

3.0 LUCELEC DESIGN AND CONSTRUCTION STANDARDS

3.1 Existing Facilities

In general, no one edict exists governing the standards employed for the design or construction of Lucelec's existing facilities. Instead, standards have been chosen on a project-by-project basis. It was more difficult to obtain standards information for older buildings than for new ones. This is not to imply that Lucelec's newer buildings are of better (or worse) design or construction than their older buildings.

3.1.1 Earthquakes

No standards information relating to earthquakes was found for Lucelec's older buildings. The specifications for newer construction at Cul de Sac, Vieux Fort and Union required that power stations, substations and buildings generally (but not overhead line structures) be designed for USA Uniform Building Code Zone 3.

3.1.2 Hurricanes

No standards information relating to hurricanes was found for Lucelec's older buildings. The specifications for newer construction at Cul de Sac, Vieux Fort and Union required that a 1-in-50 year wind speed of 54 m/s be used in design.

If a 3-second gust speed is assumed, this represents a Category 3 hurricane. However, no averaging period was given for the wind speed. The specification of design wind speeds must be done in relation a particular averaging period over which the wind is measured. Typical averaging periods are 1 hour (Canadian Code), 10 minutes (Caribbean Uniform Building Code and ISO), 3 seconds (Barbados Association of Professional Engineers Wind Code and British Standards) and fastest mile (USA traditional codes).

3.1.3 Torrential Rains

No requirements were found relating to torrential rains although, for recent projects, average monthly rainfall data over the previous 10 years was provided.

3.1.4 Tsunamis

No requirements were found relating to Tsunamis.

3.1.5 Storm Surges

No requirements were found relating to storm surges.

3.2 Proposed Facilities

As for the existing facilities, there is no policy manual stipulating the standards to be employed for the design and construction of new facilities. This matter will be addressed in greater detail in CEP's Final Report, where standards will be recommended for use in future design and construction.

3.2.1 Earthquakes

Plans for the construction of a third 7MW set at Cul de Sac require that power stations, substations and buildings generally (but not overhead line structures) be designed for USA Uniform Building Code Zone 3 with an Importance Factor, I, of 1.25.

3.2.2 Hurricanes

Plans for the construction of a third 7MW set at Cul de Sac require a 1-in-50 year wind speed of 54 m/s be resisted. (Again, no averaging period has been specified.)

3.2.3 Torrential Rains

For the proposed third 7MW set at Cul de Sac, no design requirements are given for torrential rains although average monthly rainfall data for the period 1974 to 1985 are provided.

3.2.4 Tsunamis

For proposed construction, no provisions were found relating to tsunamis.

3.2.5 Storm Surges

For proposed construction, no provisions were found relating to storm surges.

4.0 VULNERABILITY OF EXISTING FACILITIES

4.1 Investigation Procedure

Lucelec's buildings at 8 locations in St. Lucia, along with ancillary structures and drainage provisions, were examined. The examination was by way of:

- (i) visual inspections, during which several photographs (reproduced in Appendix B) were taken;
- (ii) interviews with personnel familiar with the various buildings, including:
 - Mr Christopher Mitchell - Chief Engineer,
 - Ms Celia Williams - Projects Engineer,
 - Mr Frederick Isaac - Assistant T&D Engineer,
 - Mr Anthony Modest - Buildings Supervisor,
 - Mr Alexis Compton - Drawings Manager,
 - Mr Felix - Generation Supervisor;
- (iii) reviews of available specifications and drawings;
- (iv) examination of 1:25000 map for St Lucia to obtain heights above mean sea level (msl) for the various sites. The map provided contours at 25-foot intervals. (All heights above msl given in the report are approximate.)

4.1.1 Available Specifications & Drawings

The following specifications and drawings are available, all stored at Lucelec's Cul de Sac facility:

Specifications

Cul de Sac,
Vieux Fort and

Union: Technical Specifications for Civil Works for 1986-to-1989 Development Programme;

Drawings

Castries: fairly full architectural set for Administration Building by Interisland Architects & Planners; layout drawings for Substation;

Cul de Sac: full set of general arrangement drawings and some architectural, civil and structural engineering details for the structures on site by Balfour Beatty and Higgs & Hill;

Soufrière: 1991 Power Station renovation drawings - layouts and elevations only;

Union: Power Station layout and elevations; Auxiliary Plant Building - general arrangement drawings and some details by Balfour Beatty and Higgs & Hill;

Vieux Fort: Power Station layout drawing; Substation - general arrangement drawings and some details by Balfour Beatty and Higgs & Hill; Administration Building layout drawing.

4.2 Castries

4.2.1 Administrative Offices

The Castries Administrative Office Building (Photo 1) is located near to downtown Castries at an elevation less than 25 feet above mean sea level (msl) not far from the shoreline of Port Castries. The site is part of a larger area of relatively flat land with rising land commencing at some distance away. No unusual modifications of high winds are expected for this site.

A large drain adjacent to the site (Photo 2) takes overland and collected stormwater flows from the site (and from the properties located further upstream) to the nearby bay. There is no record of flooding of this drain and the site's stormwater provisions appear adequate for a 1-in-20-year storm. However, because of its low elevation and, therefore, greater susceptibility to flooding in the event of a storm surge, further investigation will be conducted with regards to storm surge and flooding.

Full sub-strata information has not been obtained at this time but it is known that the building is founded on piles. The consultant responsible for the foundation design will be contacted to confirm what design criteria were used and to confirm that effects due to earthquake action, such as liquefaction, were taken into account, if relevant.

The Castries Administrative Office Building (Photo 1) possesses a reinforced concrete structure (columns, beams, slabs). The external cladding contains expanses of glass which would be vulnerable to breakage by airborne debris during a hurricane. The fixing details for the building's cladding will be further investigated and sturdy storm shutters should be provided to the glass windows and doors, including those windows on the roof (Photos 7 and 8).

In the middle of the concrete slab roof, there is a hipped lightweight atrium roof (Photo 3). The hipped shape is a favourable one for resisting high winds. The asphalt waterproofing tiles are liable to being stripped off by a Category 3 hurricane but the timber deck on which they are supported is likely to remain intact.

Photo 4 shows a typical connection of the lightweight roof rafters to the supporting beam. It consists of two 10mm diameter mild steel bars bent over the rafter to hold it down. The bars are nailed onto the rafter only on the legs which are embedded into the beam. This connection detail should be retrofitted by nailing the free legs of rebar onto the sides of the rafter. This will help prevent the loss of the roof due to the bars straightening out under repeated uplift wind forces. Under hurricane conditions, a lightweight roof is only as strong as the connections between its members and the rest of the structure.

It is important that hardware for external doors be well maintained. For example, even though the door to the roof (Photo 5) is of sturdy construction, it was not possible to close it securely during our visit. The bolts for this door should be repaired

Photo 6 shows a partial view of the building's roof. During our visit, the water tank on the roof was overflowing (Photo 9) resulting in pools of water standing on the slab (Photo 6). The entire roof is drained at one point only by two 8-inch diameter downpipes (Photo 10). If these outlets become blocked, then the roof would be easily flooded. However, this would result in only minor inconvenience as water cannot enter the building even from a flooded roof. Nonetheless, the drainage of this roof can be improved by installing additional downpipes and screeding the slab to greater falls.

4.2.2 Sub Station

Views of this building are shown in Photos 11 and 12. It is presently under construction and located on the site of the old Castries Power Station at an elevation of less than 25 feet above msl. The surrounding area has a history of flooding problems during torrential rains. To mitigate against flooding, the floor of the substation has been constructed at a raised level. The comments made about the Castries Administrative Offices in relation to storm surges are also pertinent for this building

No topographic modification of wind speeds is expected for this site

The substation building is of steel-framed construction with infill reinforced concrete blockwalls and double-skinned aluminium roofs. The walls are tied to the steel structure and openings are small. The standard of detailing and construction is adequate and this building is expected to show good resistance to earthquakes and Category 3 hurricanes. Steel-framed, sheeted buildings are inherently safer against earthquake loads because of their greater ductility and light weight

4.3 Cul de Sac

4.3.1 Cul de Sac Site

A view of the Cul de Sac site is given in Photo 13. It lies between 100 and 200 feet above msl. Storm surges are not relevant here

The site is fairly open on three sides (Photo 13) with more hilly ground to the south east (background, Photo 14). In essence, the Cul de Sac compound is situated within a very shallow basin which is not expected to modify significantly the speed of winds blowing over it.

During our visit, an examination was made of the stormwater drainage provisions on the site. All precipitation from roofs is collected for use in the power station. Photos 15 and 16 show two examples of drainage structures servicing pavements and landscaped areas. The drainage provisions are considered adequate for storms with return periods of not more than 20 years. All of the drainage provisions were found to be well maintained.

The structures at this site were erected as part of one contract, completed during 1989. There is a consistent standard of design and construction on the site. Comments made will more often than not apply to most structures.

4.3.2 Power Station / Administrative Offices

Views of this building are shown in Photos 17 and 18. The Administrative Offices occupy the two storey wing on the left. The Power Station / Administrative Office Building is of a compact shape with few openings in its envelope. These are favourable factors for resistance to hurricane force winds. The building's ridge ventilator (Photos 17 and 18) is a good feature which, if left open during a storm, will prevent the build up of internal pressure so reducing the chance of the roofing being lost.

The building is thought to be clad with 0.6 mm thick aluminium sheets. This is to be verified. 0.6 mm is thinner than would be recommended for aluminium roof cladding in hurricane prone areas. One mitigating factor is that the cladding screw fixings occur at every sheeting corrugation on most purlins (similar to fixings shown in Photo 49). This is a conservative fixing layout.

It is important that a building's openings not be breached during a storm. Two doors on the Power Station / Administrative Office Building are shown in Photos 19 and 20. The workshop's accordion door (Photo 19) is of relatively robust construction and is expected to show good resistance to high winds. The door and its hardware should be maintained in good condition. During the visit, the main roller shutter door to the power station (Photos 17 and 20) was not closely examined. This large door will be further inspected. It is very likely that storm stays would need to be provided to ensure that this door remains in place during a storm. Storm shutters should be provided for external glass doors and windows (Photo 21) to prevent them being damaged by airborne debris.

Photo 22 shows a view inside the power station control room. This is an important room, especially in the aftermath of a hurricane. Double-skin aluminium roof cladding occurs above the suspended ceiling. If this cladding is lost, then the control room will be exposed to the elements. It is recommended that the existing ceiling be replaced with a robust, water-resistant deck which will remain intact, as a second line of defense, even if the roof is lost. Similarly, tarpaulins should be stowed to provide cover to any equipment in the Power Station which could be damaged by water.

Views of the exhaust stacks are shown in Photos 23 and 24. On first examination, these appear adequately constructed and fixed down to resist Category 3 hurricanes. However, further investigations will be carried out for these aerodynamic structures.

The Power Station contains a varied cluster of machinery, stacks, tanks and interconnecting pipes. Under the action of an earthquake, machinery will be vulnerable to toppling (especially where "top-heavy") and pipes to breakage. A variety of machinery, tanks and pipes are displayed in Photos 17 and 23 to 31. All machinery fixing details should be bolted down, as necessary, to prevent dislodging during an earthquake. These fixing details should be maintained in good condition. Important pipes should allow for movement to prevent breakage during earthquakes.

4.3.3 Peak Lopping Station

Views of this steel-framed building are given in Photos 32 and 33. It has been erected more recently than the other buildings on the site and is of a lighter standard of construction. The Peak Lopping Station is expected to show reasonable resistance to Category 3 hurricanes.

In respect of the earthquake hazard, attention should be paid to the fuel tanks (Photo 34) and stacks (Photo 32, 35 and 36). The tanks (Photo 34) are at high level but not fixed down to their supporting frames. They therefore stand a good chance of toppling over during an earthquake. The tanks should be securely connected to their supporting frames. Lateral support has been provided to the stacks (Photos 35 and 36) by way of small plates at the base, a strap near mid-height and the connecting pipe to the engine. The strap forms an important restraint. Better restraint can be provided by adding two additional uprights on the inside of the frame to hold the stack snugly in place.

4.3.4 Stores

The Stores Building is shown in Photos 37, 38 and 39. This building is expected to show good resistance to Category 3 hurricanes.

The building's roller shutter door is shown in Photo 40. When pushed on, the door was found to deflect easily. Under high winds, excessive deflection may result in this door being removed from its tracks. It is recommended that storm stays be provided to these doors.

A typical external door is shown in Photo 41. The glass panel is of strengthened glass and the door is of sturdy construction. It is recommended that storm bolts be fixed at the top and bottom of the door. Storm shutters should be provided to glass windows (Photo 42).

4.3.5 Workshops

The Workshop Building can be seen in Photo 44. As for the Stores Building, storm bolts should be provided to external doors and storm shutters to windows.

Photo 14 shows the covered area adjacent to the Workshop Building. The loss of this building will not be critical but a discussion of it here would be illustrative. The garage possesses a relatively flat mono-pitched roof and has one completely open side and the other three closed. Flat roof shapes are the most vulnerable to high winds. Also, during a hurricane, wind blowing onto the side with the dominant opening would lead to a build up of pressure under the roof. These two factors act to increase the vulnerability of the covered area. However, the building's structure is of very conservative design and, at most, loss of sheeting only is expected during a hurricane.

4.3.6 Transmission & Distribution Building

The Transmission & Distribution Building is shown in Photo 46. It is expected to show good resistance to Category 3 hurricanes. Earlier comments made for external windows and doors apply here.

4.3.7 Garage

Views of the Garage are shown in Photos 47 and 48. Earlier comments for glass windows, roller shutter and other external doors apply here.

4.3.8 Gate House

Once storm shutters are provided to the windows and once the doors are securely bolted, this compact concrete-roofed building is expected to be undamaged by hurricanes. Because of its compact configuration and modest scale it is also expected to be resistant to earthquake loads.

4.3.9 Incinerator

The Incinerator is shown in Photo 51. Good resistance is expected to the earthquake hazard. Loss of sheeting and the possible collapse of the exhaust stack can be expected during a hurricane.

4.3.10 Fuel Tanks

Photo 52 shows a view of the main fuel tanks on the site. Enquiries will be made of the fabricators to determine the design criteria used.

4.3.11 Water Tank on Hill

The Water Tank is shown in Photos 54 and 55. It is constructed of steel plates rivetted together. Enquiries will be made of the fabricators to determine the design criteria used.

4.4 Soufrière

4.4.1 Soufrière Site

The Soufrière facility is due to be phased out as a primary facility shortly and retained for standby use only.

The site is below the level of the surrounding lots. It drains to a large channel which eventually flows into the sea. The drain connecting the site to the channel is large and unlikely to become blocked. There is no history of flooding of the facility site. The site lies between 25 and 50 feet above msl. The facility is unlikely to be damaged by storm surges or torrential rain.

4.4.2 Power Station

Photo 56 and 57 show the Soufrière Power Station. With regards to the hurricane hazard, the pitch of the gable roof is favourable (the best pitches are between 15 and 40 degrees from horizontal) and the roof structure (Photo 57) is adequate. Much of the sheeting is corroded and this renders it more vulnerable to high winds. However, the loss of the entire roof would not be critical since the machinery is housed in strong steel containers.

Many older buildings in the Caribbean possess lightly-reinforced or unreinforced concrete blockwork walls. There have been many examples of unreinforced blockwalls being damaged or destroyed by high winds and, of course, such walls are also likely to suffer during an earthquake. Collapsing walls may cause some damage to the steel containers and also to the equipment located adjacent to the walls on the outside. The adequacy of the reinforcement in the walls for hurricane and earthquake loads could be checked by destructive testing or cover-meter investigation.

4.5 Union

4.5.1 Union Site

The Union site is located at about 25 feet above msl in a wooded area. At the front (west) of the site, the land slopes very gently towards the sea. At the back (east), the land rises steeply (Photo 58). The stability of the cliff face should be investigated. The site lies on flat land near the foot of the slope.

The site drains to a nearby stream located on its west side. This stream eventually outfalls to the sea. Most of the site drainage occurs by surface flow to the stream. It was reported that no flooding has occurred on the site, at least since 1978. However, it is known that changes in upstream development have occurred. These changes may have a significant effect on runoff reaching the site. Wider watershed knowledge is necessary for a fuller evaluation of this site with respect to its flooding potential.

4.5.2 Power Station

Various views of the Union Power Station are shown in Photos 58 to 61. The building is steel-framed with low-pitched, light-weight, gabled roofs. Slopes below 15 degrees are not favourable for resisting high winds.

The roof and side cladding are of asbestos. The roof is reported to be leaking and is due to be replaced shortly. The replacement asbestos sheeting is already on site. Asbestos sheeting is not recommended for use in hurricane areas because of its brittleness. This makes it susceptible to breakage by airborne debris. It is recommended that the roof be replaced with metal rather than asbestos sheeting. J-bolt fixings should not be used as at present (Photos 62 and 63). Such fixings have a tendency to straighten out and be lost under repeated uplift wind loads.

The building features a large opening at the front (Photo 64) for which there is no door. During a hurricane, if the wind blows onto this side of the building, air pressure will build up inside. This is because there is no similarly sized exit on the other side of the building through which the wind can escape. Eventually, this may result in the outward movement and loss of the roof and/or side cladding. If feasible, the size of this opening should be reduced and a storm-resistant door installed.

The exhaust stacks and their fixing details are shown in Photos 65 to 68. The fixing details are adequate for moderate hurricane loads. The stacks can be made more secure by fixing the bases of the stacks to their support legs. It is important that these connections be inspected and repaired, when necessary, as part of a formal maintenance programme for the facilities.

As discussed earlier, it is important that machinery and tanks be secured against dislodging during earthquakes. For example, the tanks shown in Photos 69 and 70 rest under their own weight on the supporting frames but are not actually attached to them. Lateral forces could therefore result in these tanks falling. The tanks should be secured to the supporting frames.

Outdoor fuel tanks at Union Power Station are shown in Photo 71 and their supports in Photo 72. These tanks are expected to show good resistance to hurricane and earthquake forces.

4.5.3 Auxiliary Plant Building

This building occupies a site near to the Union Power Station and was constructed at the time of the Cul de Sac project. It was not viewed during the initial survey. Consideration of this building will be included in the Final Report.

4.6 Vieux Fort

4.6.1 Administrative Offices

The Vieux Fort Administrative Office Building (Photos 73 and 74) is located on flat, open ground. No features exist in the surrounding area that would produce special wind effects.

There is no history of flooding of the site. It is to be determined whether the storm surge hazard is relevant. It was not possible to read the height of the site above msl from the available maps during the initial survey.

The building was constructed during 1990 and is of concrete blockwalls with a lightweight roof. The roof is of the favourable hipped shape (although a steeper pitch than existing would have been better). It is reported that the rafters are fixed down with purpose made hurricane straps. There is a timber ceiling to the relatively short roof overhang where it is not protected by the parapet. For this building, it is recommended that shutters be provided to the glass windows and the roof sheeting retrofitted with additional screw fixings to Engineer's details. This building is expected to show fair to good resistance to hurricane conditions.

4.6.2 Power Station

Photos 75 and 76 show views of the Power Station. The facility lies close to a harbour. The site's height above msl should be measured in order to determine whether the storm surge hazard is relevant. No unusual modifications of high winds is expected for this site.

The Vieux Fort Power Station building will be prone to significant damage during a Category 3 hurricane. The steel-framed structure is clad with asbestos sheets. As previously discussed, asbestos sheets are brittle and susceptible to damage from airborne debris. The sheets are fixed using J-bolts at erratic spacings (from approximately 150mm to 750mm apart). If it is not feasible to re-clad this building with metal sheeting, then sensitive equipment should be covered against impact and water damage before a storm.

Photo 78 shows the sliding door at the front of the Power Station. The door is of robust construction and held by tracks at the top and bottom. The bottom of one half of the door needs to be repaired so that it is securely held by the track.

The adjacent Welders' Shop / Washrooms (Photo 79) is expected to show fair-to-poor resistance to Category 3 hurricanes. The building's roof and doors require strengthening and storm shutters should be provided for the glass windows.

Views of the Power Station's exhaust stacks are shown in Photos 75 and 80. It should be ensured that the stacks are securely attached to the support structure so that they are not dislodged by lateral earthquake or hurricane loads.

4.6.3 Sub Station

Photos 81, 82 and 85 show views of buildings at the Vieux Fort Sub-station site. The site is situated on flat, open land and no unusual wind effects are expected.

The structures at the Vieux Fort Sub-station site were erected as part of the contract for the Cul de Sac project. The buildings at Vieux Fort are of similar design and standard of construction as those at Cul de Sac. Storm shutters should be provided to glass windows, door hardware maintained in good condition and storm bolts added at the tops and bottoms of doors, where not already installed.

Photos 83 and 84 show the open corner of the L-shaped Office building at the Vieux Fort Sub-station site. At present, this corner possesses the most vulnerable area of roof. The loss of this roof may cause damage to adjoining areas of roof which cover enclosed spaces. It is recommended that a strong ceiling be constructed under the roof of the open area in order to reduce net uplift forces on the sheeting during high winds.

4.7 Telecommunication Facilities

Lucelec currently has installed two antennae for radio communication, one located at its Cul de Sac site (Photo 86) and the other at The Morne. The latter has next to it a purpose-made building containing repeater equipment. It is planned to install antennae at two other sites.

The Repeater Buildings should, in future, be located away from trees or structures which may collapse on them during wind storms and be of hurricane and earthquake-resistant construction. Spares should be kept of the antennae themselves for replacement if lost during a hurricane.

5.0 PROGRAMME FOR THE REMAINDER OF THE PROJECT

5.1 The Manual

An important objective of the OAS Caribbean Disaster Mitigation Project is the dissemination of findings to the wider community. Therefore, as part of the Lucelec Vulnerability Audit, a Manual will be prepared for use by other utilities. The Manual will contain recommendations for the procurement of services, goods and equipment (in respect of damage mitigation) as part of future capital programmes. The following table of contents is proposed for the Manual:

Natural Hazard Damage Mitigation Manual for the Procurement of Services, Equipment & Goods

CONTENTS

- 1 Determining Project Scope
- 2 Selecting Consultants
- 3 Briefing and Coordinating Consultants
- 4 Deciding on Design Criteria
- 5 Reviewing Vulnerability Audits and Setting Implementation Priorities
- 6 Retrofitting and Maintenance (or Abandonment) of Existing Facilities
- 7 New Construction Projects
- 8 Procurement of Equipment & Prefabricated Goods

The Manual will benefit from inputs by all of the participants and CEP will be responsible for its final compilation.

5.2 Supplementary Field Surveys

In the body of this Inception Report, several recommendations have been made for further investigations. Once Lucelec and the other participants have had the opportunity to study these, then the scope and timing of supplementary field surveys can be determined. The knowledge of Lucelec's technical officers and the other participants will inevitably add valuable insight to the issues. It is envisaged that discussion of the Inception Report and the planning of supplementary work will occur on 1994-09-30 when the Inception Report is formally presented.

5.3 Supplementary Review of Documents

This activity will be guided by the discussion referred to in Sub-section 5.2. Sub-section 4.1.1 lists those documents available at this time. More careful scrutiny of some of these may be required as part of the supplementary investigations. It may also become necessary to examine documents obtained from other parties.

5.4 Supplementary Enquiries

As part of the supplementary investigations, it may become necessary to seek advice and information from parties outside the ambit of the OAS/CDMP. Such approaches will be made in collaboration with Lucelec and CARILEC.

5.5 Estimation and Analysis of Costs

Once the supplementary surveys, document reviews and enquiries have been completed, then a final schedule of recommendations for the retrofitting of the facilities against damage by natural hazards will be presented. The retrofitting measures will be individually cost estimated and the costs and underlying assumptions presented in appropriate form.

5.6 Consultations with BL&P

As previously mentioned, ad-hoc advice will be sought from BL&P on the implementation of recommended actions in the context of Lucelec's ongoing and planned capital and maintenance programmes.

5.7 The Final Report

5.7.1 Draft Report

This will be submitted for comment to OAS, CARILEC and Lucelec.

5.7.2 Review by OAS, CARILEC and Lucelec

The three parties will be expected to review and comment on the Draft Report within a reasonable time to permit an expeditious completion of the overall exercise.

5.7.3 Final Report

Copies of the Final Report will be issued to OAS and CARILEC for distribution to other organisations. Lucelec will be sent copies for themselves.

5.7.4 Presentation

An oral presentation of the Final Report and the Manual will be made by CEP.