TIME FOR A BREAK — LET'S HAVE AN EARTHQUAKE

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SUMMARY

The following paper recounts the loss of supply and subsequent restoration of the Bay of Plenty Electric Power Board's sub transmission and distribution systems following the advent of the Edgumbe earthquake of 2 March 1987. The paper details the effects on the Board's customers and staff, restoration procedures, and matters relating to the restoration of supply and repair of the distribution system. The emphasis is more on the operational and organisational aspects of the event, rather than being a report of structural damage and remedial repairs. Technical aspects of this sort are dealt with in greater detail by other organisations.

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INTRODUCTION

The title chosen for this paper may seem at first glance to be somewhat flippant, however the title has been chosen in order to bring to the reader's attention the effect the earthquake of 2 March 1987 had on the public. The magnitude of the quake, and its resultant ground movement, ranks alongside those quakes which have struck overseas locations with disastrous consequences (in terms of structural damage and loss of life). There was no loss of life and limited serious injuries sustained as a result of the earthquake. It could have been a lot more severe, and should enable us all to scrutinise the Board's response to this event in detail, without fear of appearing judgmental of the Board's response to the disaster. The title indicates that the earthquake could be regarded as a large scale exercise. It must be stated at the onset that the Board's staff were working under considerable stress, both as a result of the magnitude of the work in hand and also as a result of the conditions the relatives and friends of Board's staff were living under in the days immediately following the quake.

Another reason for the choice of the title emphasises the speed and finality of the earthquake. The suddenness of the main quakes on the afternoon of 2 March struck everybody by surprise. A series of small tremors some days before the main quake made people aware of the potential danger of earthquakes, however the public were completely unprepared for the quakes when they struck.

Electricity suppliers are well accustomed to coping with emergency situations, however the earthquake produced a situation which is inverted to the normal emergency that a supply authority would have to deal with. With emergencies such as floods and storms there is usually an escalation of damage, and staff are called out as the need arises. The earthquake produced damage to plant and equipment in a period of some twenty seconds.

The main shock struck the area at 1.42 pm and all damage had been sustained at that time. Subsequent to this main shock the ground was moving and shaking continuously for a long period. Table 1 gives an idea of the magnitude, extent, and frequency of main shocks. This situation proves stressful on the public and on staff, in that there is no indication as to the decay of after shocks and thus makes restoration procedures disruptive.

LOSS OF SUPPLY

Incoming supplies to the Electricity Corporation substations at Kawerau and Edgumbe were completely interrupted (refer to Figure 1). All 220kV and 110kV incoming lines bringing power into the Board's area had tripped. At Edgumbe the T2 transformer bank which supplies the Opotiki Substation at 50kV suffered damage, requiring replacement of one of the single phase units. The spare transformer, which is normally out of service and de-energised, was displaced from its mountings and all three banks suffered damage. Other transformer banks supplying the Board's load at Edgumbe and at Kawerau were also damaged and shaken off their mountings.

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TABLE 1 - EARTHQUAKE SEQUENCE SUMMARY

	Time	Magnitude
(a) Main Shocks		
	1335	5.2
2 March	1341	4.7
	1342	6.3
	1351	5.6
	1402	3.5
	1403	4.7
	1407	5.3
	1412	4.3
(b) Number of shakes with magnitude greater than 3.		
	2 March	119
	3 March	46
	4 March	16
	5 March	5
	6 March	3
	7 March	3
	8 March	3

FIGURE 1 LOCATION DIAGRAM SHOWING THE EXTENT OF THE BAY OF PLENTY ELECTRIC POWER BOARD'S AREA

As a result supply was lost to the Board's entire distribution area with the exception of Galatea and Murupara.

At the time of the earthquake the Board's No.1 Generator at Aniwhenua was synchronised to the grid. No. 2 Generator had been out of service for its annual overhaul and was in the process of being reinstated. Immediately after the earthquakes No. 1 Generator became disconnected from the grid as a result of the protection operating on the 110kV line to Matahina. The Generator remained in service however, and continued supplying the Murupara area of the Board as an isolated system. Maintenance staff at the Station was diverted to immediate inspection of all plant, and to surveillance of the civil structures and embankments. Continuous readings were taken of all standpipes and drain outfalls for some hours after the main shock. Flows from drains increased as a result of the quakes, but had reduced to normal by late evening. No. 2 machine was reinstated at an accelerated rate, was commissioned shortly after midnight, following test runs, and was available for service to supply load at Whakatane. The Aniwhenua scheme continued to supply load as an isolated system until approximately 0600 hours on 3 March when grid supply was restored. Many 11kV and 415V wires were severed by the swaying motion of the poles. On all the lines there were instances of binder and cross arm breakage resulting in falling or displaced conductors. In several cases poles sunk into the peaty soil in the rural areas surrounding Edgecumbe, and the extreme movement of poles during the earthquakes caused a number of the pre-stressed concrete poles used by the Board to break at ground level.

DAMAGE TO THE BOARD'S SYSTEM

Plains Zone Substation, Edgecumbe

At the Board's Edgecumbe 33/11kV zone substation the four single phase units of

the 10MVA supply transformers toppled backwards and impacted with the overhead 11kV bus bars. The units suffered broken 11kV insulator bushings and damage to oil coolers. The 11kV overhead bus bars, isolators, and supports in the outdoor substation had been extensively damaged. Substation equipment is supported on reinforced concrete poles and a large number of these have cracked, a couple were broken at ground level.

Distribution System

There is little doubt that the overhead reticulation system suffered to a greater extent than the underground system, but this could be attributed to the bulk of the system in the damage zone being constructed overhead. Underground cables located near the areas of ground stress were damaged, and other latent cable faults undoubtedly exist. Damage to the Board's distribution and sub transmission system was sustained to an area spread either side of the evident fault line passing through Edgecumbe, Te Teko and Kawerau. Damage was also sustained by secondary causes, such as slipping and slumping of the unstable ash soil in areas surrounding Kawerau and towards the West. Aerial structures were dislodged and required straining or reblocking. At least one reticulation transformer pole collapsed.

The number of broken poles (where the concrete cracked at ground level) totalled approximately 10-20. A couple of these poles were broken as a result of a slip. The Board's wooden poles in general survived without breakage, although a few of them did actually twist, resulting in localised splitting of the hardwood poles. One pine service pole snapped at a knot.

FIGURE 2 REPAIRING DAMAGED 11KV OVERHEAD BUS AT THE PLAINS ZONE SUBSTATION, EDGE CUMBE

FIGURE 3 DAMAGE TO 415 VOLT SERVICES IN EDGE CUMBE

FIGURE 4 MOVEMENT OF 11KV TWO POLE SUBSTRUCTURE

Two 11kV underground spur lines were damaged to the extent that temporary aerial connections were required.

RESTORATION OF SUPPLY

Restoration of supply took several days, the procedure was shaped by two objectives:

1. To provide secure supply as quickly as possible to the emergency services (including hospitals, civil defence, service stations etc).
2. Provide supply as quickly as possible to customers in order to provide a sense of security and comfort in the "clean up" period (including dairy sheds for milking, streetlighting, domestic power).

It was interesting to note that the presence of the large number of Power Board vehicles in the injury zone in the hours immediately following the earthquake had a comforting effect upon the public. Likewise the speedy restoration of supply gave many customers a sense of security in a time when aftershocks were still significantly strong.

Restoration of supply consisted of five distinct phases, each one overlapping but distinct in its own right. Table 2 summarises each particular phase. Table 3 gives a chronological listing of the restoration.

TABLE 2 - PHASES OF RESTORATION

PHASE I	- Set up control room (2 hours)
	- Establish communications
	- Damage Assessment
PHASE II	- Supply to Zone substations
(24 hours)	- 33kV Transmission Lines
PHASE III	- Restore 11kV feeders
(40 hours)	- Disconnections for safety
PHASE IV	- Connect Customers (1 week)
	- Repairs to Service Lines
PHASE V	- House inspections (4 weeks)
	- Appliance inspections

Mechanics of Restoration

Restoration procedures followed the outline listed in Table 2. At the advent of the earthquake staff were scattered throughout the Board's area going about their duties. The Board's Control Room and offices in Whakatane were evacuated after the second shock. The Control Room was reoccupied and contact made with staff. Zone substations were made safe and radio checks were carried out on available radio channels. Staff in the field and at Aniwhenua immediately commenced inspection of zone substations, and of the Power Station. Once the extent of the damage had been ascertained, and information had been received on access along main routes to various localities, the procedure of

restoration of supply commenced. A large number of the Board's line staff were at the Whakatane depot, and staff were sent home about half an hour after the main shock to check up on family.

Those staff in the field and at Aniwhenua who could not contact their family had messages relayed on their behalf. Staff who did go home reported back for duties within quarter of an hour to half an hour to commence restoration work. The restoration work and the damage assessment commenced approximately one hour after the advent of the quake. The speed with which staff responded to the emergency was to be commended. Having predetermined roles in response to a major disaster builds up morale and a desire to part of the "team" involved in restoration. It is thus most important to have roles defined for those expected to respond to major emergencies, as key personnel are able to build up this team spirit.

TABLE 3 SEQUENCE OF RESTORATION TIMES

DATE	TIME	EVENT
2 March	1341	Loss of supply
	1931	Supply to Whakatane E.D.
	2246	Kawerau 11kV bus energised
	2253	Station Road zone sub energised
3 March	0017	Ohope zone substation energised
	0134	Kawerau 11kV borough feeders livened
	0406	Supply restored to Opotiki/Te Kaha
	0601	Aniwhenua synchronised to grid
	0814	33kV supply to Whakatane Board Mills
	1728	Plains zone sub livened
4 March	1800	Te Teko and Matata 11kV restored
	2023	Part of Edgecumbe livened
	0730	Edgecumbe 11kV restored
	1416	11kV restoration completed

Having evaluated the damage to the Board's system the restoration of supply commenced with the preparation of those zone substations undamaged by the earthquake for receipt of supply at 33kV. The extent of the damage sustained to the Electricity Corporation's Substations led to the decision to supply emergency services at Whakatane initially from the Aniwhenua Power Station. At the Board's Plains zone substation the damaged 33kV/11kV supply transformer had to be removed from service and replaced with a temporary unit, in order to be able to supply the Edgecumbe and Te Teko townships, which were severely damaged by the earthquake and in urgent need of supply.

While the Board's technicians checked the plant at the zone substations, line staff commenced inspection and repair of the 33kV sub transmission network. When supply was available later in the afternoon from Aniwhenua to the Edgecumbe 33kV sub

FIGURE 5 DAMAGED MAINS ENTRY POINT

FIGURE 6 DAMAGED MAINS ENTRY POINT

transmission network, the Board was able to energise zone substations near Whakatane, including the Whakatane MED's zone substation. Restoration of supply to the 11kV distribution network involved inspection of each feeder on a radial basis commencing at the zone substation, and livening as sections of lines were made safe.

Where services had come down, or seemed to be unsafe, these were simply disconnected in the initial stages. Later on in the procedures line staff were able to return to these locations and bring supply into the consumers premises. The 11kV distribution system had been completely re-energised by the late afternoon on the Wednesday following the quake, some 48 hours after supply was lost.

The final phase lasted some weeks, and involved liaison with the local Councils, in carrying out house inspections, and in ensuring that supplies brought into premises were not hazardous.

STAFF DEPLOYMENT

Staff should be utilised according to their particular skills, such that in an emergency situation staff would be most efficiently deployed. The Board's line staff, electrical fitting staff, technician staff had specific duties to carry out which were well defined. These duties even in an emergency situation are still closely related to work which would normally be carried out by the staff. The speed and effectiveness of restoration work in an emergency situation such as the March earthquake depends on supervision and direction of these specialised staff groupings. A relatively large number of staff were required to be operating in the Board's control room in order to cover the wide area of supply outage. The restoration process became very much a team effort, with Engineering Officers each finding a particular role to fulfill in the delegation and communication of tasks to the field staff. Administrative and clerical staff were also able to find, in the initial stages of restoration, a role to play for which their training gave them an advantage. For example meter reading staff, with extensive local knowledge, were utilised to supply the line gangs with stores and food.

It was found that it was most important to have one senior Engineer available in the control room with the responsibility for taking the overall direction of the restoration in its initial stages. The first stages of restoration of supply were unique in that a large amount of work had to be channelled to the field in a rational pattern in order to quickly meet the priorities of restoration. In the latter phases of restoration (i.e. the inspection of customers' premises) delegation of work was handled through various departments. However in the initial operations a quick response was often required in certain situations and it was imperative that line staff were not kept waiting for further work.

The response of neighbouring authorities to the emergencies meant that an additional five line gangs were able to be put into the field. In total, eighteen line gangs were deployed in the disaster area, alongside faultmen and inspectors.

On the night following the earthquake line staff and other staff worked until after midnight, in order to be able to bring supply to the emergency services and the urban localities. By the next day work continued until 8pm, and on the third day staff were able to finish at approximately their normal finishing time, enabling staff to obtain more time away from work as tiredness set in.

VEHICLES

The Board's line depot at Whakatane is linked to the Edgecumbe area by means of two bridges across the Whakatane River. A line truck was at one stage turned back by Civil Defence officers from the main bridge across the Whakatane River, even though a fire engine in front was allowed to proceed across the bridge. The Board intends to ensure that in future line vehicles, and other Power Board vehicles will be entitled access into restricted areas along with the other emergency services.

Fuel presented a problem for the Board in that the Board's vehicles, having being converted to run on LPG, were running short of fuel and there were no easy means available of refilling the vehicles without the supply of electricity to the refueling depots. An emergency generator has since been purchased and installed at the Board's refueling depot.

MATERIALS AND PLANT

The Board was able to repair most of the damage, and replace most of the damaged equipment from its own stocks. However some specialised plant had to be brought in from outside. To this extent the support of neighbouring supply authorities was invaluable. As a particular example the damaged 10MVA 33kV/11kV supply transformer from Plains substation had to be replaced with a temporary transformer, until such time that the damaged transformer could be overhauled. Staff from neighbouring electricity suppliers located a replacement unit and arranged to transport it to Edgecumbe on the Board's behalf. As a result of these efforts the Plains substation was re-livened by 4pm on the day following the earthquake. In a similar manner overhead conductor was able to be obtained at short notice. Mention is made of these two specific incidents in order to emphasise the essential nature of close communications and co-operation between electricity suppliers.

The Board's responsibility in terms of requirements for safety to the public did not stop at the point of entry to the customers premises. There was a need to replace broken light switches, power points, and other fittings. In many cases the movement of the heavy furniture against

FIGURE 7 DAMAGE CAUSED TO A POWER POINT BY A WATER BED

FIGURE 8 DAMAGED 11KV/415V SUBSTRUCTURE
THE TRANSFORMER WAS BOLTED TO THE
WOODEN PEDESTAL AT THE BOTTOM OF
THE STRUCTURE, WHICH SPLIT AS A
RESULT OF THE SWAYING MOTION.

appliances and fittings caused damage which made the premises unsafe electrically.

An approach was made to businesses for donations of switches, batten holders and sockets etc, to ensure that premises could be made safe without incurring costs of any significance to the consumer. The Board found these firms most generous.

Modifications to Plant

Damage sustained to various items of plant indicated the need to modify the mounting and anchoring of structures. The Board's distribution system was for expediency sake restored to its former condition. It was decided to review the mounting aspects of ground mount and pole mounted transformers and similar structures at some time in the future.

At the Board's Edgumbe substation the overhead 33kV bus has been replaced with a cable connection from the Electricorp 33kV bus structure to the single phase transformers. Likewise the 11kV overhead bus has been replaced by a disconnecting indoor bus arrangement mounted in a cubicle, with the 11kV feeder cables being ducted to the existing outdoor pole mounted 11kV circuit breakers. The 33kV/11kV supply transformers were originally mounted on wheels on a raised pedestal, which not only raised the centre of gravity of the structure but also produced point contact with the four wheels on the steel rails. The wheels have been removed and replaced with a solid bracket bolted onto a flat ground level transformer pad. The pad has been designed with a thicker section of concrete around the periphery to reduce the possibility of overturning. Control cubicles were firmly bolted to the floor inside the control building, and no damage was sustained to any equipment within the building.

Very few distribution transformers suffered damage. One transformer fell off the pole in Edgecumbe itself, and the larger pole mounted transformer on a platform with a double pole structure sheared its bolts, and the transformer slipped to one end of the platform. Another transformer close to the fault zone fell off the pole, and a third transformer in Edgecumbe broke free from its platform and was left hanging from the three phase wires. One transformer came free from the platform as shown in figure 8 when the timber pedestal split as a result of the swaying motion.

ADMINISTRATIVE ASPECTS

Several administrative areas relating to the restoration procedures are currently under review. Some facets, such as civil defence liaison and the maintenance of records of chargeable work, although causing no major problems do need some improvement. Other areas such as supply authority liaison worked well. This was primarily due to the fact that Engineers staff in supply authorities have detailed understanding of the specialised equipment, and resources which would be required to cater for an emergency.

Several deficiencies came to light in the operation of the Board's control room during the emergency. Most of these deficiencies are due to the uncompleted nature of the Board's control room, and include the lack of a large addressable wall mounted mimic diagram of the Board's distribution system, and to the temporary nature of the radio installations in the control room.

The Board has its 11kV distribution system stored on discrete video displays of its supervisory control system, on a "feeder per display" basis. Because of the extent of the emergency these schematics were not used at all during switching, because it was necessary to have an overview of the entire system on a large mimic, in order to be able to quickly assess progress during restoration of a large number of feeders emanating from each zone substation. It also enabled control room staff to be able to keep a closer track of the allocation of line gangs to various geographical areas.

The Board's SCADA system played an important part in the overview of the emergency, particularly in the early stages. The zone substations were able to be made safe, and assessments could be made very quickly of the areas where supply had been lost. During the process of restoration when extensive switching was carried out in the field it was beneficial to be able to monitor feeder loadings at the zone substations.

Staffing levels in the control room were dictated by the communications channels which were in use to direct staff and contact other organisations. Staff in the control room included system controllers to monitor the supervisory system, engineering officers to monitor each of the three VHF radio channels available to contact staff in the field, and draughting staff to

maintain records and answer customer fault calls.

Catering procedures were modified on a couple of occasions before a suitable scheme had been sorted out. On the Monday night staff were brought in from the field in small groups to the Board's offices for a meal and a short break, and food was obtained from one of the local supermarkets in Whakatane. An attempt was made to deliver lunches to linestaff in the field on the following afternoon, however it was found that the time taken to provide lunches was such that some line gangs were not fed until later in the afternoon. Staff were brought back to central locations for dinner again the Tuesday night and the following Wednesday night. It was beneficial to staff to have a break away from work and have a meal in a bit more relaxed atmosphere. The one comment that was made in the debriefing by staff was that a similar policy should have been adopted for those manning the control room (food was initially bought into the control room at meal times).

Liaison

As mentioned previously the Board's liaison with other supply authorities and Civil Defence worked well, mainly because of the co-operation of individuals in the varying organisations, rather than as a result of a formal communication network having been in place. There is a need to set up a formal method of communication between organisations. Ideally contact should be made as soon as an emergency strikes the area (whether help is required or not). By making this initial contact, and defining the nature and extent of the emergency, staff and materials can be prepared should they be required to be utilised. The Whakatane telephone exchange was badly overloaded because of the volume of incoming calls. It was found throughout the emergency that calls could be readily made out of the area, and that whenever lines did become overloaded the telephone operator in the local exchange was able to obtain a line at short notice.

Civil Defence liaison turned out to be fairly informal, and was kept to a minimum because of the extent of the workload of the Civil Defence organisation had to cope with locally. It was again found that a single point of contact with Civil Defence was necessary and standard Civil Defence message forms were supplied to the organisation at a local headquarters at regular intervals, updating the organisation of the state of restoration of supply.

It was felt that the Civil Defence organisation suffered from an "information avalanche", and thought should be given to changing the Civil Defence structure to allow "specialist" organisation to operate with greater autonomy, using the Civil Defence organisation more in a facilitating and policing role.

The Board made sure that the Civil Defence organisation was able to make contact with the control room at any time should there

be a need for support from some specialised service. (One such example was a request for an urgent temporary supply to be brought into the local fire station at Edgecumbe). Likewise Civil Defence made available equipment, such as helicopters, for Board use to facilitate speedier restoration of supply to all areas.

When house to house inspections were carried out a close liaison with the local Council was necessary. Lists were provided by the Council of houses which had been inspected by Building inspectors and Board inspectors, inspectors from neighbouring authorities, and electricians available on a voluntary basis carried out house to house inspections of the electrical wiring.

Insurance of Board Equipment

The supply authority is under pressure to provide supply on a continuing basis. Unlike a factory site, the zone substation cannot be shutdown for a period of time whilst repairs are effected. For example the Tasman Mill announced in a news release in mid August 1987 that full production of the Mill had just been obtained, completing repairs following the earthquake of March. The Board's zone substation was back into operation on a temporary basis within 26 hours after the earthquake struck. Although equipment at the substation was insured, the costs of temporary supply and of any improvement obviously are not covered by insurance. The cost of providing a temporary supply to the zone substation becomes a social cost and is not insurable under the standard material damage policies. The Board's distribution system was not covered by insurance, but a Government grant of up to 80% of the estimated costs of repair to the distribution system was made available to the Board on a "one off" basis.

Role of a Civil Defence Plan

Every organisation needs to have a current Civil Defence plan. The contents of such a plan should be limited to a few specific areas.

A Civil Defence plan needs to specify:

1. Basic communications procedures, and use of available radio and telephone channels.
2. Liaison roles of staff (including the type and frequency of contact required to neighbouring authorities and other organisations affected by emergency).
3. Alternate contact arrangements if necessary to enable an emergency control room to be set up.
4. A simple path of delegated authority for control of an emergency (bearing in mind that one person should be delegated to control restoration in an emergency situation, and bearing in mind that some staff changes will occur at frequent intervals).

The Civil Defence plan should consist of a list of contact numbers and contact procedures but should not try to identify the method of restoration of supply in different situations. Co-ordination meetings with the local Civil Defence organisations should be organised before preparing a new Civil Defence plan, in order to be able to identify liaison patterns.

An inventory of plant available for use in emergency situations should be limited and should exclude plant which is frequently used. As an example, lists should be kept of locations and contact personnel, (especially after hours numbers) of items such as cranes and low loader transporters. The Board did not have a list of portable generators available for use by either Civil Defence staff or the public. Obviously Civil Defence will have access to its own generators, but a list of contacts for emergency generating equipment is recommended.

Civil Defence plans should also if possible list contacts and procedures for transporting large equipment into a disaster area. This came to light when a supply transformer had to be transported to the Board's Edgecumbe substation. Escorts had to be arranged to accompany the equipment, contact had to be made with Ministry of Works and Development and local council engineers to ensure that a route was available for transport across damaged bridges and along damaged roads. It would thus be necessary to assess routes for access to substations and other locations, for large equipment (including bypasses around subways, or loading restrictions on old bridges).

CONCLUSIONS

The role of the electricity supplier is to provide access to a safe and reliable supply to the customers. In line with those objectives an supplier's first role is to remove electrical hazards and follow that up by a prompt restoration of supply to customers throughout the system, taking into consideration the need to restore supply to emergency services on a high priority basis. The electricity supplier is geared towards restoring supplies when an emergency strikes. The Bay of Plenty Electric Power Board experienced an emergency situation which was in excess of anything hitherto experienced, and has as a result been able to build up invaluable experience on the required response to large scale emergencies.

Electricity is an essential commodity which most of the public take for granted. However in a situation such as that described above two elements need to be considered. Firstly there is the mental and physical strain upon customers who find difficulty coping without electrical supplies, and secondly there is the question of payment for restoration of those services. Both these two elements affect the method of restoration which has to be adopted by a supply authority in a large scale emergency.

Finally an event such as has been described focuses the attention of the public on the place of an electricity supplier in the community. The presence of a large number of vehicles and line trucks goes a long way towards reassuring the public that a sense of normality is returning. It is essential that a suppliers response to an emergency situation is seen as being positive and focuses upon the expertise of staff involved in restoration. Electricity suppliers should look at the implications of the emergency upon the future with respect to changed loading patterns and changed usage patterns as a result of an emergency.

ACKNOWLEDGEMENTS

This paper should not be concluded without acknowledging the dedication, determination and enthusiasm shown by Board staff in their long hours of work which ensured that supply was restored to all areas in a very short time. Their actions were met with the admiration of the community at large. The concern and support of staff from other supply authorities, and the sacrifice of staff in travelling to Edgecumbe to support the Board in restoration of services is appreciated and has been acknowledged by the Board.