 1.4.1 shows the organizational chart of Hydro-Quebec.

1.4.2 Organization of the Transmission Line Department

The transmission line department is composed of the Transmission Lines Engineering department and the Transmission Lines Construction department. The function of the Transmission Lines Engineering department is to carry-out the feasibility and engineering phases of the new

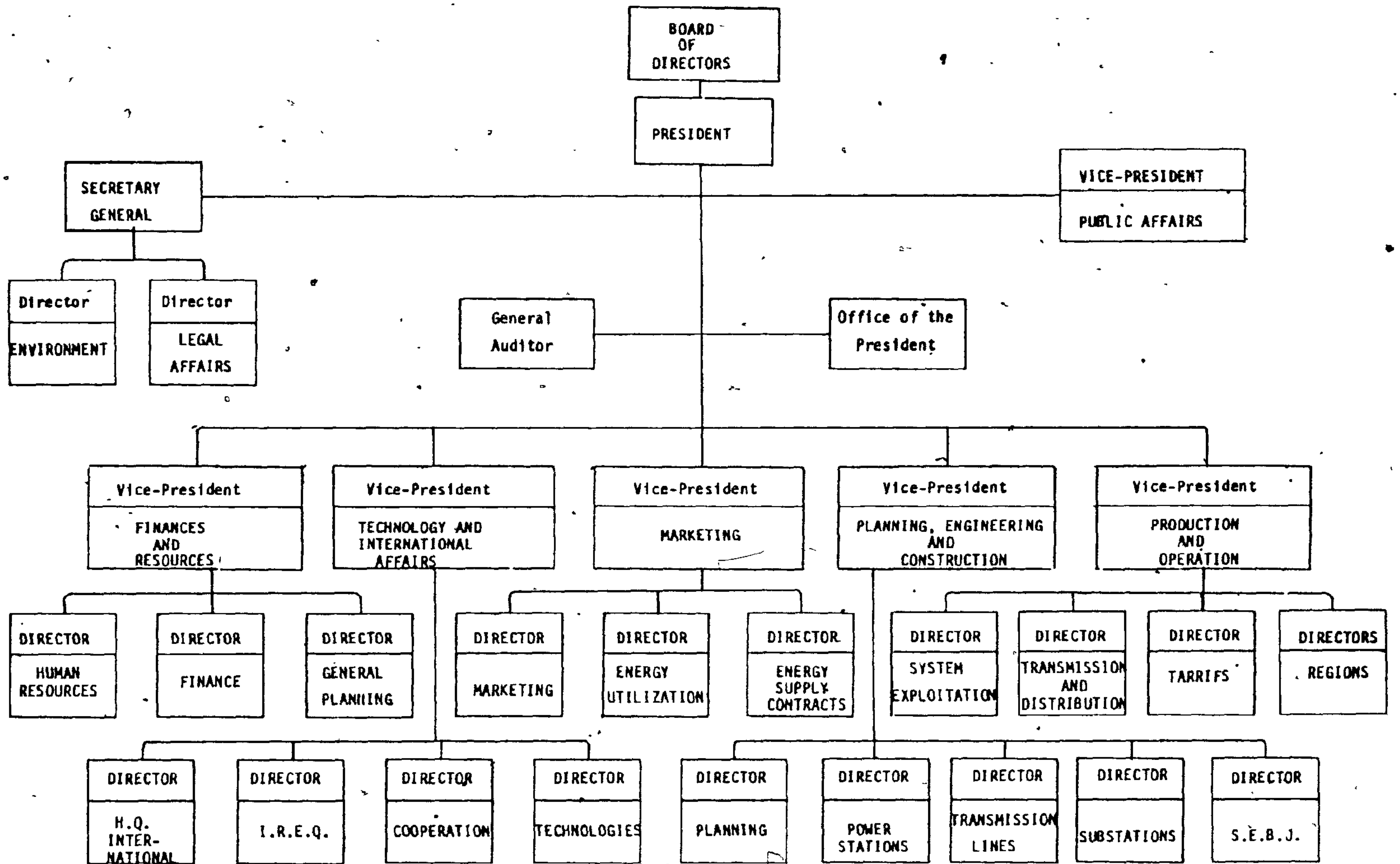


FIGURE 1.4.1: Organizational chart of Hydro-Quebec

transmission lines as well as modifications to existing transmission lines. It is also responsible for ensuring that the construction of the line is performed according to the plans and specifications, for revising drawings to as built conditions, and for maintaining up to date files and microfilms of transmission line grids.

To perform its function, the "Transmission Lines Engineering" department has five divisions: The "Projects" division, the "Scheduling and Estimating" division, the "Studies and Standards" division, the "Topography and Survey" division and the "Quality Assurance" division. The type of structure maintained in the department can be considered a matrix structure. However, in this structure individuals assigned to a project are not physically grouped together, but remains in their functional divisions and perform the work from there. For each project, planners, estimators, controllers, designers and other necessary staff are assigned to the project; and, while not being physically moved, they work under the direction of the project engineer. The title; project manager, does not exist in the departments of Hydro-Quebec. Project engineers are responsible for all technical and control aspects of the project. Each project engineer has under his direct control in his own division technicians, draftsmen, secretarial and clerical staff. The technicians, usually carry-out the design of the transmission towers and foundations, but special design and design problems are referred to the project engineer who may refer them to the "Studies and Standards" division.

While this structure may be considered rigid for consulting firms which tend more to physically move the assigned staff to form a task force group directed by the project manager, at least for major projects, the transmission lines department's structure is suited to the types of projects it has to perform, because of the permanent nature of the organization, and also because of the large number of projects each project engineer may have ongoing at the same time.

As soon as tender documents are completed the responsibility of the project moves from the "Transmission Lines Engineering" department to the "Transmission Lines Construction" department which issues the tender documents, evaluates contractor's bids, performs the procurement and expediting functions and supervises the construction. However, the project engineer is still responsible for quality control for both manufacturing of material, quality of construction, and adherance to the drawings and specifications during the construction phase.

Fig. 1.4.2 shows the organizational chart of the "Transmission Lines" department.

1.5 Description of the High Tension Transmission Line

1.5.1 The Transmission System

The population of Quebec is ranked second in the world for the consumption of electric energy per capita (15 000 Kilowatt hours/year) after Norway. Hydro-Quebec is one of the major producers of electric energy in North America and the only utility in the world which produces 99% of its electricity from hydro-electric sources. While electricity produced from natural sources has the advantage of being clean and renewable, it is usually generated from sources far from the large consumption centers. Thus, the use of hydro power requires the implementation of a large high tension transmission lines grid to transport electric energy from the generating stations to the consumption centers.

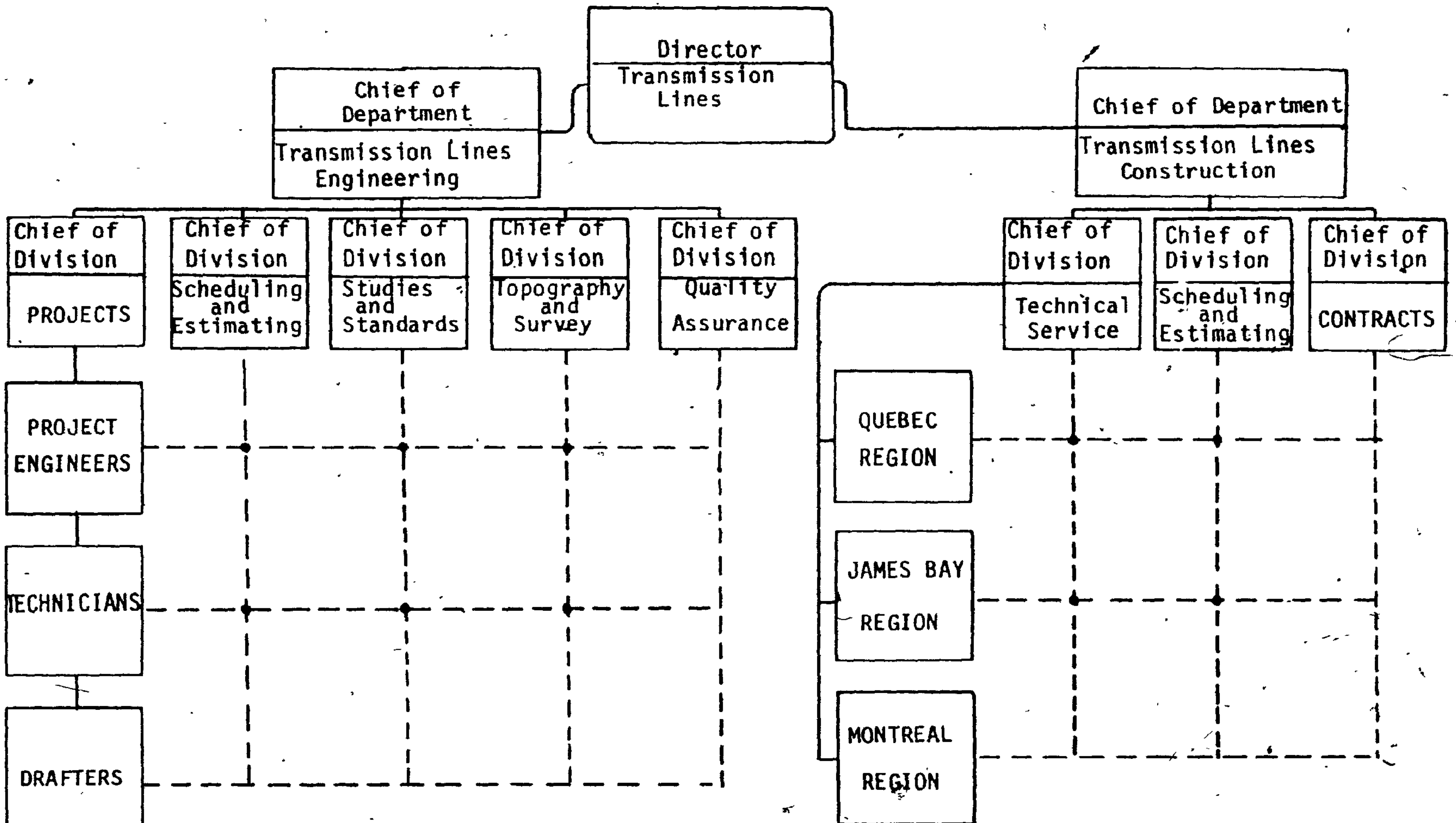


FIGURE 1.4.2: Organizational chart of the Transmission Lines Department

At the generating stations the electric energy is generally produced at tensions of about 13 Kilovolt. To increase the amount of energy transmitted, minimize transmission costs and energy losses and to reduce the environmental impact created if many low voltage transmission lines have to be built, the electric tension can be raised to up to 735 kilovolt when the energy is to be transported for very long distances. The electric tension is raised using transformers. It is then transmitted through high tension power lines to the consumption centers where its tension is gradually reduced for industrial and domestic use.

Hy dro-Quebec now has approximately 30 000 kilometers of transmission lines ranging in tension from 69 kilovolt to 735 kilovolt. The five transmission lines coming from the Bay James Hydro-Quebec complex in the north of Quebec are 735 kilovolt lines for a total of 5560 kilometers of lines.

The cost of a transmission line varies according to the line tension, the type of support, the number of circuits per line (one or two), the number of conductors per phase (each circuit has three phases and each phase is one to four conductors) and the diameter of each conductor. For lines supported on steel poles, of tension ranging from 120 kilovolt to 735 kilovolt, the cost per kilometer of line varies from $250 000 to $500 000. Table 1.5.1 compares the cost of the major levels of line tension. This cost is based on 1981 dollars for lines of 10 to 25 kilometers long. Shorter lines cost more and longer lines cost less per kilometer. The costs cited include feasibility, engineering and construction costs.

NOMINAL TENSION (Kilovolt)	TYPE OF SUPPORT	NUMBER OF CONDUCTORS PER PHASE	DIAMETER OF EACH CONDUCTOR (MCM)*	NUMBER OF CIRCUITS PER LINE	COST PER KILOMETER (Dollars)	COST PER KILOMETER PER KILOVOLT (Dollars)
120	Wood	1	795	1	190 000	1580
120	Steel-BO	1	1033	2	245 000	2040
160	Wood	1	795	1	195 000	1220
160	Steel-Bo	1	1354	2	265 000	1655
230	Steel-ES	2	1033	2	400 000	1740
315	Steel-ES	2	1033	2	390 000	1240
315	Steel-ES	2	1354	2	405 000	1285
735	Steel-FA	4	1354	1	500 000	680

*, MCM = 1000 Circular mils

TABLE 1.5.1: Unit cost of transmission lines

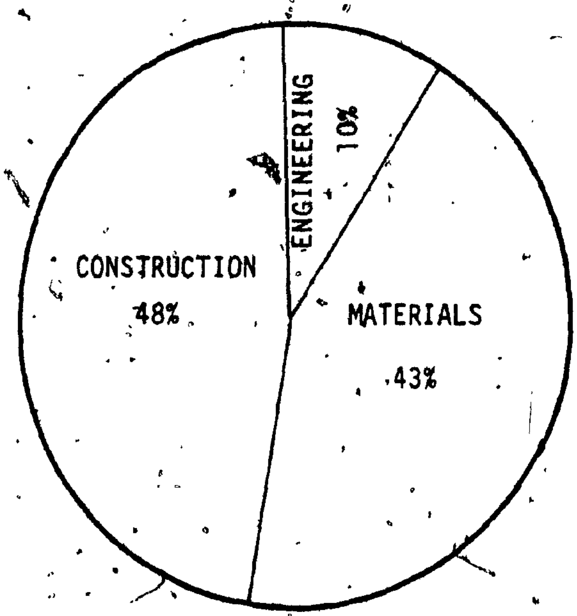


FIGURE 1.5.1: Typical cost distribution for a 735 KV transmission line

To construct a typical high tension transmission line project, the utility spends approximately 10% on the engineering of the line, 45% on material purchase and 45% on the construction of the line. For smaller projects, the engineering cost could comprise up to 25% of the total cost. Fig. 1.5.1 shows the distribution of cost for a 735 kilovolts transmission line.

1.5.2 The Transmission Line Components

Power lines of 120 kilovolt tension and up are designated as transmission lines, whereas power lines of tensions lower than 120 kilovolt are considered distribution lines. In the province of Quebec the levels of tension used in transmission lines are 120 kilovolt, 160 kilovolt, 230 kilovolt, 315 kilovolt and 735 kilovolt. Higher tensions require bigger conductor calibers, higher transmission towers in order to respect the required ground clearance, and wider right-of-way widths for the conductors mid-span swing. Power lines of up to 230 kilovolt may be constructed on wood poles or frames when designed for short spans. Power lines of 120 kilovolts and above are built on steel towers when designed for long spans. The 315 and 735 kilovolt lines are usually built on steel towers only. Beside the supporting structure, the transmission line main components are: the conductors, the insulators, the overhead ground wires, and the hardware. Fig. 1.5.2 shows an elevation view of a typical two circuits (three phase each) transmission tower. The transmission line components and their purposes are respectively described below:

Of all the components that go into making up a transmission line, the most important are the conductors. The conductor's purpose is to transport the electrical energy with the minimum possible resistance. The best metal to serve this purpose is silver followed closely by brass.

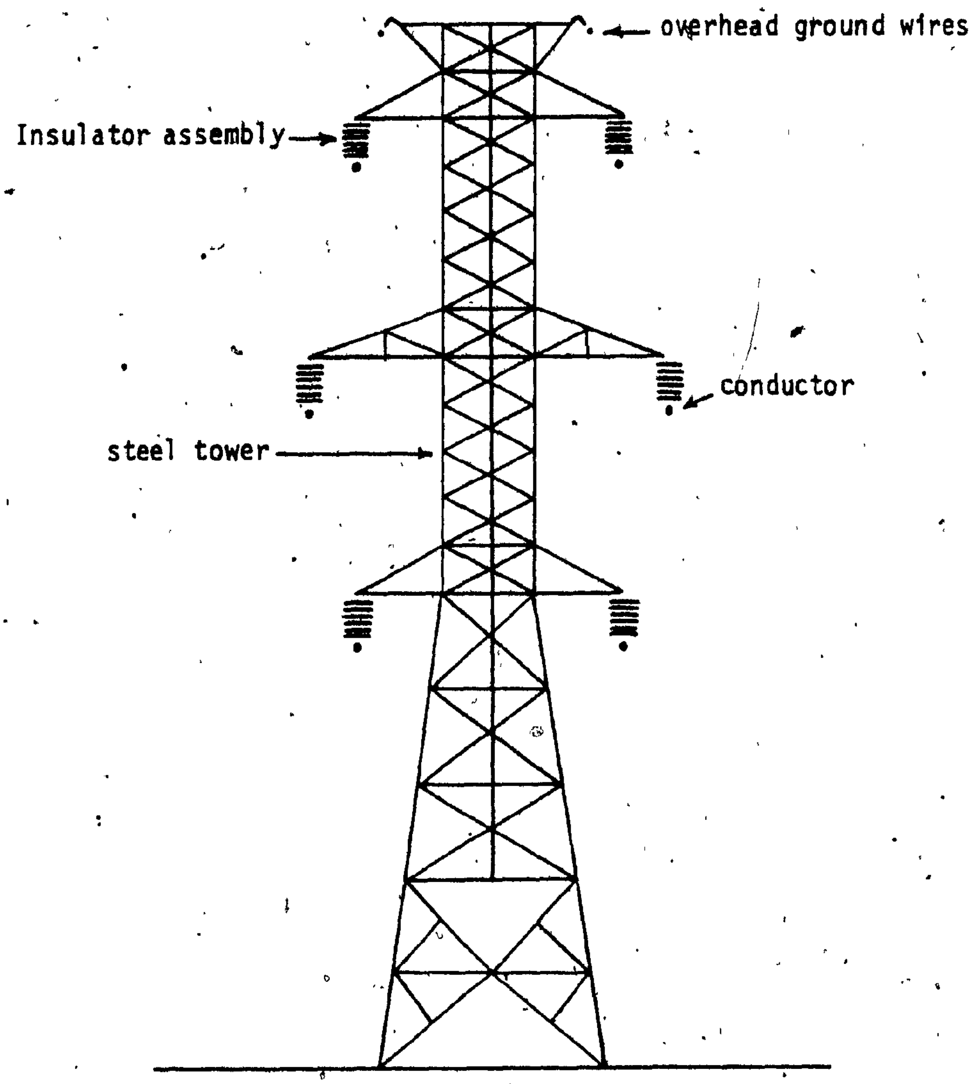
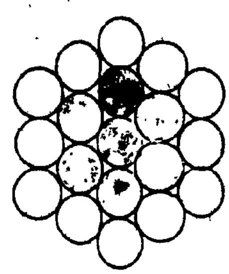


FIGURE 1.5.2: Schematic of a transmission line tower

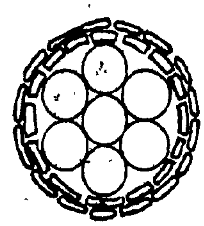
While brass conductors were used in transmission lines in the beginning of the century, they were substituted by aluminum for obvious reasons of cost. The disadvantage of aluminum is its weak mechanical resistance in tension. To compensate for this weakness a high-strength steel core is used. There are several types and sizes of conductors currently available, some of which are used more extensively than others. The most common type of conductor used today is the ACSR (Aluminum Conductor Steel-Reinforced), it is a stranded conductor composed of one or more layers of hard-drawn aluminum wire stranded with 2 high strengh galvanized steel core. The other common types available are the AAAC (All Aluminum Alloy Conductor), the ACAR (Aluminum Conductor Alloy Reinforced), the AWAC (Aluminum Clad Steel Conductor), the ACSR/SD (Aluminum Conductor Steel Reinforced-Self Damping) and the AACSR (Aluminum Alloy Conductor, Steel Reinforced). Fig. 1.5.3 illustrates the typical ACSR type strandings. The choice of the conductor type depends on corrosion considerations, strength considerations and economic considerations. Whereas, the choice of the conductor size depends on the line voltage and the thermal capability.

The function of the insulators is to maintain an adequate insulation distance between the conductors and the steel tower. There are two main types of insulators used in transmission lines today: the suspension bell type and the pin type as illustrated in Fig. 1.5.4. The pin type insulator is used for power lines up to 69 kilovolt of tension, 120 kilovolt lines and above uses several bell type insulators connected together in a string to achieve the desired insulation level which depends on the line tension. For example, a 120 kilovolts line requires seven bell insulators while 35 bell insulators are necessary for a 735 kilovolt line. The traditional insulator material is porcelain, but today synthetic insulators made of fiber glass are used. Their major advantage is their light weight compared with traditional insulators.



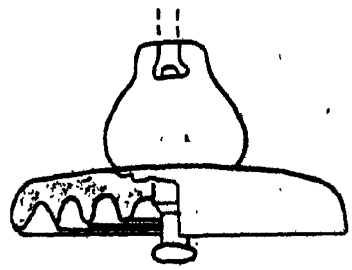
12 Al./7S.

TYPICAL ACSR STRANDING

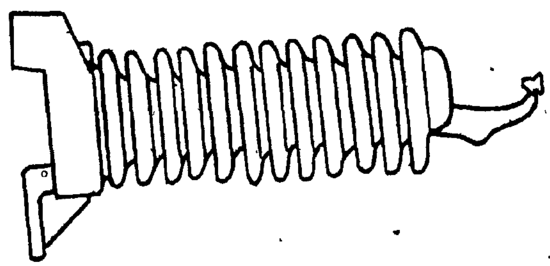


TYPICAL ACSR/SD STRANDING

FIGURE 1.5.3: Typical conductor stranding



Standard Suspension bell



Standard pin type

FIGURE 1.5.4: Main types of insulators

The supporting structure can be built using either wood or steel depending on the loads and desired spans. For tension above 230 kilovolt, steel towers are normally used. There are several types of steel towers from which the designer can choose depending on the size of tower required, the loads, the zoning of the area for which it is planned and the number of circuits (one or two). Figures 1.5.5 and 1.5.6 illustrate different types of transmission towers. The towers can be divided into three types: The self supporting type, the guyed types and the tubular types. The self supporting towers are the most common types used, the guyed towers are generaly more economical but could only be used in rural areas where space is available and the tubular towers are used in urban areas where they are more accepted by the public because of their low visual impact.

The overhead ground wires purpose is to protect the line against lightning. They are placed above the conductors to give an angle of protection of 35 degrees, thus the two circuit towers usually require two overhead ground wires. There are two main types of overhead ground wires: high strength galvanized steel wires and aluminum-clad steel strand. The selection of the type and size of the overhead ground wire depends upon only a few factors, the most important of which is how its sag coordinates with that of the conductor. Other factors that may have to be considered are corrosion resistance and conductivity.

Finally, the transmission lines contain what is commonly called the hardware, while the conductor may constitute the most expensive single component, the conductor hardware is the most exposed to damage. The purpose of the hardware components is to support, join, separate and mechanically damp overhead conductors. The most important pieces of

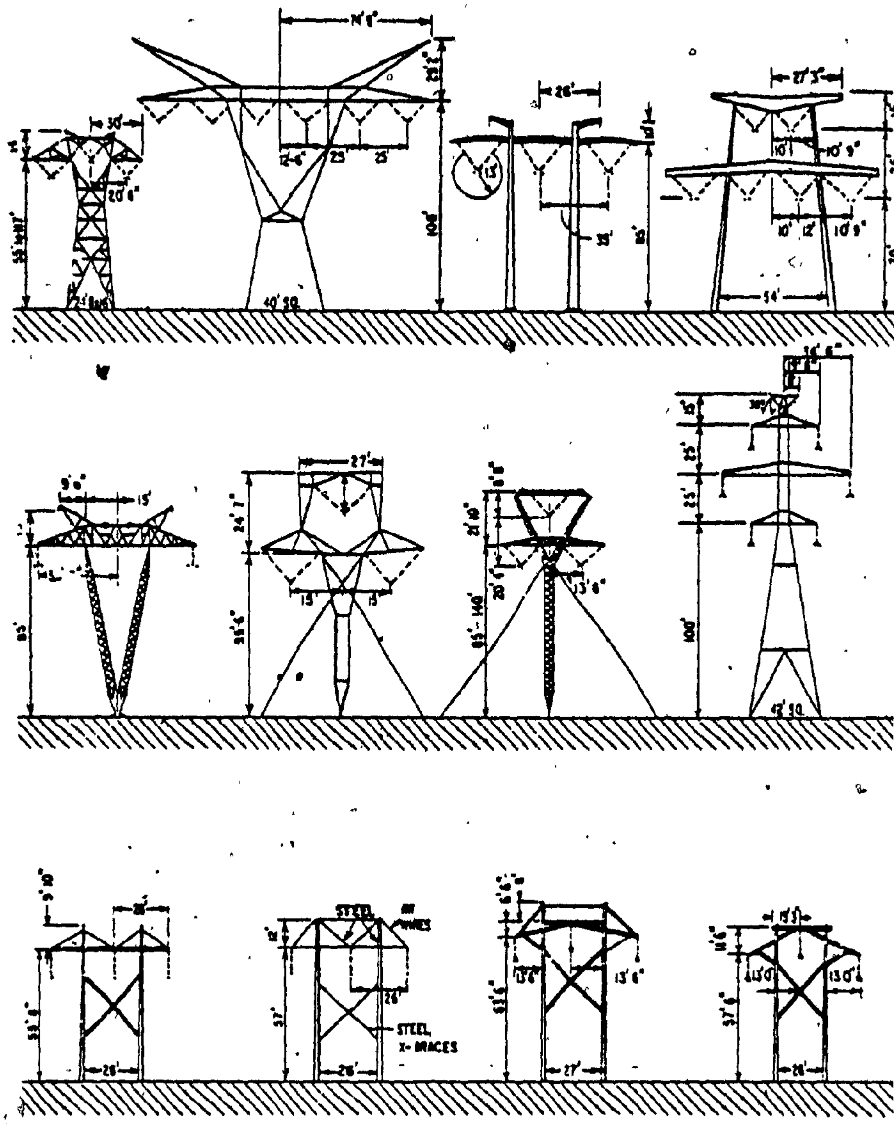


FIGURE 1.5.5: Typical Transmission line tower (A)
(courtesy, Transmission lines department,
Hydro-Quebec).

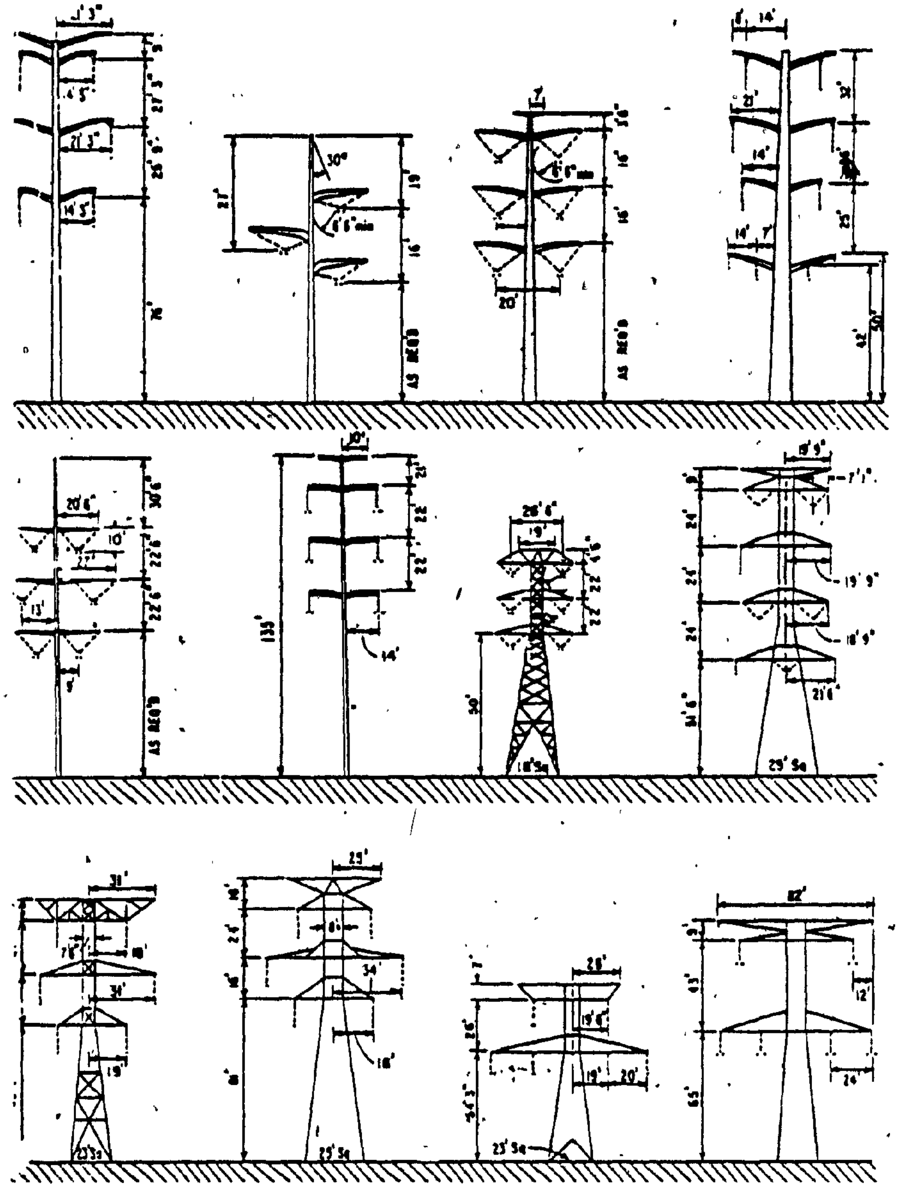


FIGURE 1.5.6: Typical Transmission Line Towers (B)
(courtesy, Transmission lines department, Hydro-Quebec).

hardware are: The suspension and deadend clamp, the conductor splice and the dampers. The suspension end deadend clamp join the conductor and the insulator string, they are selected to match the conductor diameter. The conductor splice join two pieces of conductors together, they are usually formed utilizing automatic compression type splice. The dampers are used in areas of severe vibration in order to attenuate aeolian vibration amplitudes, thereby reducing the bending stress at hardware locations and extending conductor life. Fig. 1.5.7 illustrates the above three types of hardware.

Fig. 1.5.8 illustrates the cost distribution of material and construction of the major line components.

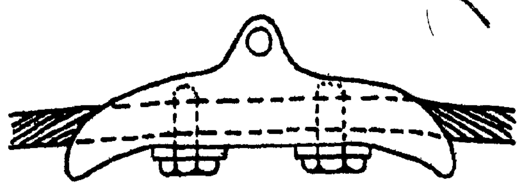
1.6 The Different Phases of a Transmission Line Project

Basically a transmission line project involves the same stages as any other construction project. The three basic sequential phases of this type of project are the feasibility phase, the engineering phase and the construction phase. Depending on the size of each project, typical durations of the three phases of the project are: 1 year to 2.5 years for the feasibility phase, 2 years to 3 years for the engineering phase and 1. 5 year to 3 years for the construction phase. Consequently, the total length of the project, from start to commissioning is anywhere from 4. 5 years to 8. 5 years.

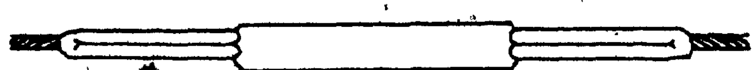
The feasibility phase of the project begins with the recognition of the need of the new line and goes through mapping of the area, preliminary design and environmental studies. It ends with a feasibility phase report that contains the description of the construction work required, an estimate of how much the project will cost, a schedule to indicate how long the engineering and construction are expected to take and a description of the environmental impact of the project and what steps will be taken to minimize this impact.

The engineering phase of the project starts with the approval of the project by the board of directors. In this phase the following activities are performed: detailed design, site survey, acquisition of line corridor preparation of drawing, specifications and tender documents.

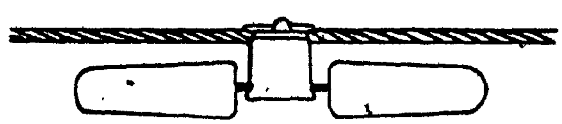
The last phase of the project is the construction phase. This phase only starts when we have in hand the required government authorizations. It starts by the award of the construction contract, fabrication of materials, tree clearing and site construction and ends with the commissioning of the transmission line. Fig. 1.6.1 shows the three phases of a project and their main activities.



Typical suspension clamp



Typical aluminum splice



Typical damper

FIGURE 1.5.7: Some typical transmission line hardware components

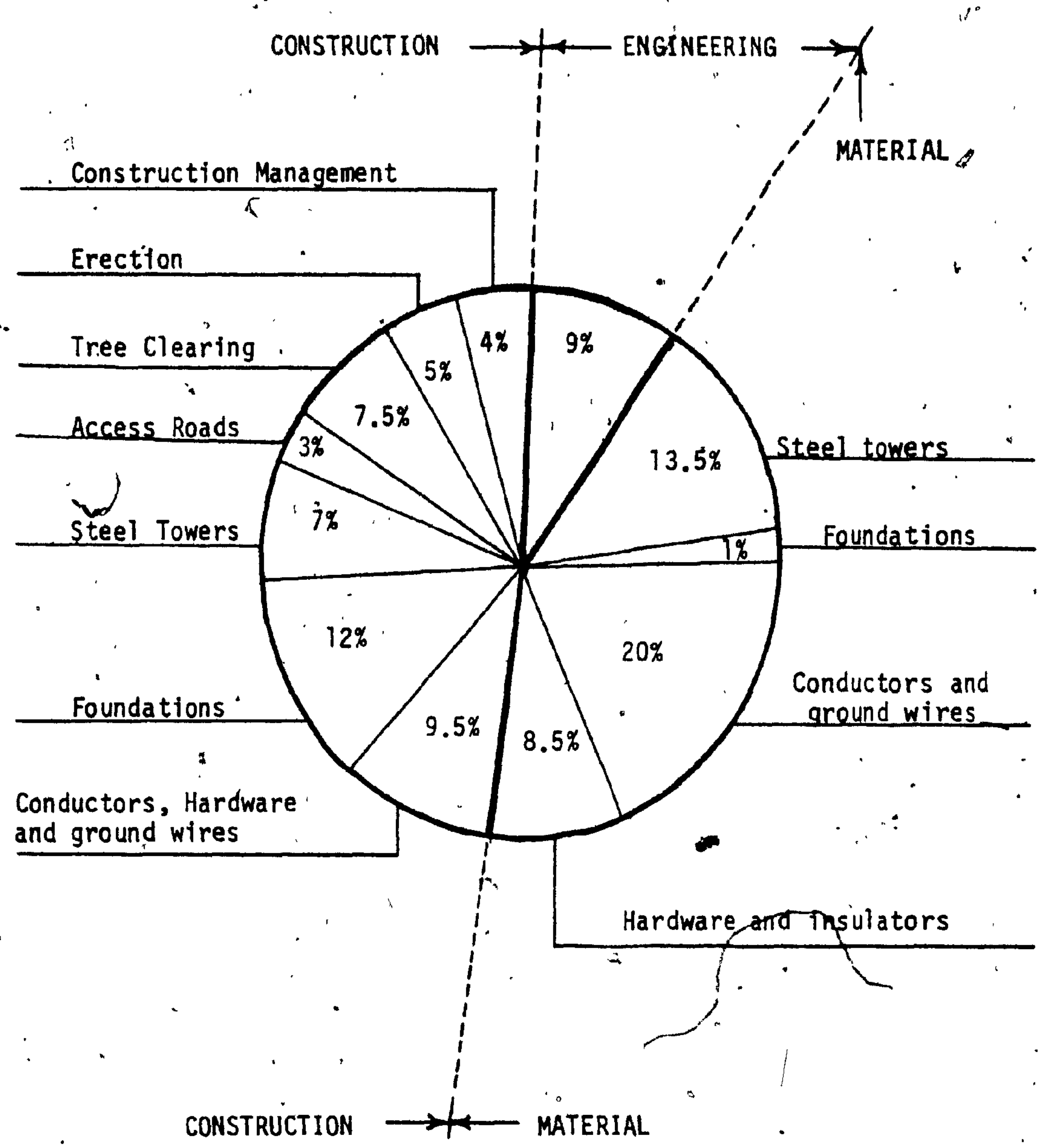


FIGURE 1.5.8: Typical cost distribution of
Transmission lines components

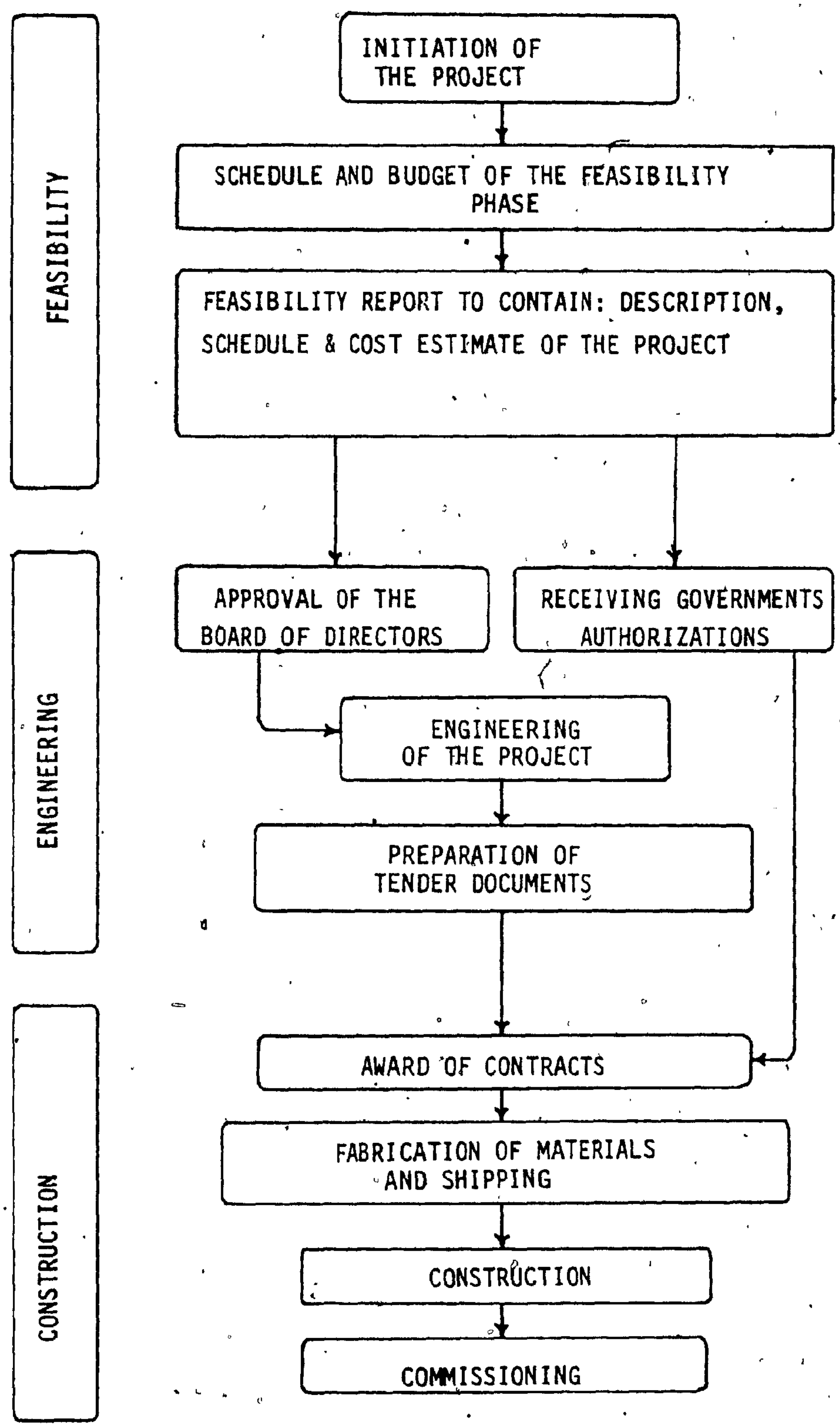


FIGURE 1.6.1: The different phases of a Transmission line project

CHAPTER 2

FEASIBILITY PHASE OF THE PROJECT

2.1 Initiation of the Project

The initiation of any new project is the responsibility of the planning department, which is part of the Equipment Vice-Presidency. To be able to decide when the studies for a specific project have to start, the planning department has to perform long term planning of all necessary facilities. Since the total length of a project varies from six to ten years, long term planning is done for a minimum of fiteen years. The plan essentially is based on the forecasted peak demand for the province of Quebec. The historical trends of the increase in peak demand as well as estimated upper and lower limits are shown in Figure 2.1.1.(These figures were forecast in 1980, they are presently lower due to the recession and the energy conservation programs).

Figure 2.1.2 illustrates the planned power stations construction until the year 1995. New power stations have to be constructed to respond to the increase in electricity demand, and thus additional transmission lines and substations are needed to transport the electric energy to the consumption centers.

The planning department is essentially responsible for performing the following duties:

- Preparing, maintaining and revising the necessary documentation to establish the forecast of electric energy demand,
- Establishing general characteristics of the production equipment, substations and transmission lines, and
- Coordinating the required activities to choose sites for future production facilities, substations or transmission lines and to ensure coherence in the territorial use.

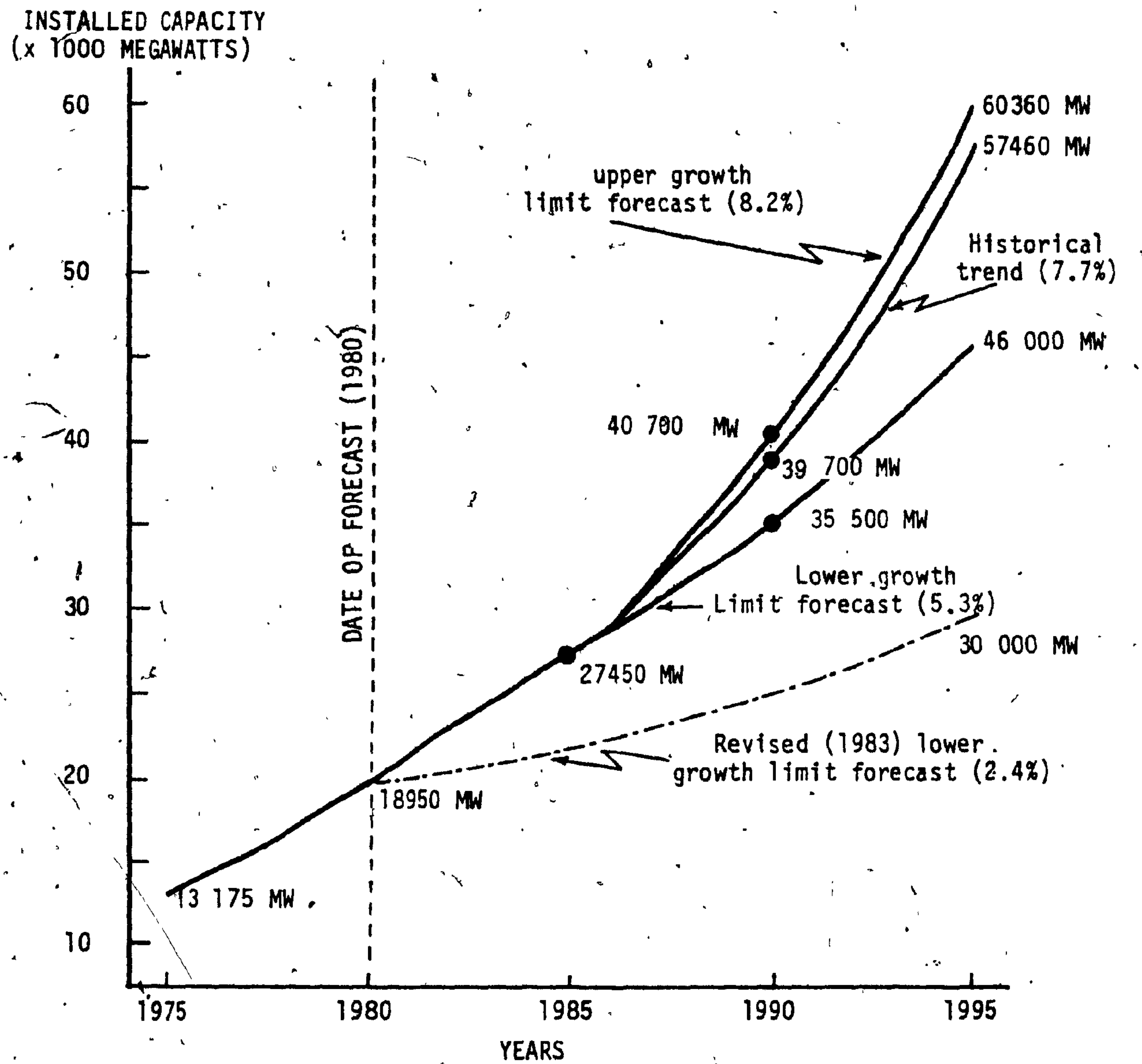


FIGURE 2.1.1: Forecast peak Electric capacity demand for the province of Quebec

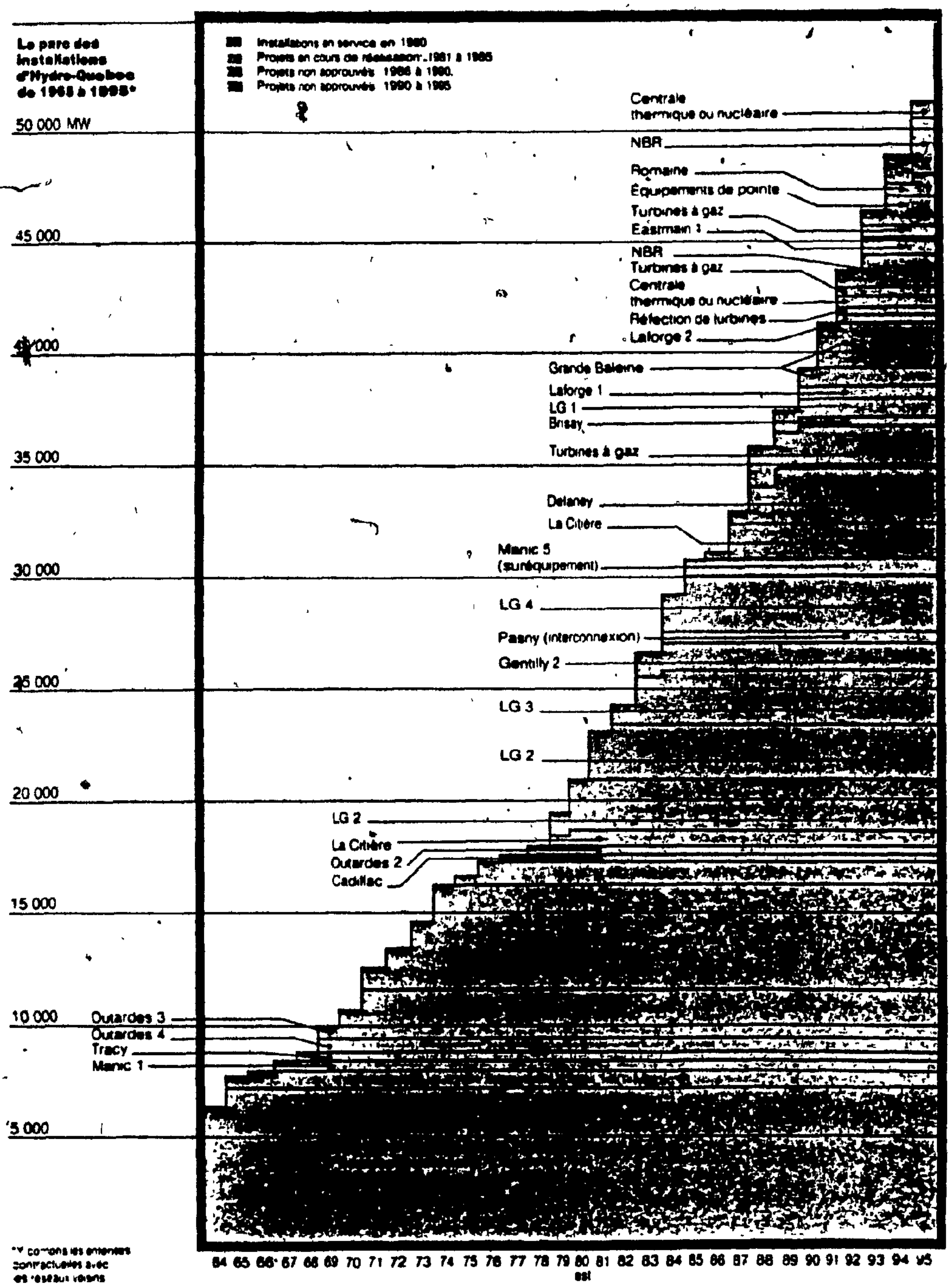


FIGURE 2.1.2: Planned power station construction
(courtesy: Transmission lines department, Hydro-Quebec)

Based on the planning of all types of facilities for each region of the province, the planning department will put forward a proposal to initiate a project in due time to the executing department which, in this case, is the transmission line department. The planning department acts as the client, whereas the executing department acts as the contractor, such that the planning department requests a cost estimate and schedule of the feasibility study for a specific transmission line from the transmission line department. The estimate, the schedule and a brief description of the work to be performed during the feasibility phase is, in turn, prepared by the project engineer in the transmission line department and forwarded back to the planning department for acceptance.

The project proposals are then accepted or rejected by the planning department. In the case where they are accepted, the initiation of the project is considered completed and the transmission line department then begins the feasibility studies for the project. The proposals are only rejected by the planning department.if there is an alternative project to be explored which could cost less and fulfills the same needs.

2.2 Schedule and Budget of the Feasibility Study:

The responsibility of the project engineer starts from the activity and, as mentioned under Section 2.2.2, the project engineer has to perform his duties under a matrix system. Specialized personnel perform work for the project while they remain in their functional division. To prepare the feasibility phase budget, the project engineer may, as a first start, use computerized statistical data on previous projects to obtain a preliminary schedule and estimate. To use this service the project engineer describes what is known on the project parameter sheet, such as total new transmission line length, line tension, type of towers to be used, number of conductors per phase, diameter of each conductor, number of circuits, etc. The resulting schedule and estimate are then used as a base document which may be adjusted according to the special situation of each project. A statistically derived schedule is presented in Figure 2.2.1.

The first adjustment that has to be made to the schedule deals with the number of activities. Some of the activities produced by the computer may not be required for the project at hand, depending on the documentation available prior to start of the project. For example, if the project is in an urban area, detailed maps may be already available from previous projects, so mapping activities may not be required. On the other hand, if the tranmission line is to be constructed in a rural area, and no maps exist, then the cartography activities are required. Another necessary adjustment of the initial schedule deals with the project total duration. The initial schedule is a normal one (i.e. activities are scheduled using a normal duration). However, in many projects time to follow the normal schedule may not exist and the durations may have to be compressed in order to meet an earlier commissioning date specified by the client (the planning department).

The most effective method to compress the schedule is to call a meeting to which the project engineer invites the persons assigned on the project from their functional department or division in order to work-out with them a way of compressing the schedule which satisfies the project commissioning date set by the planning department. The key people invited to this meeting are those assigned from the information Vice-Presidency, the Environment department and from the various divisions of the Transmission line department. All activities that fall on the project

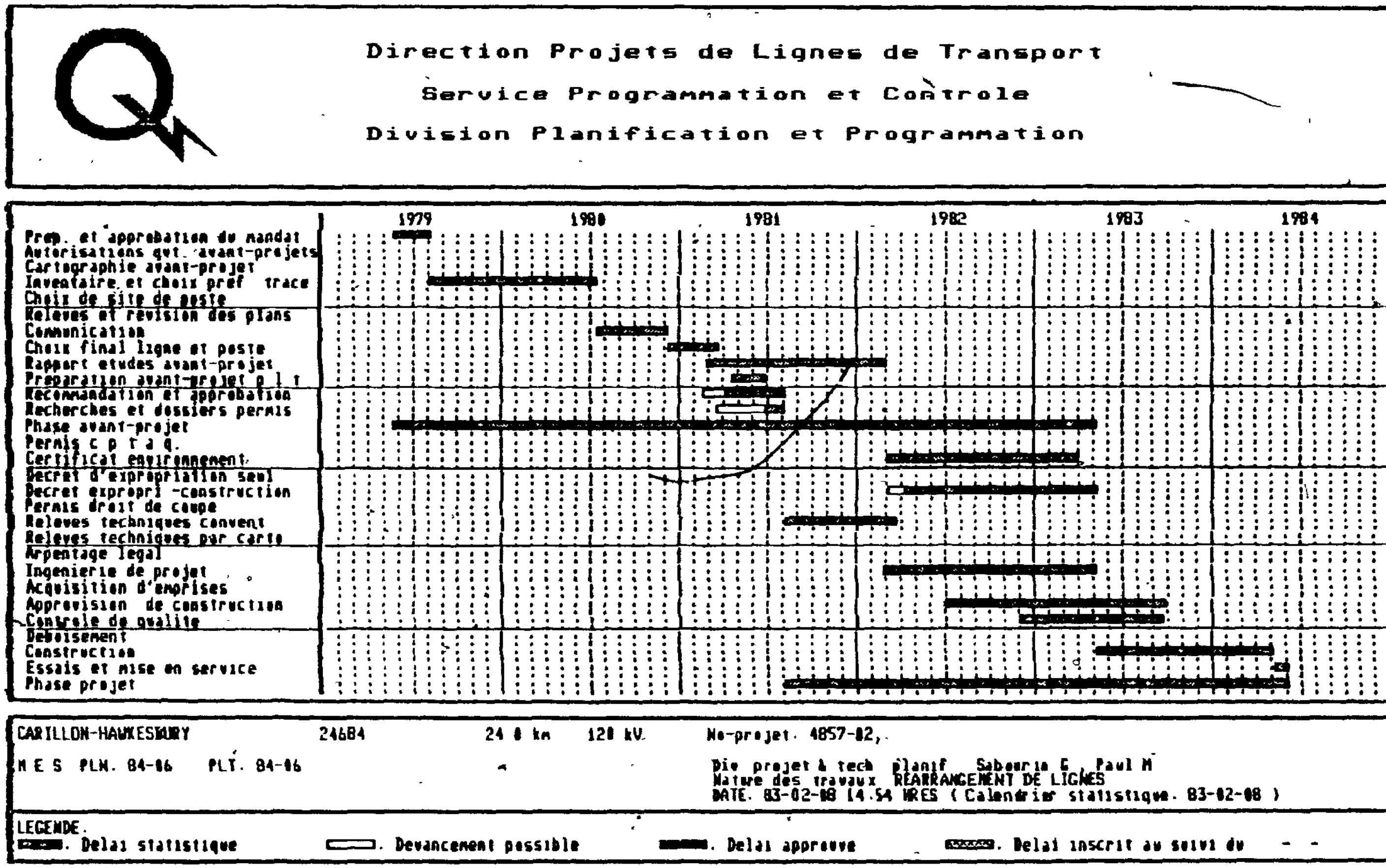


FIGURE 2.2.1: Statically derived schedule
(courtesy: Transmission lines department, Hydro-Quebec)

critical path are reviewed. The project engineer attempts to obtain from the persons responsible for executing these activities the maximum possible compression. When a final schedule is agreed upon, the project planner will prepare a manual schedule, using the agreed durations, and circulates it for approval by all executing departments. Copies of the approved schedule are then distributed and used for feasibility phase follow-up of progress. An example of a finalized manual schedule is presented in Figure 2.2.2.

After the schedule is adjusted, the statistical cost estimate is adjusted. This adjustment is based on the actual project activities, the degree of schedule compression and on the specific requirements of each activity. First, man-hours for each activity are evaluated. Then, using a computer program, the estimator inputs the man-hours of each activity using the relevant cost code and the program transfers the hours into dollars, adds administration fees, interest charges, inflation charges and a contingency allowance. Interest is added to the project direct cost yearly until the commissioning date when the project is considered productive (i.e. used for electricity sales). The interest and inflation rates built in the program are adjusted every three months based on information received from the finance Vice-presidency. The interest rate to Hydro-Quebec is computed by the Finance Vice-presidency based on the averate rate of interest the enterprise is paying on the money borrowed from the international money market, and the inflation rate is based on financial studies and historical trends. The contingency allowance is provided to the estimator by the project engineer, who evaluates it based on the conditions and risks of each project. It usually varies from 10 percent to 25 percent. The summary page of the feasibility study estimate is presented in Figure 2.2.3.

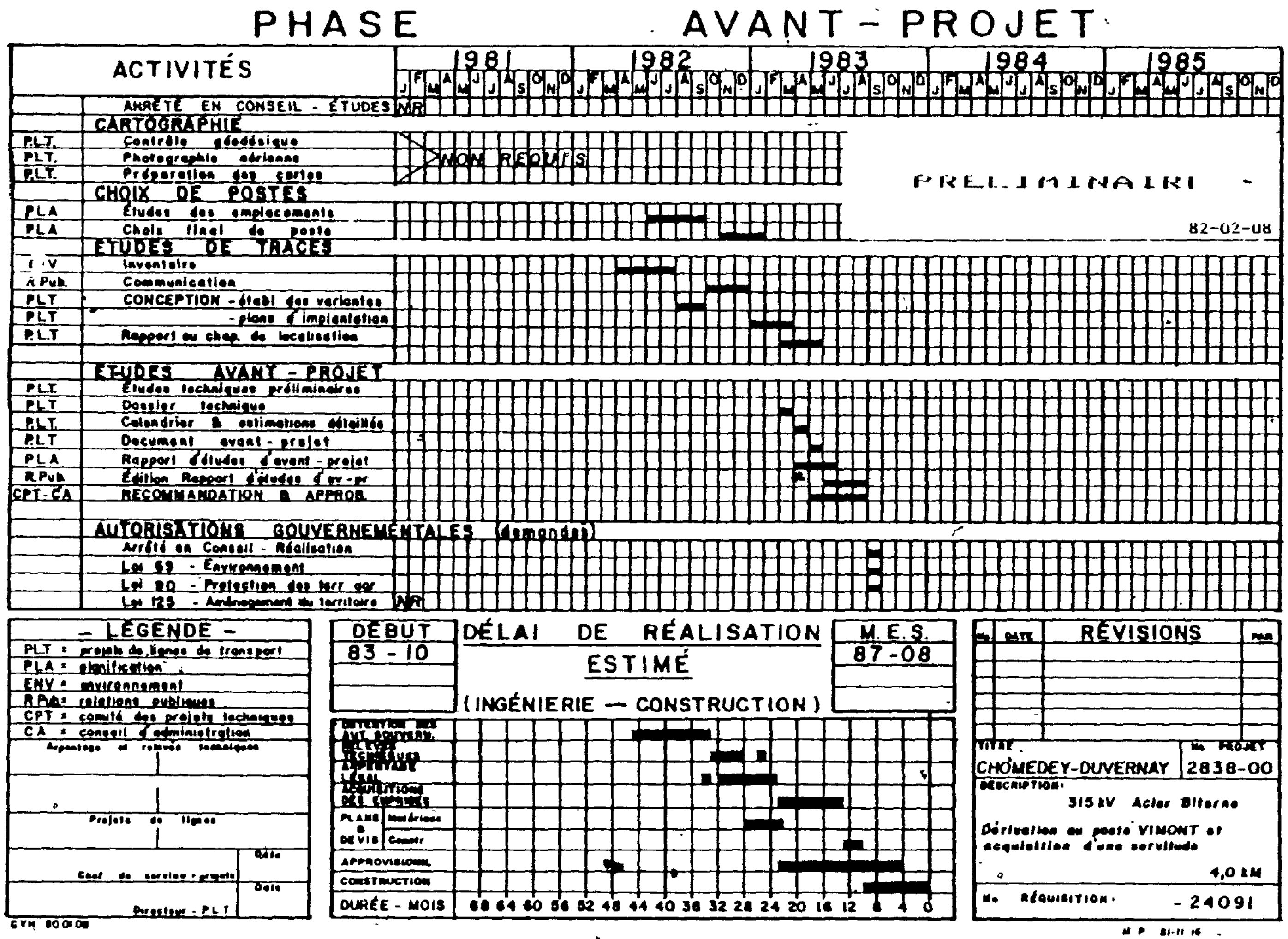


FIGURE 2.2.2: Ajusted manual schedule
(courtesy: Transmission lines department, Hydro-Quebec)

DIRECTION PROJETS DE LIGNES DE TRANSPORT
ESTIMATION DETAILLEE SYSTEME (2)
(000 $)

DATE: 83-03-17 13:25 HRES

INTITULE : CARILLON-RIGAUD
DESCRIPTION : Ligne et servitude. (Haus-se d'exploitat ion vers Niagara Mohawk Power Corp)
TENSION : 120-KV PYLONE : BOIS MONOTERNE
NO. DE PROJET : 470600
STATUS DU PROJET : CENTRALISE
ARTICLE BUDGETAIRE: R. DE T. : -24691-

MISE EN SERVICE : 85-10-01
DATE EST. CALCULEE 03-03-09
DATE EST. COUR. AP 83 03-17 RE
LONGUEUR : 17,0 KM
DATE D'INFLATION: 82-02-
TYPE DE PROJET : 1
REVISION NO : 4

SUFFIXE	DESCRIPTION	PREVISIONS GLOBALES	DEP. AU 31/12/82	1983	1984	1985	1986	1987	1988	1989	A VENIR
937	Etude avant-projet	69,8		69,8							
938	Cartographie photo	0,5		0,5							
999	Administration (p.l.t)	3,0		3,0							
	COUT DIRECT	73,3		73,3							
998	ADMINISTRATION	1,5		1,5							
997	INTERETS	29,6		5,6	12,0	12,0					
988	RESERVE EVENTUALITE	14,6		14,6							
	TOTAL DU PROJET	119,0		95,0	12,0	12,0					

COUT DE L'INFLATION

DIVISION ESTIMATION: PREPARE PAR: DATE: APPROUVE PAR: DATE:

FIGURE 2.2.3: Summary of feasibility study cost estimate (courtesy: Transmission lines department, Hydro-Quebec)

When both schedule and budget of the feasibility phase are finalized, they are forwarded with the work description to the planning department for their acceptance.

2.3 Mapping and Properties Investigation

The activities of mapping and properties investigation are performed by the survey department at the request of the project engineer, who identifies the project needs regarding the limitation of the area under study, the required map scale and the type of maps.

The preparing of maps for a specific area is one of the major project activities. However, for projects conducted in developed areas, this activity may not be required as maps at scales of 1:20 000 are already available. The types of cartography used for transmission line projects are: mosaics, topographic maps, cadastral maps, and profiles.

The mosaics, topographic and cadastral maps are required for the environmental studies, the selection of the corridor and for the communication program with the public. The profiles are required for the distribution of the towers in the chosen corridor. The mosaic is a reconstruction of aerial photos either in color or in black and white. The topographic maps are prepared also using aerial photos, they may be combined with the cadastral maps.

The property investigation is an activity performed in all cases where the line corridor was not previously acquired by Hydro-Quebec. Usually when an environmental study is required, a property investigation is also required and it is performed in parallel with the environmental study. The purpose of the property investigation is to try to minimize the number of expropriations when choosing the line corridor. The decision as to whether or not a property investigation is necessary is made during the preparation of the schedule and budget of the feasibility phase and its cost is integrated in the budget. The project engineer identifies the area in which he wants the investigation to be conducted. It is preferred that the identification be made on a map scaled 1:20 000.

The property investigation is performed at the registration offices of the provincial ministry and municipalities. The objective is to identify all properties which the line will cross, to identify whether each property is privately owned or publicly owned and to prepare a preliminary price evaluation for each property. The data collected are documented in an inventory form and the boundaries of each property are drawn on a 1:20 000 map of the area. They are presented in a form of report which may also contain photos of the properties as well as a description of each.

The property investigation report is used in the process of choosing a line corridor which minimizes conflicts with the public. No property acquisition or expropriation is attempted before the project is approved. The issue of property acquisition is discussed in Chapter 3.

2.4 Environmental Studies and Selection of the Line Corridor

Environmental studies prior to the construction of a transmission line are performed for projects where the transmission line is 2 kilometers or more and of a tension of 315 kilovolt or higher. Environmental considerations are not only a public duty which have to be taken into account by any public utility company, they are also required by law in Quebec and a permit from the ministry of the environment of Quebec has to be obtained before the construction of the project starts.

There are two types of environmental impacts created by the implementation of a high tension transmission line in a certain territory. The first type of impact is the electric related impact: electric shocks, audio-noise electromagnetic interference and electric fields created near the conductors. The electric related impacts are dealt with by standardizing minimum clearance distances between the line conductors and every different type of obstruction. The second type of environmental impact is the physical impact generated by the implementation of the transmission line itself. It is this type of impact that the environmental study aims to minimize.

The environment department is responsible for performing the environmental studies and it is also responsible for obtaining the permit from the ministry of environment of Quebec as well as all other necessary government permits and authorizations required for each specific transmission line project (The government permits are detailed in Chapter 3). The first step the environment group has to do is to forward a notice to the ministry of the environment. By this notice, the ministry is advised that Hydro-Quebec have started the studies to construct a new transmission line. The base parameters of the project are given in this notice. The purpose of this notice is firstly to comply with the law and secondly to obtain feed-back from the ministry with regard to any special requirement to be respected in the course of the study.

The environmental studies are composed of six main parts. The environment report is a main factor in the choice of the preferred line corridor. It forms part of the final project report, entitled, "Rapport Hydro-Quebec", which is used to obtain the approval of the project by the board of directors, and to obtain the necessary government authorizations. The "Rapport Hydro-Quebec" is discussed in Chapter 3).

The six main parts of the environmental studies are:

- Zone limitation: In this first part, the zone chosen for the study is framed. Naturally the zone contains the two points that are to be linked by the new transmission line. Fig. 2.4.1 shows the zone limitation for a project to implement a transmission line between the "Duvernay" substation and the "Terrebone" substation.
- The natural medium: This part contains the physical characteristics of the zone under study, an inventory of the natural woods, the type of natural vegetation and trees, and an inventory of the medium natural fauna such as migrating birds or wild animals. The effect of the transmission line, if any, on the area natural medium is analysed.
- The human medium: This part is considered the most important part of the study. First it indicates the residential and commercial areas in the study zone and the potential future residential and commercial areas; it identifies the existing and planned industrial zones; it indicates the agriculture zones and finally, in this part existing heritage resources, if any, are identified. Fig. 2.4.2 shows the same zone of Fig. 2.4.1 with identification of the agricultural potential of this zone.
- The visual medium: In this part the potential visual impact of the new transmission line is evaluated. The results of this part determine the type of transmission towers to be used for the project. It should be noted here that only a part of the line could be built with the tubular tower, which are considered to have a lower visible impact, if the line crosses more than one type of zones.
- Identification of the levels of opposition: This part leads to the development of the line corridor options. To identify the levels of opposition, to the new line beside environmental criteria the

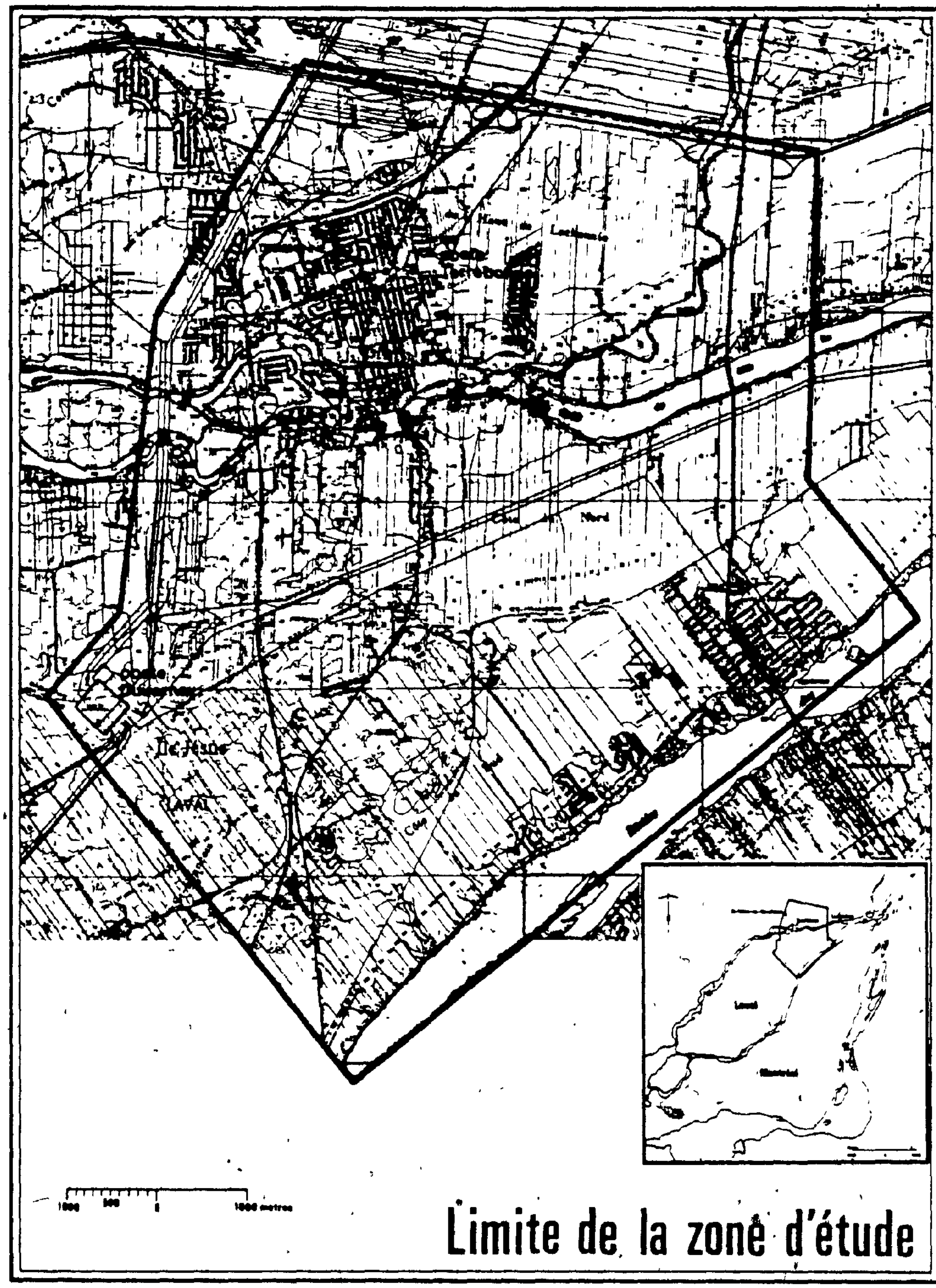


FIGURE 2.4.1: Zone Limitation Plan
(courtesy: Transmission lines department, Hydro-Quebec)

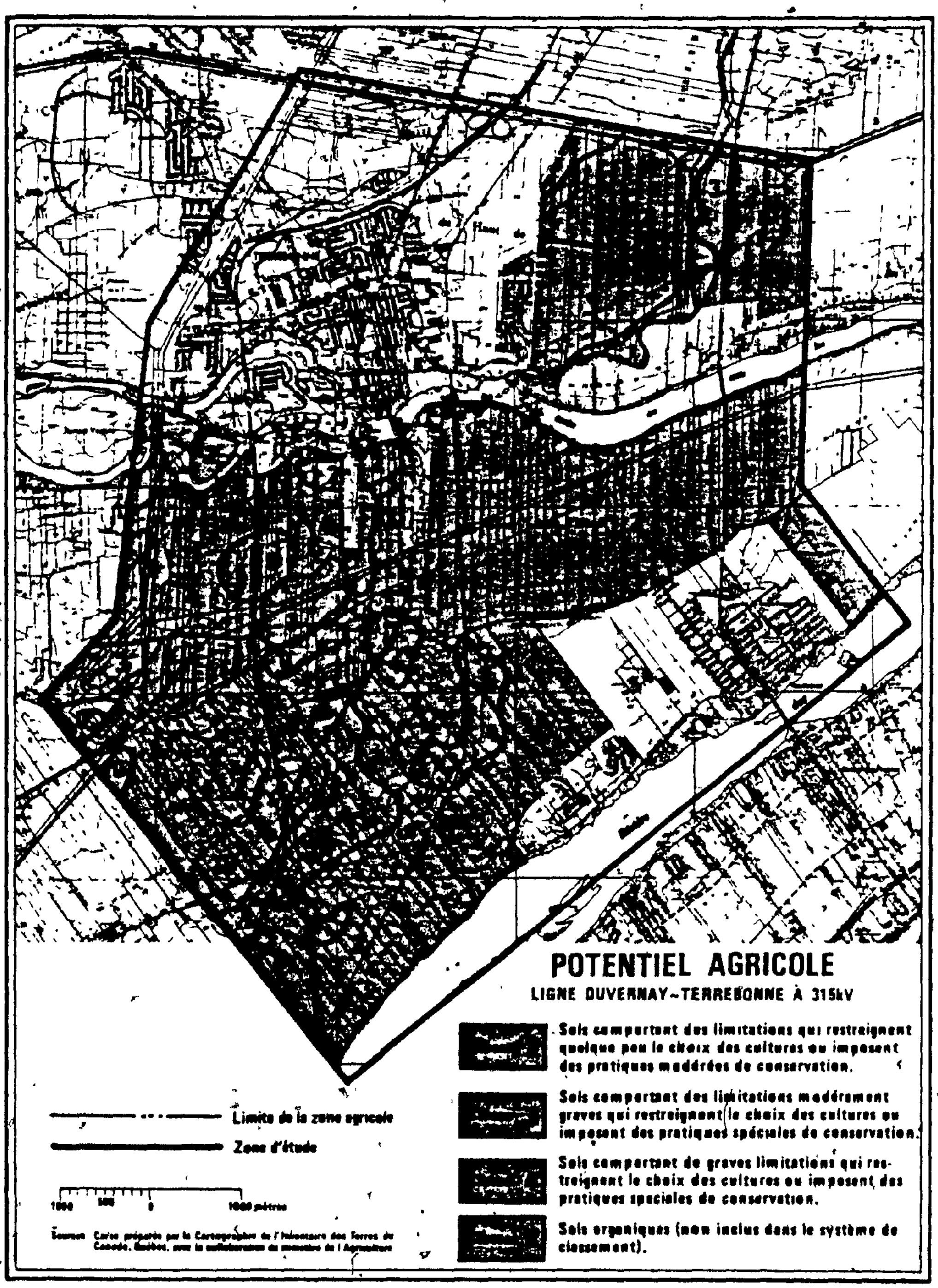


FIGURE 2.4.2: Agriculture potential plan
(courtesy: Transmission lines department, Hydro-Quebec)

technical and economical criterias are taken into consideration. The levels of opposition are identified as very strong opposition (Residential areas, parks, schools, T.V. antennas,...), strong (Agricultural areas), medium (future agriculture of residential areas and present industrial areas), and weak (future industrial, unexploited soil,..).

- The corridor options: based on the levels of resistance identified for each area of the study zone, options to where the new line corridor should be are identified in this part. This part involves joint work between the Environment department and the Transmission line department. Technical and economic criteria are considered besides environmental criteria. In all new transmission lines more than one corridor option is explored; even if it is very obvious to the project group which corridor is the best, this may not be clear to the ministry of the environment or for the residents and farmers of the area. Fig. 2.4.3 shows the four corridor options identified for the same zone shown in Fig. 2.4.1.

The choice of the preferred line corridor then follows, and is based on the environmental studies. The word "preferred" is used here because the final choice of the line corridor cannot be made before the communication program is carried-out, and this choice has to be confirmed by the government during the approval of the project process.

After the corridor options are identified by the environment group, detailed analysis is performed for each corridor option by both the environment department and the transmission line department. The analysis identifies for each option the environmental impact, the technical aspect, and the economical aspects. The transmission line analysis takes into account factors like the total distance of each option, the type of tower

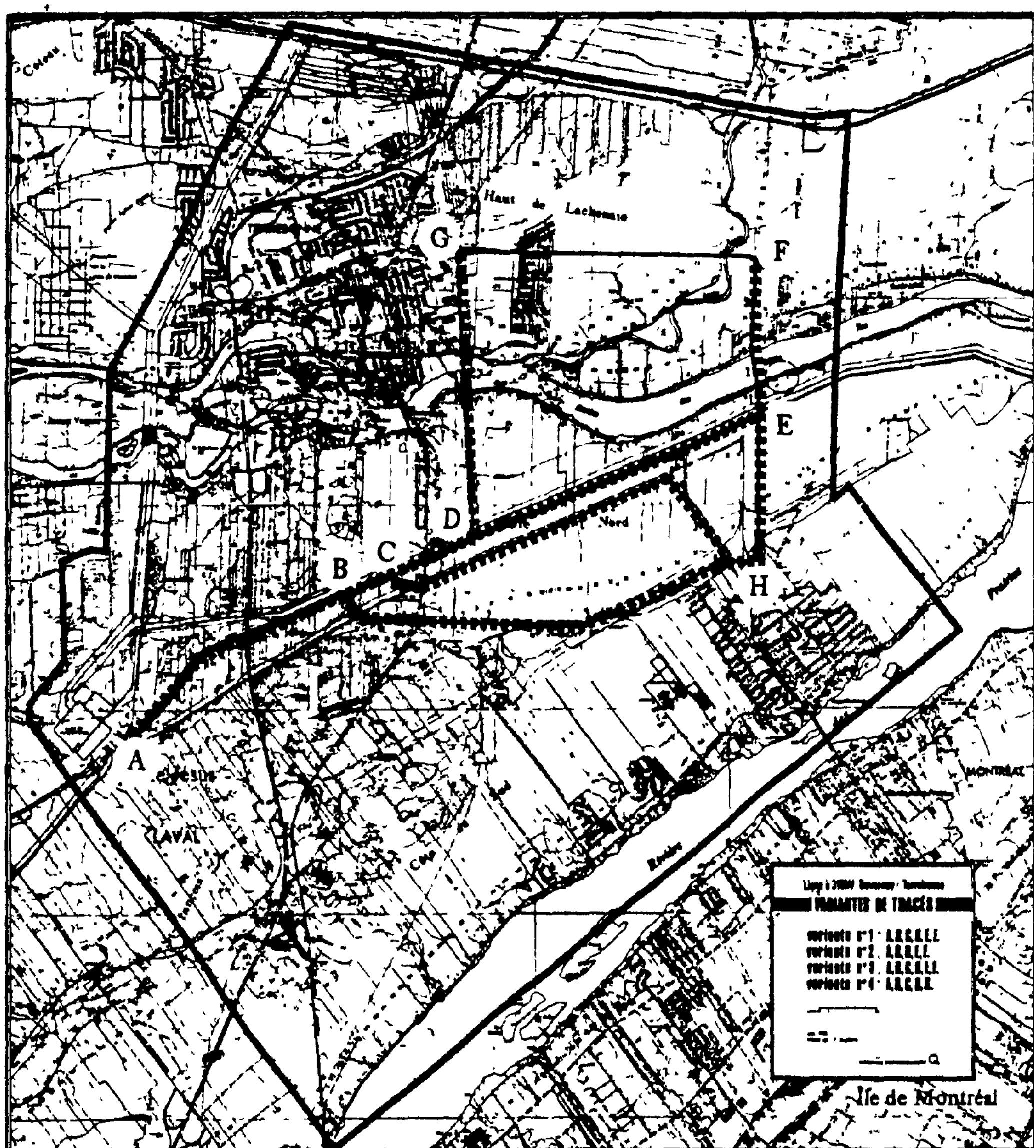


FIGURE 2.4.3: Corridor options plan
(courtesy: Transmission lines department, Hydro-Quebec)

to be used, and the expropriation cost for each option. Once the analysis is completed, the results are combined, and based on the final result, one corridor option is chosen. The chosen corridor is identified on a maps scaled 1:5000 to prepare for the next activity, which is the consultation of the public and in which all options are presented and Hydro-Quebec choice explained.

2.5 Consultation and Communication with the Public

The communication activity is under the responsibility of the "Public Affairs" Vice-Presidency. However, a representative of the environment department as well as the project engineer takes part in what is called "The Communication Group". The Communication activity is carried out as described below.

- <u>Preparation of the Communication documents</u>: Besides the map which shows the corridor options, a document is prepared by the communication group. This document is prepared for the use of the group members and it contains all the information relevant to the project and which may be of interest to the concerned public. This document contains information regarding the reason for constructing the new line, the reason for choosing this specific corridor, the environmental impact of the new line and the construction schedule. Also a pamphlet which contains a summary of the project may be prepared for distribution to the concerned public.
- <u>Information of the public concerned</u>: In this activity, the communication group first publish in the local media advertisements to inform the public of the planned project. Then, they organize meetings in which the affected property owners are specifically invited to attend. They also organize meetings with the local and

regional organizations like the municipal government, the farmers unions or the local environmental associations. In these meetings besides informing the public, the communication group also answer their queries.

- Collecting the public reaction to the project: The collection of the public reaction is made during the information meetings and from the letters and memorandum formulated in writing to Hydro-Quebec by the public and organizations concerned. A summary of the collected information is then prepared by the "Communication group". This summary is to be included in the "Rapport Hydro-Quebec". An example of such a summary is presented in Tables 2.5.1 and 2.5.2.

- Integration of the possible corrective measures: Depending on the results of the communication program, some corrective measures may be implemented by Hydro-Quebec to make the project more accepted by the local public. An example of a transmission line impact and the possible corrective measures that can be taken is the visual impact on nearby residence; the corrective measures may be the planting of a tree screen between the affected residences and the visible transmission tower or towers. Another concern by the public may be regarding the disturbance which is created in the area during the construction phase, to reduce the effect of this disturbance to the residences of the area of the traffic of the construction equipment could be restricted to a limited number of streets and the construction work could be limited to 10 hours per day Monday to Friday only. Other measures may be considered depending on the type of project, the type of crossed area, and the reaction of the public to the project.

Résultats de la consultation

PUBLICS	RENCONTRE	AVIS — DATE	AVIS — COMMENTAIRES
LOCAUX			
Ville de Laval	82/10/28	82/11/17	"Nous sommes d'avis que le projet n'aura pas de répercussions significatives en autant que les propo-propositions de Ville de Laval contenues à la section 2.2.3 du présent rapport et que les mesures proposées par Hydro-Québec (avec les modifications proposées par Ville de Laval) soient intégralement appliquées."
		82/12/15	Réponse d'Hydro-Québec aux propositions de Ville de Laval.
		82/12/22	Lettre du service du Génie de la ville de Laval demandant des renseignements supplémentaires sur le drainage.
		83/01/20	Réponse d'Hydro-Québec à la lettre ci-dessus.
Résidents de la rue Geoffrion	82/05/18		Rencontre préliminaire.
	82/11/03	82/11/16	Les résidents ne s'objectent pas au projet et recommandent des mesures additionnelles de protection concernant les impacts sonores d'utilisation du sol, de drainage, de construction.
		82/12/15	Réponse d'Hydro-Québec aux résidents de la rue Geoffrion.
Comité de la protection de l'environnement de Saint-François-de-Laval		82/11/18	Le comité a fait parvenir un mémoire présentant des commentaires critiques et des suggestions pour minimiser les désagréments susceptibles d'être causés aux citoyens.
	82/11/03	82/12/15	Réponse d'Hydro-Québec aux propositions du comité.

TABLE 2.5.1: Communication results (A)
(courtesy: Transmission line department, Hydro-Quebec)

Résultats de la consultation (suite)

PUBLICS	RENCONTRE	AVIS: DATE	AVIS: COMMENTAIRES
RÉGIONAUX			
Fédération de l'U.P.A. des Laurentides		82/11/22	"Il est évident que l'agrandissement du poste actuel n'aura aucun impact dommageable à l'agriculture."
PROVINCIAUX			
Ministère de l'Environnement		82/01/18	"Nous considérons qu'une seule variante pour l'emplacement du poste ci-haut mentionné serait acceptable". Recommandations: Consulter les résidents de la rue Geoffrion sur l'aménagement paysager.
Commission de la protection du territoire agricole		82/05/25	"Autorise la demanderesse à utiliser à des fins autres qu'agricoles les lots précités pour les fins spécifiques de l'agrandissement du poste de transformation d'énergie de Saint-François."
Ministère de l'Agriculture, des Pêcheries et de l'Alimentation		82/10/19	"La Direction de la protection du territoire agricole ne s'objecte pas au projet."

FIGURE 2.5.2: Communication results (B)

(courtesy: Transmission lines department, Hydro-Quebec)

- Informing the concerned public of Hydro-Quebec choice: In this activity all persons and organizations involved in the communication process are informed of Hydro-Quebec's choice of corridor option and of the planned corrective measures. Hydro-Quebec choice is still not considered final at this stage as it is still subject to the Quebec government approval. This is discussed in Chapter 3.

The details of the communication program and the results of the consultation with the affected public program are included in a report prepared by the public affairs vice-presidency. This communication report is forwarded to the members of the communication group and to the Planning department who integrates it in the "Rapport Hydro-Quebec".

2.6 Preliminary Design of the Transmission Line

Preliminary design of the transmission line usually starts with the environmental studies in order to answer queries of the environment team regarding the possibility of using a special type of transmission tower or to the possibility of modifying tower locations. The purpose of the preliminary design is to prepare an estimate of the total cost of the project including procurement of material and construction.

The following design parameters and information are chosen or collected before preliminary design starts:

- Large scaled maps of the area.
- Loading conditions of the area, including wind force and maximum ice thickness. This information is obtained from the studies and standards division.
- Types of conductors and ground cables to be used. This information is provided by the planning department and depends on the tension (Volts) and the capacity (Watts) of the line to be constructed.

- Type of transmission tower. This choice is a function of environmental requirements, width of available corridor and loading conditions.

Once the information is collected the technician, under the direct supervision of the project engineer first prepares the general layout of the line as to the position of each transmission tower, the position of the line angles and the length of each span. After the plans are prepared the design of the transmission line profile is carried on. For this step, minimum clearance from the ground has to be respected using the maximum temperature to which the line will be exposed. If the line is crossing a river, a railroad, another electric line or a telecommunication line there are specific minimum clearances which have to be respected. Also if the line is in the neighbourhood of an airport, special lighting will have to be provided for each transmission tower. After setting the minimum clearance for each span, templates in "plexiglass" are prepared at the profile scale to show the conductor curves, which take into account the cable tension and sag. Using these templates, the line profile can be drawn. Finally a preliminary list of material is prepared and the drawings and material lists are forwarded to the estimating division so they can prepare an estimate of the construction cost of the line.

Some special requirements may have to be taken into account during the preliminary design. For instance, feed-back obtained from the communication process with the public may have an affect on the position of some towers.

2.7 Schedule and Budget of the Engineering and Construction Phases

The schedule and budget of the engineering and construction phases can be prepared at this stage as all the necessary activities for the next phases are identified based on the result of the property investigation, the environmental studies, the communication with the public and the preliminary design of the transmission line. Although the statistically derived schedule prepared at the beginning of the feasibility phase and presented in Figure 2.2.1 contains engineering and construction durations, this schedule is not considered final and it is only used as a guide until the preparation of the detailed engineering and construction schedule.

There are two types of activities in the next phases of the project:

- Engineering related activities, performed by the same group responsible for the project, at the transmission line engineering department, since its initiation; and,
- Construction related activities, performed by the construction group, at the transmission line construction department.

Accordingly, the engineering and construction schedules and budgets are prepared jointly between the two departments.

The preparation of the schedule and budget of the engineering phase is a task performed by the assigned planner and estimator of the project. The project engineer, first informs the planner as to which activities are to be performed in the engineering phase and of the target dates. The planner then meets the person responsible for each activity and works out with him his part of the schedule. Usually, in normal projects, this task is completed smoothly within just a couple of days. However, if the planner encounters difficulties setting up the engineering schedule, the matter is referred to the project engineer who will, in turn, work out a compromise with the persons responsible. After the engineering part of the schedule is completed, a copy of the schedule is forwarded to the transmission line construction department together with a description of the project, which is the result of the preliminary design basically, a request to prepare the construction part of the schedule, and the construction budget. The engineering schedule is also forwarded to the assigned estimator in the transmission lines engineering department to prepare the engineering phase budget. Essentially the engineering phase budget is prepared in the same manner the feasibility phase budget is prepared, i.e. the man-hours of each activity are fed to the computer using the relevant cost codes, and the computer program outputs the dollar figures, administration fees, interest and inflation charges and contingency allowance. In this case the interest and inflation rates built in the program are based on information received from the finance Vice-presidency, but the contingency allowance is provided by the project engineer based on the special conditions of the project. The summary page of the engineering estimate, which becomes the budget when approved is presented in Figure 2.7.1.

The schedule and budget of the construction phase are prepared in parallel by the Transmission line construction department. The construction schedule contains durations for procurement of materials, tree clearing, foundation, erection and commissioning. The scheduling of the construction duration is based on the preliminary design of the project. The construction budget, includes besides administration fees, interest and inflation charges. Two major parts: The first one is the material cost and the second one is the construction cost. Materials are generally purchased by Hydro-Quebec while construction activities are generally contracted and supervised by the enterprise personnel. An example of a completed engineering and construction phase schedule is illustrated in Figure 2.7.2.

DIRECTION PROJETS DE LIGNES DE TRANSPORT — DATE: 83-06-10 11:16 HRES

BUDGET D'IMMOBILISATION - 1984 - (EN MILLIERS DE DOLLARS)

INTITULE	: CARILLON-RIGAUD	PHASE	: AVANT-PROJET	PROJET	
DESCRIPTION	: Ligne et servitude. (Hausse d'exploitation vers Niagara Mohawk Power Corp)	DATE DE L'ESTIMATION	: 83-06-06	M.E.S. APPROUVEE	: 85-10-01
		DATE DU BUDGET DYNA.	: 83-06-10	RECOMMANDE LE	: - -
		DATE DU BUDGET ORIG.	: - -	APPROUVE LE	: - -
NO. DE PROJET	: 4706-00	DATE TAUX D'INFLATION	: 82-12		
		LONGUEUR	: 17,0 KM	DEBUT PREVU	: 83-03-15
ARTICLE BUDGETAIRE	: 086-3002	TENSION	: 120 KV	FIN PREVUE	: 85-10-01
NO. DE R. DE T.	: 00682-24691-	MISE EN SERVICE	: 85-10-01		
STATUT	: Centralise				
STRUCTURE	: Bois-monoterne				

BUDGET ORIGINAL [ ]

SUFFIXE	PREVISION GLOBALE	PREVISIONS 83-12-31	MONTANT REQUIS 1984	***** PREVISIONS ANNEES SUBSEQUENTES ***** 1985	1986	1987	1988	TOTAL AUTRES ANNEES
052 Arpentage legal	143,6	0,0	143,6	0,0	0,0	0,0	0,0	0,0
053 Etudes foncieres&rech.cadastrale	11,6	2,2	9,4	0,0	0,0	0,0	0,0	0,0
931 Etudes preliminaires	69,8	69,8	0,0	0,0	0,0	0,0	0,0	0,0
932 Etudes de projets	19,7	0,0	19,7	0,0	0,0	0,0	0,0	0,0
937 Etude avant-projet	61,0	30,2	30,8	0,0	0,0	0,0	0,0	0,0
938 Cartographie photo	0,5	0,5	0,0	0,0	0,0	0,0	0,0	0,0
943 Ligne d'axe	138,8	0,0	138,8	0,0	0,0	0,0	0,0	0,0
946 Depenses operationnelles	74,8	0,0	74,8	0,0	0,0	0,0	0,0	0,0
947 Plans et profils	136,5	0,0	136,5	0,0	0,0	0,0	0,0	0,0
988 Reserve pour eventualites	165,0	****26,0	****139,0	******,0	******,0	******,0	******,0	******,0
999 Administration (p.l.t)	9,0	3,0	3,0	3,0	0,0	0,0	0,0	0,0
COUT DIRECT	830,3	131,7	695,6	3,0	0,0	0,0	0,0	0,0
998 Administration siege social	15,2	2,4	12,8	0,0	0,0	0,0	0,0	0,0
997 Interet	77,5	6,9	51,6	19,0	0,0	0,0	0,0	0,0
TOTAL DU PROJET	923,0	141,0	760,0	22,0	0,0	0,0	0,0	0,0
996 Regularisations	(22,0)			(22,0)	(0,0)	(0,0)	(0,0)	(0,0)
TOTAL DES AFFECTATIONS	901,0	141,0	760,0					
MONTANT DEJA AUTORISE	0,0							

REPARTITION PAR TRIMESTRE POUR 1984 (1.(190,0)) (2.(190,0)) (3.(190,0)) (4.(190,0))

DIVISION ESTIMATION	DIVISION BUDGET	SERVICE PROJETS DE LIGNES		
Bourassa P.	Ouellette D.	TECHNICIEN	INGENIEUR	CHEF DE DIVISION Sabourin G.

FIGURE 2.7.1: Summary of the Engineering Phase estimate (courtesy: Transmission lines department, Hydro-Quebec)

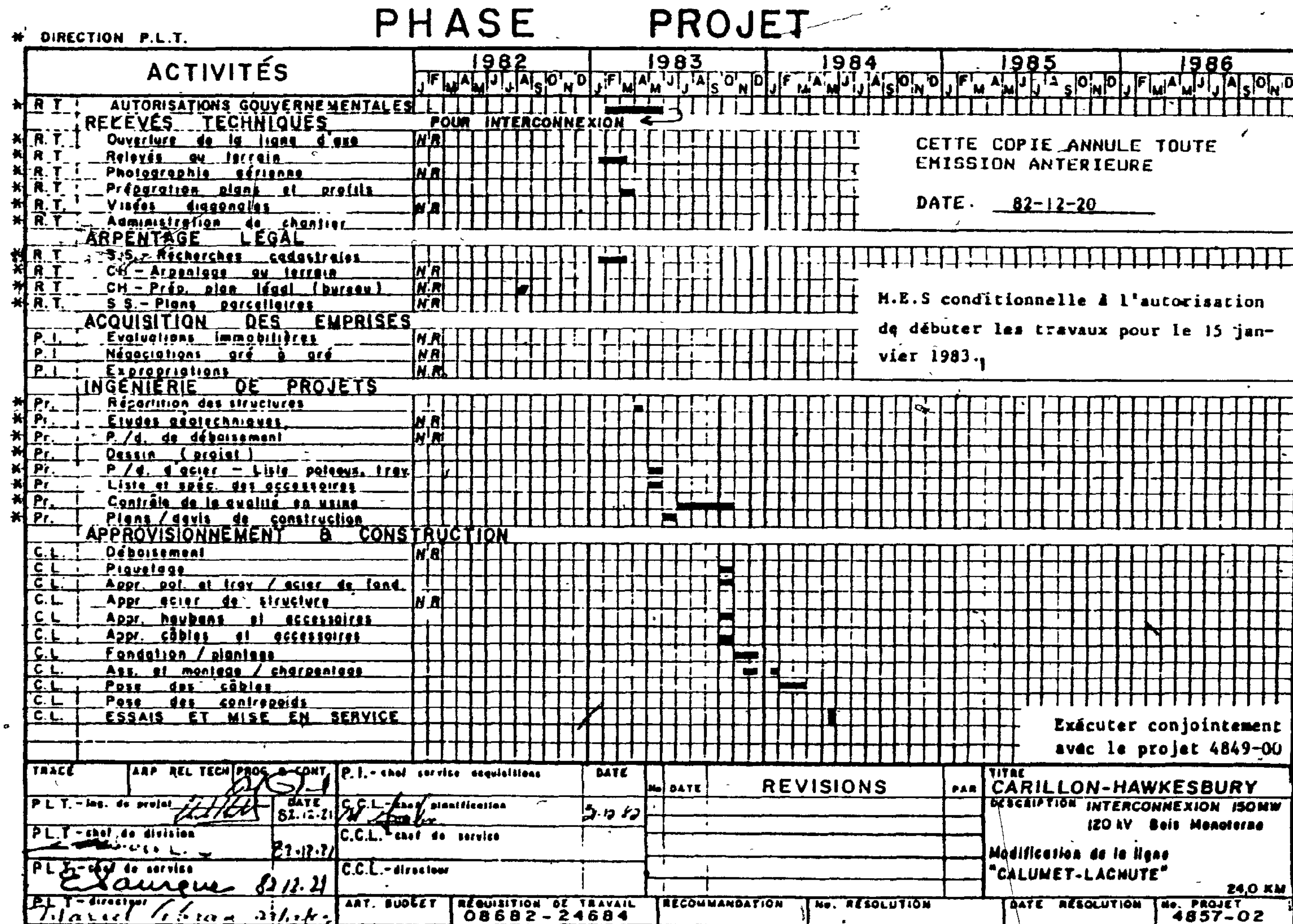


FIGURE 2.7.2: Engineering and construction phase schedule
(courtesy: Transmission lines department, Hydro-Quebec)

The preparation of the schedule and budget of both engineering and construction phases is the feasibility phase final step. A four part summary report is prepared at the end of this phase to contain the following:

- An introduction presenting the reasons the project is being undertaken;
- A description of the work to be performed in the engineering and construction phases, including a summary of the required materials;
- The project expenditure to date, and the budget of the project coming stages (Engineering and Construction), i.e. How much the project is expected to cost from the initiation stage to the commissioning stage. The project expenditure to date is the actual cost of the feasibility phase; and
- The schedule of the engineering and construction phases.

The purpose of the summary report is three fold: first, to be integrated in what is known as "Rapport Hydro-Quebec" which contains besides the tranmission line part, the part prepared by the environmental department, (this part was analyzed in Section 2.4 of this chapter) and a third part prepared by the Public Affairs Vice-presidency regarding the communication program. The "Rapport Hydro-Quebec" is discussed in Chapter 3. The second purpose of the report is to give the Finance Vice-presidency dollar figures of the planned projects. The cost of future projects are included in the enterprise money procurement strategy. Thirdly, the schedule and budget included in the report are used for control purposes. The transmission line engineering and construction departments are committed for their respective parts of schedule and budget and have to justify any budget overrun.

2.8 Feasibility Phase Control Tools and Proposed Improvements

The existing control tools in the transmission lines department do not basically differ from the conventional tools found in many organizations. The three major items controlled in any project are the activities progress, the budget and the technical content. Below is a description of how they are controlled in the transmission lines department.

The schedule presented in Figure 2.2.2 is used as the base for reporting the feasibility phase activities progress. The schedule is a bar chart schedule (Gantt chart) which describes the necessary activities for the feasibility phase and the dates they are planned to start and to end. Although the constraints between activities are respected in the schedule, the critical path is not identified, neither is the activities float, if any. The prepared bar chart schedule is not used itself for progress reporting, but a computer derived sheet entitled "Feasibility phase activities follow-up" is used for that purpose. The sheet identifies the dates each activity is planned to start and to finish, the person responsible for each activity, the revisions in starting and finishing dates and the percentage completed for each activity. The project planner inputs monthly the percentage of progress as given to him by the person responsible for the activity. The computer output is only used for the convenience of not having to type the follow-up sheet each month. A "Feasibility phase activities follow-up" sheet is presented in Table 2.8.1. A copy of the sheet is forwarded to the project engineer and to the other persons responsible for the feasibility phase activities.

The estimate prepared in the beginning of the feasibility phase and exposed in Figure 2.2.3, when approved, is considered the budget of this phase and is used as the base of comparison with actual spendings. The

PROJETS D. LIGNES DE TRANSPORT - Suivi des acti ites de PROJET en date du 82 .2-15

4360-03 DUVERNAY-TERREBONNE
0,1 km. 120 Kv. Acier-biterne
Seq: 23551 Region: Maisonneuve

M E.S.de Planif:83-06
M E S.de PLT:83-11
Statut: Deconcentre

Description: Raccordement au Poste ST-FRANCOIS

	ACTIVITES au 82-02-15	Calendrier Debut	Calendrier Fin	Prerequis satisfaits	Revision Debut	Revision Fin	Progres
AUTORISATIONS GOUV.	Decret pour realisation	-NR-	- -	- -	- -	- -	
	Loi 69, Environnement	-NR-	- -	- -	- -	- -	
	Loi 90, Prot.Terres agr	-NR-	- -	- -	- -	- -	
	Loi 125, Amenagement terr.	-NR-	- -	- -	- -	- -	
RELEVES TECHNIQUES	Ouverture de la ligne d'axe	-NR-	- -	- -	- -	- -	
	Releves au terrain/cntl.geod	82-01-01	82-02-01	- -	82-02-15	82-03-01	0%
	Plans et profils	82-02-01	82-03-01	- -	82-03-01	82-03-15	0%
	Signalisation	-NR-	- -	- -	- -	- -	
	Photographie aerienne	-NR-	- -	- -	- -	- -	
	Traitement des donnees	-NR-	- -	- -	- -	- -	
	Restitution	-NR-	- -	- -	- -	- -	
	Releves complementaires	-NR-	- -	- -	- -	- -	
	Integration de cadastre	-NR-	- -	- -	- -	- -	
	Visees diagonales/piquetage	-NR-	- -	- -	- -	- -	
ARPENTAGE LEGAL	Recherches cadastrales	-NR-	- -	- -	- -	- -	
	Arpentage terres couronne	-NR-	- -	- -	- -	- -	
	terrains prives	-NR-	- -	- -	- -	- -	
	Plan legal: terres couronne	-NR-	- -	- -	- -	- -	
	terrains prives	-NR-	- -	- -	- -	- -	
	Plan parcellaires	-NR-	- -	- -	- -	- -	
PROPRIETES IMMOBIL	Evaluation immobilieres	-NR-	- -	- -	- -	- -	
	Negociation de gre a gre	-NR-	- -	- -	- -	- -	
	Expropriations	-NR-	- -	- -	- -	- -	
INGENIERIE DU PROJET	Repartition des structures	82-02-01	82-04-01	- -	82-03-15	82-04-15	0%
SAGOURIN C	Etudes geotechniques	82-04-01	82-04-15	- -	82-04-15	82-05-01	0%
KOOT E.	Etudes de deboisement	-NR-	- -	- -	- -	- -	
CHAPDELAINE Y.	Plan et devis de deboisement	-NR-	- -	- -	- -	- -	
	Dessins - Materiaux	82-04-01	82-05-01	- -	82-04-15	82-09-15	0%
	P/D d'acier - liste pot. trav.	82-06-01	82-11-01	- -	- -	- -	0%
	Liste et spec. des accessoires	82-06-01	82-11-01	- -	- -	- -	0%
	Controle de qualite en usine	83-01-01	83-09-15	- -	- -	- -	0%
	Dessin - Construction	83-01-01	83-03-01	- -	- -	- -	0%
	Pl et devis de construction	83-02-01	83-04-01	- -	- -	- -	0%

TECHNICIEN DE PLANIFICATION: PAUL H

R=date reelle

TABLE 2.8.1: Feasibility phase activities follow-up
(courtesy: Transmission line department, Hydro-Quebec)

monthly cost report consists of a separate computer output which contains the cost code (which also identifies the activity), the cost incurred during the last month and the cumulative cost per activity and the total. The spendings are given in both man-hours and dollars. The monthly cost report sheet is presented in Table 2.8.2. The costs reported on the sheet are based on the actual hours reported on time sheets and fed weekly to the computer and on bills or invoices, in the case where some services are purchased. A copy of the cost report sheet is forwarded monthly to the project engineer.

The feasibility phase follow-up and cost report sheets are only reporting tools to the project engineer and to those responsible for the activities. Action and activities expediting are activated by the project engineer. For that purpose the project engineer uses as a tool the project summary report, a sample of which is presented in Figure 2.8.1. The project engineer prepares monthly a summary report for each project under his responsibility. For most projects the summary report consists of only one sheet, but a second sheet is used when necessary. The report consists of an identification of the feasibility phase major activities, the date they are planned to be completed, anticipated delays and a part for comments. The comments part is mainly used to identify problems and persons responsible to take action. This report is forwarded to all persons responsible for action, to the chief of the project division, the chief of the transmission lines engineering department and to the transmission lines director.

The progress of activities according to schedule does not necessarily mean that the quality of the engineering or the projects saving are optimized through some sort of value engineering techniques. Although

COMPTE RENDU DE PROJET

no de projet	nom de projet	mas.
chef de division	préparé par	date

DATES DE FIN DE CERTAINES ACTIVITÉS - POINTS DE CONTRÔLE *

AVANT-PROJET	DATE	PROJET	DATE	DEMANDE DE PERMIS	DATE
• Proposition de variantes		• Répartition des structures		• Premier Décret (Projet relevant Convention Baie James / Nord-Ouest)	
• Choix du tracé préférentiel		• Plans parcellaires		• Permis-Protection des Terres Agricoles (C.P.T.A.Q.)	
• Rapport synthèse P.L.T. - Environnement		• Plans & Devis Accessoires		• Permis-Qualité de L'Environnement (S.P.E.)	
• Document d'avant-projet		• Plans & Devis Acier		• Permis - Aménagement & Urbanisme	
• Rapport d'études d'avant-projet		• Plans & Devis Déboisement		• Décret - Expropriation & Construction	
		• Plans & Devis Construction		• Dépot - Tribunal expropriation (prise de possession)	

ACTIVITES EN COURS ☐ Avant-Projet ☐ Projet ☐ Demande de permis — Retards anticipés (mois)

COMMENTAIRES — **ACTION PAR**

* T: Activité Terminé — R: Permis Reçu

FIGURE 2.8.1: Project Summary report
(courtesy: Tansmission line department,
Hydro-Quebec)

83/02/24

PROJETS DE LIGNES DE TRANSPORT

DETAIL DES DEPENSES
TRI ALPHABETIQUE
(PLN027A2)

SLEE	SOURCE	QTE. REEL ANT.	MNT. REEL ANT.	QTE. REEL COUR.	MNT. REEL COUR	QTE-TOTALE	MNT-TOTAL
24091	CHOMEDEY-DUVERNAY (VIMONT)		2838-00	*** RESPONSABLES:	PAUL M. /OUILLETTE D.		
932	11	68	$1,454	0	$0	68	$1,454
	44	0	$23	0	$0	0	$23
	79	0	$1,773	0	$0	0	$1,773
SOUS-TOTAL >>			$3,250		$0		$3,250
937	11	1,023	$16,565	0	$0	1,023	$16,565
	21	0	$150	0	$0	0	$150
	41	0	$86	0	$0	0	$86
	43	1	$615	0	$0	1	$615
	44	0	$136	0	$0	0	$136
	75	0	$15,181	0	$0	0	$15,181
SOUS-TOTAL >>			$37,137		$0		$37,137
957	50	0	$16,259	0	$626	0	$16,525
SOUS-TOTAL >>			$16,259		$626		$16,525
958	50	0	$835	0	$0	0	$839
SOUS-TOTAL >>			$839		$0		$839
959	11	25	$484	0	$0	25	$484
	44	0	$6	0	$0	0	$6
	79	0	$983	0	$0	0	$983
SOUS-TOTAL >>			$1,473		$0		$1,473
TOTAL DE REQ. >>			$58,558		$626		$55,624

83-01-

TABLE 2.8.2: Monthly cost report
(courtesy: Transmission line department,
Hydro-Quebec)

application of value engineering techniques to control both design and construction operations is growing. Barrie and Paulson [5] note that value engineering has in general not been consistently adopted in any organized form by major design construction organizations.

The quality of the engineering in the transmission line department is controlled by the project engineer. He may request more details or more information on a certain activity or he may request a different way of presenting the information. The quality of the engineering is also controlled by the Chief of the Projects division, especially regarding the preliminary design itself, which is performed in his division. As for optimizing the project saving, this is, generally speaking, a trade-off between environmental requirements and cost, i.e. to respect the environment recommendations using the less costly alternative. The project life cycle have to be taken also into consideration; some lines are constructed for use of only five to ten years for electricity export purposes or as a temporary solution, in these cases lines of lower quality and which requires frequent maintenance are used.

The existing feasibility phase control tools can be improved using relatively uncomplicated methods. As a general rule, most transmission lines projects do not need sophisticated and detailed tables and curves for control purposes, otherwise the control could end up costing more than the study itself. The reason this type of projects do not need a large control system is that; first, the same project engineer is responsible for multiproject control, between four and six active projects simultaneously; Secondly, the amount of money involved in the feasibility phase of each project is relatively low, usually below half a million dollars; and thirdly because the length of the feasibility phase is relatively short, anywhere from four months to one year.

The existing feasibility phase control tools lack two major items. First they lack the integration of cost, schedule and performance. Thus falling short of giving the project engineer and top management the total overview of the project and the reconciliation of the work performed to date for the cost incurred. Second they do not provide any kind of early warning for cost overruns.

An improvement can be made in the manner the project status is reported by presenting an integration of cost, schedule and progress reporting. Such integration will enable management to assess project progress quickly and determine which project requires special attention. It also gives the relation between the cost incurred for the work accomplished and the budget, thus giving an evaluation of the true percent completion. This integration also gives some sort of early warning of budget overruns or schedule delays. The benefits of such an integrated system has been investigated by Howell [7].

An example of how cost, schedule and progress may be integrated in the project status report is illustrated in Figure 2.8.2. In this illustration the report is divided into four parts: The project identification, the cost curves, the schedule and a summary of progress and difficulties. The schedule dates have to coincide with the cost curves to relate progress to date with budget and spendings. This type of reporting also obliges project engineers to assume more responsibility of the final result of their project and set higher but realistic goals.

A critical path bar chart schedule can easily be used in the project status report. The limited number of activities makes it a simple task to indicate the critical path on the schedule, thus giving an additional information on the same sheet. It can be useful to know if the delayed activity is on the study critical path or not.

PROJECT ENGINEER	PROJECT STATUS REPORT	YEAR-MONTH

PROJECT IDENTIFICATION
PROJECT NUMBER:
LINE TITLE:
TENSION:
LINE LENGTH:
SUPPORT:
BRIEF DESCRIPTION:

YEAR	1983									
MONTH	J	F	M	A	M	J	J	A	S	O
BUDGET & SPENDING x1000$ 70								$70 000		
60										
50										
40										
30										
20										
10										
0										

RESPONSIBLE	ACTIVITY	J	F	M	A	M	J	J	A	S	O
	Feas. Schedule and budget										
	Photos										
	Mapping										
	Environmental Studies										
	Selection of corridor										
	Communication										
	Preliminary design										
	Integ. Mitigation measures										
	Eng. Schedule and budget										
	Summary Report										

PROGRESS AND DIFFICULTIES:	ACTION BY

FIGURE 2.8.2: Project status report

CHAPTER 3

ENGINEERING PHASE OF THE PROJECT

3.1 Approval and Authorization of the Project

Once the feasibility study is completed, some steps are taken before proceeding to the next phases of the project. These steps are directed at obtaining both internal approval of the project from Hydro-Quebec board of directors and the necessary governments authorizations. The board of directors approval is a pre-requisite for starting the engineering activities of the project and the governments authorization is a pre-requisite for the construction of the line to begin as indicated in Figure 1.6.1 of Chapter 1.

Figure 3.1.1 illustrates the steps required to obtain both the internal and the governments authorizations. After the end of the feasibility phase, the transmission line report, the environment report and the communication report are forwarded to the planning department. The planning department, in turn, integrates the reports and prepares a recommendation to approve the project. The project is recommended in most cases. If for example, the feasibility study demonstrates, however, that because of environmental constraints the planned transmission line route is very costly to construct; or if there is strong rejection from the public affected based on valid reasons; or because the line route poses technical problems that substantially raises the cost of the project, the planning department may decide to study other alternatives. The "Rapport Hydro-Quebec" and the recommendation of the project are forwarded to the board of directors which approves the project by adopting a resolution to that effect. The resolution is forwarded to the secretary general of Hydro-Quebec who requests the necessary government permits.

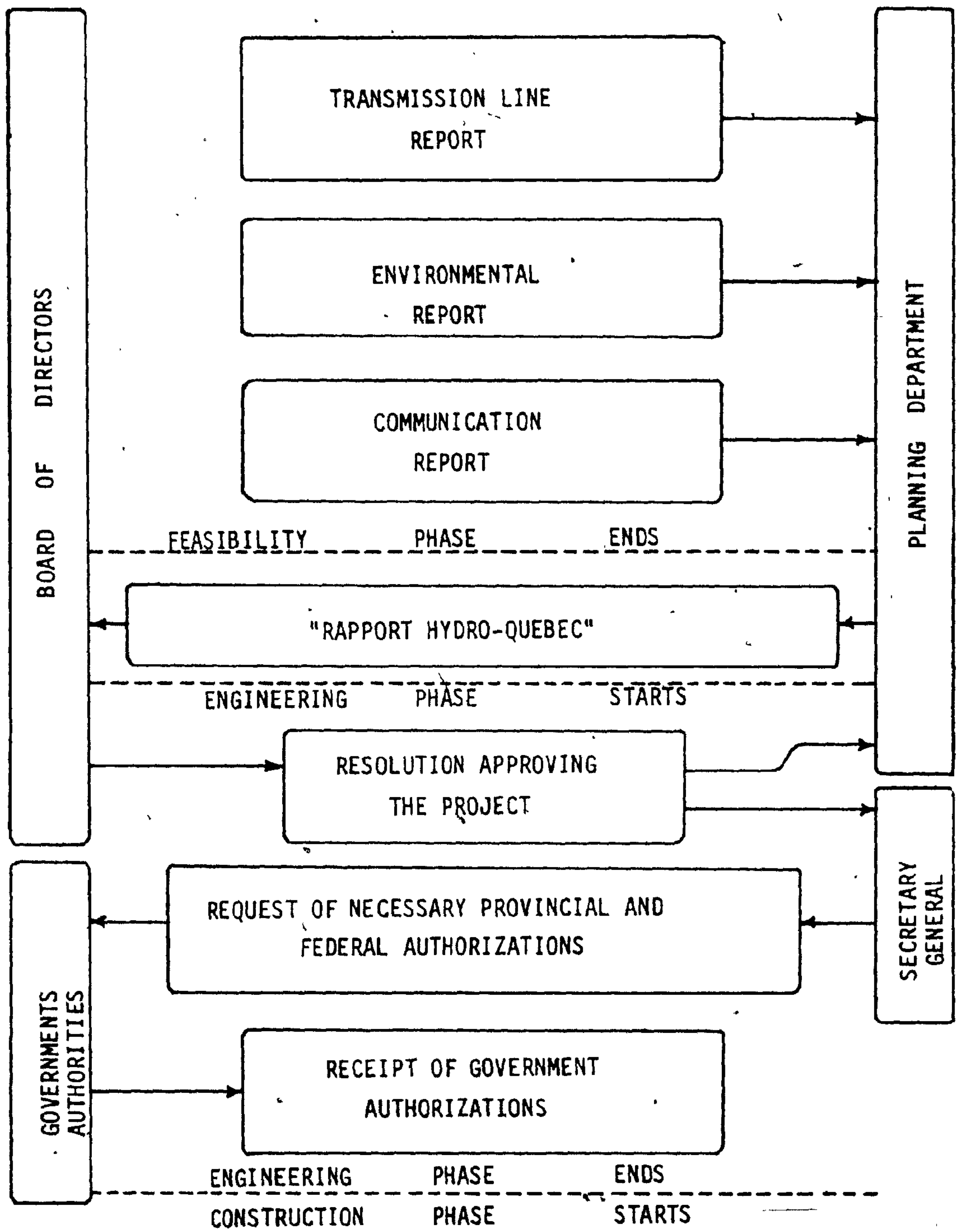


FIGURE 3.1.1: Approval of the project process

Meanwhile, the engineering of the project starts. The necessary government authorizations are defined jointly by the environment and the transmission lines departments. Some governments authorizations may take up to one full year to be granted. Meanwhile, the engineering of the project proceeds but no contracts can be awarded before the governments authorizations are obtained.

There are two types of government authorizations to be obtained, authorizations from the Federal government, and those from the Provincial government. The permits required from the Federal government deal mainly with the project technical aspects, while the permits required from the Provincial government deal with environmental, legal and expropriation aspects and also with aspects concerning the protection of the agricultural land. Table 3.1.1 lists the major permits that are required by the Federal government and when they apply. These permits are basically to ensure to the Federal government authorities that clearances between transmission lines and between facilities under Federal jurisdiction are respected.

Table 3.1.2 lists the three major permits that are required by the Government of Quebec and when they apply. The so called Hydro-Quebec Law governs the activities of the enterprise since its foundation, and its purpose is to allow the control of construction and expropriation activities by the government. This law was modified twice, the first time, in June 1978 and the second time in February 1981. The quality of environment's law was sanctioned in December 1972 to give the Quebec government control over environmental aspects of the projects. This law requires the enterprise to undertake studies on the environmental impacts of major projects as stated in Table 3.1.2. The law sanctioned in 1972

LAW	CASE OF APPLICATION	DOCUMENTS TO BE FORWARDED	DOCUMENTS TO BE RECEIVED
National Energy Board Law	1. Construction of International lines 2. Construction of lines parallel to a pipeline	Formal request and drawings. Forwarded to the National Energy Board	Authorization from the National Energy Board
Law on Protection of navigable waters	Construction, modification and restoration of lines crossing navigable waters	Formal request and drawings, Forwarded to the Federal Ministry of Transport	Approval of the Federal Ministry of Transport
National Ports Council Law	Construction and modification of lines crossing national ports	Formal request and drawings. Forwarded to the Federal Ministry of Public works	Approval of the Federal Ministry of Public works
Aeronautical Law	Construction works near an airport	Formal request and drawings. Forwarded to Federal Ministry of Transport	Approval of the Federal Ministry of Transport
Railways Law	Construction and modification of lines crossing to a railway	Formal request. Forwarded to the Canadian Commission of Transport	Permit of Crossing from the Canadian Transport Commission

TABLE 3.1.1: Required authorizations from the federal government

LAW	CASE OF APPLICATION	DOCUMENTS TO BE FORWARDED	DOCUMENTS TO BE RECEIVED
Quality of Environment law	Construction and restoration of lines $\geq$ 120 Kilovolt and $\geq$ 2 Kilometers	Results of feasibility studies including environmental studies and communication program to be forwarded to the Ministry of environment of Quebec	Certificate from the Ministry of Environment of Quebec
Hydro-Quebec Law	1. All expropriations 2. Construction of lines $>$ 120 Kilovolts and $\geq$ 2 Kilometers 3. Construction of lines to export energy	Request with description to the Ministry of Energy of Quebec	1. Permit authorizing the expropriation 2. Permit authorizing the construction
Agriculture territory protection law	All project located in the agricultural zone. Exemption: corridors previously acquired.	Request with description to the agricultural land protection commission.	Authorization of the commission

TABLE 3.1.2: Required authorizations from the provincial government

applies only to a limited territory in the south of the province. However, after the 1976 convention between the Federal Government, the Quebec Government, and the representatives of the local Inuit and Cree groups, a second chapter was added to the law to regulate the rest of Quebec territory. Figure 3.1.2 illustrates the environmental laws governing the province of Quebec. The third major provincial permit concerns the protection of agricultural lands of Quebec. The agricultural zoning law was santioned in November 1978 to regulate any change of status of what is known as the "Green Zone", which covers all the St. Lawrence valley lands in Quebec. There are other provincial laws that govern some of Hydro-Quebec projects, among them: The urban disposition law, the protection of heritage resources law, the protection of parks law and the protection of ecological reserves law.

Because of the differences in the nature and numbers of permits required for the construction of a specific project, there could be certain conflicts between the requirements of the different authorities solicited for these permits. For example, the agriculture land protection commission will favor a line corridor outside of the "Green Zone", but the impact of such a corridor in urban or semi-urban zones may not be accepted by the Ministry of environment of Quebec. For these reasons it is important for the project engineer to be aware of all types of permits required for his project and to consider all the different aspects involved in his project during the planning and design of the facility.

3.2 Site Survey and Legal Survey

The site survey of the line "Right of way" is the first engineering activity that begins after the resolution of the board of directors is issued. At this stage, site survey activities are required to prepare

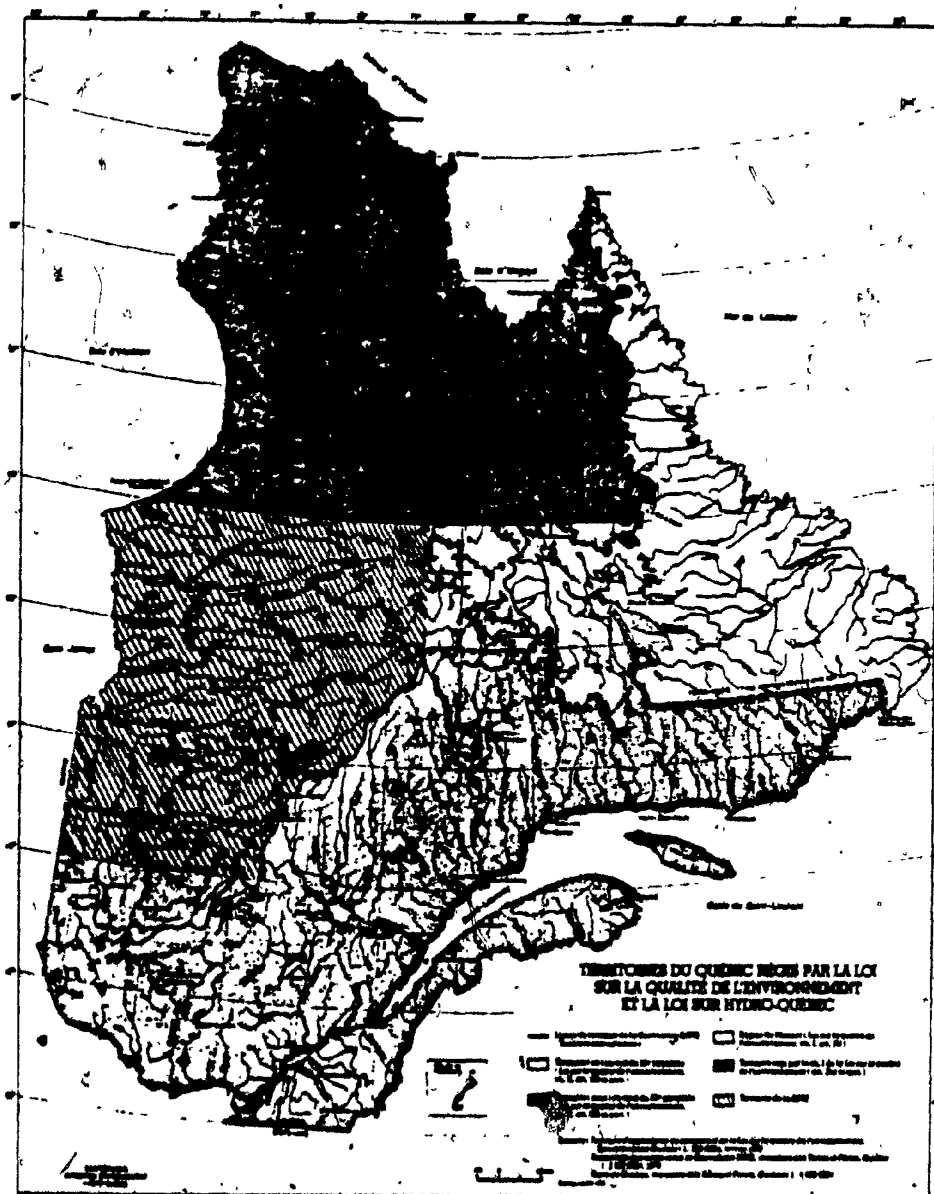


FIGURE 3.1.2: Environmental laws governing the province of Quebec
(courtesy: Transmission lines department, Hydro-Quebec)

new plans and profiles, if never prepared before, or to update existing plans and profiles if they were prepared previously for another line in the same corridor. A distorted scale is used for the profile preparation, the horizontal scale used is 1:2500 and a scale of 1:500 is used vertically. The plans and profiles are essential tools for the engineer to enable him to start the detailed design of the line. The type of land topography can affect the following design items:

- The type of planned tower;
- The location of each tower, and consequently, the line spans;
- The width of right of way; and
- The type of tower foundations.

Figure 3.2.1 illustrates the logic sequences of major engineering and construction activities and shows that site survey is a pre-requisite activity for the line detailed design and that legal survey is a pre-requisite activity for the right of way properties evaluation.

The purpose of the legal survey is to define the lands and properties that must be acquired.for the new transmission line right of way. While the necessary right of way is defined on a preliminary basis during the project feasibility phase, its width is confirmed by the project engineer, to the survey division, before the start of the legal survey activity.

To perform this task,a compilation of different types of maps is made. The topographic map is combined with the cadastral map and the site take-offs of existing building is placed on the combined map. On the combined map the exact location of the future right of way is indicated.

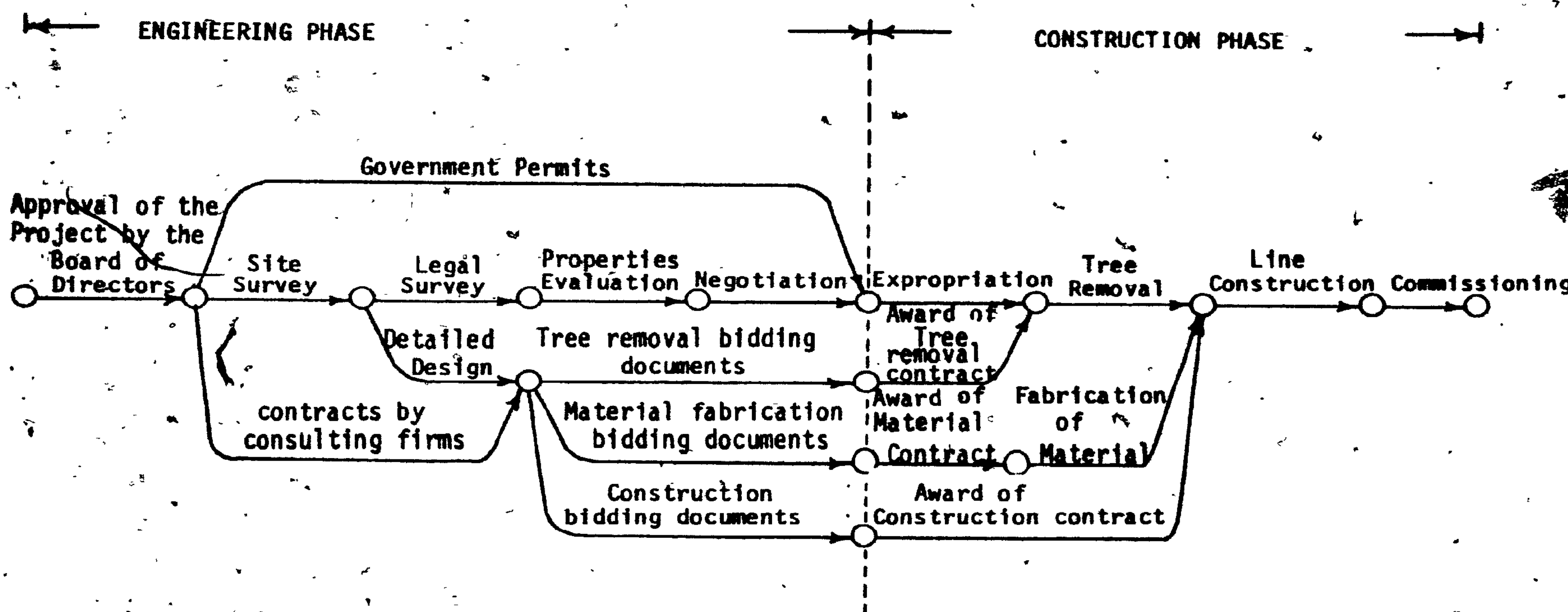


FIGURE 3.2.1: Arrow diagram of engineering and construction activities

3.3 Detailed Design of the Transmission Line

The detailed design of the transmission line is based on the results of the preliminary design, and its purpose is to give the details of the line components by preparing the specifications, drawings, list of materials and by defining the work packages.

Based on the preliminary design and on the corridor plans and profiles prepared at the beginning of the engineering phase, the final and exact position of each tower is determined. In the case where the position or height of a tower is modified from the preliminary design, the conductor profile in the affected spans is corrected accordingly using the same steps described in Chapter 2. The width of the right of way is verified to ensure that there is no change from what was identified in the preliminary design, and the type of tower is also verified.

There are three types of packages to be developed during this phase:

- Specifications, list of material and plans for the fabrication of the line materials: This package includes the line towers, the conductors, the ground wire, the insulators and the hardware. This is the first package developed. The bidding and award of this package is completed before the others so as the material can be fabricated on time, before the construction is scheduled to start;
- Specification and plans for the corridor tree clearing: This package is developed only for lines planned in wooded areas. A study is generally requested from a specialized forestry consulting firm on a contract basis to prepare a forestry inventory of the area, to specify the method of tree clearing, the surfaces to clear, the access road for the clearing activities, to identify whether or not the cleared wood can be reclaimed, and to specify the methods of

reclaiming it if applicable. The study takes into account environmental aspects, for example selective cutting is specified when possible and only the woody vegetation that would affect the construction and safety of the line is removed; and

- Specification, plans and profiles for the construction of the line: To develop this package, and in the case some towers are to be located in places where poor soil is foreseable, a geotechnical investigation is requested from a specialized geotechnical consulting firm on a contract basis. The geotechnical study is required to identify the type or types of existing soils and suggesting the appropriate foundation types. For transmission towers there is generally three types of foundations used: The Grillage-type on earth or rock, the augered foundation and the foundation piles. The choice of foundation type, depends on the nature of soil. The connection of the towers legs to the foundation depends on whether the tower is guyed or rigid, the former one is hinged to the foundation, while the latter one is bolted to the foundation. In addition to the type of foundation, the methods of construction of the transmission line are identified in this package. Methods treated include assembly of tower steel, erection of towers, stringing of conductors, installation of counterpoise and right of way restoration.

The work awarded to an external consulting firm on a contract basis is discussed in Section 3.4, and the preparation procedures of the bidding documents are discussed in Section 3.5 of this chapter.

3.4 Consulting Firms Contracts and their Control

During the engineering of the project process, some activities are given to exterior consulting firms on a contract basis. The activities generally performed outside of the enterprise are those activities of a very specialized nature and for which there is no justification of maintaining full time personnel within the enterprise to perform them. The studies mainly given to consulting firms by the transmission lines engineering department are the geotechnical studies and the tree clearing studies for specific projects.

Figure 3.4.1 illustrates the cycle that an externally awarded engineering contract undertakes. The cycle contains three main stages: The recommendation stage, The award of the contract stage and the control of the contract stage. The first step in the recommendation stage is the choice of the firm. The choice of the consulting firm is made from a list of pre-qualified firms maintained in the transmission lines engineering department. The choice is based on the fair distribution of work among exterior firms, the technical capability of the firm for the specific requirements of the contract and the availability of the firm personnel at the time the work is requested. The project engineer then prepares a recommendation in which he identifies the chosen firm, the reasons for the choice, the description of the work and the total amount the contract is expected to cost. The next step is to forward a letter of intention to the consulting firm stating that, subject to the Vice-President approval, they will be awarded the contract to perform the specific work. In this letter the consultant is requested to submit a cost estimate of the work requested. After the firm estimate is received, a budget validation is prepared to ensure that an amount of money is planned for the study in the initial budget.

The second stage of the cycle, the award of the contract stage, contains the approval of the recommendation by the Vice-President followed by the signature of the contract and the authorization to start the work.

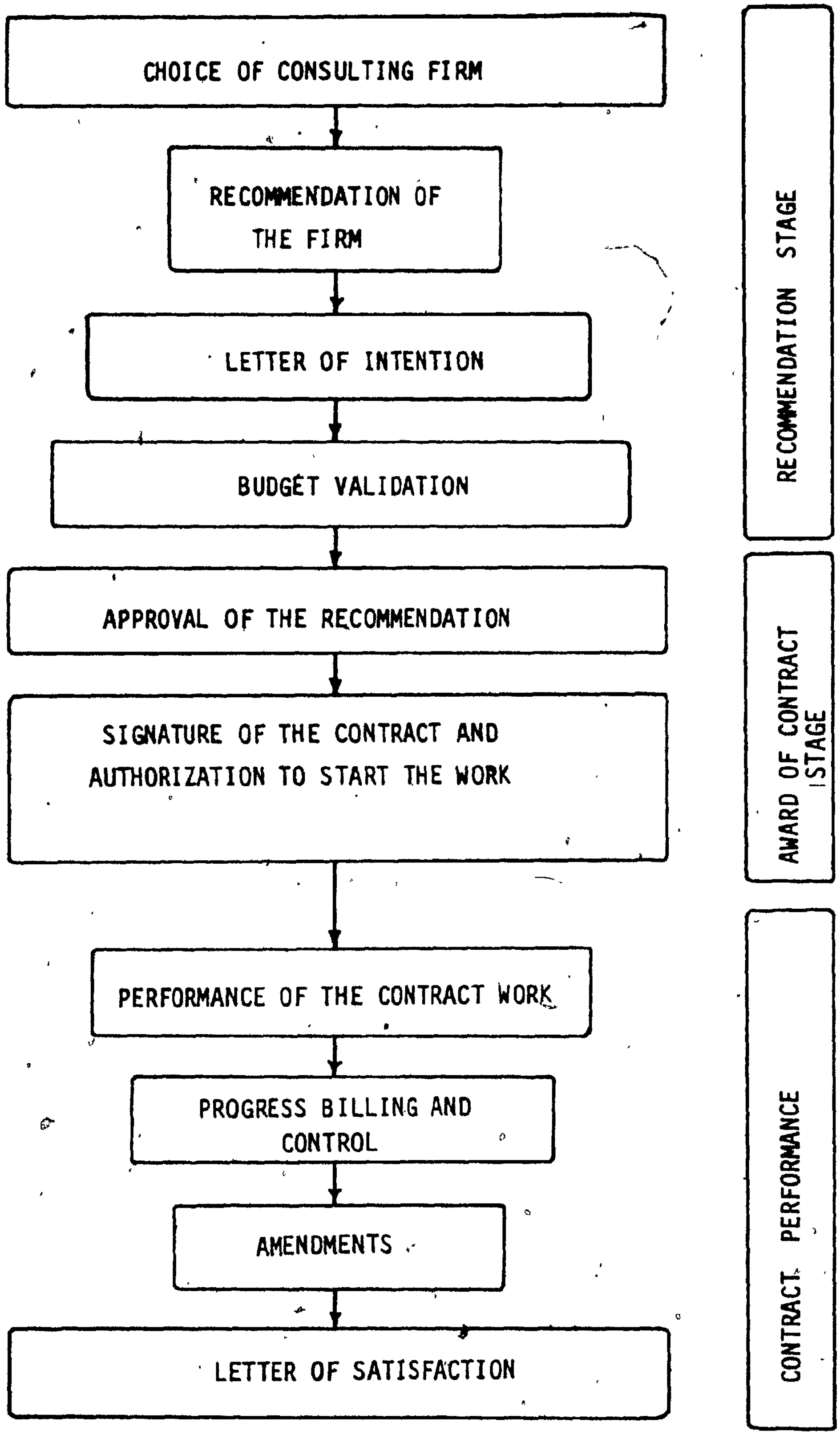


FIGURE 3.4.1: The cycle of externally awarded engineering contracts

The third, and final, stage of the cycle is the performance of the contract work, from one side, by the consulting firm and the control and progress billing payments by Hydro-Quebec from the other side. This stage ends by preparing contract amendment, if necessary, preparing the consulting final report and the issuance of a letter of satisfaction by the projects division.

The contracts awarded to consulting firms contain three parts: The first part, the general conditions, is a common part for all consulting firms contract. This part identifies the requirements of the owner regarding the contract control, billings and payments, safety measures, insurance, termination of contract and changes in the scope of work. The second part, the special conditions, states the description of services required, the type of final report required, the duration of the contract, the maximum cost allowed and the hourly rate payable to the consulting firm personnel. The third and final part of the contract, the supplemental provisions, identifies the modalities of payments as to the travel time, refundable expenses, overtime premium and cost of materials and equipment used during the course of the work.

Engineering contracts awarded to consulting firms during the engineering phase generally never exceed half a million dollars in fees, and 6 months in duration. During the performance of the contract, the transmission line department maintains certain controls on the consulting firm work to ensure that the content of the study is carried-out in accordance with the scope of work and that the monthly billing corresponds with the work progress. To apply this type of control the executing firm is required to, first, submit the following within one month of the start of work:

- The detailed schedule of activities;
- The organizational chart of the group assigned for the job; and
- The curriculum vitae of each person assigned to the project.

Secondly, the executing firm is required to submit at the end of each month a report containing the following:

- A two to three page description of the work performed during the expired month and the work planned to be performed the following month;
- A two part cost report summary indicating the actual and the forecasted status of the project. The information provided in these cost reports are: The initial budget, the cumulative cost to date, the estimated cost to completion, and the total cost to completion. Also, as additional information, the cost report provides two columns, the first for the percentage of spending to date and the second for an evaluation of the work percentage completed to date. The first part of the cost report is in terms of man-hours and the second part in terms of dollars. Tables 3.4.1 and 3.4.2 illustrate the two parts of the cost report summary.
- Monthly billing of man-hours and expenses with justification pieces. i.e.: Copies of time sheets and bills.

The weakness of the cost report summary lies in the difficulty for the owner to verify the estimated cost to complete and the work percentage completed to date. The executing firm may tend to calculate the cost to completion by deducting the cost to date from the initial budget, thus having a total cost to completion equal to the budget instead of evaluating the estimated cost to completion. Also, it may tend to indicate the percentage of the work completed to date similar to the percentage of

1° PARTIE

CO-CONTRACTANT: ____________

PROJET: ____________

NATURE DES TRAVAUX: ____________

NUMÉRO DE LA COMMANDE: ____________

AVANCEMENT DES TRAVAUX - RAPPORT PROGRESSIF
POUR LA PÉRIODE DU: ________ AU ________

DESCRIPTION DES ACTIVITÉS	PRÉVISIONS INITIALES TOTALES EN HOMMES/JOURS	HOMMES/JOURS DÉPENSÉS CUMULATIVEMENT	PRÉVISIONS DES HOMMES/JOURS POUR COMPLÉTER LES TRAVAUX	TOTAL

NOTE: UNE JUSTIFICATION EST EXIGÉE POUR TOUT ÉCART ____________

TABLE 3.4.1: Cost summary report (Part I)
(courtesy: Transmission lines department, Hydro-Quebec)

2ᵉ PARTIE

AVANCEMENT DES TRAVAUX - RAPPORT PROGRESSIF
POUR LA PÉRIODE DU: ________ AU ________

CO-CONTRACTANT: ________
PROJET: ________
NATURE DES TRAVAUX: ________
NUMÉRO DE LA COMMANDE: ________

DESCRIPTION DES ACTIVITÉS	BUDGET INITIAL TOTAL ($) PAR ACTIVITÉ	DÉPENSES À CE JOUR ($)	COÛTS PRÉVUS POUR COMPLÉTER LES TRAVAUX	TOTAL	% DÉPENSES À JOUR SUR BUDGET INITIAL TOTAL	% D'EXÉCUTION DE L'ACTIVITÉ

NOTE: UNE JUSTIFICATION EST EXIGÉE POUR TOUT ÉCART ________

TABLE 3.4.2: Cost summary report (Part II)
(courtesy: Transmission lines department,
Hydro-Quebec)

spending to date. When such practice is used, the cost reports show the project on budget until the job is somewhere between 75 and 90 percent complete; then the overruns, many of which have existed since the early stages of the project start to show up. To deal with this weakness the owner's project engineer should be aware of the details of the work progress through telephone contacts with the consulting firm, meeting and, if necessary, visits to the consulting firm offices to physically assess the work progress. While other methods of reporting can be used to overcome the weaknesses stated above, as for instance the application of earned value method of reporting, the cost and duration of these types of contracts does not justify such additional expenses for controlling the work progress.

3.5 Bidding Documents and Award of Contracts

Based on the results of the line detailed design and on the output of the consulting firms work, if any, the work packages scopes are identified. The bid package is the contractual document where the work is defined and the obligations of each party are determined. There are three types of contracts to construct the transmission line: The fabrication of material contract, the tree clearing contract and the construction contract. It is Hydro's practice to separate the fabrication and purchasing of material from the construction contract. The owner by doing this, keeps adequate controls on the type of material selected for the job and on the quality of fabrication. Purchased materials are kept at the owner's warehouse on site and turned over progressively to the contractor.

The preparation of the bid package is a joint task between the engineering department and the construction department. The engineering department is responsible for preparing the bid forms part, the specifications part, and the plans and profiles of the line, while the construction department is responsible for preparing the general and special condition part. In some packages a section may be prepared by the environment department if special instructions of environmental nature are to be respected during construction. The reason for this distribution between the engineering and construction departments is that the former is responsible for the technical content of the project, while the latter is responsible for the supervision and the administration of the contracts.

The typical bid package consists of the following items:

- The bid form: The bid form is completed and signed by the bidder and it states that he has examined the plans, specifications and the job-site location. The total amount of compensation to be received for the work performed, the amounts of liquidated damages and performance bond, overhead and profit percentages applicable to extra work and the total number of days required to complete the work;
- General Conditions: The general conditions state conditions applicable to all contracts such as definitions, inspection by owner, health, sub-contracts, workmen's compensation, revision to drawings, specifications and quantities, extra work, payment, provisions for cancellation of contract, cleaning up, default of the contractor, site recruitment of personnel and safety;
- Special Conditions: The special conditions set forth specific conditions applicable to the particular contract to be awarded such as insurance, labour rate escalation, arbitration, layout and measurement, union labour, terms of payment, holdback, tests

on completion, guarantee, publicity and security;

- Specifications and addendums: The specification and addendums provide the technical requirements of the contract based on the final desin of the transmission line;
- Plans and profiles: The plans and profiles complement the specifications; and taken together, they fully define the scope, extent and quality of work; and
- Environmental instructions: The environmental instruction, when applicable, set forth required mitigation or restoration measures such as Right of Way selective cutting, selection of access roads, control of audible noise, protection of heritage resources, good housekeeping, stabilizing or improving the environment disturbance of farm operation, loss of topsoil and fish and wildlife.

The completed bid packages are then forwarded to a special division of the finance and resources Vice-Presidency which is responsible for handling all construction contracts. The contract division verifies the documents from the legal aspect before publishing them for public bidding. Once all proposals are received at the contract division, they are forwarded back to the transmission line department for analysis. The transmission line department first prepares a spread sheet tabulating all quotations, the "Quotation spread sheet" used for that purpose is shown in Table 3.5.1. The quotations are analysed afterward from the following point of view:

- Compliance of the quotation technical content with the specifications;
- The schedule of work and the completion date; and
- A review of alternates requested or proposed by the bidders.

Hydro-Québec

Compilation des soumissions

projet	soumettre à	requérant	nº dossier
description			nº demande d'achat
livraison requise		endroit	

	fournisseur	place d'affaires	endroit de fabrication %	montant soumission (transport inc.) (taxe vente exc.)		montant plus préférentiel	F. à B.	livraison
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
observations								

préparé par	j	m	an	vérifié par	recommandé par	approuvé par

963-1200 (6/71)

TABLE 3.5.1: Quotation spread sheet (courtesy: Transmission line department, Hydro-Quebec)

When the analysis is completed, the acceptable quotations are identified and forwarded back to the contract division, who will award the contract to the lowest bidder among the acceptable quotations identified by the transmission line department. The lower bidder is selected only after a preferential percentage is applied to conform with the enterprise purchase policy, which is a reduction of fifteen percent for bids from Quebec based companies and a reduction of ten percent for bids from Canadian based companies.

The process of preparing bidding documents and analysing the quotations can be performed before the government permits are received but no contracts can be awarded before the permits are received. (Refer to Figure 3.2.1).

3.6 Right of Way Acquisition

The acquisition of a right of way for a specific transmission line permits the limitation of a zone outside of which electric effects of the line are negligable: The right of way acquisition process has to be completed before tree removal starts.

The first step in the right of way acquisition process is the request from the provincial government of a permit authorizing the expropriation of the transmission line right of way (refer to Table 3.1.2). The expropriation permit may not be used if, as in most cases, a negotiated settlement with the owner is reached. The permit is still requested from the government at the start of the engineering phase to prevent possible future long delays in case a negotiated settlement cannot be reached between Hydro-Quebec and the owner.

The second step is the evaluation of the properties to be acquired for the line right of way. The properties evaluation is based on the results of the legal survey and of the properties investigation performed during the feasibility phase. While the evaluation contained in the property investigation is informal and used only to give an order of magnitude of future acquisition cost, the present évaluation is of a final nature and it is the basis of a negotiated settlement offer by Hydro-Quebec. To perform this activity, the survey division examines the owerships, the price at which the property was previously sold, the sale price of neighbouring properties, and the amount of municipal taxes. The surveyor also visit the properties and take pictures when necessary.

The third step consists of negotiations with the various owners to obtain a negotiated settlement based on the properties evaluation obtained. It is Hydro's policy to favor a negotiated settlement over an expropriation or a court settlement.

The final step of the right of way acquisition is the expropriation of properties for which no negotiated settlement could be reached. Expropriation cannot be done before receiving the necessary government permits. The expropriation of the right of way is the first activity of the construction phase and it allows the tree removal to start. This is shown on the arrow diagram of Figure 3.2.1. The property owners can contest the evaluation of their property in court, in this case it is the price decided by the court that is paid to the owner, regardless of whether it is higher or lower than Hydro's evaluation.

3.7 Engineering Phase Control Tools and Proposed Improvements

The engineering phase of the project is an extension of the feasibility phase. In this phase the design of the line is detailed and the three types of work packages are developed. The project engineer, technicians, planner, estimator and other assigned personnel to the project are usually the same as in the feasibility phase. Also, the control tools are basically similar to the tools used in the former phase.

The engineering and construction phase bar chart schedule prepared by the end of the feasibility phase, a sample of which is shown in Figure 2.7.2 is used as the basis for the activities progress reporting, and a sheet similar to the "Feasibility phase activities follow-up sheet" shown in Table 2.8.1 is used for reporting the percentage completed of each activity.

The estimate prepared by the end of the feasibility phase is used as the basis for cost reporting. The cost report itself is similar to the report used during the former phase and shown in Table 2.8.2. The report indicates the budget cost, the monthly spending and the cumulative spending per activity, according to its cost code, per man-hours and dollars. The report is based on the actual hours reported on time sheets and on the bills and invoices received.

During the engineering phase the project engineer prepares monthly, a project summary report similar to the one prepared during the former stage of the project and shown in Figure 2.8.1. The project summary report is for progress reporting purposes.

Regarding the quality and value of the detailed design, optimization and value engineering techniques are practiced more in this phase than they are in the feasibility phase as we are one step closer to construction of the facility. The project engineer and the chief of the projects division are responsible for ensuring that the estimate, schedule and other work, performed by the other departments, are of a good quality.

As for the value of the final engineered product, the following techniques are applied:

- The basic concepts identified in the preliminary design are reviewed to ensure that they are the most economical, while preserving environmental and other project requirements;
- Alternative materials and construction methods together with cost comparisons are reviewed as the design and construction of transmission lines generally are still considered recent and room for improvement is available;
- Sensitivity analysis, when appropriate, may be performed, especially with regard to the type and height of towers versus different span length. i.e.: By installing higher and stronger towers, spans length can be reduced, thus reducing the number of towers required; and
- A life cycle cost study is performed when the line is planned for a temporary period and not for maximum life. In such a case, a line of lower structural quality, which requires above average maintenance may have a lower life cycle cost than a line of higher structural quality which requires little maintenance.

The control tools of the engineering phase can be improved specifically concerning the method of reporting. This improvement can be accomplished by the application of the integrated project status report illustrated in Figure 2.8.2 instead of the presently used separate reports, the integration of schedule, cost and progress is an effective tool for forecasting future performance and completion costs after sufficient reporting periods have established performance trends. Also, for projects of high financial commitments and where engineering work produced is numerous, it would be justified to apply a control system where the value of the work performed is measured against time and cost. The weakness in conventional cost and progress reporting is that they do not reconcile the cost to date for the work performed and the cost budgeted for the same work. Such reports lack an objective measurement of performance against budget. Without knowing the relationship between the cost to date for the work performed and the cost budgeted, it is not possible to evaluate the true percent completion of the project. In major projects that use conventional reporting without comparing actual progress to date to the budget, the project may finish up as shown in Figure 3.7.1. This example shows that the project ended up 15 percent behind schedule and 20 percent behind budget, and that the cost overruns and expected schedule delay did not show up before the project was approximately 80 percent completed.

What is missing from conventional reporting is a measure of the relation between budgeted cost and actual performance, these two measures are related by the value of work performed or "Earned value". To apply an "Earned value" based control system, the project budget is prepared by breaking the project cost estimate down into relatively large numbers of small and defined work packages and by assigning a cost and quantity to each work package. Engineering work packages are usually broken down into the number of drawings, reports, studies, specification items,...etc. Then, the man-hours and/or cost for the different stages of the preparation cycle are assigned. At each reporting period, first, the percentage complete is relatively accurately computed from the broken down work packages. Then, the earned value is calculated by multiplying the appropriate percentage completed by the budget allowance for the work package. An earned value based cost report is illustrated in Figure 3.7.2. From this figure we can see that the earned value adds a new dimension to

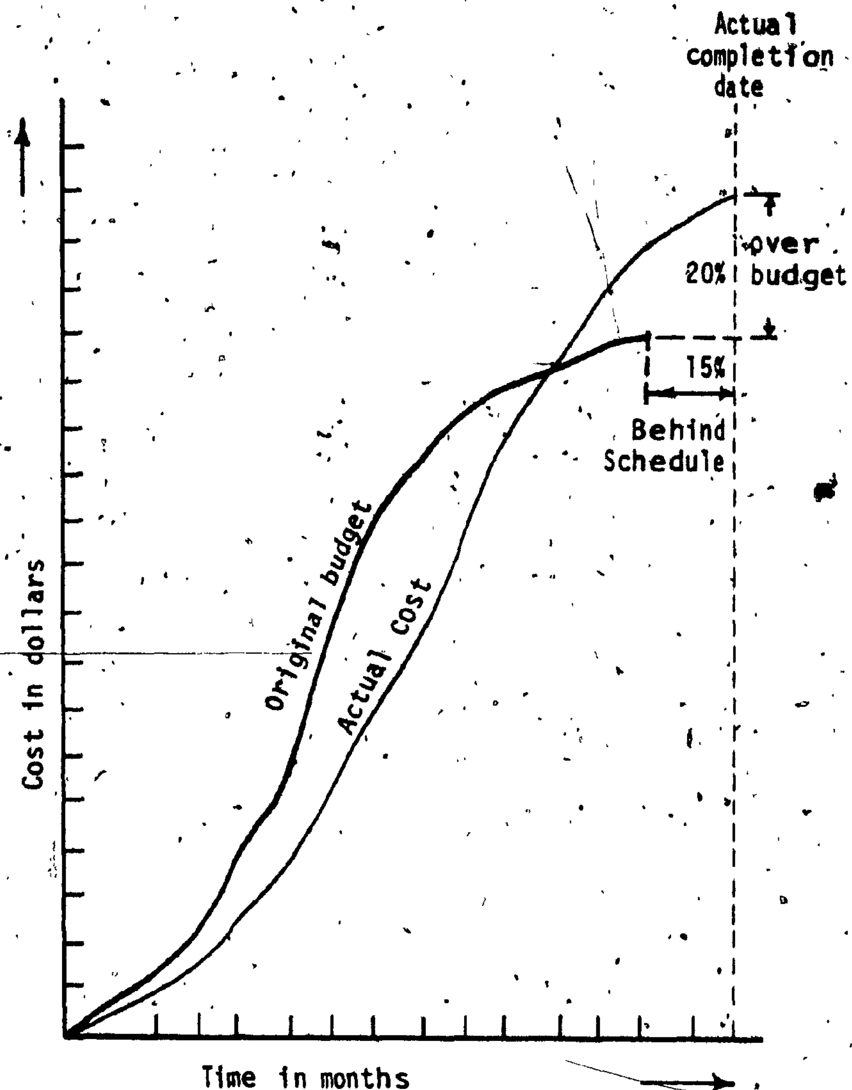


FIGURE 3.7.1: Conventional cost report

project status with the addition of the earned value we can see that the project is not below budget, as it would appear from the actual cost curve, but it is actually both over budget and behind schedule. The "Earned value" based reporting system clearly indicates where control is needed and it does so in time to permit effective action.

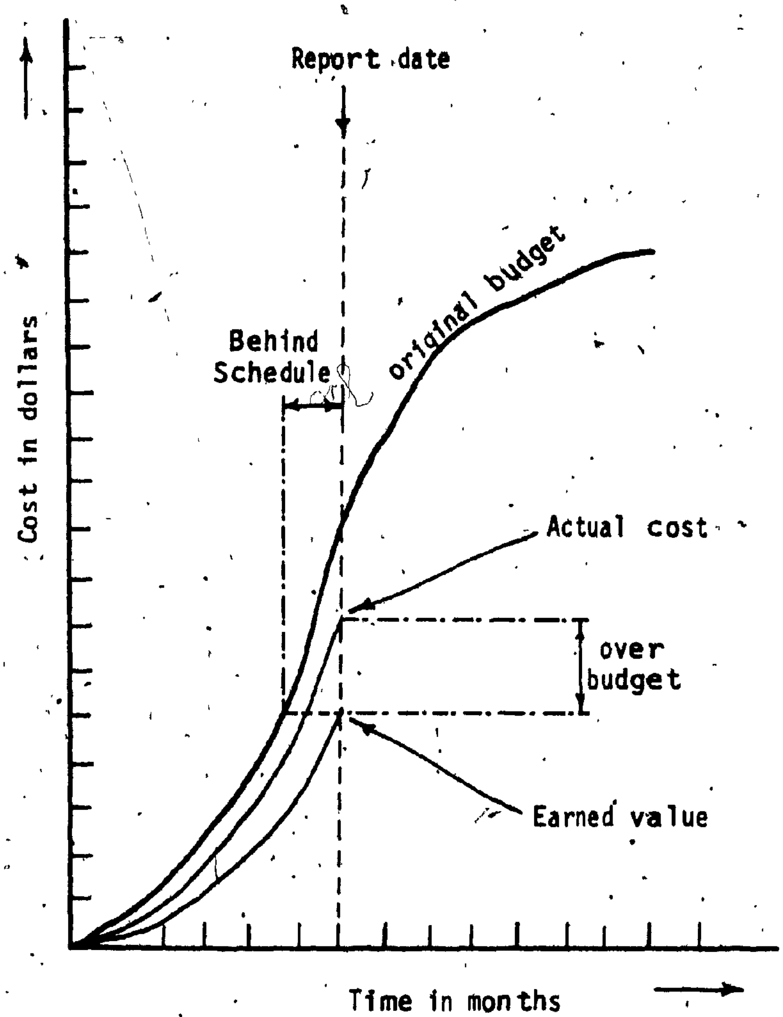


FIGURE 3.7.2: Earned value cost report

CHAPTER 4

CONSTRUCTION PHASE OF THE PROJECT

4.1 Home Office Construction Management Assistance

After the planning, design, bidding and contracts awards are accomplished, the field construction of the line remains for the successful completion of the project. The construction phase starts with the award of the materials fabrication contract, and ends with the commissioning of the transmission line. For major lines, the various construction activities overlap together to complete the project within minimum time. The first site activity is the construction of access roads and tree clearing of right of way, followed by foundation construction, assembly and erection of towers, hardware and guys installation, and finally stringing of conductors. The staffing of the project is done accordingly.

The construction supervision and management of the line construction are the responsibility of the transmission lines construction department. However, the technical content of the project is the responsibility of the transmission lines engineering department. Table 4.1.1 details the responsibilities of each department during the construction phase of the project. To enable the engineering department to exert control over the technical content of the project, the following actions are maintained:

- A copy of the technical construction records and reports, and the weekly progress report are forwarded to the project engineer;
- Technical construction problems, excluding construction methods, are referred to the project engineer for advise; and
- The project engineer visits the construction site on a regular basis during the construction period to spot check the technical aspect of the activities in progress.

Transmission line engineering department	Transmission line construction department
- Quality control of materials fabrication - Fabrication expediting - Technical content of the project - Technical problems that arise during the construction of the line	- Construction methods - Site supervision and control - Contract administration - Construction cost and schedule - Site Safety - Commissioning of the line - Providing staff for site supervision
- Construction claims (Joint)	- Construction claims (Joint)

TABLE 4.1.1: Construction phase responsibilities distribution

The construction department is responsible for the administration and coordination of the contract. This task is performed by a contract administrator, who remains in the home-office. The contract administrator is responsible of the following:

- Establishing contact with the contractors and ensuring that they have at hand all necessary documentation relevant to the contract;
- Preparing and issuing change order documents. The change order is generally written on a standard form and includes a complete but concise description of the change and its effect upon the contract schedule and price;
- Preparing "progress payment reports" monthly to authorize and document progress payments to the contractors;
- Preparing the "Contract completion and acceptance certificate", after advise from site that all the contractual works are completed, to release the final payment; and,
- Assisting in the settlement of contract claims by contractors.

The construction department home-office, maintains records, curves and schedules for the progress of site construction works and progress payments. The records of construction progress are based on the informations received on a weekly basis from the site, and the records of progress payments are based on the actual payments made to contractors and provided by the contract administrator. The types of information forwarded to the home-office from the site office are discussed in the following sections of this chapter.

The staffing of the site supervisory personnel is the responsibility of the construction department, which establishes the scheduling and levelling of its construction personnel over the different projects.

4.2 Fabrication and Quality Assurance of Materials

The procurement of the transmission line material is included in a separate contractual package and is not part of the construction package, thus leaving Hydro responsible for controlling and handling the materials until the construction. This practice is applied to maintain tight control over the type, cost, quality and delivery schedule of the materials selected for the transmission lines. The manufactured materials are shipped to the owner's warehouses at the construction site and handed over to the contractors according to the schedule of erection.

The process of assuring the quality of material selected for the job starts during the engineering phase. In this phase, through consultation with the quality assurance division, the project engineer makes certain that the material specified for the job is in accordance with all applicable codes and that it meets the desired performance criteria.

The quality assurance method applied in Hydro-Quebec is based on the Canadian Standard Association, Standard Z299, but only the requirements of this standard which are judged necessary for Hydro are retained.

The manufactures fabricating materials for Hydro-Quebec equipments have to prepare and submit for acceptance a quality assurance manual before the contract is awarded. The manual contains the following:

- Organization of quality assurance program: In this section the manufacturer defines the objectives and responsibility for quality assurance and provides an organization chart, and provides for the regular review of the status and adequacy of the program and also appoints a representative for the quality assurance program;

- Inspection and test plan: The manufacturer indicates the inspection program and test activities, and identifies the characteristics to be insepcted, examined and tested at each point;
- System function procedures: The manufacturer shall have documented procedures for the main system function such as design assurance, measuring and testing equipment, inspection, handling and storing, packaging and shipping, non-conformance and corrective actions; and
- Manual review: The manufacturer periodically reviews and updates the manual to reflect current quality assurance policies and documented quality program procedures and resubmits the manual for the acceptance of Hydro-Quebec. The submitted manual is verified by the quality assurance division which reviews it and accepts it or requests modifications if necessary.

After the quality assurance manual is accepted and the fabrication contract is awarded, the inspection and audit for major contracts is assigned to a specialized inspection firm which is responsible for the following:

- Ensure that all documents affecting quality are reviewed for adequacy and that changes are approved by Hydro-Quebec;
- Ensure that all measuring and testing equipment used for quality control are controlled, maintained and calibrated against certified equipment;
- Inspect, test and identify items as required by the inspection and test plan and identify and refuse nonconforming items;
- Prepare and forward to Hydro-Quebec a checklist of all inspection and test records;

- Ensure that a system is maintained that indicates final acceptance of items;
- Ensure that handling of materials through the entire manufacturing process and subsequent storage is free of abuse, misuse, damage deterioration or loss;
- Inspect the packaging and marking, and verify shipping operations to ensure contract requirements are met; and
- Investigate the cause of nonconformance and suggest appropriate action to prevent its repetition.

The inspection firm forwards to Hydro-Québec an inspection and progress report on a monthly or weekly basis depending on the duration of the fabrication contract. The report contains, besides a description of the general activities of the reported period, one or more sheets entitled "Fabrication progress report" and one or more sheets entitled "Fabrication inspection report". Samples of both reports are shown in Tables 4.2.1 and 4.2.2 respectively. The fabrication inspection report identifies the item inspected, the drawing number from where it originated and the different inspection control points. If an item is refused for nonconformity it is identified, on the report, at which control point if was rejected. The fabrication progress report identifies for each item: the required quantity of each, the accepted quantity at this period, the cumulative accepted quantity, the quantity delivered this period and the cumulative delivered quantity. This report serves as an expediting tool of fabrication. Delays on critical items, identified through the fabrication progress report, are brought to the attention of the manufacturer and corrective measures to accelerate the fabrication of these items are requested.

HYDRO-QUEBEC
CONTROLÉ DE LA QUALITE
PROJETS DE LIGNES DE TRANSPORT

RAPPORT D'AVANCEMENT
DES TRAVAUX NO: 7

PAGE 1 DE 1

NOM DU FOURNISSEUR: D. Bridge-Sulzer	NOM DE(S) L'USINE(S):	COMMANDE D'INSPECTION PJ-395250	COMMANDE D'ACHAT PJ-384451	QUANTITE INITIALE: ADDITION 1: ADDITION 2: ADDITION 3: ADDITION 4: TOTAL:
NOM DU PRODUIT: Pièces découpées - Acier			APPEL D'OFFRES PCL-10183	
AGENCE DE SURVEILLANCE X-Per-X Inc.	PREPARE PAR: A. Bélec	DATE DU RAPPORT 22 septembre 1982	PERIODE 1982 DU 25/7 AU 30/7	

DESCRIPTION DES ARTICLES	QUANTITE				
	REQUISE	ACCEPTEE	CUMULATIVE ACCEPTEE	LIVREE	CUMULATIVE LIVREE
QUANTITE TOTALE					

TABLE 4.2.1: Fabrication progress report
(courtesy: Transmission line department, Hydro-Quebec)

X-PER-X INC.

Hydro-Québec : PJ-384451
Hydro-Québec : PCL-10138-OP
X-Per-X Inc. : 82082
Inspecteur : A. Bélec

RAPPORT DE FABRICATION No. : 10 Date : 30 juillet 1982
Pièces découpées / Acier pour suspension à 735kV
Fabricant : Dominion Bridge-Sulzer No. : 399-498

Page 2 de 2

Inscr. No.	Description	Dessin H.Q.	Coupe	INSP.	Meulage	INSP.	Usinage	INSP.	Ass.	INSP.	Soud.	INSP.	Galv.	INSP.	Inspection finale
06 488	Barre de rallonge 25 mm x 1270 mm (528 requis)	G735-60119-752 fig. 2	x	x	x	170 refusées									
07 739	Palonnier principal 25 mm (796 requis)	G735-60119-752 fig. 1	x	x	x	x	x	x	N/A	x	N/A	x			
08 108	Plaque de raccordement 20 mm x 136.5 mm (12 requis)	G735-60119-063 Détail 'D' fig. 1	12 Bal.96	Refusées											
09 54	Palonnier secondaire 25 mm (6 requis)	G735-60119-759 fig. 1	6 Bal.48	x	x	x	x	x	N/A						

TABLE 4.2.2: Fabrication inspection report
(courtesy: Transmission line department, Hydro-Quebec)

4.3 Organization and Operation of the Construction Site

A typical construction site organizational chart for a transmission line project is illustrated in Figure 4.3.1. The site is managed by a construction manager who may or may not be assisted by a senior construction engineer, depending on the project size. The construction manager has under his supervision an office clerk, a warehouse suprintendent, a safety officer and a senior inspector for each one of the various construction disciplines. Each senior inspector may have one or more inspectors under his supervision depending on the number of construction crews assigned by the contractor for each discipline. Generally the number of crews assigned for foundation construction are double the ones assigned for the other construction activities because of the lower rate of progress of this activity.

A temporary site office is set-up for the owner staff in a central location along the line. The site office allows space for the construction manager, the senior construction engineer, the safety officer and the inspectors. It also allows space for the office clerk, the construction files and for a meeting room.

A temporary warehousing yard is also set-up. It is used mainly for the storage of the construction materials. For short times, the warehousing yard is located near the site office, whereas, for long lines, a number of yards are established at distances of approximately 40 kilometers along the line. The office of the warehouse supervisor is located on site with the other site staff, if only one warehousing yard is required, and it is located in a separate trailer in the largest yard when more than one yard is required. The warehouse yard is chosen as close as possible to main highways to facilitate delivery of materials. It is set on a flat

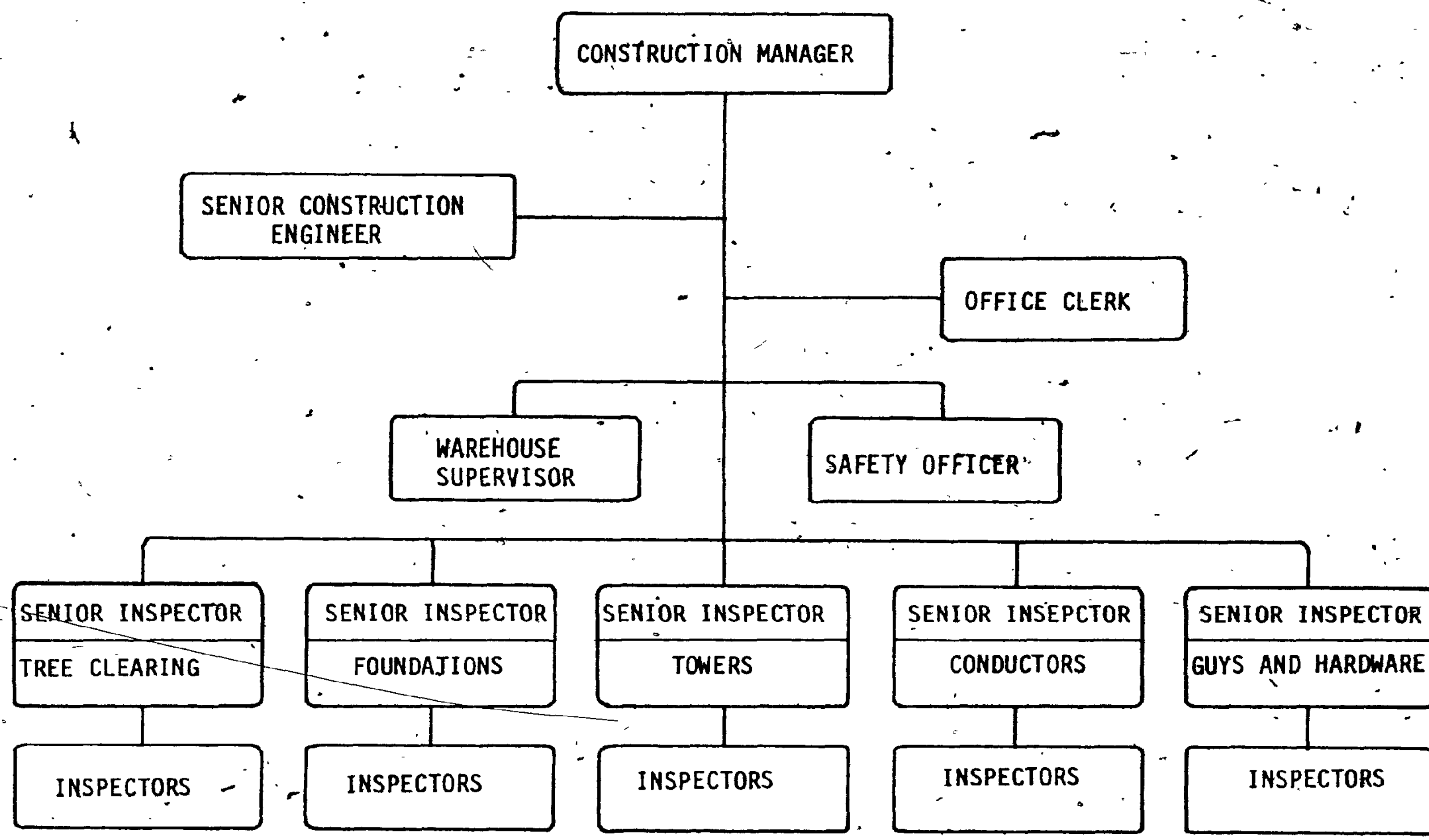


TABLE 4.3.1: Construction site organizational chart

surface with stable soil, and it should not be near overhead conductors that would create a craning hazard.

As a contribution to the economy of the region, during the construction of the transmission line, the contractors are advised to use the accomodation facilities of the region when such facilities are available. In regions where facilities are not available, Hydro-Quebec provides trailers for the lodging and meals of the contractors staff. The trailers are planned for the use of more than one contractor and levelling of resources are applied, whenever possible, to reduce the total number of site trailers at construction peak.

At the start of the project construction, the construction manager establishes what reports or technical records need to be prepared for his project depending on the type and size of activities necessary to complete the project. There are three different types of site reports/records: The daily report, the weekly report and the technical records. Table 4.3.1 describes the frequency and the purpose of each type of report. The detail of the preparation of the daily report and of the technical records is discussed later in this chapter. The weekly report consists of a brief summary of the weeks activity progress as well as a progress curve for each construction activity. Figures 4.3.2 through 4.3.7 show an example of a complete weekly report. Figure 4.3.2 is the report summary sheet and it contains, for each activity, the following information: Identification of the activity, the total contractual quantity, the actual date the construction started, the number of weeks remaining, the up to date quantity, the percentage completed, the percentage scheduled to be completed at this date and the date the work is completed. Figures 4.3.3 through 4.3.7 contain respectively the piling progress

TYPE OF REPORT/RECORD	FREQUENCY	PURPOSE
Daily report	Daily for each construction crew	- To maintain a daily historical record of contracts progress - To assist in evaluating possible claims
Weekly report	Weekly for every project	- To report project progress to management - To inform project engineer of project progress
Technical records	per construction item	- To record the construction technical data - To inform project engineer of technical data - To assist in evaluating possible claims

TABLE 4.3.1: Types of reports and technical records prepared by the site office

curve, the tower assembly progress curve, the tower erection progress curve, the conductors stringing progress curve and the conductors clamping progress curve.

An additional essential item in the operation of the construction site, besides the site supervision, the preparation and distribution of the site reports/records, and the keeping of an adequate filling system, is the weekly site meeting. In the weekly meeting all the contractors representatives are called and the following items are discussed.

- Work progress for each contract,
- Quality of work,
- "Move in" and "Move out" dates,
- Schedule critical items,
- House keeping, and
- Problems encountered by the contractors.

The minutes of the meetings are prepared by the construction manager or the senior construction engineer and prompty distributed to all participants and a copy is forwarded to the home-office.

4.4 Access Routes and Right of Way Tree Clearing

The tree clearing construction contract is awarded before the other construction contracts are awarded as it is the first construction activity on a transmission line site, and it includes the clearing of both access roads and right of way to enable vehicles and equipments to reach the work site.

The construction equipment normally used to build the access routes include:

- A bulldozer;
- A front end loader;

Rapport hebdomadaire
Construction de lignes de transport
sur structures d'acier

nº de projet	nº de réquisition de travail	du j	m	a	au j	m	a	nº
3038 - 3041-01	PANTD	10	06	82	16	06	82	#33

nom de la ligne: Albanel - Lemoyne
section: Lemoyne - Point "O"
entrepreneur: Transelec Inc.
nº d'appel d'offres: ECL-81-1918?
limite fixée le: 31 08 82 — limite révisée le:
pénalité:

description des travaux		quantité totale	début des travaux j	m	a	semaine courante	à ce jour	% exécuté	% prévu	fin des travaux j	m	a
distribution des fondations (nombre de pylônes)		258	26	10	81	0	258	100	100	09	03	82
installation des fondations (nombre de pylônes)		258	28	10	81	12	254	98,45	93,80			
battage de pieux (nombre de pylônes)	Pylône Mètre	5 1004	08	10	81	0 0	5 1698,68	100 169,15	100	01	12	81
ancrage de hauban (nombre d'unités)		948	09	11	81	32	912	96,20	91,09			
ancrage de hauban (longueur)	Mètre	6171	09	11	81	246,10	5231,48	84,78	91,09			
essai d'ancrage (nombre d'unités)		948	08	12	81	44	800	84,39	73,58			
distribution de l'acier (nombre de pylônes)		258	12	11	81	0	258	100	100	03	06	82
assemblage des pylônes (nombre de pylônes)		258	25	11	81	11	198	76,74	76,74			
montage des pylônes (nombre de pylônes)		258	11	12	81	17	196	75,97	71,71			
câbles de garde (nombre de milles ou km.)		112,78	01	02	82	0	63,18	56,02	58,92			
conducteurs (nombre de milles ou km.)		112,78	01	02	82	0	63,18	56,02	53,43			
contrepoids (nombre de milles ou km.)												
inspection finale de l'entrepreneur (nombre de pylônes)		258	10	03	82	0	143	55,43				
inspection finale de H.-Q. (nombre de pylônes)		258	10	03	82	0	143	55,43				
Inspection finale H.Q. région Baie James (nombre de pylônes)		258	09	04	82	0	141	54,65				

* Voir observations en annexe.

PROJETS DE LIGNES
22 JUIN 1982

863-7003 (78-04) M 15/TAB

DISTRIBUTION:
BLANC / directeur
VERGE D'OR / chef de service, Serv. techn.
ROSE / chef de service Approv.
VERT / chef de service, Plan et C
BLEU / administrateur de projets
CHAMOIS / dossier

administrateur des travaux:

FIGURE 4.3.2: Weekly report, summary sheet
(courtesy: Transmission line department, Hydro-Quebec)

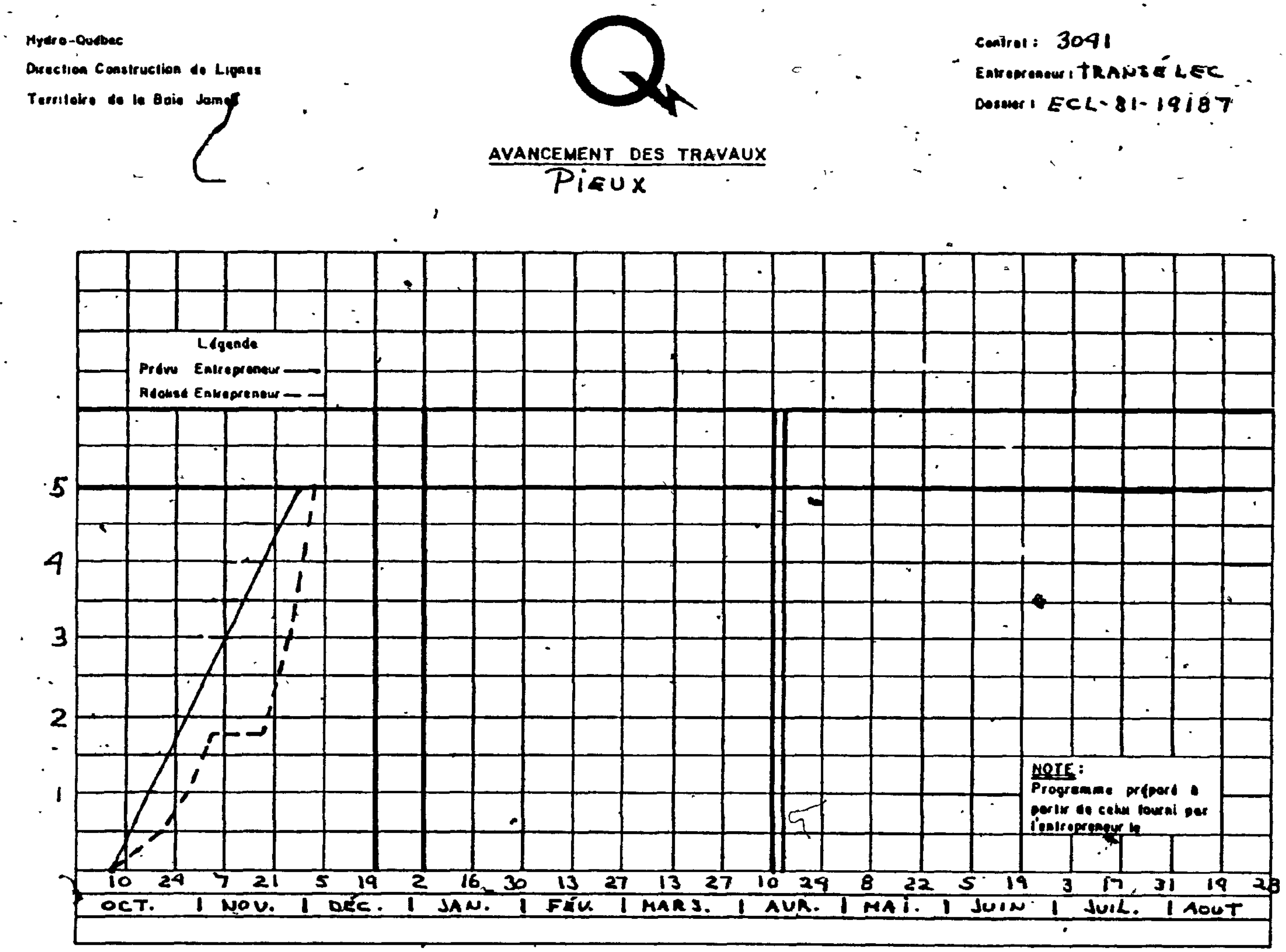


FIGURE 4.3.3: Piling progress curve
(courtesy: Transmission line department, Hydro-Quebec)

Hydro-Québec
Direction Construction de Lignes
Territoire de la Baie James

Contrat: 3091
Entrepreneur: TRANSELEC
Dossier: ECL-81-19187

AVANCEMENT DES TRAVAUX

ASSEMBLAGE

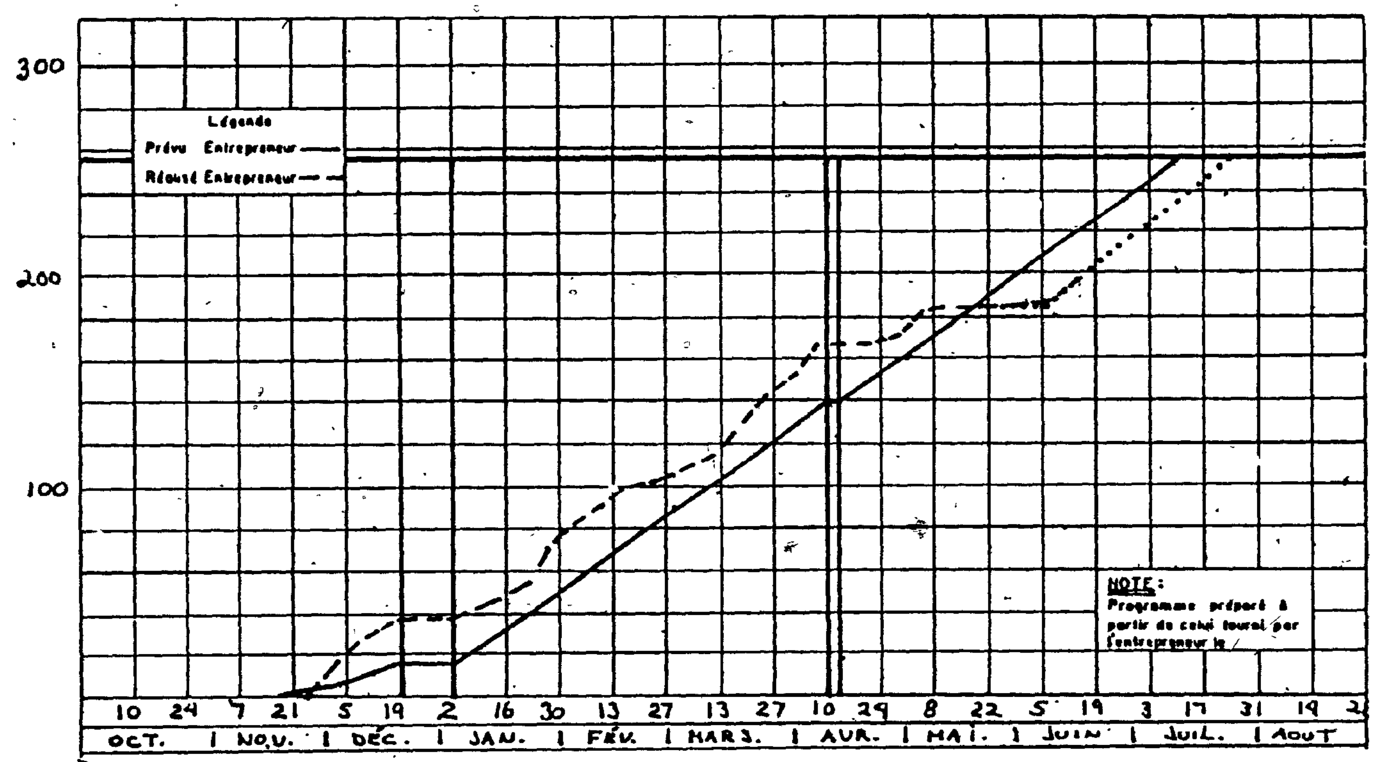


FIGURE 4.3.4: Tower assembly progress curve
(courtesy: Transmission lines department, Hydro-Quebec)

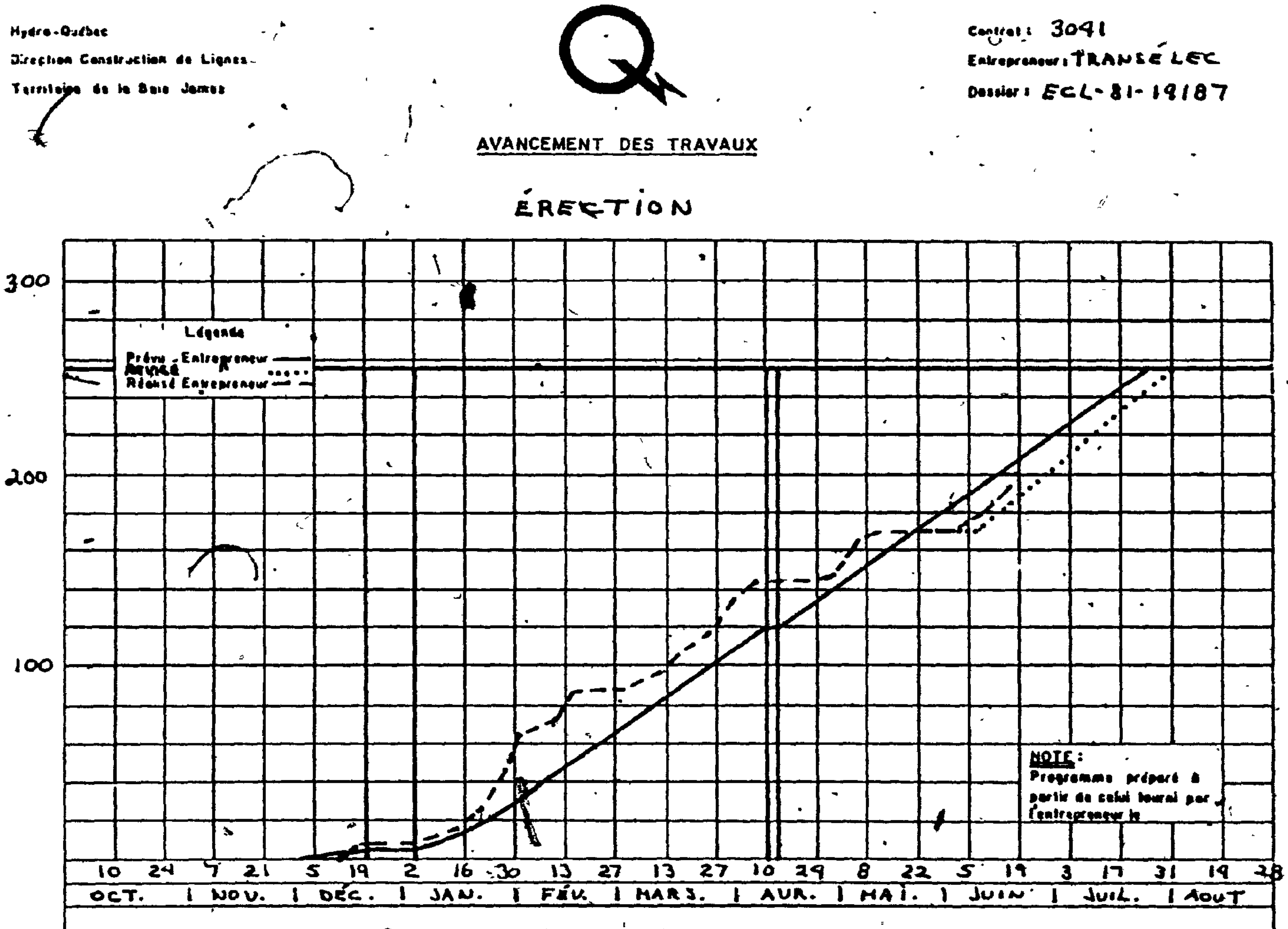


FIGURE 4.3.5: Tower erection progress curve,
(courtesy: Transmission lines department, Hydrö-Quebec)

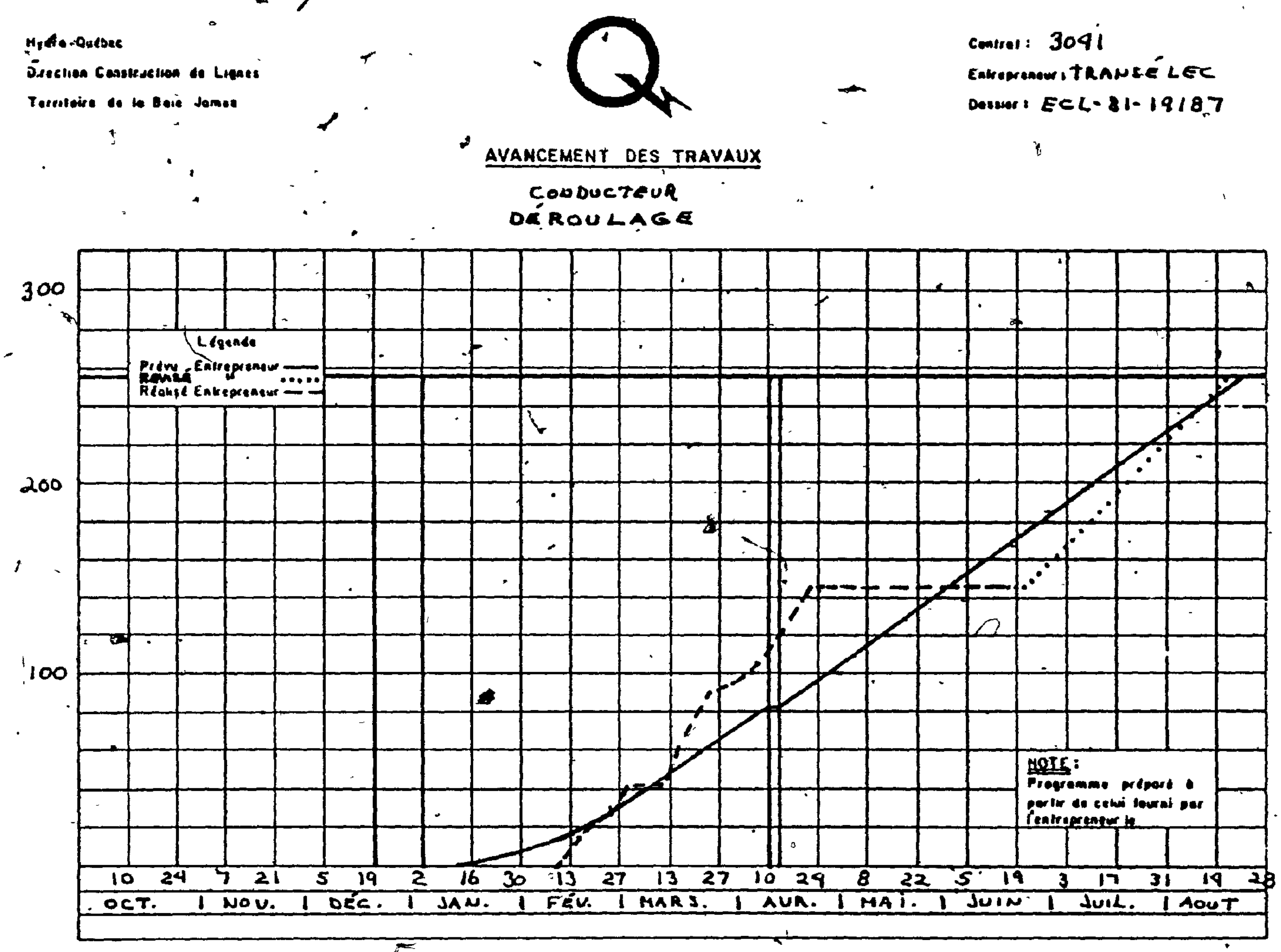


FIGURE 4.3.6: Conductors Stringing progress curve
(courtesy: Transmission lines department, Hydro-Quebec)

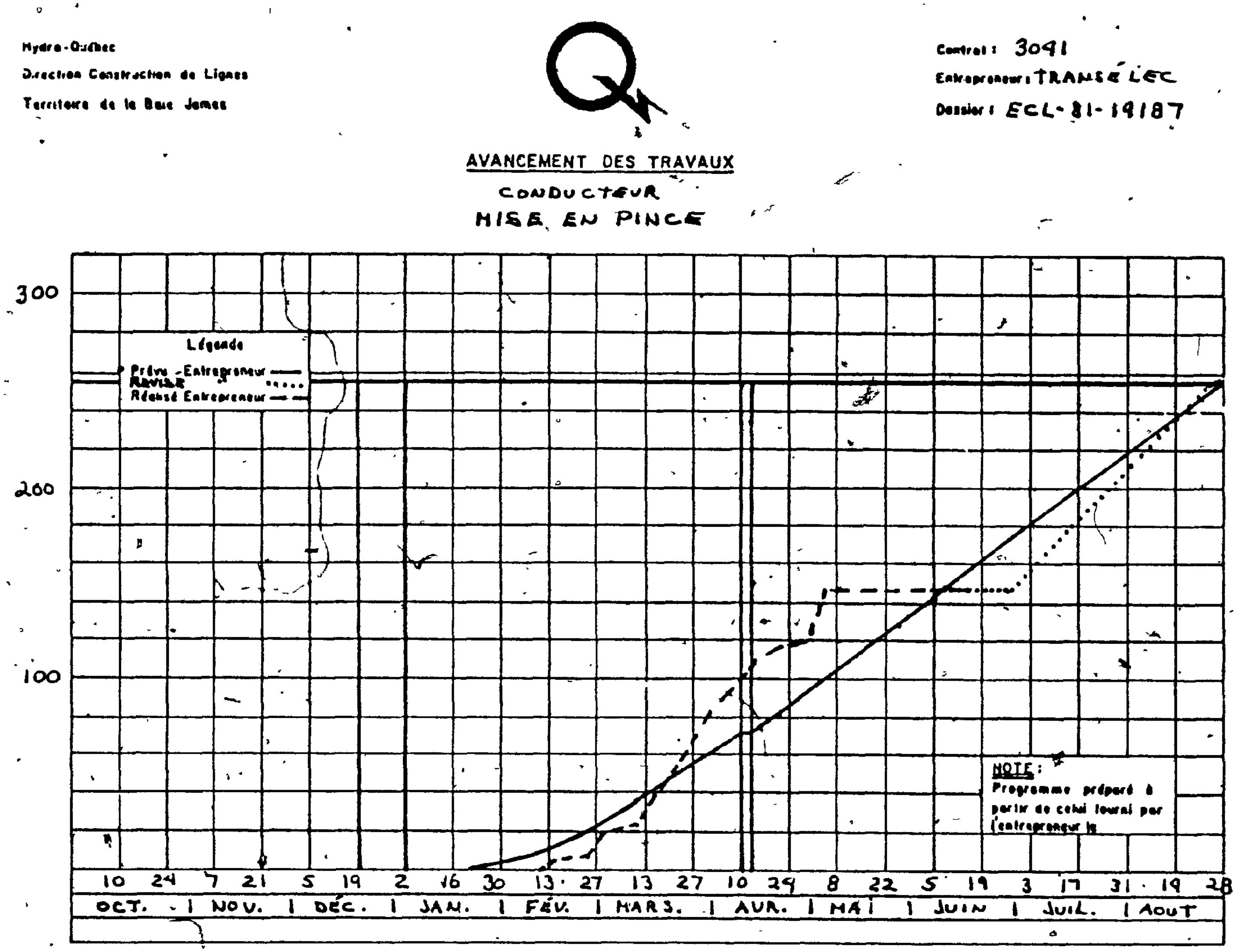


FIGURE 4.3.7: Conductors clamping progress curve
(courtesy: Transmission lines department, Hydro-Quebec)

- A backhoe, truck mounted with telescopic boom for clearing ditches; and
- A dump truck, tandem axle.

The actual location of access roads depends not only on environmental information, but also on economic considerations and properties owner preferences. Access routes are clear-cut, their width and configuration are determined by the type of equipment used and the construction techniques employed. Access routes are usually kept to a width of 4, 6 meters.

Existing roads are used wherever possible. These routes may occasionally require upgrading by using a grader or by adding gravel hauled in by dump trucks and graded. In wetlands, ice roads are used where they can be established. This is accomplished by packing the snow, usually using a soft-track carrier, in such a fashion that frost will penetrate. Corduroy roads, constructed from trees removed from the right of way and consisting of one or more layers of 10 to 15 centimeters in diameter logs, are used in wetlands where the bearing capacity is insufficient to support construction traffic. Access roads are kept within the confinements of the right of way wherever possible. However, on rocky or uneven terrain, the route is usually erratic, and the best route may be off the right of way.

Today, for environmental reasons, the right of way is not fully cleared from woody vegetations. Only the vegetation that would adversely affect the construction and safety of the transmission line is removed. This type of clearing is called right of way selective cutting. The construction equipment normally used for this activity includes:

- Chain saws;
- Rubber-tires skidders;
- Rubber-tires loaders or small bulldozers;
- Logging trucks with self loading cranes; and
- Two or four-wheels drive trucks.

In selective cutting, the compatible vegetation is normally left on the right of way. The characteristics and location of such vegetation are of a kind that will not compromise standards of safety, realiability or cost, and can be considered to require little or no maintenance. Normally included in this category is vegetation that at maturity will not come within the minimum clearance from the conductors. Also included is slow growing vegetation that may be left for screening the right of way. Pruning may be required to provide the specified conductor clearance for this slow growing vegetation.

Clear-cutting is necessary to make way for structure assembly areas and tower sites. The trees are usually felled, skidded, and piled in tree lengths adjacent to the access road. In wetlands or other sensitive areas, trees may simply be cut up and piled by hand, or left in contact with the ground. Brush is disposed of by burning or they may be lopped and scattered, piled, chipped, or removed from the right of way. The land owner has the option of retaining ownership of the wood in his property or accepting the cash value for it. After the cutting is completed, salvaged wood by Hydro-Quebec is sold by tender.

During the performance of the right of way tree clearing and access route contract, the owner inspectors carry out the following control tasks:

- Ensure that contractor work methods and equipment are adequate,
- Verify that selective and clear-cut are performed in the areas

identified in the contract,

- Check the dimensions of access roads and right of way,
- Check that stumps are cut as close to the ground as practical,
- Ensure that all salvageable wood is recovered,
- Verify the disposal of brush,
- Verify if safety standards are maintained,
- Estimate salvaged wood quantities,
- Evaluate and supervise extra works,
- Prepare the daily report,
- Maintain a complete file on the contract to serve in cases of claims, and
- Prepare the final work acceptance report.

For the tree clearing and access road contract, as well as for the other contracts, the responsible inspector prepared a daily report. This type of report is shown in Figure 4.4.1. In case there is more than one crew and more than one inspector assigned to the job, a daily report is prepared for each crew. The daily report contains the following information:

- weather conditions and working hours;
- work completed during the day;
- discrepancies, if any, and whether the contractor was notified by memo;
- list crew equipment and manpower;
- identify if any memos concerning environment or safety problems were forwarded to the contractor; and
- working hours and down time.

HYDRO-QUEBEC
CONSTRUCTION DE LIGNES
FORMULAIRE CL-11 Rev. 0

RAPPORT JOURNALIER
RESSOURCES - RENDEMENT (Equipe: ________)

DATE: ___/___/19___

PROJET:

Entrepreneur ______________________

Condition climatique: ______________________

Heures de travail: de ________ à ________

OUVRAGE COMPLETE: ______________________

DISPARITE: endroit ______________________ Mémo ☐

MATERIAUX: (Disponibilité & Anomalies) pièces ______________________

______________________ Mémo ☐

SECURITE. rapport ☐

ENVIRONNEMENT mémo ☐

EQUIPEMENT		
Description	Identification	Nombre

MAIN D'OEUVRE	
Fonction	Nombre

NOTE: Identifier d'un [illegible] (*) le temps donné par l'entrepreneur

	DUREE (hres)	ENDROITS
Transport du personnel	De ______ à ______	______
	De ______ à ______	______
Déplacement de l'équipe	De ______ à ______	______
	De ______ à ______	______
	De ______ à ______	______
	De ______ à ______	______
Travail effectué	De ______ à ______	______
	De ______ à ______	______
	De ______ à ______	______
	De ______ à ______	______

	DUREE (hres)	RAISONS
Pertes de temps	De ______ à ______	______
	De ______ à ______	______
	De ______ à ______	______
	De ______ à ______	______

OBSERVATIONS: ______________________

Mémo: ☐ Inspecteur: ____________ Date: ________

Contremaître: ____________ Approuvé ____________ Date: ________

FIGURE 4.4.1.: Inspector daily report
(courtesy: Transmission lines department,
Hydro-Quebec)

4.5 Construction of the Transmission Line

Once access routes and right of way tree clearing activities are at a relatively advanced phase, the construction of the transmission line begins. The construction of the line includes the activities of soil testing; installation of tower foundations; delivery and assembly of tower steel; erection of towers; delivery, stringing and clamping of conductors, and installation of counterpoise.

The soil testing is performed at the actual site of each tower to confirm or modify the type of foundation already designed for the specific tower. The equipment used for this operation is a rotary drill mounted on an all terrain vehicle. At the tower site a 10 centimeter drill bore holes to a depth of up to 15 meters. Soil samples or cores are retrieved at regular intervals during the drilling operation. If bedrock is encountered at a shallow depth, rock cores are recovered using conventional diamond drilling techniques. All recovered samples are promptly returned to a research laboratory for analysis. The laboratory, after analysing the samples, advises the project engineer of the results. He then revises or maintains the original foundation design.

The foundations of the transmission line towers may consist of one or more types of foundations depending on the type of soil encountered at each tower site. The following types are generally used for transmission line towers:

- Augered foundation: The equipments normally used for this type are an augering machine, a self loading truck, a 25 ton crane, a bulldozer and a ready-mix concrete truck. The operation consists of drilling an earth hole to the designed depth, filling it with reinforced concrete and inserting anchor bolts at the top for attachement of the tower leg;

- Grillage foundation: The equipments normally used for this type are a crawler mounted backhoe, a bulldozer, a 25 ton crane, a ready-mix concrete truck, and a dump truck. The operation consists of installing a structural steel type grillage foundation in the earth at each leg position of a tower. The foundation is composed of a mat of I-beams bolted together and attached to the tower legs; and,
- Pile foundations: The equipments usually used for this type are are a diesel driven pile driver, a bulldozer, a 25 ton crane, a ready-mix concrete mix and a dump truck. The installation of the pile foundations consists of driving vertical wood or steel piles into the ground. The piles are equipped with suitable caps at the ground surface for the support of the tower legs.

The towers foundations are the major item of technical problems among the components of the transmission line. For that reason, adequate controls have to be applied on their engineering and construction. Besides the inspectors daily report discussed earlier in this chapter and shown in Figure 4.4.1 there are three types of technical records prepared for the tower foundations and presented in Figures 4.5.1, 4.5.2 and 4.5.3. Figure 4.5.1 illustrates a sample of the technical record prepared for the augered and grillage types of foundations. One sheet is prepared per tower. The record contains the following information: type of foundation initially engineered for each leg and actual type installed if changed after soil testing; level of natural soil, level of rock, level of excavation bottom, extentions length, type of existing soil and types of tests performed during the foundation construction. Figure 4.5.2 shows a sample of the pile driving technical record. For this type of record one sheet is prepared for each tower leg. This record contains the following information: identification of the type and location of the leg piles, number of blow per centimeter for the last four centimeters and the total drivel pile length and salvage pile lenght. Figure 4.5.3 shows a sample of the foundation concrete test technical record and it contains the following data: The tower number and type, the sample number, the dates the sample is collected and the day it is tested and the concrete tested strength. Copies of each type of the foundation records are forwarded to the project engineer.

When the foundations are advanced enough the delivery, assembly and erection of the transmission line towers begins. The delivery of tower steel from the temporary warehousing yard to each tower site is made using a self-loading truck. Once at the tower, the steel is unloaded and piled in the area cleared for tower assembly. The tower is generally assembled in sections, depending on the tower size and on the lifting capacity of the erection crane. After the alignement of the pieces is carried-out, the bolting of each section is made by powered impact wrenches.

The tower erection is usually done in two passes through a number of tower bases; the initial pass, made with a small crane, erects the lower section of each successive tower; the final pass, made with a bigger crane, erects the top section of each successive tower. Slings are used to rig each section for hoisting into place. After each section has been positioned it is bolted in place and the crane is cleared. After the whole tower is erected, a follow-up crew checks and tightens all bolts to specified torque and installs missing bolts and tower members.

For progress reporting purposes of the tower erection, the contractor submits weekly an updated progress curve, an example of this curve is shown

HYDRO-QUEBEC
CONSTRUCTION DE LIGNES
FORMULAIRE CL-21 Rev.0

FICHE TÉCHNIQUE
FONDATION

PYLONE # 37

PROJET: LEMOYNE @ POINT "O"
3041

Entrepreneur TRANSELEC

TYPE DE PYLONE: CH-0
CHAINAGE: prévu 15240.0 réalisé 15240.0
DATE: début 82-05-31 fin 82-05-31
CONDITION CLIMATIQUE: Soleil

TRAVAUX D'EMPATTEMENT	1 ou G		2 ou C		3 ou D		4	
EMBASE PREVUE	R-5				R-5			
EMBASE REALISEE	R-7				R-5			
SURFACE DU TERRAIN NATUREL (datum) élév.	99.27				100.00			
NIVEAU DU ROC (dessus) élév.	98.52				99.71			
FOND D'EXCAVATION élév.	98.31				99.71			
COUSSIN GRANULAIRE (dessus) élév.	—				—			
NIVEAU DE SOL PROPOSE élév.	99.27				100.00			
NIVEAU DE SOL INSTALLE (final) élév.			PLUS TARD					
EPAISSEUR DE MATIERE ORGANIQUE (m)	0.05				0.05			
PROFONDEUR DE LA NAPPE D'EAU (m)	—				—			
GABION — Rayon et hauteur	—	—			—	—		
NIVEAU DE PLATINE OU TALON (théo. réel)	100.35	100.38			100.35	100.37		
DISTANCE DU DESSUS DU TALON (A-B)		1.824				0.380		
DISTANCE DE LA PLATINE - Lm (théo. réel)	15.72	15.73			15.72	15.74		
POSITION OU CAS								
RALLONGES OU COMPOSANTES		44.0				44.0		

DESCRIPTION DU SOL

Fondation 1 ou G: Roc
Fondation 2 ou C:
Fondation 3 ou D: Roc
Fondation 4 :

QUANTITE-ESSAIS	1 ou G	2 ou C	3 ou D	4
EXCAVATION M.T. Prof. (m)	0.75		0.29	
EXCAVATION ROC Prof. (m)	0.21		—	
COUSSIN GRANUL.(m)-Ess. densité	— ☐	☐	— ☐	☐
REMBLAI PRIMITIF(m)-Ess. densité	☐	☐	☐	☐
REMBLAI EMPRUNT(m)-Ess. densité	☐	☐	☐	☐
BETONNAGE — Echantillon	☑ ☑	☐ ☐	☑ ☐	☐ ☐

DESCRIPTION

Equipement de compaction : /

Coussin granulaire: /

Remblai d'emprunt: /

OBSERVATIONS: 1 changement de colonne à gauche

Mémo ☑
Contremaître: M. Tremblay
Inspecteur: [signature] Date: 82-05-31
Approuvé: [signature] Date: 82/06/01

FIGURE 4.5.1: Foundation technical record
(courtesy: Transmission lines department,
Hydro-Quebec)

HYDRO-QUEBEC
CONSTRUCTION DE LIGNES
FORMULAIRE CL-2.2 Rev.0

FICHE TECHNIQUE
BATTAGE DE PIEUX

PYLONE #

PROJET

Entrepreneur : ____________________

TYPE DE PYLONE: ____________________
MAT/pat: ____________ RALLONGE. ____________
DATE: début ____________ fin ____________

EQUIPEMENT

TYPE DE PIEU
TUBULAIRE: ____________
HP: ____________

SOUS TRAITANT: ____________________
NOMBRE DE PIEUX: ____________ LONG. DE PIEUX PREVUE. ____________________
MARTEAU: marque ____________ poids ________ chute ____________ coups/minute ____________
MATELAS D'AMORTISSEMENT. ____________________ REFUS DEMANDE: ____________ coups/cm

PIEU TYPE No.
Nombre ________ coups/m.

1		11		21		31	
2		12		22		32	
3		13		23		33	
4		14		24		34	
5		15		25		35	
6		16		26		36	
7		17		27		37	
8		18		28		38	
9		19		29		39	
10		20		30		40	

SCHEMA & LOCALISATION

N: NOMBRE DE COUPS/Cm. POUR LES DERNIERS CENTIMETRES.

PIEU No 1		PIEU No 2		PIEU No 3		PIEU No 4		PIEU No 5	
Cm	N	Cm	N	Cm	N	Cm	N	Cm	N

PIEUX	PIEU No.1	PIEU No.2	PIEU No 3	PIEU No.4	PIEU No.5	TOTAL
LONGUEUR FONCEE (m)						
LONGUEUR RECUPERABLE (m)						
LONGUEUR NON-RECUPERABLE (m)						
JOINT D'EPISSURE						
SABOT						

OBSERVATIONS: ____

Mémo: ☐ Inspecteur: ____________ Date. ____________
Contremaître ____________________ Approuvé: ____________ Date: ____________

FIGURE 4.5.2: Pile driving technical record (courtesy: Transmission lines department, Hydro-Quebec)

HYDRO-QUEBEC
CONSTRUCTION DE LIGNES
FORMULAIRE C-...

COMPILATION DES RESULTATS D'ESSAI
— BETON (Fondations) —

PROJET:

Entrepreneur: ______________________

PERIODE.
Du ______________ au ______________

PYLONE		ECHANTILLON		DATE		ENDROIT	RESISTANCE			OBSERVATIONS
No.	Type	Moule	No.	Prélevé	Essai					

COMPILE PAR: ______________ VERIFIE PAR ______________ DATE: ______________

FIGURE 4.5.3: Foundation Concrete test record (courtesy: Transmission lines department, Hydro-Quebec)

in Figure 4.3.4. After the progress curve is verified by the responsible inspector, it is attached to the weekly report.

The delivery of the line conductors begins during the erection of towers. The conductors are delivered to set up points along the right of way, the conductors reels are hauled to these locations by a truck, then transferred from the trucks to the reels supports using a truck mounted crane. When the reels are empty, they are loaded on the trucks and returned to the suppliers.

Before the stringing of the conductors starts, the reel supports are set-up along the line, They are spaced at intervals which vary from 3 kilometers to 8 kilometers depending on the terrain, the design of the line and the ease of access. Roadway structures, if necessary, are also erected before the stringing operation. They consist of a wooden structure to hold the conductors at sufficient height during stringing to prevent interference with traffic or with aerial facilities.

The stringing of each conductor is performed with a bulldozer that drags the conductor along the right of way from tower to tower. At each tower, the conductor is detached from the bulldozer and a lead line is used to pass it through a traveller on the tower arm. The conductor is then re-attached to the bulldozer and dragged to the next tower and so on until the conductor is pulled along all the line. It is then attached to the anchor tower, with a dead-end insulator assembly. The next step is to connect a winch to the conductor at the starting end of the line, The slack is then pulled out of the conductors until the designed tension and ground clearance are obtained. Then, the conductor is cut and attached to the starting tower with a dead-end insulator. Finally linemen replace the travellers at each intermediate tower with permanent clamps that connect the conductor to the insulators.

The contractor submits updated weekly progress curves for the conductors stringing and for the conductors clamping. The reports are verified by the responsible inspector, then forwarded to the construction manager who includes them in the weekly report.

The installation of the counterpoise may precede or follow the conductors stringing and clamping. The operation consists of burying a galvanized iron wire under the line conductors to reduce system outages caused by lightning. The conterpoise is buried along the right of way using a bulldozer. It is buried about 50 centimeters deep and connected to the tower legs.

The activities discussed above are the main activities of the transmission line construction. The less critical and time consuming activities are the installation of guys, for guyed towers; the installation of the overhead ground wires, the insulators and the hardware. The guys are installed after the tower is erected and bolted, but before the conductor stringing; the overhead ground wires are installed in the same manner the conductors are, but faster because of their smaller number, one for each phase, and lighter weight; the insulators and the hardware installation starts as soon as the tower is erected and are carried-out by linemen parallel to the other construction activities.

4.6 Restoration Measures and Commissioning of the Transmission Line

During the site construction of the transmission line mitigation measures, to reduce the negative environmental impacts of construction are applied whenever possible. When the transmission line is completed, restoration measures to reinstate the site and correct any environmental impact that has occured are applied. The restoration measures begin once the construction of the line is completed and usually end before the acceptance and commissioning of the transmission line. Applicable restoration measures are part of the contractor scope of work.

The main items restored in a transmission line project are the right of way, the warehousing yard and the access routes. The right of way restoration consists of the rehabilitation of areas disturbed by construction activities. Tower assembly and erection areas are graded to fill in ruts and holes. On arable land, the top soil is reinstated and surplus excavated material is removed to a disposal area. All disturbed and selective cut areas are seeded to a cover crop. Trees and shrubs may be planted at visually sensitive locations to increase vegetation left on the right of way. Planting is also done as an errosion control measure.

The restoration of the warehousing yard begins when all materials are removed and the yard is of no futher use. The fencing and gravel are removed and topsoil is redepposited. However, when it is planned that the yard will be used for another line to be constructed in the same right of way in the future, the restoration measures are limited to clean-up, grading and seeding.

Once construction is completed, the access routes are restored to as close as possible to their original condition. To achieve this restoration it is necessary to carry-out some or all of the following measures.

- Removing culverts and bridges,
- Grading access routes,
- Relieving soil compaction,
- Removing road gravel from arable land,
- Replacing top soil, and
- Seeding with cover crop.

Besides the three main measures discussed above, other restoration or compensation measures are applied in special cases where different items are affected. For example, crop loss in arable land or loss of livestock are financially compensated and damaged areas restored. Damage to farm equipment is also offset by financial compensation.

The final acceptance of the work and commissioning of the line, is carried-out once all the construction and restoration measures are completed. The commissioning of a transmission line is a very straight forward operation to compare with other construction projects where the interaction between the different mechanical and electrical systems are numerous. On short lines, the acceptance is carried-out for the whole line once it is completed. For long lines, the acceptance is usually accomplished by sections varying from 10 to 20 kilometers in length depending on the type and on the size of the line. Before the acceptance certificate is prepared and signed, the contractor site agent, together with the construction manager or their representatives, perform an inspection on all the line components and record discrepancies, if any. Once the discrepancies are rectified, parts (A) and (B) of the completion and acceptance certificate, a sample of which is shown in Figure 4.7.1, are completed and signed. In part (A) completed work and work not included or performed by others is identified. Also in part (A), both parties certify that their respective staff are advised of the date at which the line is planned to be under tension and that the site will be cleared.

After the line is accepted by the construction department from the contractor, it is transfered to the "Production and operation" Vice-Presidency, (refer to Figure 1.4.1 of Chapter 1). Before the line is

Réception des travaux de ligne
Construction de lignes

Certification (partie A)

ligne	section	
entrepreneur	nº d'appel d'offres	nº de réq. de travail

Item 1 à 12 – aériens / 10 à 16 – souterrains

1 ☐ Déboisement
2 ☐ Montage des structures
3 ☐ Installation des câbles de garde et des conducteurs
4 ☐ Installation des cavaliers de ligne
5 ☐ Remblai final
6 ☐ Installation des contrepoids
7 ☐ Raccord aux structures des postes
8 ☐ Branchement de l'appareillage 1) 2)
9 ☐ Raccord des dérivations au pylône Nº de la ligne
10 ☐ Installation des dérivations aux postes 1) 2)
11 ☐ Enlèvement des mises à la terre temporaires
12 ☐ Inspection et vérification finale
13 ☐ Canalisation, puits d'accès et socles
14 ☐ Pose de câbles et jointage
15 ☐ Stabilisation de pression d'huile
16 ☐ Essais: continuité électrique, etc.

observations:

Nous certifions en outre que:

☐ Notre personnel a quitté les chantiers
☐ Nous avons avisé notre personnel de considérer cette ligne sous tension à compter de

heure	j	m	a

pour l'entrepreneur	j	m	a	pour l'Hydro-Québec	j	m	a
surintendant				coord. des travaux			

Réception (partie B)

Les travaux susmentionnés sont reçus et acceptés. La ligne

Circuits, Nºs

Être mis(e) à l'essai

adm. des travaux territoire	j	m	a

Transfert à l'exploitation (partie C)

Par la présente, nous transférons officiellement la ligne susmentionnée pour essais et exploitation commerciale.

chef de service Liaisons	j	m	a	directeur Construction de lignes	j	m	a

Mise en exploitation (partie D)

☐ La ligne susmentionnée, a été reçue pour essais et mise en service le

j	m	a

Mise en service commerciale (partie E)

essais ☐ tension ☐ ohmmage

signature	j	m	a

FIGURE 4.7.1: Completion and acceptance certificate (courtesy: Transmission line department, Hydro-Quebec)

transfered, the chief of the transmission line construction department completes part (C) of the acceptance certificate, certifying that the line is officially transfered for commissioning and commercial operation. The responsible region, before accepting the line for commissioning, verify that the new line can be integrated safely into the electric grid. Once this verification is completed, the line is put under tension and the commercial operation of the line may begin. Parts (D) and (E) are completed and signed after this last stage to certify that the line is officially a part of Hydro-Quebec grid and is in commercial operation.

4.7 Construction Phase Control and Proposed Improvements

Presently, during the construction phase, control is performed on the project technical content, the quality of materials, the schedule and the cost. The control over the project technical content is carried-out by the engineering department through the verification of the technical records presented in Figures 4.5.1, 4.5.2, and 4.5.3, and through site visits. The control over the quality of materials procured for the transmission line is performed through the inspection of fabrication. The material quality control is described in detail in section 4.2 of this chapter. The construction schedule is controlled through the progress reports of the various construction items like piling, tower assembly, tower erection, conductors stringing and clamping. The progress reports of the transmission line construction components is presented in Figures 4.3.3 through 4.3.7. Because the transmission line construction contracts are awarded on a lump sum basis, the project the project construction cost does not substantially deviate from the final estimated based on the control figures. For this reason, the construction cost control is basically a reporting of cost incurred to date and revising the final cost forecast, if necessary. Monthly payments are approved on the basis of the percentage of work completed to date as stated in the various progress reports and verified by Hydro's inspectors. The cost control in the case of lump sum contracts, is obviously more important to the contractors than to the owner.

There is room for improving the construction control, particularly when it relates to schedule. The presently used system does not directly give a picture of the overall status of the project without combining and analysing figures. The transmission line construction schedule deserve more attention, also, due to the fact that the commissioning of the line is usually linked with the operation of other facilities as substations or industrial plants.

Figure 4.8.1 shows a proposed bar-chart schedule which indicates at the end of each month the scheduled and actual percentage complete. This bar-chart schedule should be consistent with the critical path of the project. An extra information can be provided on this sheet by superimposing the budget and up-to-date project cost in the form of S curves. A monthly update of this schedule will directly demonstrate the weak areas where more field effort is required to meet the project commissioning date.

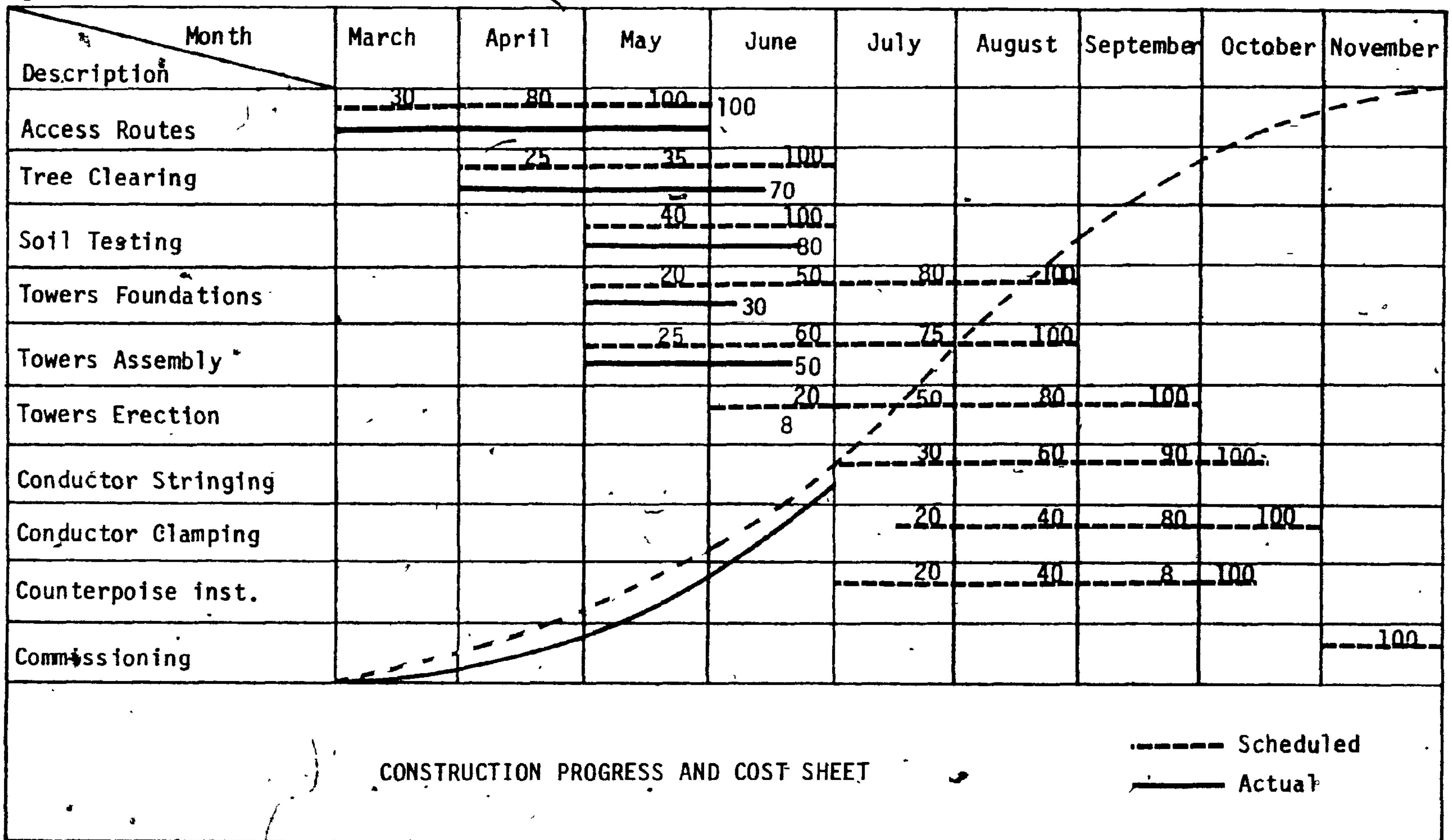


FIGURE 4.8.1: Construction Schedule and cost summary

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Highlights of the Investigation

The investigation has attempted to provide an in depth description of the aspects related to the design, environmental impacts, governments approvals, information of the public and of the management of engineering and construction of a high tension transmission line project in the province of Quebec.

Based on present practice in the province, the organizational structure of the public utility firm responsible for the planning, production, transmission and distribution of electric power is first described with a focus on the operation of the transmission line department. A description of the transmission line and its components is also included.

The three different phases of a transmission line project: the feasibility phase, the engineering phase and the construction phase are investigated. The process of planning and initiating the start of a transmission line project is described and the studies necessary to complete the feasibility phase are identified. Further, the feasibility phase control tools are exposed and possible improvements to them are proposed.

The different studies necessary in the engineering phase are investigated, the process of awarding engineering works to consulting firms and how they are controlled are studied, and the process of preparing bidding documents and awarding the construction contracts are also studied. Further, the engineering phase control tools are exposed and proposed improvements are analysed.

The organization and control of the transmission line construction site are discussed. Further, the quality assurance of the line materials, the methods of construction of the transmission line and the restoration measures carried-out once the construction is completed are investigated. Construction control is described and improvement to the reporting system is suggested.

5.2 Discussion of the Results

The investigation presented in this report provides information on the management of engineering and construction of the transmission line projects. The investigation shows that, although the engineering and construction of a transmission line are, generally speaking, similar to other construction projects, they have specific aspects which differ from other construction projects. The engineers and managers working on transmission lines should be aware of those aspects and should accomodate them in order to be able to successfully complete the project within the target date and the budget. The aspects specific to the Transmission Line are discussed below.

To construct a Transmission line project numerous government authorizations have to be obtained from both the provincial and the federal governments before starting the construction. The reasons for that are the great number of other public facilities the line may cross. The environmental impact the line may have on urban and agricultural areas, and the possible expropriation of land necessary for the line right of way. Accordingly, the engineer should be aware of the government authorizations required, which apply to his project, how long do they take to obtain and is it feasible to modify the design or the line route to avoid some of the authorizations which are prospect for contestations and delays.

On transmission line projects, environmental considerations play an important role in the choice of the line corridor, on the type of supports to choose, and on the type of government authorizations to request. The engineering of the line as well as the duration of the project and its cost are largely affected by the results and recommendations of the environmental study.

The public reaction to the project and to the different options of the line corridor plays an important role on the choice of corridor decision, on the inclusion of mitigation measures during the line construction and on the inclusion of restoration measures upon completion of construction.

Because of the expropriation power, that the public utilities can obtain from the government to acquire the right of way, negotiations with the land owners have to be accomplished based on a careful evaluation to offer a fair price to the landlords. Expropriation is only attempted when negotiated settlements cannot be reached.

In transmission line construction, to compensate for the negative visual effect of the towers and conductors, selective tree cutting to clear the right of way and restoration measures once the line construction is completed are becoming increasingly important and should be considered in the planning and cost estimates of the future transmission lines.

5.3 Recommendations

The control tools presently used in the management of transmission line projects could be improved in some areas. The feasibility phase control tools lack an integration of cost, schedule and performance. Also, they do not provide an early warning for cost overruns. To improve the control of this phase, the project cost, schedule and progress should be integrated in the form of a status report. This will enable management to assess project progress quickly by giving an evaluation of the true percent completion.

The engineering phase control tools are, generally speaking, similar to the ones used for the feasibility phase. They can be improved by providing the relation between budgeted cost and actual performance. This relation can be provided by applying an "Earned value" based control system. Such a reporting system can clearly indicate where control is needed and it does so in time to permit effective action.

The construction schedule of the transmission line deserves more attention too, because the commissioning date of the line is generally linked with the operation of other facilities. The inclusion of a bar-chart schedule which indicates at the end of each month the scheduled and actual percentage complete will directly demonstrate the construction weak areas to management.

Finally, because of the special nature of transmission line projects, it is recommended that the engineers and managers dealing with this type of project, study the following aspects of their project at an early stage of planning:

- government authorizations required for their specific project. How long do they take to obtain and the process of obtaining them;
- environmental constraints of the project and by how much do they affect the project cost;
- reaction of the local public to the project and the possibility of accomodating their concerns; and

- types of land crossed by the line, and the nature and number of properties affected by the construction of the future transmission line.

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