The Geoscience Australia Building.

Photo credits: Jeremy Simons

Groundbreaker

Such is the reputation of the Geoscience Australia building that its 15-year anniversary couldn't pass without Ecolibrium taking a closer look at this pioneer of sustainable design. As **Sean McGowan** reports, it continues to stack up well against modern-day counterparts.

Just mention Geoscience Australia to any member of the original design team and the enthusiasm and pride for this project is immediately palpable.

Located on a large open site in Symonston, about 5km south-east of Canberra, the building enabled the integration of several remote governmental divisions onto the one site when it was completed in 1997.

Architects Eggleston Macdonald (now DesignInc) designed the 42,000 sq m facility that takes its aesthetic cues from the worn nature of the Australian geological landscape and surrounding Brindabella mountain range.

Internally, the space was designed to bring over 600 staff together and encourage synergies and operating efficiencies to emerge. Any sense of segregation was avoided by accommodating all offices and laboratories in one large building complex, while a sky-lit internal pedestrian "street" and courtyards were designed to encourage informal interaction and chance meetings.

The client brief emphasised flexibility and good daylighting to provide an efficient working environment, the latter achieved by limiting the number of levels to three, and visually linking the floors via open stairways.

Flexibility in space planning and services was provided by the large floor plates, with a full interstitial floor allowing for future alterations without disruption to laboratory operations.

> 'The overall energy efficiency of the building was approached by incorporating good, passive design principles'

As an early example of sustainable building, ESD and energy efficiency formed a major part of the brief, despite no specific energy targets being set (the building pre-dates the formation of the Green Building Council of Australia and Green Star).

However, a pragmatic approach to the selection of ESD elements was taken, meaning any feature that could not stand up to the scrutiny of cost, life-cycle or maintainability would not be considered.

The Geoscience Australia building predates many of the innovations we now consider common in high-performing structures, including displacement ventilation, active mass cooling and mixed-mode ventilation.

Rather, says DesignInc director John Macdonald, the overall energy efficiency of the building was approached by incorporating good, passive design principles.

These included orientation of the building on an east axis, with north-south orientation of primary facades to minimise exposure to solar gains; a low ratio of external wall to gross floor area to minimise the impact of external thermal conditions; passive sun shading; and light shelves to increase uniformity and penetration of daylight into the workspace.

"Geoscience could have resulted in four linked buildings," says Macdonald. "But combining offices and laboratories under the one roof resulted in not only a lower cost due to a smaller façade – one of the highest cost components – but also accommodated the cost of the sky-lit internal street and courtyards within a thermally superior building envelope."

This latter point remains salient, with the use of low-E performance, double-glazing throughout, as well as heavy insulation to the roof and walls protecting the interior from Canberra's cold climate. Similarly, thermal breaks were created for glazing frames and roof sheeting to minimise thermal bridging between hot and cold surfaces.

> The Geoscience Australia building features the largest geothermal heat pump air conditioning system in the southern hemisphere

Although a high-quality constant-volume air conditioning system was installed to provide the high number of air changes and stringent controls laboratory environments require, it is the use of geothermal energy for which the building has become known.

The Geoscience Australia building features the largest geothermal heat pump air conditioning system in the southern hemisphere. It uses the stable temperature of the ground as a massive heat exchanger to transfer heat to the ground in summer and extract heat from it in winter, thereby maintaining the earth's temperature equilibrium.

The sky-lit internal street and courtyard encourage informal interaction.

COOKING THE GROUND, A RISK

Although many ESD innovations failed to pass the pragmatism test, the use of a geothermal heat pump system was embraced with great enthusiasm, not only by the design team, but also the client.

The system was designed by mechanical services consultants Bassett Consulting Engineers (now AECOM), led by director for the project, John Coffey (now deceased); then associate mechanical engineer Michael McPhee, M.AIRAH, (now an associate director with Umow Lai); and acoustic engineer Matthew Stead, M.AIRAH (now director of Resonate Acoustics).

McPhee says he came across an advertisement for a geothermal heat pump system while reading AIRAH's journal (the forerunner to Ecolibrium) not long after Bassett had been appointed to the project. Recognising the synergy between the technology and the particular work of the client, he investigated the opportunity further.

With Coffey also having previously completed a thesis on the subject, it led to the idea that a geothermal heat pump system could supply energy-efficient air conditioning to the Geoscience Australia building's office areas.

"We investigated the technology and felt that it could be adapted to our project," recalls McPhee.

"The client was also very keen on the idea, as it could be directly linked to their business, and they were very helpful in providing information on the rock types under the proposed site, as well as the location of underground aquifers. Without this information, a successful outcome may not have been possible."

As the use of cooling towers were ruled out due to heightened concerns following a number of Legionnaires' disease outbreaks at the time, the low return-water temperatures of a geothermal heat pump system meant higher efficiencies could be achieved compared to air-cooled plant.

"Coefficient of performance (COP) for an air-cooled air conditioning unit could be in the order of 1.8 to 2.5," McPhee says, "Whereas with geothermal heat pumps where the ground loop could be as low as 17°C, the COP could be as high as seven."

With very little local experience to draw upon, similar installations in the US were investigated, involving site inspections in Texas, Oklahoma, Indiana and California. Various configurations were inspected, including horizontal, vertical and pond-type ground loops.

The building houses the largest geothermal heat pump system air conditioning system in the southern hemisphere.

A detailed life-cycle costing report was subsequently prepared by Bassetts, revealing a 25-year saving of over $900,000, when compared with a traditional central plant system.

However, this research had also revealed a potential problem – a phenomenon known as "cooking the ground."

> The 42,000 sq m facility takes its aesthetic cues from the worn nature of the Australian geological landscape and surrounding Brindabella mountain range

"During our research, we noted there had been a number of geothermal systems installed in the US where the ground temperature had risen in a relatively short time, such that the temperature made the system unusable," recalls McPhee.

Although the Canberra climate typically requires substantial heating energy, there were concerns that a tight building envelope, passive design features and the building's occupancy levels would result in more heat being rejected to the ground for cooling than would be drawn out for heating.

This would increase the risk of "cooking the ground."

To counter the problem, it was determined that a ground temperature of 35°C was the maximum that the system should be designed to, with all geothermal units selected on a condenser water temperature of 35°C when operating on cooling. This meant that over a 30-year life of the air conditioning equipment, the ground temperature could rise from 15°C to 35°C.

The ground loop was then sized to this criterion by a computer program developed by the University of Oklahoma. Using sophisticated heat-transfer theory the program determined that 350 bore holes to a depth of 100m were required.

With the theory behind the program's calculations unavailable, and validation of its outcome required, the heat pumps' suppliers provided their own data. Based on their own empirical measurements of different types of rock to ascertain ground loop performance under different conditions, they found that 300 bore holes were necessary.

Erring towards a conservative design in terms of the number and spacing of the bores, and with the knowledge that located below the site was an aquifer that could assist in removing excess heat during cooling, the team adopted the computer program's recommendation.

The subsequent geothermal field design comprised of 352 100m deep bores into which a flow-and-return polyethylene pipe was grouted. These bore holes were grouped into a number of sets, with each connected in reverse-return configuration via horizontal, larger diameter flow-and-return pipes to the headers in the geothermal plant room.

This resulted in four sets of flow-and-return headers in each plant room, each with its own associated primary geothermal pump. A fifth pump was provided for manual stand-by capability in the event that any of the four main pumps failed.

Geoscience Australia predates Green Star but features a range of sustainable design elements.

The 2000kW system continues to work today, with the four separate geothermal fields brought into operation sequentially, with the order determined by a control system that is adjusted regularly.

Flow rates are around double the minimum allowed and contribute to a slightly better COP. At full load, the overall energy consumption of the unit and pump combination is slightly less at the highest flow. But at low load, this relationship reverses, and the overall energy consumption is higher at the highest flow rates, because at low loads the pump power is more significant relative to total power requirements.

“One of the things I was most interested in when it came time to revisit the project 15 years on was the geothermal loop temperature,” says McPhee.

According to figures supplied by Gordon Cheyne of Geoscience Australia, any concerns of “cooking the ground” have not come to pass.

As at early last month, loop field one showed a return water temperature of 17.9°C. Loop fields two, three and four showed respective return-water temperatures of 18.3°C, 19.6° and 19.9°C, respectively. At the header on the field return side, the temperature showed 17.2°C while at the header on the building return side the temperature was 16.1°C.

“This is a good news story for the project, and we can expect that the energy savings achieved in the first years of operations are still being achieved,” notes McPhee, adding that the number of building occupants has now risen to over 800.

The geothermal heat pump system has proven to be a highly energy-efficient source of air conditioning for the Geoscience Australia building for over 15 years. Yet its application was not without challenges.

For example, the design required 220 individual heat pumps to be installed throughout the building. In preference to ceiling locations, these were located in acoustically designed cupboards positioned along circulation routes, which allowed for ease of access for maintenance.

Stead designed these systems to provide a level of background noise for masking and privacy purposes while not causing excessive noise from what were 220 “mini plantrooms”.

A downside of this design was that the failure of one unit results in an area of the building being without air conditioning until the unit is replaced. To address this problem, each unit was specified with plugs and snap-on connections to the acoustically lined ductwork to allow quick and easy removal and replacement.

Additional spare units with plugs and connectors were included in the specification to allow maintenance staff to quickly replace a unit.

“In practice, the planning of the building has changed over the years to a more open-plan arrangement, so this means that the failure of a unit is now less noticeable,” says McPhee.

PROJECT AT A GLANCE

The professionals

Acoustic engineer: Bassett Acoustics (now AECOM)

Architect: Eggleston Macdonald (now DesignInc)

Client: Geoscience Australia (formerly AGSO)

Electrical and communication: Barry Webb and Associates

Geotechnical engineer: Coffey Partners International

Head contractor: Baulderstone Hornibrook

Hydraulics: CR Knight and Associates

Mechanical services engineer: Bassett Consulting Engineers (now AECOM)

Project manager: Australia Pacific Projects Corporation

Structural engineer: Scott Wilson Irwin Johnston

He says another shortfall of the packaged-unit approach was their shorter life compared to, for example, built-up units with conventional chilled and heating water supply.

"Theoretically, the geothermal units should be at their end of life now, being 15 years old; however, feedback from Geoscience Australia advises that the main reliability issue has been compressor failure and replacement, but this has been relatively low and within acceptable limits."

According to Cheyne, thus far this issue has only affected about 15 of the 220 units over the life of the building. An end-of-life assessment for the heat pumps has been made, and Geoscience Australia has flagged this with the landlord for asset replacement review.

The high-level interface of the units also caused compatibility problems with the original BMS installed in the building.

"Remember, this is 15 years ago and high-level interfaces were just coming into control installations," says McPhee. "Unfortunately, the technology was not far enough advanced at the time, and low interfaces would have provided fewer problems.

"Having said that," says McPhee, "I would have no hesitation in specifying a high-level interface these days, now that BACnet protocols and other open architecture are more developed."

These issues were rectified following the replacement of the interface cards during a BMS upgrade in 2007 and 2008.

THE BENEFIT OF HINDSIGHT

Although the mechanical services accounted for a relatively high 18 per cent of the $109 million total build cost, Macdonald says the selection of the geothermal system saved plantroom space, reduced peak and annual energy consumption, and reduced risk of a central plant breakdown.

"When the reduced construction cost of a smaller plantroom was taken into consideration, the geothermal system was installed for a lower capital cost and lower running cost than a typical VAV air conditioning system," he says.

Independent analysis has since indicated the award-winning design delivered a building almost equivalent to a 5 star Green Star rating; however, all believe there are things that would have been done differently if the building was to be designed today.

For instance, McPhee says today's energy-efficient boiler and chiller technology would deliver further improvements in building energy consumption.

Additionally, he says the tightening of regulations in the control and maintenance of cooling towers has resulted in the Legionella risk now being better managed, such that water-cooled plant would also substantially reduce building energy consumption.

"The geothermal system with multiple packaged units doesn't lend itself to the installation of economy cycles," McPhee says. "And it would have been good to introduce some free air cooling to the space, as the Canberra climate is ideal for economy cycles."

From a client perspective, Cheyne says ecologically sustainable development has evolved significantly in the past 15 years, such that there would be many more features considered if building today.

Though some of these, such as a new BMS and enhanced metering, have been retrofitted into the building, he says others – such as finer metering, water harvesting and alternative energy – may be included in future refurbishments.

Both Cheyne and Macdonald, who recently revisited the building and was proud to see it looking virtually as good as when it was built, say on-site alternative energy generation would also be considered if the building was built today.

The Geoscience Australia building is also considered to have been an excellent example of efficient design and construction processes. Variations

Vale John Coffey

Ecolibrium was saddened to hear of the passing on September 6 of John Coffey, director at Bassett Consulting Engineers at the time of the Geoscience Australia project. His passing came as this issue was in the throes of completion.

Having retired in July last year from Davis Langdon – a firm he joined in 2000 to build its engineering services cost-planning capability – Coffey's engineering skills combined with his inquisitive and solution-focused mind saw him add value to projects across Australia.

"You would describe John as the eternal optimist," says Michael McPhee, M.AIRAH. "I worked with John for over 14 years during my time at Bassett, and his approach certainly influenced me in my career.

"He was always positive about his work and the projects he was working on, and his enthusiasm for engineering ensured that the concepts proposed were adopted by the client and were successful.

"John devoted his working life to this industry, working well past the normal retirement age, ensuring the knowledge gained through his significant career was passed on to others. The building services industry in Australia is certainly better for having John Coffey as a contributor."

The geothermal system has proven to be highly efficient.

totalled just 1.125 per cent of the construction cost, with the project completed on budget and within program.

"The project differs from many projects today in terms of having a very astute client who had developed a well resolved brief, a reasonable budget that allowed quality to be designed in, and a very competent team," says Macdonald.

"This formula is sadly lacking in many of today's projects and reflects in the quality of the outcomes."

McPhee says the design approach was also better than that often experienced today.

"Today less time is provided for design, and projects are delivered under the builder's design-and-construct contracts, meaning the consulting team is novated to the builder, resulting in designs more often tailored to meet the builder's cost model rather than the client's requirements," he says.

"The fact that the client is still happy with the original design 15 years after the building was completed backs this up."

So too does the fact that the building's value has increased significantly.

It has been sold twice since 1997 – the first time to MTAA Super for $152.4 million in 2000 and then again in 2007 for a reported $234 million to German pension fund Real IS.

Fifteen years on, the Geoscience Australia building remains a groundbreaker in more ways than one.