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AN INTRODUCTION TO ENGINEERED WOOD PRODUCTS (EWPs)

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Recent decades have seen growing use of engineered wood products (EWPs) – composite and laminated products where smaller wood components are bonded together with adhesive.

EWPs include structural and non-structural products. They have been used as primary structural elements to construct buildings up to 11 storeys here and 25 storeys overseas.

This bulletin gives an overview of EWPs, how they can be used, the main challenges around using them and the opportunities they provide.

1 INTRODUCTION

1.0.1 Recent decades have seen increasing use of engineered wood products (EWPs). In some cases, they are replacing use of sawn timber, but they are also replacing steel and concrete products, including in projects such as multi-storey buildings where timber has not been commonly used in the past. Some of the interest is a response to demand from government, companies and consumers for buildings with a lower carbon footprint.

1.0.2 The government has said it wants to see better use made of Aotearoa New Zealand timber resources. The timber industry also wants to grow domestic demand for our wood products and to increase investment in manufacturing advanced wood-based products – goals expressed in Te Uru Rākau New Zealand Forest Service Forestry and Wood Processing Industry Transformation Plan.

1.0.3 EWPs are composite products where smaller wood components are joined together with a structural adhesive under pressure. The wood components used to manufacture these products vary widely from wood flakes in the case of particleboard to full wood planks in the case of cross-laminated timber (CLT). In some cases, EWPs can be manufactured from lower-grade radiata pine than is required for sawn timber. EWPs include structural beams and posts, panel products and non-structural and decorative components used on the interior and exterior of buildings.

1.0.4 Despite its vast forest resources, New Zealand lags behind European countries in its use of EWPs. There have been some false starts in production – for example, while a production plant for CLT was established in Nelson in 2010, it was soon bought out by an Australian company and production taken offshore.

1.0.5 Recent years have seen a number of new plants opening that manufacture EWPs, often involving computer numerical control (CNC) lines, automated computer control of machining tools and robotic handling.

1.0.6 Long-term market trends and government policies favour greater use of EWPs. As New Zealand moves towards a net-zero carbon economy by 2050, EWPs can make a significant contribution to lower embodied carbon in buildings. They have captured and stored (sequestered) atmospheric carbon dioxide as the trees were growing. This gives them a much lower embodied carbon footprint than other materials whose manufacture typically releases greenhouses gases.

1.0.7 EWPs are available with chain of custody certification from the Forest Stewardship Council (FSC) or the Programme for the Endorsement of Forest Certification (PEFC). This gives assurance that the product is produced from renewable and well-managed forests.

1.0.8 Beyond carbon and sustainability considerations, EWPs have other advantages:

- They typically have more consistent material properties than sawn timber, are less likely to twist or warp, have greater strength and stiffness and are available in larger dimensions.
- The prefabrication available with EWPs such as large CLT floor, wall or roof panels means that they can contribute to faster construction times than when these building elements are constructed on site. Because mass timber is such a lightweight material, large sections can be prefabricated and lifted into place, reducing the number of site lifts required.
- They can be extremely resilient to earthquakes. Testing at the University of Canterbury used dissipators in building elements constructed with EWP beams and posts. These dissipators yielded during a simulated earthquake, absorbing seismic energy. After a significant earthquake, dissipators could be replaced and the buildings returned to service.
- Many people like the appearance of timber as a finished surface. This means that, where EWPs are used structurally, they do not always need to be covered with suspended ceilings, bulkheads or linings for appearance reasons. EWPs can be more durable than other commonly used lining materials, and adding covering materials can add cost. However, exposed timber may contribute to fire growth and duration and therefore covering can be required for fire protection.

Extensive use of LVL (laminated veneer lumber) in Scion's Rotorua headquarters meant that the building achieved net-zero embodied carbon when it was completed.

1.0.9 Being timber-based, EWPs can potentially contribute fuel to fires and rot when they get wet if their specification, design and installation is poorly done. EWPs receive different timber treatments for durability depending on application, as required under the New Zealand Building Code and applicable standards, and EWPs can be designed to accommodate substantial fire resistance.

1.0.10 There are many EWPs such as CLT that are not yet included in Acceptable Solutions to the Building Code. For applications using these products, a chartered professional engineer will be required to design/certify a design for a building consent application.

1.0.11 Almost all buildings are hybrid to some degree, making the best use of materials such as timber, steel or concrete. While EWPs can play an increasing role in construction, even in the structure of tall buildings, they do not replace steel and concrete completely. For example, in the 86 metre, 25-storey mass-timber Ascent tower in Wisconsin, USA, which opened in July 2022, while CLT and glulam (glued laminated timber, sometimes referred to as GLT) were extensively used, the foundation, elevator housing and stair shafts were still made of steel-reinforced concrete.

2 WHAT ARE EWPS?

2.0.1 EWPs fall into several broad categories.

2.0.2 Structural EWPs:

- Laminated veneer lumber (LVL) beams, lintels, joists, rafters and so on are produced by bonding thin (typically around 3 mm) wood veneers together with the grain typically running parallel in all the veneers. LVL now makes up around 10% of timber framing in New Zealand. LVL can be relaminated together in a secondary fabrication process to produce large-format LVL beams and column members.
- Glulam beams, lintels, columns, posts and other elements are typically made from thicker sections of timber than LVL – 15–45 mm thick is not unusual. Glulam members can be straight or curved.
- CLT panels can be used in prefabricated structural applications as floors, walls or roofs. The timber grain in the sheet generally (but not always) alternates at 90° for each layer, with the exterior layer's grains usually running lengthways. There can be as few as three layers or as many as 11 layers or more. Panels can be large – up to 15–17 m long depending on the manufacturer and transportation considerations.
- Finger-jointed sawn structural timber has timber members connected end to end by a joint of glued interlocking 'fingers'. Defects such as knots can be removed during the process, allowing for members that are longer and stronger than regular sawn timber.

2.0.3 Panel EWPs (bracing, cladding, flooring):

- Plywood – thin sheets (plies) of wood veneer glued together with the direction of the grain rotated 90° between different layers.
- Oriented strand board (OSB) – layers of wood strands bonded together in different orientations with heat-cured adhesives.
- Strand board – layers of wood strands bonded together with no specific orientation of strands.
- Particleboard – wood shavings and chips glued together.
- Medium-density fibreboard (MDF) – wood fibres glued together. MDF is denser than plywood or particleboard and is for interior uses.
- Fibre-cement board – made from cellulose fibre (often from radiata pine), cement, sand, water and some other additives.

2.0.4 Composite products and systems:

- I-beams – can be used as floor joists, rafters and so on. The flanges at the top and bottom can be made from LVL or graded solid timber. These are held apart by a vertical web, which can be structural plywood, OSB, LVL or a proprietary product.
- Structural insulated panels (SIPs) – composite panels with an insulating foam core sandwiched between two structural facings that may be made of wood or other materials.
- Wood plastic composites – timber ground to flour, blended with ground plastic such as polyvinyl chloride (PVC) or high-density polyethylene (HDPE), moulded and extruded.
- Timber-concrete composites – a range of structural systems that optimise the properties of timber and concrete to create high-performance roof, wall and floor systems. These composites seek to make use of the high-tensile strength of timber (often LVL or glulam) with the high compression strength and weight of concrete by locking the materials together often using specialty fasteners and/or notched connections. One example is a timber-concrete composite floor where LVL joists are connected to a concrete floor slab using coach screws and notches in the timber joists. This combination provides long-span floors with suitable acoustic and fire resistance properties and can be manufactured off site for quick and simple installation.
- Post-tensioned timber (Pres-Lam) – a system of prefabricated timber components (which can be CLT, glulam or LVL) that are tied together with steel bars or cables. Pres-Lam buildings have good seismic resilience. The Pres-Lam system focuses on damage avoidance design with a high ductile response and self-centreing characteristics in an earthquake.
- Stressed-skin panels – a structural panel that usually has structural members such as joists or rafters that are skinned on one or both sides to create the panels. These panels can form floor or roof cassettes.

OSB

CLT

2.0.5 Many EWPs are proprietary products. Manufacturers often provide their own design and installation guides, durability information, span tables, specific engineering design guides, CAD designs and design software.

2.0.6 A 2019 BRANZ survey of construction industry practitioners found that:

- the most common type of building using EWPs were residential stand-alone buildings, followed by commercial building projects and residential multi-unit projects
- the most frequently used EWPs (other than plywood and MDF) were LVL followed by glulam and CLT
- the top perceived advantages of EWPs were performance, speed of construction and environmental benefits, while cost and material availability were seen as the main drawbacks.

2.0.7 A 2022 industry survey found that:

- panel products such as plywood are still being used most often, structural LVL is also frequently used

and CLT, glulam and timber I-joists also featured as popular options
- the most frequently mentioned reasons for using LVL, CLT and glulam were performance (improved stability, greater spans and strength), environmental impact and speed of construction, while cost and material availability are still perceived as barriers
- the provision of more information and training were the most commonly cited ways of reducing barriers and increasing the use and uptake of EWPs in New Zealand.

2.0.8 Most EWPs can be worked with standard woodworking machinery and tools. Health and safety measures similar to those for working with solid timber should be followed, including wearing protective clothing and footwear, gloves and dust masks, eye and ear protection when sawing, drilling, planing or sanding.

3 EWPS AND CARBON

3.0.1 The building sector is a significant contributor to greenhouse gas emissions from the materials used in constructing buildings and the energy and water used in operating them. Using EWPs in new building can help New Zealand achieve its target, set in law, of a net-zero carbon economy by 2050 through reducing the embodied carbon in new buildings.

3.0.2 Some of the buildings mentioned in section 8 are good examples of low-carbon construction – for example, Scion's building in Rotorua, Te Whare Nui o Tuteata. The construction materials (550 m^3 of timber products – in particular LVL, CLT and glulam) and methods used mean that the building was assessed as achieving zero embodied carbon at completion without any offsetting of carbon credits.

3.0.3 BRANZ has a suite of tools that can help in designing and constructing low-carbon buildings using EWPs. For example, CO_2NSTRUCT – a database of embodied carbon and energy figures for building materials and products – gives data for CLT, glulam, LVL, engineered wood I-joists and other products.

3.0.4 Use of EWP materials can also help a building achieve a particular level in Green Star or Homestar and similar schemes.

4 DURABILITY AND TIMBER TREATMENT

4.0.1 Durability of EWPs depends largely on the design and construction of the building, the level of timber treatment the EWPs have received and the long-term performance and durability of the structural adhesives used to put them together.

4.0.2 Under the Building Code, EWPs used for structural purposes (such as roof joists or lintels and beams in wall framing) must be durable in service for the life of the building – not less than 50 years unless the building has a specified intended life. Components that are moderately difficult to replace must be durable in service for at least 15 years, and those easy to access and replace at least 5 years.

4.0.3 Because they are wood-based products, EWPs should in most cases follow the broad specification, design and construction requirements that apply to timber:
- EWPs must be treated with a wood preservative to make them resistant to decay fungi or wood-boring insects (borer) to render them sufficiently durable.
- As with all timber-based materials, design and construction must be carefully carried out to ensure penetration by moisture will not occur.
- The material used for fixings and connections must be compatible with the type of treatment the EWP has received. Timber preservatives that contain copper such as chromated copper arsenate (CCA) and alkaline copper quaternary and micronised copper azole (MCA) can lead to faster corrosion of mild and galvanised steel fixings, so alternative materials such as stainless steel are likely to be required.

4.0.4 EWPs are available in New Zealand that are treated to satisfy the requirements of a wide range of purposes. Examples include:
- LVL framing for use where a minimum hazard class of H1.2 is required such as enclosed structural framing in a house
- CLT treated to H1.2 for enclosed building elements or H3.2 (CCA) for use in wet areas such as bathroom floors
- glulam posts treated to H5 to support above-ground applied loads such as veranda beams
- plywood treated to H3.2 with CCA for use as a substrate under roof membranes
- proprietary timber composite sheet flooring treated to H3.1 for use in wet areas.

4.0.5 Some EWP products have CodeMark product certification, a BRANZ Appraisal or other third-party documentation. These can include statements that, in the opinion of the agency involved, the products meet the Building Code requirements of clause B1 *Structure* and clause B2 *Durability*, including performance of not less than 15 or 50 years, as required. Products with CodeMark certification must be accepted by building consent authorities if the product is being used according to the certificate and its instructions. (BRANZ is an accredited product certification body for CodeMark.)

4.0.6 Traditional formaldehyde, phenolic or resorcinol-based adhesives have a long history of use in New Zealand and are known to perform well over a long period. PUR adhesives have a long history of use overseas and are starting to become the adhesive of choice for many EWPs.

4.0.7 Adhesive formulation, wood species, timber preservative treatment and in-service conditions are key parameters in determining durability. A joint BRANZ-University of Auckland study did not find any concerns around the use of commercially available one-component PUR adhesives for bonding radiata pine preservative treated with CCA or to hazard class H3.2 under environmental conditions typical of New Zealand's climate.

4.0.8 Like any materials, EWPs can fail if there is faulty design, specification or construction (or a combination of these, which is not unusual in material failures). As an example, in the UK, problems were found with an 8-year-old building that had wall insulation covering CLT wall panels. Because of poor construction, water penetration had caused parts of the CLT to rot – a problem found during invasive testing but not apparent from external inspection. This is an example of why preservative treatment to EWPs is essential.

5 FIRE

5.0.1 All major building construction materials can be negatively affected by fire. However, unlike steel and concrete, timber is combustible in typical building fire conditions and can contribute to fire growth and duration. In most cases, designers specifying EWPs must demonstrate that the building will maintain its stability during and after a fire, complying with Building Code clause C6 *Structural stability*.

5.0.2 There are reaction-to-fire requirements that can limit the use of timber, particularly exposed timber surfaces. Internal surface spread of flame is characterised by group numbers. Materials achieving a group number of 1 have the lowest propensity to spread flame while group number 4 is the highest. Unmodified timber typically achieves a group number of 3. This means that exposed timber can be limited in building areas such as exitways. Some minor amounts of exposed timber can be allowed.

5.0.3 There are also external reaction-to-fire requirements that may limit the use of timber in façade construction. Buildings exceeding 10 m in height fall under external reaction-to-fire controls. There are also limits on materials used within 1 m of a boundary, which may affect the use of timber in external walls.

5.0.4 Apart from the fact that timber burns, another key issue is that its strength is reduced at relatively low temperatures – at 100°C, compressive strength reduces by 75%, shear strength by 60% and tensile strength by 35%.

5.0.5 Fire safety during construction also needs to be considered. Before all final fire protection measures are put into place, timber building elements can be particularly vulnerable to fire. While this is not generally a life safety problem, fires during construction can cause major property loss.

5.0.6 Considerable research is ongoing into the impact of fire on EWPs, including around specifically EWP-related aspects such as delamination (see section 9 for some published reports).

5.0.7 EWP manufacturers commonly produce data around the fire ratings/fire testing of their products that can be used in building consent applications. In practical terms, these indicate that people have sufficient time to safely evacuate a building in a fire. One New Zealand manufacturer of CLT panels has had them tested and achieved a fire resistance rating (FRR) of 60/60/60. This means that the CLT panel has achieved at least 60 minutes for all three criteria in the standard fire resistance test:

- The element maintains loadbearing capacity for at least 60 minutes – the structural adequacy component.
- The element prevents the transmission of flames and hot gases that could lead to fire spread for at least 60 minutes – the integrity component.
- Conducted heat/radiation from the non-fire side of the element is low enough that ignition is prevented for at least 60 minutes – the insulation component.

5.0.8 The required FRRs are set out in Building Code compliance documents. For example, as of January 2023, in C/AS1 (the Acceptable Solution that applies to stand-alone houses, boarding houses and medium-density housing), the minimum FRR required for elements such as external walls is 30/30/30. This is due to change, however – check for the latest requirements.

5.0.9 Most houses constructed to NZS 3604:2011 *Timber-framed buildings* do not require a fire rating. When the external walls are within 1 m of a property boundary, they need rated systems. They must be protected from ignition and post-fire stability should also be considered. Buildings outside the scope of NZS 3604:2011 typically require ratings, and these are usually determined for systems using full-scale tests or extrapolations from these tests for other materials and layers.

At the time of its construction, the 11-storey Auckland City Mission building was Aotearoa New Zealand's tallest mass timber building, built with CLT walls and floors. Overseas, mass timber buildings of 25 storeys have been built.

5.0.10 As well as supporting data from manufacturers, there are a number of more specialised resources such as the B-RISK design fire tool software for fire engineers that can be downloaded for free from the BRANZ website. This covers some EWP options such as allowing for modelling of CLT compartments with full or partial CLT wall and ceiling linings. The output would be evaluating design fire severity when timber building products may contribute fuel to the fire. B-RISK is well suited to more complex buildings where a fire engineer may need to carry out a performance-based design in accordance with Verification Method C/VM2.

5.0.11 Another useful resource in the fire protection area is the *Fire Safe Use of Wood in Buildings* design guide. This is a more comprehensive and state-of-the-art view, including a brief overview of some of the recent B-RISK work. BRANZ funding contributed to making the book available free as an open-access resource. It also has a wider potential readership than just fire engineers, covering such aspects as fire during construction, building execution and firefighting considerations.

5.0.12 Encapsulating EWPs with a non-combustible material such as plasterboard is the most common form of increasing fire resistance. Research is also going into the use of intumescent coatings – specialised coatings that swell when they get hot are applied to EWPs in the early stages of the build, adding not only to enhanced fire safety during construction but over the life of the building.

5.0.13 While not perfectly reliable, automatic fire sprinklers can significantly reduce the risk of fire in all buildings including those incorporating EWPs. There are several concessions in the New Zealand building compliance documents that reflect the impact of sprinklers on fire risk. These concessions include relaxation of both reaction-to-fire and fire resistance controls that may allow greater use of timber.

5.0.14 EWP manufacturers have modified their products to make them safer as a result of fire protection research. For example, some studies found that, in CLT panels without fire-resistant adhesives, the charred timber layers delaminated during a fire and fell away, exposing fresh timber that sustained the burning process. Most CLT manufacturers now use fire-resistant adhesives so that char layers do not fall away prematurely and the panels perform in the same way as solid timber.

6 CONNECTIONS

6.0.1 There are a wide variety of EWP connection methods, joint details and fasteners. EWP manufacturers typically give details and recommendations about connections and fixings for their products in their design guides and other documentation. Many supply the fixings. There are a number of suppliers of fasteners who specialise in mass timber. Considerable research has been done in New Zealand and globally to help designers specify ways of connecting mass timber buildings.

6.0.2 Large timber construction requires specifically designed connections. Bolts, dowels and more importantly screws are being used to connect mass timber. The connections required are significantly different from our traditional concepts of nails and small screws. All the large EWP buildings are being screwed together, and suppliers have very big ranges of fastening and fastening systems for holding together timber buildings. Connection specification is very important because it is the connections that provide the ductility in timber buildings, which is crucial to seismic performance.

6.0.3 Particular attention must be paid to the fire resistance of connections detailed in large timber buildings. The connections and the full structure must perform adequately over the full duration of the fire.

7 STANDARDS

7.1 NZS 3604:2011 *TIMBER-FRAMED BUILDINGS*

7.1.1 EWPs – specifically LVL, glulam, plywood and particleboard – are included in NZS 3604:2011, with requirements that:

- LVL or glulam are manufactured from radiata pine or Douglas fir
- LVL is manufactured in accordance with AS/NZS 4357 *Structural laminated veneer lumber* (Parts 0–4)
- glulam is manufactured in accordance with AS/NZS 1328 *Glued laminated structural timber* (Parts 1–2)
- plywood must be manufactured to meet the requirements of AS/NZS 2269 *Plywood – Structural* (Parts 0–2)
- wood-based components such as particleboard or wood-based flooring must be manufactured to AS/NZS 1860 *Particleboard flooring*
- the preservative treatment used complies with NZS 3602 *Timber and wood-based products for use in building.*

7.1.2 NZS 3604:2011 allows EWPs to be used as a direct substitute for SG 6, 8 or 10 "provided that they are of the same finished size as the member to be substituted and that the strength and stiffness properties have been verified and marked in accordance with NZS 3622 and are no less than the strength and stiffness properties of the grade to be substituted".

7.1.3 The standard allows LVL or glulam products to be used in place of solid timber framing members that are already within the scope of the standard, provided certain requirements are met (2.3.9.6 in NZS 3604:2011 and the comment beside it). This gives options for using EWPs in limited spaces where sawn timber would be too bulky and also allows for EWP lintels to be used for larger-span openings such as garage doors. C2.3.9.6 states: "The expectation is that supporting documentation [in a building consent application] will include a producer statement from a chartered professional engineer."

7.1.4 NZS 3604:2011 is currently being updated. It is likely that the updated version, when it is released, will make greater provision for EWPs in timber-framed construction.

7.2 NZS 3603:1993 *TIMBER STRUCTURES STANDARD*

7.2.1 This standard sets out "in limit state design format the requirements for methods of design of timber elements of buildings and applies specifically to sawn timber, glue laminated timber, natural round timber and construction plywood. Includes a section on design for fire resistance".

7.2.2 NZS 3603:1993 has been superseded by NZS AS 1720.1:2022 *Timber structures*, but because NZS 3603:1993 is still the standard referenced in the Building Code, it retains its current status.

7.2.3 NZS AS 1720.1:2022 makes even greater provision of EWPs in timber-framed construction. The major difference between the old and new standard involves connection design. NZS AS 1720.1:2022 can be used by designers, although as noted above, it is not (yet) referenced in the Building Code.

7.3 NZS 3602:2003 *TIMBER AND WOOD-BASED PRODUCTS FOR USE IN BUILDING*

7.3.1 NZS 3604:2011 says that the preservative treatment of EWPs must comply with NZS 3602:2003. Although NZS 3602:2003 allows untreated LVL for subfloor framing, several of the NZS 3602:2003 tables do not have LVL and glulam options. Where the level of treatment for EWPs is not listed in NZS 3602:2003, NZS 3604:2011 requires the same level of treatment that would be required for kiln-dried radiata pine to comply with NZS 3602:2003.

7.3.2 NZS 3602:2003 is closely linked to NZS 3640:2003 *Chemical preservation of round and sawn timber.*

7.4 NZS 3640:2003 *CHEMICAL PRESERVATION OF ROUND AND SAWN TIMBER*

7.4.1 NZS 3640:2003 is the main timber treatment standard and covers EWPs, in particular LVL, as well as sawn timber. The standard notes: "Some special requirements are ... included for softwood Laminated Veneer Lumber (LVL). Refer to AS/NZS 1604 Parts 2 to 5 with the exception of H1.2 treatment for LVL for which this Standard will apply."

8 EWPS IN NEW ZEALAND BUILDINGS

8.0.1 A wide range of buildings have been constructed in New Zealand with EWPs in recent years, illustrating the potential benefits. These are a few examples:

- Wynn Williams House in Christchurch, a 6-storey hybrid structure. The building uses a post-tensioned frame structure with LVL timber beams and with precast concrete columns. It has lead-rubber base isolators.
- The Kaikōura District Council Civic Centre building was only just completed before the Kaikōura earthquake and performed extremely well without sustaining damage. It was used as the Civil Defence coordination centre. The structure included rocking CLT shear walls (post-tensioned) with an engineered timber post and beam structure, including prefabricated roof panels.
- The 11-storey Auckland City Mission on Queen Street was built with CLT walls and floors.
- Scion's Rotorua building Te Whare Nui o Tuteata has 88 diamond and triangle-shaped frames made up of 4,248 parts of LVL. The structure also includes CLT floor panels, CLT in the lift shaft and the entry canopies and stairs as well as glulam elements.
- Tauranga City Council's new office building is set to be the largest new timber office building in New Zealand (at 10,000 m²). It will use engineered timber in place of many traditional concrete and steel elements, aiming to reducing its embodied carbon to the lowest possible level.

9 RESOURCES

Multi-storey light timber-framed buildings in New Zealand: Engineering design

SR476 *Durability of polyurethane-based structural adhesives and bonded interfaces* (2022)

SR468 *Fire performance of structural insulated panels (SIPs) for residential buildings* (2022)

SR453 *Usage and uptake of engineered wood products in New Zealand* (2020)

ER68 *Passive fire protection of cross laminated timber* (2022)

Webinar: *Engineered wood product (EWPs)*

CO_2NSTRUCT – an Excel spreadsheet database of values for embodied greenhouse gas and energy for a range of construction materials and products, including CLT, glulam, I-joist profiles, LVL and more.

WPMA (Wood Processors and Manufacturers Association of New Zealand)

Timber design guides

New Zealand Timber Design Society

Design aids

Wood Solutions (Australia)

Wood products

International

Fire Safe Use of Wood in Buildings – a global design guidea

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Private Bag 50 908, Porirua 5240, New Zealand
Telephone 04 237 1170 - Fax 04 237 1171
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