Securing and enabling acces to knowledge for the future: archiving digital architectural records

PROJECT REPORT

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Top: *RMIT Storey Hall Gallery interior, Swanston Street Melbourne (2015)*
Middle: *9-track magnetic tape media at Woods Bagot (2015)*
Bottom: *RMIT Storey Hall Annexe interior, Swanston Street Melbourne (2015)*
Photographs by Chris Burns

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7. Appendices

Please note these appendices are only available for viewing at the University of South Australia Architecture Museum:

Acknowledgements

The project team gratefully acknowledge the assistance of the following:

Woods Bagot (Adelaide studio)

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1. Introduction

1.1 Project Aims and Objectives

1.1.1 The Project

This project is named *Securing and enabling access to knowledge for the future: archiving digital architectural records* (ADAR).

ADAR was initiated as a collaboration between the Architecture Museum at the University of South Australia, Adelaide, and the RMIT Design Archives, Melbourne. The project leaders from each institution were, respectively, Associate Professor Christine Garnaut and Professor Harriet Edquist. Both attended the ICAM Conference hosted in 2014 by the Canadian Centre for Architecture (CCA), heard presentations on the *Archaeology of the Digital* project and viewed the exhibition of the same name. They recognised an opportunity to initiate a small-scale project in a similar vein in Australia. Organising a team of collaborators, they approached architectural practices, invited them to become industry partners and secured funding through the University of South Australia. The funding enabled the team to employ a research assistant (Mr Chris Burns) and to organise a symposium in April 2016. The project concluded in July 2016.

A short video introducing the project may be viewed online.

1.1.2 Overview

The records of the process of designing a building cover a broad spectrum. They include virtual and physical models that explore potential shape and form, sketches, plans, renderings, correspondence (including faxes and emails) and other documents such as photographs, specifications and contracts. These records, increasingly, are created in digital environments. This project addressed the challenge of archiving and collecting born digital records, specifically in the field of architecture and the built environment, in order to secure and enable their future access by practitioners and researchers.

Australian cultural collecting institutions are yet to systematically interrogate the challenges of born digital architectural records but investigations are underway overseas. ADAR adapts one approach, the *Archaeology of the Digital,* an ongoing project underway at the CCA.

1.1.3 Scope

ADAR was devised as a narrow-focus pilot study, approaching the challenge of archiving born digital architectural records by (1) closely examining the digital archives of two case study buildings, designed and built during the mid-1990s in two Australian cities, and (2) investigating the context within which records from the case studies were created and archived, with a focus on the architectural practices in question during the years c1985-2000.

The case study buildings were:

- The **Ridgway** apartment building (Charlick Circuit, Adelaide 1995) that formed the first stage of a major residential redevelopment, revitalising a derelict precinct which was the original home of Adelaide's East End markets. Ridgeway was designed by Adelaide-based Woods Bagot architects. It was selected as one of the earliest Woods Bagot projects to be designed using PC-based CAD software and archived on CD-ROM (therefore, its file corpus is one of the earliest easily accessible).
- **RMIT Storey Hall** (Swanston Street, Melbourne 1995), is an award-winning renovation and extension of a heritage-protected building for RMIT University. It was designed by Melbourne-based firm ARM Architecture (Ashton Raggatt McDougall). RMIT Storey Hall was selected as it is regarded as a leading early example of an Australian building designed within a digital environment.

1.1.4 End Outputs

The project led to a range of outputs:

1. Archival research and digital analysis resulted in a detailed database describing the nature and quantity of surviving born digital records from the two case studies (see Appendices 5, 6 and 7).
2. A qualitative evaluation of the condition of the born digital case study records, and a discussion of the issues associated with (1) accessing their contents and (2) their long-term preservation, is presented later in this report (see Section 4).
3. Interviews with five key informants. Transcripts of interviews are in Appendices 1, 2, 3, 4 and 5.
4. A two-day public Symposium on 18-19 April 2016 titled *Born digital: a symposium exploring digital architectural and built environment records,* at which initial findings from the pilot

study research were presented, reviewed and discussed. Representatives from the case study practices were invited to the symposium, which also hosted delegates from cultural collecting institutions in Australia, the ICAM Australasia group, and other relevant bodies. Tim Walsh, Digital Archivist at the CCA, gave two workshop presentations and participated in the symposium.

The full *Born digital* symposium program can be found in Appendix 15. Podcasts and presentations are available at www.unisa.edu.au/born-digital

5. Arising out of the pilot study and symposium discussion are (1) preliminary guidelines for (1a) architectural practitioners and (1b) archival practitioners and (2) suggested directions for future research. Practitioner guidelines are included in Section 5 while directions for future research are in Section 6.

6. Preliminary findings are to be disseminated through several peer-reviewed and professional journal articles. Papers will be targeted at outlets in the digital humanities, architecture, archives, building construction and information management.

1.2 Project Team

The project team comprised representatives from a range of disciplines including architecture, architectural history, information technology, construction, and education. Within these disciplines, team members contributed specialised knowledge of traditional (paper and objects) and digital archival records management, software engineering, artificial intelligence, present-day architectural practice and Building Information Modelling (BIM).

Assoc Prof Christine Garnaut

Christine Garnaut is a planning and architectural historian and the inaugural Director of the Architecture Museum (formerly the Architecture Archive) at UniSA. The Museum collects records of South Australian-based architects and related professionals. It is Australia's only Architecture Museum and a member of the International Confederation of Architectural Museums (ICAM). Christine Garnaut is an ICAM Board member and Convenor of the regional network ICAM Australasia. E: Christine.Garnaut@unisa.edu.au

Prof Harriet Edquist

Harriet Edquist is the inaugural Director of the RMIT Design Archives (RDA). RDA collects design and architecture archives of Melbourne designers and is a member of ICAM and of ICAM Australasia. Harriet has published widely on and created numerous exhibitions in the field of Australian architecture, art and design history. E: harriet.edquist@rmit.edu.au

Prof Markus Stumptner

Markus Stumptner is a Professor of Computer Science at UniSA, with a background in databases, software engineering and Artificial Intelligence. He has worked extensively on interoperability, exchange, and long-term management of design data. Past projects include management of engineering design knowledge in multiple industries, as well as support for multiple design perspectives in urban planning. He has also worked on formal ontologies and information models for designed artefacts. E: Markus.Stumptner@unisa.edu.au

Dr Julie Collins

Julie Collins holds a B. Arch. and a PhD in architecture. She is Collections Manager and researcher at the Architecture Museum, School of Art Architecture and Design. She has extensive knowledge including of best practice in architectural archival records management. She provides advice to the architecture profession about how to manage their hardcopy records. E: Julie.Collins@unisa.edu.au

Mr John Gelder

John Gelder is an Adelaide-trained architect who worked in the UK before joining UniSA in 2014. He is a specialist in project documentation. He has extensive knowledge of Building Information Modelling (BIM) which derives from his work in developing a BIM specification library (NBS Create) and a BIM classification (Uniclass 2015). E: John.Gelder@unisa.edu.au

Mr Stephen Ward

Stephen Ward is a South Australian trained architect who worked in professional practice before joining UniSA in 2002. He is a Fellow of the Australian Institute of Architects, an Architectural Practice Examination (APE) Examiner and National Program of Assessment (NPrA) Assessor. Having worked in architectural practices in the 1990s, Stephen has personal experience and knowledge of the use of digital environments since their introduction. E: Stephen.Ward@unisa.edu.au

Dr Tim McGinley

Tim McGinley completed his Architecture studies and Engineering doctorate in the UK, and joined UniSA in April 2014. He has worked in professional practice in the UK (Foster + Partners, 2007-9) and in The Netherlands (ONL [Oosterhuis_Lénárd] 2006-7). He has recent experiences of designing buildings in fully digital environments including the concept development for Apple HQ in Cupertino and the development of parametric models for a 720m tower, from concept through to detail design. The practices where Tim has worked provide industry-leading examples of the management of digital projects. E: Tim.McGinley@unisa.edu.au

Dr Georg Grossman

Georg Grossmann is working on the integration of business processes and complex data structures for systems interoperability and has applied his knowledge successfully in industry projects. He received a PhD from UniSA in 2008 and the Ian Davey Research Thesis prize for the most outstanding PhD thesis. He is currently Co-Chief Investigator in the Data to Decisions CRC (D2D CRC) and on a Premier's Research Infrastructure Fund (PRIF) funded project on 'Software Interoperability for the Oil and Gas Sector.' E: Georg.Grossman@unisa.edu.au

Mr Chris Burns

Chris Burns is the Research Assistant for the project 'Securing and enabling access to knowledge for the future: archiving digital architectural records'. He holds a B. Industrial Design and a M. Education (Design and Technology) from the University of South Australia. He teaches within the School of Art, Architecture and Design. E: Chris.Burns@unisa.edu.au

1.3 Partners

ADAR involved external partners that create and/or collect architectural records.

Two architectural firms collaborated as in kind industry partners: Adelaide-based **Woods Bagot** and Melbourne-based **Ashton Raggatt McDougall (ARM)**. These practices were selected because they (1) introduced digital technology in the 1980s-90s, (2) survive today and (3) have retained their archives. The firms provided access to surviving archives – both digital and hardcopy records – related to the selected case study buildings, as well as access to staff members involved in their design. Representatives from each practice were invited to participate in the project symposium.

RMIT Design Archives (RDA) collects design and architecture archives of Melbourne architects and designers. RDA is a member of the International Confederation of Architecture Museums (ICAM) and of ICAM Australasia.

The **Canadian Centre for Architecture (CCA)** in Montreal is an international research institution, which aims to increase public awareness of the role of architecture in contemporary society and to promote scholarly research in the field. The CCA was conceived as an organization to fulfil several functions: to collect (as a museum and research library); to archive and document; to support research (as a study centre); and to conceptualize and broadcast knowledge (through exhibitions).

ADAR was an adaption of the CCA's ongoing project *Archaeology of the Digital.* Tim Walsh, Digital Archivist at the CCA, participated in and gave two presentations at the project symposium *Born digital: a symposium exploring digital architectural and built environment records.*

1.4 Methods

1.4.1 Archival research (hardcopy records)

A sample of the hardcopy archive from each case study was examined prior to examining the respective born digital archives. The hardcopy records established a benchmark by which to assess the born digital records, and in particular, to assist identifying what kinds of records may possibly be missing or under-represented in the born-digital archive.

1.4.2 Data analysis (born digital records)

Born digital files from the two case studies were collected from the partner firms on physical media and backup copies made. The collected files were then subjected to (1) qualitative and (2) quantitative analysis.

Qualitative analysis involved:

a) Examining file and folder structures in order to understand the logic of their organising principles.
b) An attempt to open representative files from each surviving format.
c) Documenting problems preventing particular file formats from opening.
d) Where possible, taking steps towards identifying solutions that would allow problematic formats to open.
e) Examining representative files for problems (for example formatting abnormalities in documents or graphics errors in 3D CAD models).

Quantitative analysis involved tabulating file metadata (including, for example, file format, dates modified and created, file size and file location). Initially, metadata was tabulated manually; later, the process was automated using 'Siegfried'[1] and 'Brunnhilde'[2] software tools developed, respectively, by Richard Lehane and Tim Walsh.

[1] http://www.itforarchivists.com/siegfried
[2] https://github.com/timothyryanwalsh/brunnhilde

1.4.3 Interviews

A series of formal, recorded interviews with key staff from the partner firms enabled the researchers to capture some of the tacit knowledge and experiences of architecture professionals who were a) involved in the design process for the case study buildings, b) were closely involved in the emergence and early use of digital technology at one of the partner firms or c) responsible for or involved with archiving records associated with the project. Information gathered through interviews served to contextualise the born-digital records surviving from each of the case study projects.

The interviews aimed to address the following key questions:

- What was the early role and influence of digital technology in architectural practice?
- How did design processes change as a result of the introduction of digital technology into architectural practice?
- What kinds of knowledge are embodied in digital architectural records? What is their relevance to the architectural profession and research communities?
- What are the challenges associated with archiving digital architectural records? How can these challenges be addressed?

Prior to the commencement of the interviews an application was submitted to the University of South Australia's Human Research Ethics Committee. The application was approved and assigned protocol 0000034893.

All of the interviews were conducted in accordance with the approved application.

2. Literature overview

2.1 Emergence of digital technology in Australian architectural practice c1980-2000

The first widespread appearance of digital technology in Australian architectural practice occurred in the early 1980s, in parallel with the emergence of the first generation of affordable microcomputers (now usually referred to as desktop computers or PCs). While digital technology was often adopted for administrative tasks, such as word processing or spreadsheet creation, computer aided design (CAD) technology did not find immediate acceptance within Australian architectural practice.

Antony Radford and Gary Stevens, present extensive technical information on the implementation of then state-of-the-art digital technology, while also providing a thorough discussion of the reasons underlying the reluctance of architectural practitioners to fully embrace CAD technology in *CADD Made Easy: a comprehensive guide for architects and designers*.[3]

It is interesting to note that Luscombe and Peder's seminal text *Picturing Architecture: Graphic Presentation Techniques in Australian Architectural Practice*, which presented a case for the creation of architectural drawings as 'an end in themselves'[4] contained only two examples of computer-generated drawings in a large collection of case studies.[5] Their inclusion was justified, in the first instance, by stressing the impossibility of accurately representing the design accurately by traditional means, while the discussion of the second example emphasised the hand-finished application of colour to the rendered drawing.

Antony Radford's *Computers in Australian Architectural Practice: Conversations with Practitioners* explores the early engagement of Australian architectural practitioners with digital technology through a series of case studies. Fifteen Australian architectural firms are discussed, supported by direct quotations from interviews with directors, architects and CAD managers, providing an invaluable insight into the reception of digital technology and its patterns of use in late-1980s Australian architectural practice.[6]

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[3] Antony Radford and Garry Stevens, *CADD Made Easy: a comprehensive guide for architects and designers,* New York: McGraw-Hill (1987)

[4] Desley Luscombe and Anne Peder, *Picturing Architecture: Graphic Presentation Techniques in Australian Architectural Practice,* Tortola, BVI/Roseville East, NSW: Craftsman House (1992), p. 1

[5] Ibid, pp. 190-193

[6] Antony Radford, *Computers in Australian Architectural Practice: Conversations with Practitioners,* Red Hill, ACT: RAIA Education Division (1988)

Further Reading:

John Aspinall, “The Computer: Master or Servant of Architecture?” in *Architecture Australia,* May/June 1988, pp. 82-85

Hazel Baker, “CAD: The Wave Flows on” in *Architecture Australia,* May/June 1988, pp. 76-79

Andrew Begg, “Building Industry Computer Aided Technology” in *Building + Architecture (Official Journal of the Royal Australian Institute of Architects, SA Chapter),* June 1985, Vol 12, No 15, p. 14

Andrew Davies, “Architects and Computers 2” in *Building + Architecture (Official Journal of the Royal Australian Institute of Architects, SA Chapter),* June 1985, Vol 12, No 15, pp. 12-13

Natalie Leighton, *Computers in the Architectural Office*, New York: Van Nostrand Reinhold Company Inc. (1984)

Keith Neighbour, “Architects and Computers 1” in *Building + Architecture (Official Journal of the Royal Australian Institute of Architects, SA Chapter),* June 1985, Vol 12, No 15, pp. 8-12

David Ness, “Facing the Future: Computers in Architecture (editorial)” in *Building + Architecture (Official Journal of the Royal Australian Institute of Architects, SA Chapter),* June 1985, Vol 12, No 15, p. 6

Antony Radford, “Computers” in *Architecture Australia*, March 1983, Vol 72, No 2, pp. 54-59

John Schenk, “Studio and CAD Learning Environments” in *Architect South Australia,* September 1994, pp. 15-17

James R. Stewart, “Computers” in *Architecture Australia*, March 1981, Vol 20, No 3, pp. 72-74

2.2 Preservation of born-digital objects

All commercially available digital carrying media, including writable optical disks, hard disk drives (HDDs) and flash memory, are inherently unstable and susceptible to degradation over time (known as "bit rot"), leading to the eventual likelihood of data loss. While traditional paper-based records are able to remain readable over decades or centuries in archival conditions with little or no maintenance, digital files require ongoing, active stewardship in order to remain viable, even over relatively short timeframes.

The skills necessary to achieve long-term preservation for born-digital objects are accordingly different to those required in traditional archival practice. Elford et al discuss commonalities as well as differences, drawing a contrast between the innovation and experimentation that characterise the emergent field of digital preservation and the tried-and-tested methodologies and techniques employed in traditional conservation.[7]

Lindlar and Saemann identify three digital object layers[8], forming a helpful conceptual framework for thinking about digital objects:

- The bitstream layer refers to the physical storage of binary code that comprises digital objects. At the bitstream level, access to digital objects may be impeded by obsolescence of physical carrying media, while their integrity may be compromised by technical failure or accidental deletion.
- The logical layer refers to the content of digital files. At the logical layer, access to digital objects may be impeded by a dependency on proprietary file formats or software. Digital files themselves may also be inadvertently modified or overwritten.
- The semantic layer refers to human understandings and interpretations of, as well as interactions with, the content of digital files. At the semantic layer, the interpretation of digital files may be dependent upon their context or provenance, while the specialised, tacit knowledge may be required to interact with digital files in complex software environments.[9]

[7] Douglas Elford, Lisa Jeong-Reuss, Somayal Langley and Melanie Wilkinson, 'Getting the whole picture: finding a common language between digital preservation and conservation' 2012, https://www.nla.gov.au/content/getting-the-whole-picture-finding-a-common-language-between-digital-preservation-and; accessed 23 August 2015

[8] Michelle Lindlar and Hedda Saemann, *The DURAARK Project – Long Term Preservation of Architectural 3D-Data* (conference proceedings). CIDOC 2014, Annual conference of the International Committee for Documentation/The International Council of Museums, Dresden, 2014, http://duraark.eu/presentations; accessed 5 December 2016

[9] Ibid.

A number of institutions have acquired a Forensic Recovery of Evidence Device (FRED), which is used to create copies of digital information at the bitstream level using disk imaging, without risking damage to, or alteration of, original carrying media.[10] Prael and Wickner chronicle their experiences with FRED at the University of Maryland Libraries, Special Collections and University Archives, and provide a discussion of digital preservation workflows, in 'Getting to know FRED: Introducing Workflows for Born-Digital Content.'[11]

The Digital Preservation team at the National Library of Australia (NLA) have developed an online, searchable database of carrying media, called Mediapedia,[12] designed to enable the identification of various media formats, for example magnetic tape, optical disks and Zip drives.

In order to address the limitations and inherent instability of currently available physical media, US based company Group 47 are currently in the process of commercialising DOTS (Digital Optical Technology System),[13] a technology originally developed by the Eastman Kodak company. DOTS is a non-magnetic and chemically inert storage media, described as 'a low-cost, environmentally friendly way to truly archive data long term.'[14]

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[10] Digital Intelligence 'FRED' http://www.digitalintelligence.com/products/fred; accessed 5 December 2016

[11] Alice Prael and Amy Wickner, 'Getting to know FRED: Introducing Workflows for Born-Digital Content' in *Practical Technology for Archives,* No 4, May 2015, http://practicaltechnologyforarchives.org/issue4_prael_wickner; accessed 27 October 2015

[12] National Library of Australia, 'Mediapedia' http://mediapedia.nla.gov.au/; accessed 23 August 2015

[13] Hal Hodson, 'Archives live forever' in *New Scientist,* 10 October 2015, p. 19.

[14] Group 47, 'What is Dots?' http://group47.com/what-is-dots/; accessed 5 December 2016

Further Reading:

The personal website of Tim Walsh, Digital Archivist at the Canadian Centre of Architecture (CCA), provides an extensive further reading list, 'Access to Born-Digital Architectural Records: Independent Study Reading List,'[15] with links to online resources including reports, journal articles and online video content.

Ann R.E. Armstrong, 'Architectural Archives/Archiving Architecture: The Digital ERA' in *Art Documentation: Journal of the Art Libraries Society of North America,* Vol. 25, No. 2, Fall 2006, pp. 12-17

Christopher Becker, Hannes Kulovits, Mark Guttenbrunner, Stephan Strodl, Andreas Rauber and Hans Hoffman, 'Strategic planning for digital preservation: evaluating potential strategies and building preservation plans' in International Journal of Digital Libraries Vol 10, No 4, 2009, pp. 133-157

Henry M. Gladney, 'Long-Term Preservation of Digital Records: Trustworthy Digital Objects' in *The American Archivist,* Vol 72, No 2, Fall/Winter 2009, pp. 401-435

Nick del Pozo, Andrew Stawowczyc Long and David Pearson, '"Land of the Lost": a discussion of what can be preserved through digital preservation' in *Library Hi Tech,* Vol 28, No 2, 2010, pp. 290-300

Kenneth Thibodeau, 'Overview of Technological Approaches to Digital Preservation and Challenges in Coming Years' in *The State of Digital Preservation: An International Perspective* (conference proceedings), CLIR Report 107, pp. 4-31, http://www.clir.org/pubs/reports; accessed 5 December 2016

Colin Webb, David Pearson and Paul Koerbin, '"Oh, you wanted us to preserve that?!" Statements of Preservation Intent for the National Library of Australia's Digital Collections' in *D-Lib Magazine,* Vol 19, No 1/2, January/February 2013, http://www.dlib.org/dlib/january13/; accessed 23 August 2015

Ines Maria Zalduendo, 'Paradigm shift: curatorial views on collecting and archiving architectural drawings in an evolving born-digital landscape.' Paper presented at the Society of American Archivists Conference, Washington D.C., August 2014, http://nrs.harvard.edu/urn-3:HUL.InstRepos:13442962; accessed 27 October 2015.

[15] Tim Walsh (2015) 'Preservation and Access of Born Digital Architectural Design Records in an OAIS-Type Archive,' http://bitarchivist.net/projects/independentstudy/walsh_CADArchiving2015_final.pdf; accessed 5 December 2016.

2.3 Digital preservation standards, guidelines, policies and models

The *Reference Model for an Open Archival Information System (OAIS)* is an international standard for digital stewardship, has been adopted by many repositories of born-digital objects, including the CCA.[16]

A good starting point towards understanding the OAIS model and its implementation may be a self-directed study conducted by Tim Walsh, 'Preservation and Access of Born Digital Architectural Design Records in an OAIS-Type Archive.'[17]

The National Library of Australia (NLA) has developed a Digital Preservation Policy[18], with the objective of 'maintaining the ability to meaningfully access digital collection content over time.' NLA conducts ongoing research into digital preservation, results of which are also made available online.[19]

Digital Curation Centre (DCC) is the national digital curation centre for the UK. The DCC Curation Lifecycle Model represents a holistic approach to digital preservation.[20]

The PREMIS Data Dictionary for Preservation Metadata (PREMIS) is the international standard for metadata supporting the preservation of digital objects in order to ensure their long-term accessibility.[21]

The Dublin Core Metadata Initiative (DCMI)[22] is 'an open organisation supporting innovation in metadata design and best practices across the metadata ecology,' actively conducting research in the field of architecture.[23]

The Metadata Encoding and Transmission Standard (METS) 'is a standard for encoding descriptive, administrative, and structural metadata regarding objects within a digital library.' This standard has been developed by the Network Development and MARC Standards Office of the US Library of Congress, as an initiative of the Digital Library Federation.[24]

[16] http://public.ccds.org/publications/archive; accessed 5 December 2016
[17] Tim Walsh, *Preservation and Access of Born Digital Architectural Design Records in an OAIS-Type Archive*, 2015, http://bitarchivist.net/projects/independentstudy/ walsh_CADArchiving2015_final.pdf; accessed 5 December 2016
[18] www.nla.gov.au/content/policy-and-planning/digital-preservation-policy; accessed 5 December 2016
[19] http://www.nla.gov.au/digital-preservation/related-staff-papers; accessed 5 December 2016
[20] http://www.dcc.ac.uk/resources/curation-lifecycle-model; accessed 5 December 2016
[21] www.loc.gov/standards/premis; accessed 5 December 2016
[22] http://dublincore.org; accessed 5 December 2016
[23] http://dublincore.org/groups/architecture; accessed 5 December 2016
[24] www.loc.gov/standards/mets; accessed 5 December 2016

Further Reading:

AIMS Work Group, 'AIMS Born-Digital Collections: An Inter-Institutional Model for Stewardship,' 2012, http://www2.lib.virginia.edu/aims/whitepaper/AIMS_final_A4.pdf; accessed 5 December 2016.

Architectural Archives in Europe, 'GAUDI A2 AAE, Guidelines to managing architectural records, Version 01,' December 2004, https://www.architecture.com/RIBA/Visitus/Library/Assets/Files/Collections/ArchivingTheDigital/Resources_GaudiGuidelinesonMangaingElectronicRecords2004.pdf; accessed 5 December 2016

2.4 Special challenges of preserving 3D CAD Models

3D CAD models, which are often created in proprietary software, pose unique challenges for preservation and access at the logical level (see section 2.2). 2D file formats can be converted to open-source archival formats (for example AutoCAD .DWG can be converted to TIFF or PDF/A), enabling long-term accessibility, without compromising the predicted needs of most archive users. However, interactive 3D objects are more difficult to reformat without incurring a significant loss of information and functionality, especially in the case of parametric models, which in most cases can only be viewed in their original software environment.[25]

While legacy CAD software can be run on virtualised computer platforms, emulation as an access strategy poses practical as well as legal obstacles, since most proprietary CAD software packages contain licencing protection mechanisms.[26]

MIT Libraries conducted the FACADE project in order to investigate preservation strategies for born-digital files from architectural design projects involving 3D CAD. This project resulted in a recommendation that collecting institutions generate three versions of each original parametric CAD model, as well as maintaining the original, catering for different use cases:

- Export to open standard STEP or IFC format to capture solid geometry
- Export to open standard IGES format to capture surface geometry
- Export to 3D PDF format for public access and web upload
- Unaltered model in native format, allowing for future software emulation[27]

The FACADE project also involved 'semantic enrichment'[28] of 3D CAD models by embedding them in a PIM (Project Information Model) comprised of related project data including other 3D project models, correspondence and 2D drawings, in order to reinforce the context of digital objects at the semantic level.

Innovations in interoperability brought about by Building Information Modelling (BIM) and standards such as Industry Foundation Classes (IFCs) go some way towards addressing logical level accessibility

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[25] MacKenzie Smith, 'Curating Architectural 3D CAD Models' in *The International Journal of Digital Curation*, Vol 4, No 1, 2009 p. 103
[26] Ibid pp. 100-101
[27] Ibid p. 103
[28] Ibid p. 103

for BIMs that may be created in the future.[29] However, these standards cannot necessarily be applied retrospectively to ensure the ongoing accessibility 3D CAD models created in the past.

[29] Michelle Lindlar, 'Building Information Modelling – a game changer for interoperability and a chance for digital preservation of architectural data?' 11th International Conference on Digital Preservation (iPRES 2014). Melbourne, Australia, October 2014, pp. 199-208

Further Reading:

Alex Ball, *Preserving Computer-Aided Design (CAD),* DPC Technology Watch Report 13-02 April 2013, www.dpconline.org/component/docman/doc_download/896-dpctw13-02pdf; accessed 5 December 2016

Jakob Beetz, Stefan Dietze, Rene Berndt and Martin Tamke, 'Towards the long-term preservation of Building Information Models.' Proceedings of the 30th CIB W78 International Conference – October 9-12, 2013, Bejing, China, https://pure.tue.nl/ws/files/3894661/601748022970181.pdf; accessed 5 December 2016

DURAARK Project, http://duraark.eu; accessed 5 December 2016

DURAARK Publications, http://duraark.eu/publications/; accessed 5 December 2016

Kurt G. F. Helfrich, 'Questions of authenticity: challenges in archiving born-digital design records' in Art Libraries Journal, Vol 35, No 3, 2010, pp. 23-29

Margaret L. Hedstrom, Christopher A. Lee, Judith S. Olson, Clifford A. Lampe, '"The Old Version Flickers More": Digital Preservation from the User's Perspective' in *The American Archivist,* Vol 69, No 1 Spring/Summer 2006, pp. 159-187

Michelle Lindlar, and Hedda Saemann, *The DURAARK Project – Long Term Preservation of Architectural 3D-Data* (conference proceedings). CIDOC 2014, Annual conference of the International Committee for Documentation/ The International Council of Museums, Dresden: http://duraark.eu/presentations; accessed 5 December 2016

MIT, *FAÇADE Project* Website, http://facade.mit.edu/ accessed via Internet Archive, http://web.archive.org/web/20130412222615/http://facade.mit.edu/; accessed 5 December 2016

MIT, *FAÇADE Project Final Report*, accessed via Internet Archive, http://web.archive.org/web/20130412222615/http://facade.mit.edu/files/FACADEFinalReport.pdf; accessed 5 December 2016

Kathryn Pierce, 'Collaborative Efforts to Preserve Born-Digital Architectural Records: A Case Study Documenting Present-Day Practise' in *Art Documentation: Journal of the Art Libraries Society of North America,* Vol 30, No 2, 2011, pp. 43-48.

3. Case Studies

3.1 50048 Garden East: Ridgway Apartments

3.1.1 Woods Bagot

Woods Bagot is a global architectural practice, founded in the late 1860s in Adelaide, South Australia. Woods Bagot expanded rapidly in the late 1980s and early 1990s and currently operates six offices in Australian capital cities (Adelaide, Brisbane, Canberra, Melbourne, Perth and Sydney) and a further nine internationally (Abu Dhabi, Beijing, Dubai, Hong Kong, London, New York, San Francisco, Shanghai, and Singapore).[30]

Unusually, the Woods Bagot Adelaide office holds a near-complete[31] hardcopy archive, covering the history of the practice form earliest beginnings to the present day. The hardcopy archive contains material including (for example) drawings, specifications, photographs and correspondence. Moved offsite in the late 1980s, the archive is now stored and administered by Recall Total Information Management at 64 East Avenue, Beverly.[32]

The firm also maintains an archive of born-digital records.

Woods Bagot employs an archivist in the Adelaide office, David Holliday, to manage the hardcopy archive and mediate access to both hardcopy and born-digital archives.

Emergence of Digital Technology at Woods Bagot

By the late 1980s Woods Bagot boasted one of the largest CAD systems in private Australian architectural practice,[33] comprised of an Adelaide-based Mini (Minicomputer – a small mainframe computer) serving all of Woods Bagot's other Australian offices. Archival research within the office suggests the existence of a Digital Equipment Corporation VAX/VMS operating system c1985-1991.[34] However by c1992[35] the office operated a Prime mini (from Prime Computers, Inc.) running a CAD package called GDS (General Drafting System). Output from native CAD files was achieved through the use of pen plotters, which translated vectors in a CAD drawing into drawn lines on a page.

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[30] www.woodsbagot.com (accessed 12 December 2015).
[31] Unfortunately, some correspondence files were culled during a brief period (possibly during the 1970s) but records exist detailing which files were destroyed (*Interview with David Holliday,* 22 June 2016; SLSA OH 1112/3).
[32] See Appendix 9 for an overview of Wood Bagot Adelaide office hardcopy archival storage.
[33] Antony D. Radford, *Computers in Australian Architectural Practice: Conversations with Practitioners*, Red Hill ACT: RAIA Education Division (1988) p. 6
[34] Extant data tapes contain installation files for VAX/VMS. See Appendix 14.
[35] A Prime-based system is recalled by Glen Collingwood (*Interview with Glen Collingwood*, 8 March 2016; SLSA OH 1112/1) and Suresh Dhillon (*Interview with Suresh Dhillon*, 22 June 2016; SLSA OH 1112/2). Both commenced work at Woods Bagot in the early 1990s.

Initially, microcomputers (more commonly referred to as PCs today) were used for administration (including word processing and spreadsheet creation). The arrival of MircoGDS, a Windows-based derivative of GDS, resulted in the experimental deployment of two licences on PCs in the Adelaide office with a small standalone server. MicroGDS offered several advantages over the original GDS, notably an icon-driven interface in lieu of keyboard commands.

The arrival of Windows PCs led to the phasing out of the large Minis at Woods Bagot. The large minis at Woods Bagot were phased out and replaced entirely by PCs by the mid-1990s, due to the new possibilities afforded by desktop publishing within the office, along with the arrival of inkjet printers capable of reproducing colour images from raster image files.

Data was backed up daily on magnetic tape media.

MicroGDS CAD software was ultimately superseded by ARCHICAD and, more recently, Autodesk Revit.

In the early 1990s Woods Bagot introduced its *Quality Management System*,[36] a document that prescribed protocols for many aspects of operating the office, including stringent regulations for the naming, filing, archiving and disposal of hardcopy records. In the document in use during the Ridgway era (March 1994), archiving procedures were described under the heading 'Dead Files':

> Archived or long term files including drawings shall be maintained for not less than 7 years. The Office Manager is responsible for determining in and when archived material is no longer required and may be destroyed.[37]

Interestingly, similar protocols for born digital records are not mentioned at all, neither are they mentioned in the in-house *CAD Reference Manual*[38] (April 1997); however, they may have been formalised in documents which are no longer available.

The introduction of the *Quality Management System* coincided with the introduction of a new numbering system for Woods Bagot projects.[39]

Born-digital archives at Woods Bagot

[36] See Appendix 16
[37] *Woods Bagot Quality Management System: (Appendix D) Records Maintenance, Filing & Drawing Procedures,* (1994) p. 4; see Appendix 16.
[38] See Appendix 17
[39] See Appendix 10

Initially, the born-digital files archived annually were those captured as part of the tape backup cycle. While a large number of magnetic tapes from the 1980s-90s are extant in the Adelaide office they cannot be read, because the necessary tape drives no longer exist within the office (Fig. 1).

Fig. 1 *9-track magnetic tape media at Woods Bagot Adelaide office* (2015); photograph by Chris Burns.

Beginning in 1996, born-digital records were archived on optical media (CD-ROM and later on DVD-ROM disks). Disk failures mean that some data from this era may have been lost; it is also believed that some data created prior to 1996 and stored on magnetic tapes was not subsequently transferred to CD. The full extent of data loss from the digital archive due to these two causes cannot be fully known.

Additionally, born-digital CAD files created using Mini-based CAD systems are unable to be opened, even where their bit streams are intact and accessible, since the original GDS software no longer exists in the office.

The loss of digital files is particularly acute in the case of material from the late-1990s. During this period, a growing trust in digital technology led to a diminishing ingest of paper records into the hardcopy archive. While (some of) the CAD files from the Ridgway project (for example) had a redundancy in the form of hardcopies, for later projects soft copy files (often in .PDF format) are the primary record of the project, and their loss is not mitigated by the existence of hardcopy equivalents.

More recently archived data has been stored on a dedicated, read-only server, based in Sydney, with an approximate total approaching 3TB of data stored from the Adelaide office,[40] and an approximate grand total of 40TB from all of Woods Bagot's international operations combined. The born-digital archive is also backed up by an external cloud storage provider.

Access to files on the archive server is limited to key individuals. Within the Adelaide office access is mediated by archivist David Holiday. Each time files are added to the archive, a new folder must be created. Previously created folders are permanently closed, and cannot be supplemented at a later time. When records are requested from the archive server, they are copied into a so-called 'Restore' drive, to which all staff members have read and write access.

Data originally archived on CD and DVD has since been uploaded onto the main archive server. However, there are noticeable discrepancies between the original data held on extant optical media and data transferred to the server.[41] Once again, the full extent of this discrepancy is not currently known.

The Adelaide office maintains active licences for a number of legacy CAD packages, including MicroGDS and ARCHICAD, which are no longer used on a day-to-day basis, in order to secure access to projects and proprietary CAD files created on these platforms.

[40] Information supplied by David Holliday, 24 February 2016.

[41] Since there are a relatively small number of optical disks (for example, all of the projects from 1996 were archived on a single disc), creating images of extant discs in the Adelaide office seems an appropriate and advisable course of action.

3.1.2 50048 Ridgway project overview

The Ridgway apartment building (in Charlick Circuit, Adelaide), designed by Woods Bagot, formed the first stage of the Garden East redevelopment, revitalising a derelict precinct which was the original home of Adelaide's East End markets.

Fig. 2 *Digitised (scanned) hand drafted elevation of Ridgway apartments from the born digital project archive*

Woods Bagot personnel involved on Ridgway included Chris Parker (Design Director), Russell Prescott (Design Leader), Peter Hoare (Quality Auditor), Richard Wunderlich (Office Quality Manager), Glen Collingwood (Senior Technician), Suresh Dhillon (IT Manager and CAD Draftsperson) and Nick Bendys (CAD Draftsperson).

Client Max Liberman (Liberman Group/Kinsmen Pty Ltd) envisaged an 'urban residential village development,' of which Ridgway would be the first stage:

> …[Max] had a reputation as a reliable developer. And a fairly innovative developer. He had a vision that urban living could be revitalised in South Australia. He had an uncompromising attitude towards quality, and he was determined that he was going to re-educate the unwashed public in Adelaide and South Australia that they could expect better – (laughs) one of his quotable quotes was – he said to me one day, "Glen always

remember that people in South Australia, in Adelaide, insist on mediocrity." And he chose to change that.[42]

Conceptual design unfolded very quickly, largely in conversation between Russell Prescott and Max Liberman:

> …Russell would fly into town from Melbourne, he would have a day session with Max, they'd go up to Max's office, sit in the boardroom, and they would sketch the requirements, and by the end of that day there would be freehand plans, freehand elevations – signed. By Max… it was as quick as that… and that design would then be handed to the likes of myself and some of the juniors.[43]

Ridgway was the first project to use an elemental system of project documentation, in which written annotations on drawings were replaced by symbols cross-referenced to schedules. This system can be regarded as an analogue predecessor to what is now known as Building Information Modelling (BIM).

Consultants on the project included Skyator, Kinhill Engineers, Dare Sutton Clarke, DCS/EMF, Fyfe Surveyors and Bassett Engineers.

[42] *Interview with Glen Collingwood*, 8 March 2016; SLSA OH 1112/1
[43] Ibid.

3.1.3 50048 Ridgway hardcopy archive[44]

Records are stored across two business cartons labelled DS1314 and DS1361, and in a tube containing several rolled drawings (these are hand-drafted sections on tracing paper, together with drawings from other projects). The shelf length of records in cartons is approximately 45 cm.

Records are organised in foolscap size file folder-binders, labelled according to contents. “A” prefixed (pink) folders contain general records pertaining to the client and Woods Bagot. “B” prefixed (blue) folders contain records pertaining to consultants. Most of the folders are also labelled with a date range. In general, records appear to be bound in folders sequenced with the latest (newest) records first and the earliest (oldest) records last.

Most of the project files are stored in carton DS1314, however folders A05 and A03 were found in DS1361. These two folders may have been filed in DS1361 because they were not ready to be archived (or were missing) at the time when DS1314 was dispatched to the external storage provider.

The hardcopy archive mainly contains records from the design documentation phase, including faxes, meeting minutes, detail drawings (often freehand), inkjet-printed presentation drawings and hand-drafted, pencil coloured elevations. There is a low volume of conceptual material evident. Russell Prescott’s initial sketches (described by Glen Collingwood) are missing from the archive, as are the final contract drawings.

Strongly evident in the hardcopy archive are the effects of the proliferation of analogue electronic technology in Australian architectural practice, notably photocopiers and fax machines (by contrast, there is no evidence of the formerly prevalent dyeline copying process in the archive). Many documents have undergone several iterative transformations – for example, annotations in pen or ink, alteration with white-out, photocopying to reduce scale or produce a clean drawing, or transmission or reception by fax. There are also many examples of cut-and-paste alterations to documents using adhesive tape – another aspect of the workflow afforded by photocopiers. Quite often documents exhibit a distinct ‘layered-ness’ – not only has each iteration left visible traces, but the order in which various iterations were carried out is easily discernible.

[44] See Appendix 8 for a more detailed description of the hardcopy archive.

3.1.4 50048 Ridgway born digital archive

Born digital records from the Ridgway project examined during this case study were copied directly from the original CD-ROM disk burned in 1996. The total size of these files is approximately 85MB.

The organisation of the Ridgway born digital archive (Fig. 3) is based on the same folder structure as the hardcopy archive, which is in turn prescribed by the *Woods Bagot Quality Management System*. The born digital archive contains mainly Microsoft Word documents (.doc), Microsoft Excel spreadsheets (.xls) and MicroGDS CAD files (.wnd, .dat, .own). There are also several digitised (scanned) images (.tiff) among other formats.[45] While opening early legacy .doc and .xls files proved initially problematic, changing the default settings in Microsoft Office 2013 allowed all such extant files to be opened successfully.[46]

Many of the .doc and .xls files are letterhead pages created for hardcopy printout and subsequent fax transmittal. Often, these documents refer to attachments that are absent from the digital archive (although corresponding hardcopy attachments can be located). Prior to the widespread use of email, most of the communication passing through the Adelaide office was not captured in the digital archive because it was not created or transmitted in digital form. In general, the 'layered-ness' observed in the hardcopy archive is not present in the born digital archive.

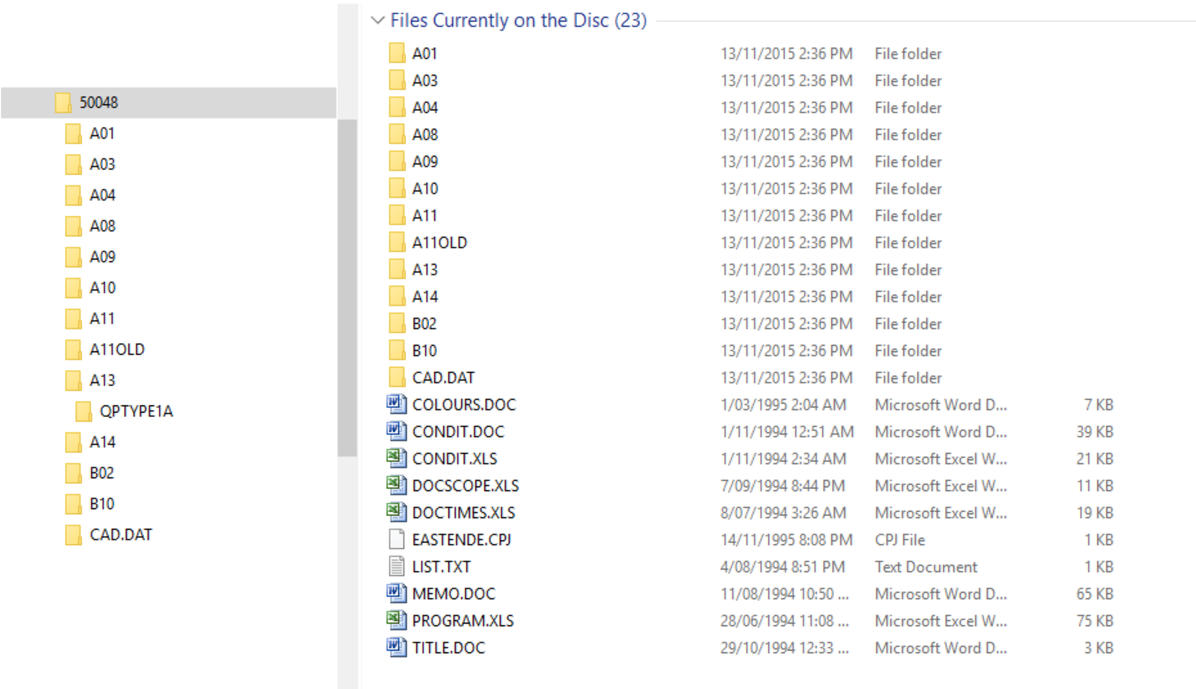

Fig. 3 *50048 Ridgway born digital archive folder structure.*

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[45] See Appendix 5 for a full breakdown of file types.
[46] See Appendix 13 for details and instructions.

CAD files from the Ridgway project were created using proprietary MicroGDS software. Access to either the original software or a newer version of MicroGDS is required to read the files. CAD files consist predominantly of site and floor plans, many of which appear to have been created in colour for presentation purposes. These drawings are exclusively two-dimensional.

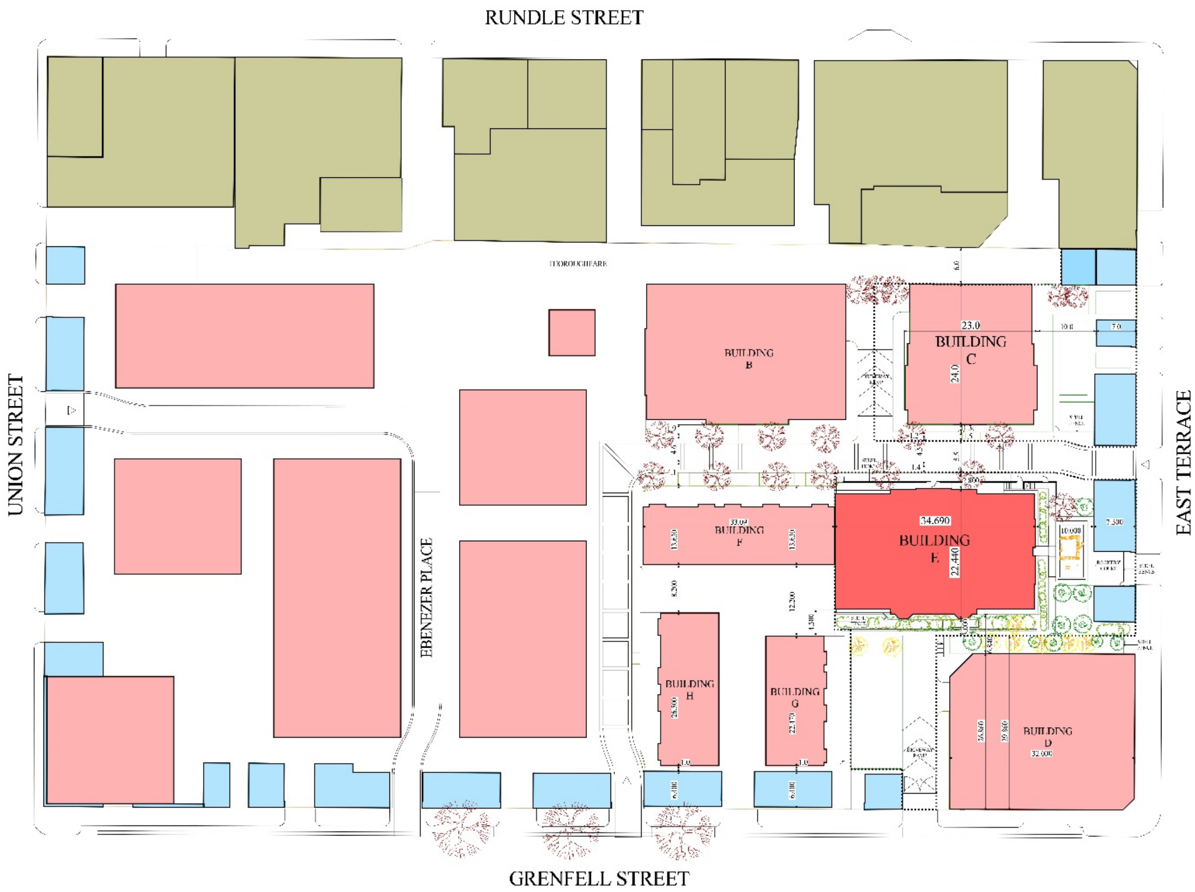

Fig. 4 *Garden East Site Plan including Ridgway apartments (Building E), generated using MicroGDS CAD software.*

Elevations were not created using CAD. Instead they were hand-drawn (fig 2) and pasted onto CAD/inkjet generated title blocks. Sections and details appear to have been exclusively hand-drawn and can only be found in the hardcopy archive (or as digitised copies thereof, in the digital archive).

CAD files created in MicroGDS for the Ridgway project consist mainly of a large number of Window Definition (.WND) and Layer (.DAT) files. A single Cad Project file (.CPJ) is key to compiling all of the other related project files in the virtual MicroGDS environment.

Window Definition Files (.WND) are located in the directory 50048>A11. Each .WND file defines the layout of a particular drawing. In the Ridgway archive this directory contained a number of anomalous .OLD files, which are temporary files created when a .WND file has not been closed properly (possibly due to a system crash, power failure, or hard shutdown).

The Ridgway digital archive also contains a directory named A11OLD (50048>A11OLD), which seems to contain a redundant version of the project, possibly retained as a backup. The .WND files in this directory were last modified on 2 July 1994 at about 7 pm (the one exception is EEMSITE.WND which was last modified on 20 September 1994), strongly suggesting that this subfolder represents a snapshot of the project from that moment in time.

Layer files (.DAT) are located in the CAD.DAT directory (50048>CAD.DAT) and most are numbered in an incomplete sequence beginning with 1 and ending at 1486. The CAD.DAT directory contained a number of .OWN files which exist for the same reasons as, and are analogous to, the .OLD files in the A11 directory, mentioned above.

Finally, the .CPJ file is located in the main project directory (50048>EASTENDE.CPJ). In rare instances the .CPJ file has been missing from a project's digital archive, resulting in a disordered 'soup' of lines that are no longer organised into layers. In these cases, while it is possible to separate layers manually and rebuild a project, the process is laborious and very time-consuming, even in the hands of a skilled CAD operator, taking many days (if not weeks) and possibly calling upon first-hand tacit knowledge of the project in question.

File header examination (achieved by changing the file extensions to .txt and opening the files in Notepad) revealed that most of the files were created in MicroGDS version 4.

In order to open the Ridgway CPJ. in the latest version of MicroGDS (version 5.1 is current in the Adelaide office), the entire project needed to be updated by running a series of proprietary batch processing applications on the project files.

The update applications, once begun, are automatic and irreversible – the original project files and metadata are overwritten. For this exercise, a copy of the project files was made for updating.

Before beginning the update, a prompt appeared on the screen indicating that the .OWN and .OLD files should be renamed with .DAT and .WND file extensions, respectively. In this case, the files were simply deleted since they appeared to be duplicates of existing files.

First the project was updated from version 4 to version 5 using one application, then from version 5 to version 5.1 using a second application. After this, the project was successfully opened in MicroGDS version 5.1.

While born-digital CAD drawings created in MicroGDS are occasionally resurrected from the digital archive for reference (this happens twice per year on average), technical limitations mean that the geometry cannot be reused directly. A common practice is to import drawings into AutoCAD and trace over them on a new layer -- a fairly time-intensive operation resulting (effectively) in a new drawing, since the original geometry is finally discarded.

Nick Bendys maintains an unofficial archive of CAD drawings on his desktop PC, comprising floorplans of some of Adelaide's larger commercial buildings which were designed by Woods Bagot using MicroGDS software in the late 80s and early 90s. Tenants of these buildings are frequent return clients, so Nick created this personal working archive to avoid the repeated inconvenience of recovering files from the digital archive CDs and updating them to the latest version of MicroGDS (version 5.1 is current in the office).

3.2 RMIT Storey Hall

3.2.1 ARM Architecture

ARM Architecture was founded in Melbourne in 1986 by Steve Ashton, Howard Raggatt and Ian McDougall. The firm soon became well known in Australia and overseas for their work a succession of innovative and award-winning projects, including the St Kilda Town Hall Redevelopment (1995), National Museum of Australia (2002) and Marion Cultural Centre (2002). Recently ARM has received awards and commendation for their work on the Melbourne Recital Centre & MTC Theatre (2009) and renovations to Hamer Hall (2013).

ARM currently has offices in Melbourne and Perth.

Like Woods Bagot, ARM retains comprehensive born digital and hardcopy archives; both were drawn upon extensively during the creation of a recent in-house publication, *Mongrel Rapture: the architecture of Ashton Raggatt McDougall.*[47]

Emergence of Digital Technology at ARM architecture

In the early 1990s ARM Architecture was a medium-sized practice with approximately ten employees, spread over several floors of a Victorian-era building in Carlton. Drawing upon connections with the School of Architecture at RMIT University, ARM intentionally selected and employed students and graduates with skills in areas such as 3D modelling and coding. This in-house knowledge base enabled ARM to pioneer, in Australian architectural practice, emerging digital technologies; in particular, the use of 3D CAD as a design tool.

> …the possibilities of the computer itself became something that the office was interested in – as being a set of ideas that can change the way architecture can be considered.[48]

In the early-to-mid 1990s ARM employed standalone Intel 286 and 386 PC workstations running MS-DOS. One limitation of DOS was the inability to multitask – a capability taken for granted on present-day operating systems. Meanwhile, Apple Macintosh computers appear to have been employed for administration (including the preparation of correspondence) and desktop publishing.

Data was stored on workstation hard drives and transferred between machines and plotters or printers via floppy disks.

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[47] Mark Raggatt and Maitiú Ward (eds), *Mongrel Rapture: the architecture of Ashton Raggatt McDougall* Melbourne: Uro Publications (2014)
[48] *Interview with Paul Minifie,* 14 June 2016

> By today's standards everything was unspeakably slow, but it was enough, in fact, if you worked in a parsimonious and organised manner. You could do enough. You just had to be economical with the size of your mesh, and so on.[49]

During the design of RMIT Storey Hall, ARM used two DOS-based programs, both released by Autodesk: AutoCAD (a 2D drawing program with some 3D capability) and 3D Studio (a 3D modelling and animation program originally developed for the entertainment industry). Neither AutoCAD nor 3D Studio alone were capable of meeting the creative requirements demanded by the design process at ARM. Therefore ARM employed these programs in tandem, allowing AutoCAD to compensate for the shortcomings of 3D Studio, and vice versa. In addition, scripting allowed the limited capabilities of AutoCAD, in particular, to be extended in powerful ways.

For example, 3D studio allowed the creation of complex geometries unachievable by traditional means, but did not contain tools to accurately extract coordinates from which to create documentation. Meanwhile AutoCAD could display, but not manipulate or interrogate, the geometry of a polygon mesh imported from 3D Studio. Custom written scripts allowed AutoCAD to slice through a polygon mesh and define numerical coordinates allowing complex forms created in 3D space to be documented, and ultimately, built.

The challenge of interacting with a 3D model through a small and blurry CRT screen contrasts strongly with the immersive interface experiences architects and designers are familiar with today: '…the screen only offered glimpses of the worlds you knew, intellectually, were beyond.'[50]

Born-digital archives at ARM architecture

The backup process at ARM was initially achieved using floppy disks. Files in working directories on workstation hard disks were periodically packaged (usually by workstation operator) into an archive file – possibly weekly – before being split across multiple floppy disks for backup, a very time consuming operation. Files were split using proprietary software, since lost; extant backup files divided in this way can no longer be repaired.

Floppy disks received digitally-generated labels printed on adhesive paper, and were locked away for long-term storage in custom made filing cabinets. Later files were backed up on CD-ROM disks, when this medium became available. IT staff soon discovered CDs to be less reliable than floppy disks. Environmental factors (for example moisture leading to mould growth on disk surfaces) and human error (for example solvent damage caused by labelling disks with unsuitable pens) led to disk

[49] Ibid.
[50] Ibid.

corruptions and data loss. These problems were partially mitigated through a policy of producing two copies of each CD and the introduction of plastic sleeves to protect disks.

Subsequently data was backed up on hard drives. Some data originally archived on floppy disks and CD-ROM was uploaded to hard drives, usually when a building project was revisited. It appears this may have occurred with RMIT Storey Hall, and at this time, the original carrying media was probably discarded. Most of ARM Architecture’s data on floppy disk and CD-ROM was not transferred to hard drives because of the large time commitment involved.

Eventually ARM invested in dedicated archive hard drives with lower performance specifications, choosing to trade faster read/write speed for a lower capital cost.

More recently data has been archived on an active server. While all staff members have read access to records on the archive server, only the principals have read/write access. The ARM archive server currently contains (as of November 2015) approximately 4TB of data.

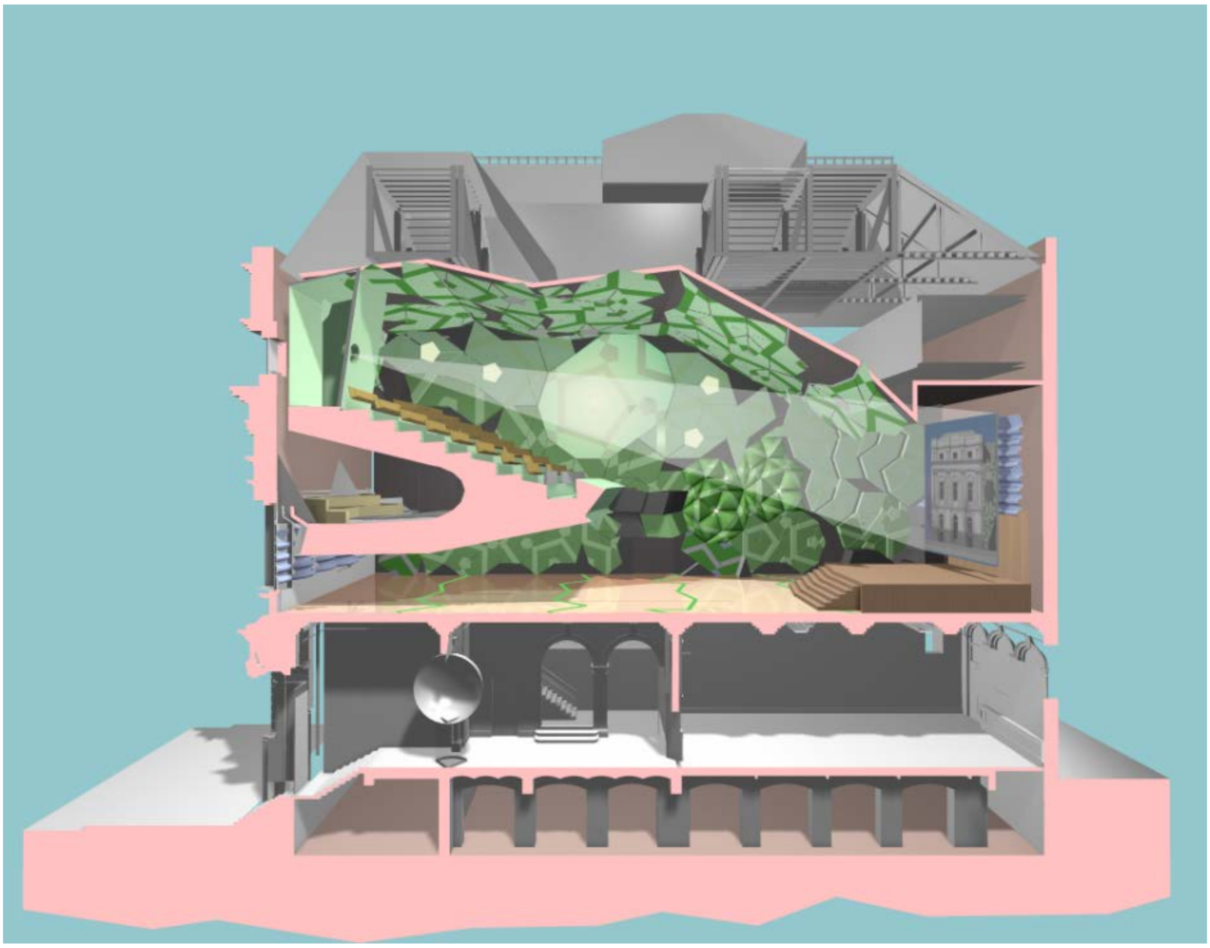


Fig. 5 *An early iteration of the RMIT Storey Hall auditorium, cross-section view, modelled in 3D Studio. Note the absence of the heritage balcony feature present in the design as constructed.*

3.2.2 RMIT Storey Hall project overview

RMIT Storey Hall (Swanston Street, Melbourne 1995), designed by ARM Architecture (Ashton Raggatt McDougall) is an award-winning renovation and extension of a heritage-protected building for RMIT University. RMIT Storey Hall is regarded as a leading early example of an Australian building designed within a digital environment.

Fig. 6 *Storey Hall Auditorium Interior (2015); photograph by Chris Burns*

For their work on RMIT Storey Hall, ARM Architecture received the RAIA (National) Interior Architecture Award; the RAIA (Vic. Chapter) Victorian Architecture Medal; the William Wardell Award for Institutional Architecture; and the Marion Mahoney Award for Interior Architecture.

3.2.3 RMIT Storey Hall hardcopy archive

Unlike Ridgway, the RMIT Storey Hall hardcopy archive contains large quantities of conceptual material, including hand-drawn sketches and output derived from exploratory born digital models. The archive also contains a considerably greater quantity of documentation than is present for Ridgway, since the construction of RMIT Storey Hall involved the fabrication of many custom-made components. Extant documentation includes, for example, hand drafted shop drawings, overlay drafted section drawings and "green copies" of final contract drawings, xerographically reduced to A3 size. There is a large quantity of correspondence, including fax output. Thermal fax printouts appear to be prevalent; while most suffer some degree of fading, they are not necessarily illegible.

Only a sample of hardcopy records from the RMIT Storey Hall archive were examined due to (1) the large number of records, (2) the cost per unit of recall, and (3) the fact that records were not collated before archiving – instead, they are dispersed across many cartons and tubes, intermixed with records from other projects in the archive.[51]

While ARM's electronic database suggested the presence of unspecified disks (either floppy or CD-ROM disks) in the RMIT Storey Hall hardcopy archive, none could be recovered when requested from the external provider. It is probable that the content from these discs was uploaded onto the archive server at some point in the past, and the original media discarded without a corresponding update to the database.

As well as offsite storage, ARM holds in-house an extensive slide collection and archive of promotional materials, stored in side-by-side filing cabinets in the Melbourne office (Fig. 7). Both include extensive material on RMIT Storey Hall including original large-format transparencies.

In November 2015 there was at least one scale model of the RMIT Storey Hall site extant in the ARM office.

[51] For an overview of the RMIT Storey Hall hardcopy archive, see Appendix 11.

3.2.4 RMIT Storey Hall digital archive

Born digital records from RMIT Storey Hall examined during this case study were copies made from files on the ARM Architecture archive server. These files total approximately 1GB in size.

The RMIT Storey Hall born digital archive is initially divided into two subdirectories – 'Correspondence' (Fig. 8) and 'Design' (Fig. 9). Beyond this, records are organised into an arbitrarily-named series of subfolders and subfolders-within-subfolders. Occasionally subfolders named 'old' and 'more' indicate an intention to distinguish between iterations of digital files. Some subfolders and files are duplicated, suggesting that born digital records from several separate sources were redacted together at the time of uploading, to produce the file corpus that is seen today.

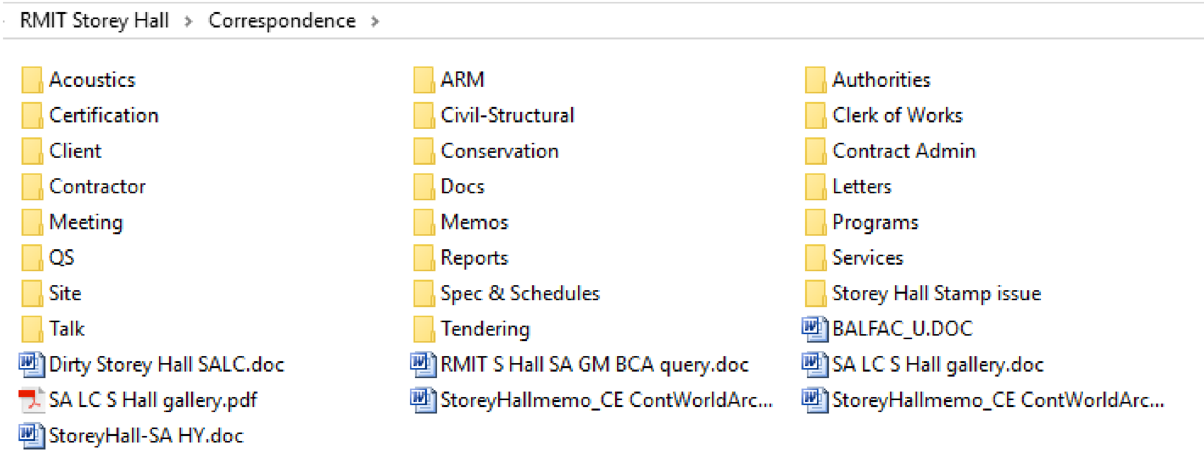


Fig. 8 *RMIT Storey Hall born digital archive folder structure – 'Correspondence' subdirectory*

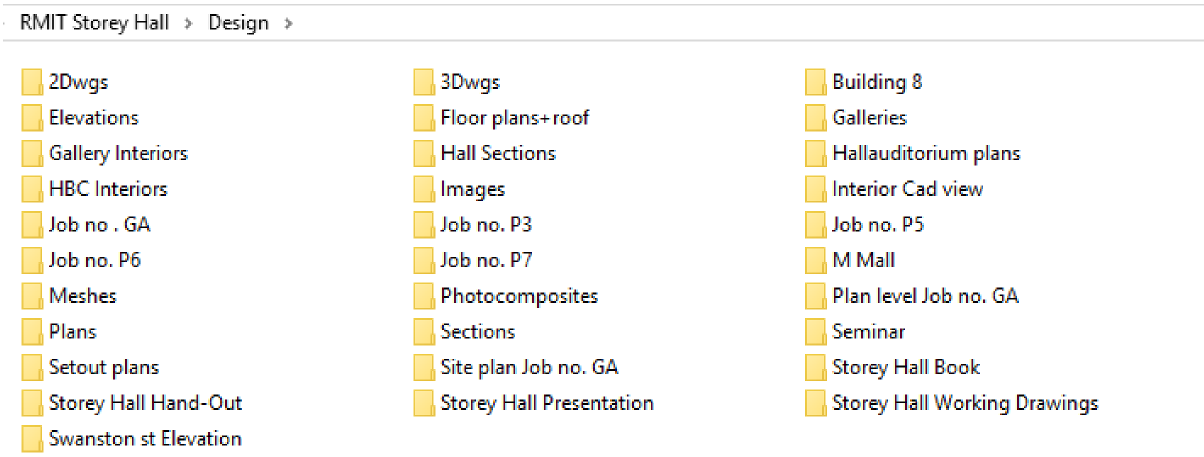


Fig. 9 *RMIT Storey Hall born digital archive folder structure – 'Design' subdirectory*

The ‘Correspondence’ subdirectory contains a large number of Microsoft Word and Excel documents. Most of these files have lost their file extensions, probably as a result of the files being created within an early Apple Macintosh operating system.[52] Files thus damaged cannot be easily opened, but are easily re-identified using the Siegfried/Brunnhilde tools, and restoration of missing file extensions is a simple process of double-clicking on the filename and replacing the extension with appropriate keystrokes (either .doc or .xls). The large number of affected files (1603 in total) means that restoring all missing extensions would be an onerous and time-consuming operation. However, in future it may be possible to compose a script (possibly an extension to Siegfried/Brunnhilde) for automatically reinstating missing file extensions.

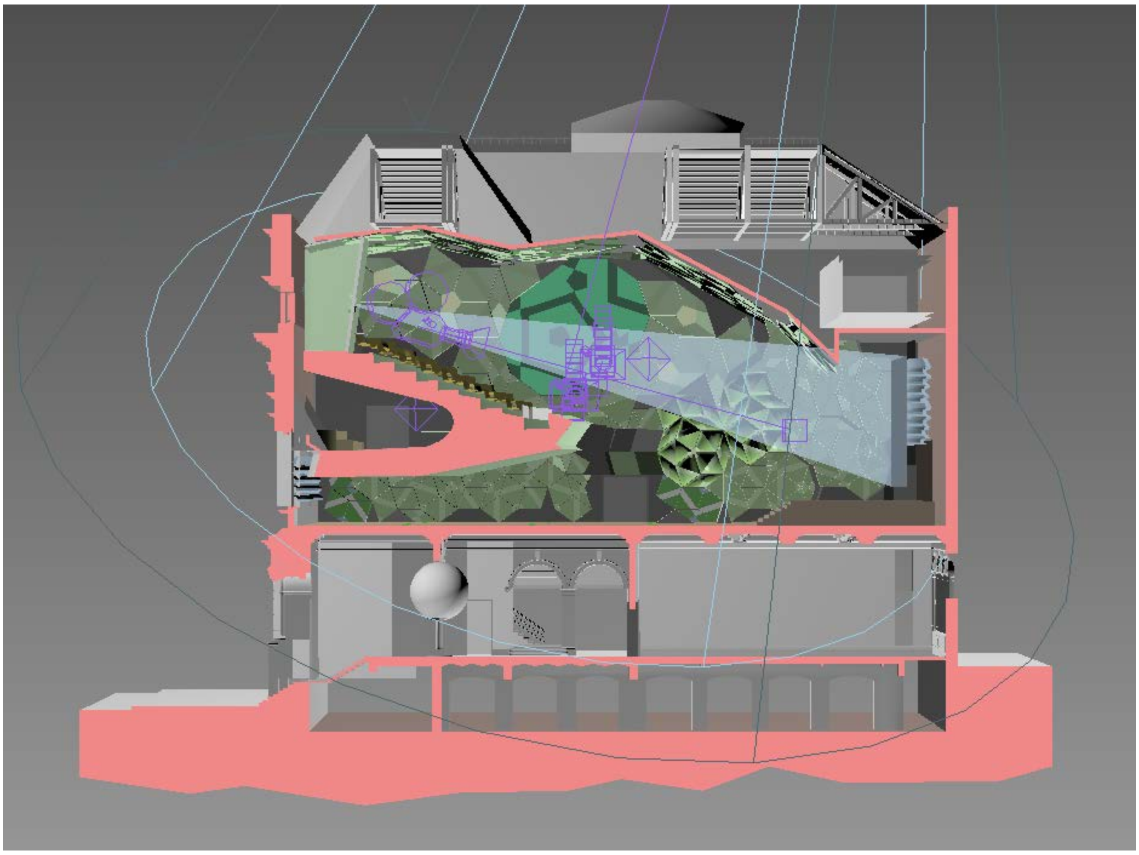


Fig. 10 *M-SEC.3ds* (located in Storey Hall > Design > 3Dwgs) *opened in Autodesk 3ds Max Design 2014. An original render generated from this mesh is shown in Fig. 5*

The ‘Design’ subdirectory contains a large number of Autodesk AutoCAD drawings (.dwg) and 3D Studio meshes (.3ds). Remarkably, these files, which were originally authored in a command-driven MS-DOS environment, may be opened successfully in current versions of Autodesk AutoCAD and 3ds Max (a version of 3D Studio for Windows did not become available until 1996, when 3D Studio MAX was written for Windows NT).

[52] Similar problems have been encountered at the Canadian Centre for Architecture.

Several 3D Studio files, for example M-SEC.3ds, contain original rendering parameters, including cameras and lighting setups, used to generate rendered images that appear elsewhere in the born-digital archive. The image file M-SEC.TGA (shown in Fig. 5) was generated from M-SEC.3ds.

Two issues complicate the possibility of generating new, high resolution renderings from original files. In some cases surface normals appear to be inverted, meaning that surfaces will appear invisible when they should be opaque, as illustrated in Fig. 11. This is an easily addressed if time consuming problem to correct.

More problematically, M-SEC.3ds is missing several texture files (specifically CODB.TGA, PARQUET.GIF, PENROSE.GIF, PLANK.GIF and RONDELL.GIF) which are not present in the archive. Without these image files, textured elements will be rendered as flat colours, compromising the illusion of reality.

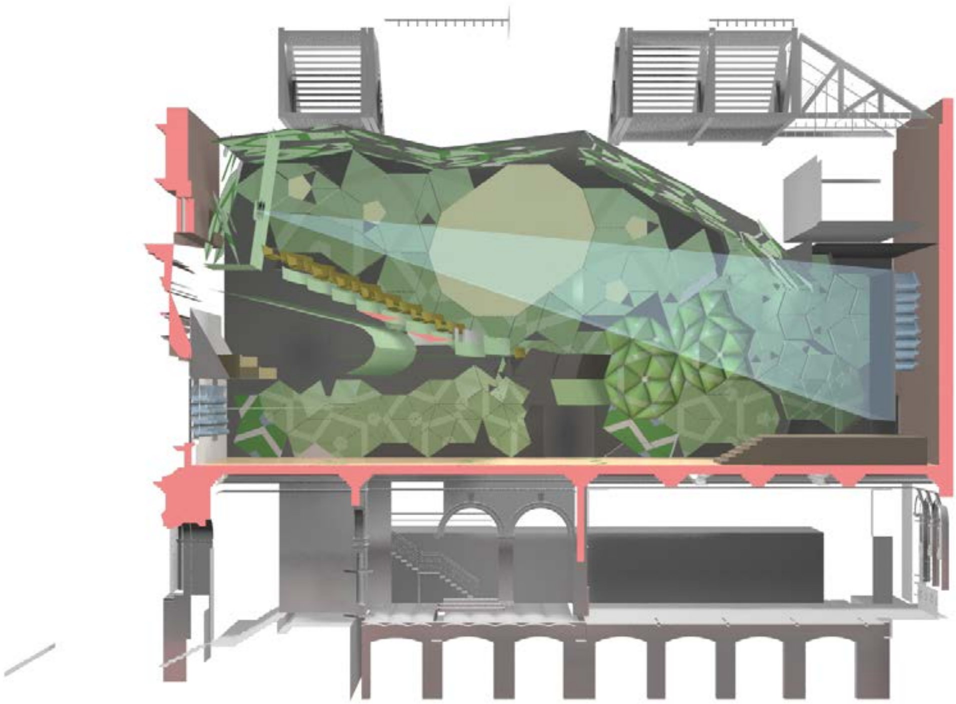


Fig. 11 *A new render created from M_SEC.3ds in Autodesk 3ds Max Design 2014. Note missing surfaces evident possibly due to inverted normals, and the absence of some textures, notably image on the projection screen. Compare with Fig. 5.*

There are only sixteen individual .3ds files in the RMIT Storey Hall archive, all of which appear to be intended for presentation to the client, rather than part of the design development. At least two iterations of the auditorium configuration are evident.

There are two renderings extant in the born digital archive for which no .3dm files exist: SHALL1.TIF (illustrated in Fig. 12) and SHALL2.TIFF. Both are located in the directory *Design > Images*.

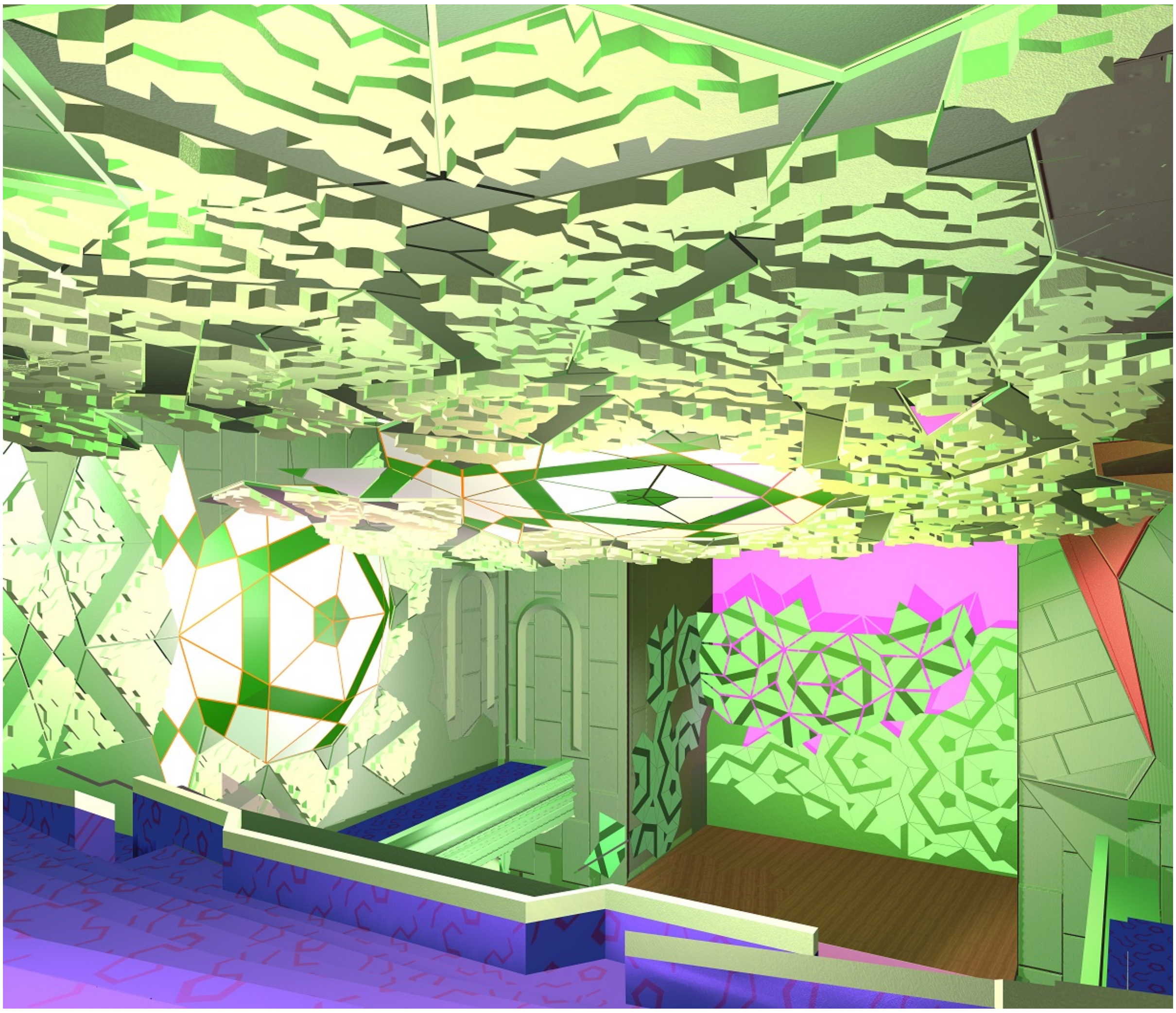


Fig. 12 *Rendering of RMIT Storey Hall auditorium (SHALL1.TIFF). Regrettably, the model from which this render was generated is missing from the archive. This appears to be a presentation rendering of the final design.*

Many of the AutoCAD .dwg files are accompanied by script files (.scr); the scripts themselves can be easily read by changing the file extension from .scr to .txt (Fig. 12). Also present in the 'Design' subdirectory are a large number of image files (.tga, .tif, .jpg, .eps). These include born digital renderings, digitised images and digital photo-manipulations.

Digital files used to create a publication on RMIT Storey Hall, comprised mainly of .eps images and Adobe PageMaker 6.0 (.pm6) documents, are present in a directory called 'Storey Hall Book.' While the .pm6 files can be opened successfully using Adobe InDesign, some documents comprising the sequence of the book appear, unfortunately, to be missing.

```
STRUC.txt - Notepad
File Edit Format View Help
LAYER
SET 0
FREEZE
*
THAW
0,?-TIT,SHEET,TITLE,PSHEET,PTITLE,LOGO,-*,P*,E*
THAW
?BRIK,?-BRH,?EXST,6-SOL,?-grd,?conc,?stel,*-s,*|?EXST,*|6-SOL,*|?-grd,*|?conc,*|?stel,*|*-s
```

Fig. 13 *A short script file located in the directory* Design > Plans.

Several subdirectories contain backup files which appear to contain working directories on ARM PCs in the mid-1990s. Backup files have file extensions numbered sequentially (for example .001, .002, .003 etc.) and are roughly 1.4MB in size, in order to fit onto 3 ¼ inch floppy disks (Fig. 14). File header analysis reveals that these files were created using proprietary Norton software.[53] Within the file examples located in the directory *Design > Interior Cad view* are recognisable software names, including WINWORD (Microsoft Word), PHOTOSHP (Adobe Photoshop), CORELDRW (Corel Draw) and even the PC game SIMCITY (SimCity), as well as the name PAUL, possibly referring to Paul Minifie, who worked on RMIT Storey Hall (Fig. 15).

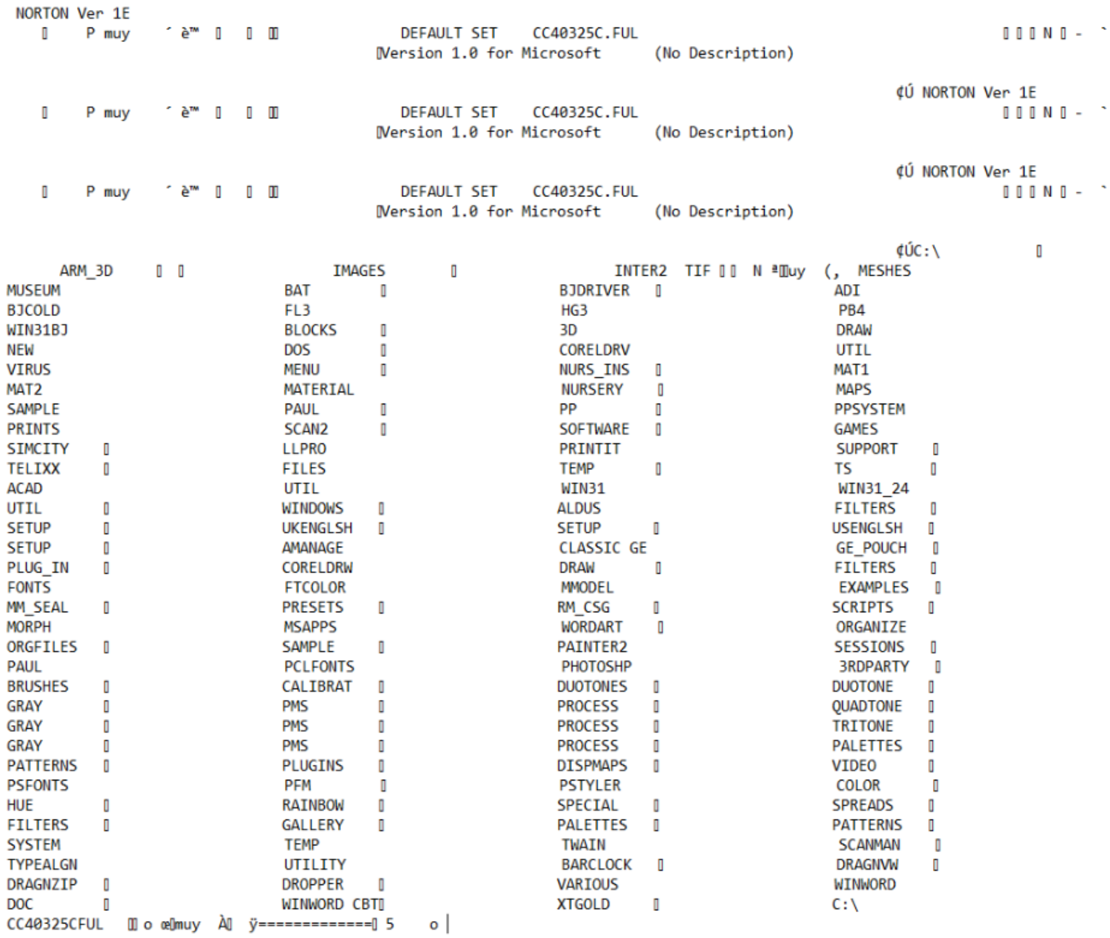
› Design › Interior Cad view

Name	Date modified	Type	Size
CC40325C.001	25/03/1994 4:43 PM	001 File	1,424 KB
CC40325C.002	25/03/1994 4:43 PM	002 File	1,424 KB

Fig. 14 *Backup files located in* Design > Interior Cad view.

For a period during the 1990s Autodesk, Inc. used a "hardware lock" copy protection system on international and educational versions of their software. Under this system a special dongle (plugged into the PC's parallel port) was required to run the application. Thus while users could install software on multiple PCs from one set of installation media, the number of sessions that could actually run at any one time was limited by the number of hardware locks available.

[53] Further information on Backup files created using Norton Version 1E backup software can be found at http://www.willsworks.net/dosbkup.htm (accessed 20 July 2016).



```
NORTON Ver 1E
  ▯    P muy    ´ è™  ▯   ▯  ▯▯            DEFAULT SET    CC40325C.FUL                              ▯ ▯ ▯ N ▯ -  `
                                         ▯Version 1.0 for Microsoft      (No Description)

                                                                                     ¢Ú NORTON Ver 1E
  ▯    P muy    ´ è™  ▯   ▯  ▯▯            DEFAULT SET    CC40325C.FUL                              ▯ ▯ ▯ N ▯ -  `
                                         ▯Version 1.0 for Microsoft      (No Description)

                                                                                     ¢Ú NORTON Ver 1E
  ▯    P muy    ´ è™  ▯   ▯  ▯▯            DEFAULT SET    CC40325C.FUL                              ▯ ▯ ▯ N ▯ -  `
                                         ▯Version 1.0 for Microsoft      (No Description)

                                                                                     ¢ÚC:\          ▯
    ARM_3D     ▯  ▯              IMAGES       ▯               INTER2  TIF ▯ ▯  N ª▯uy  (,  MESHES
MUSEUM                         BAT        ▯                BJDRIVER   ▯                ADI
BJCOLD                         FL3                         HG3                          PB4
WIN31BJ                        BLOCKS     ▯                3D                          DRAW
NEW                            DOS        ▯                CORELDRV                    UTIL
VIRUS                          MENU       ▯                NURS_INS   ▯                MAT1
MAT2                           MATERIAL                    NURSERY    ▯                MAPS
SAMPLE                         PAUL       ▯                PP         ▯                PPSYSTEM
PRINTS                         SCAN2      ▯                SOFTWARE   ▯                GAMES
SIMCITY    ▯                   LLPRO                       PRINTIT                     SUPPORT    ▯
TELIXX     ▯                   FILES                       TEMP       ▯                TS         ▯
ACAD                           UTIL                        WIN31                        WIN31_24
UTIL       ▯                   WINDOWS    ▯                ALDUS                       FILTERS    ▯
SETUP      ▯                   UKENGLSH   ▯                SETUP      ▯                USENGLSH   ▯
SETUP      ▯                   AMANAGE                     CLASSIC GE                  GE_POUCH   ▯
PLUG_IN    ▯                   CORELDRW                    DRAW       ▯                FILTERS    ▯
FONTS                          FTCOLOR                     MMODEL                      EXAMPLES   ▯
MM_SEAL    ▯                   PRESETS    ▯                RM_CSG     ▯                SCRIPTS    ▯
MORPH                          MSAPPS                      WORDART    ▯                ORGANIZE
ORGFILES   ▯                   SAMPLE     ▯                PAINTER2                    SESSIONS   ▯
PAUL                           PCLFONTS                    PHOTOSHP                    3RDPARTY   ▯
BRUSHES    ▯                   CALIBRAT   ▯                DUOTONES   ▯                DUOTONE    ▯
GRAY       ▯                   PMS        ▯                PROCESS    ▯                QUADTONE   ▯
GRAY       ▯                   PMS        ▯                PROCESS    ▯                TRITONE    ▯
GRAY       ▯                   PMS        ▯                PROCESS    ▯                PALETTES   ▯
PATTERNS   ▯                   PLUGINS    ▯                DISPMAPS   ▯                VIDEO      ▯
PSFONTS                        PFM        ▯                PSTYLER                     COLOR      ▯
HUE        ▯                   RAINBOW    ▯                SPECIAL    ▯                SPREADS    ▯
FILTERS    ▯                   GALLERY    ▯                PALETTES   ▯                PATTERNS   ▯
SYSTEM                         TEMP                        TWAIN                       SCANMAN    ▯
TYPEALGN                       UTILITY                     BARCLOCK   ▯                DRAGNVW    ▯
DRAGNZIP   ▯                   DROPPER    ▯                VARIOUS                     WINWORD
DOC        ▯                   WINWORD CBT▯                XTGOLD     ▯                C:\
CC40325CFUL   ▯▯ o œ▯muy  À▯  ÿ=============▯ 5     o |
```

Fig. 15 *Backup file header contents located in* Design > Interior Cad View > CC40325C.002.

During the project, copies of AutoCAD Release 14 Educational (Autodesk Inc., 1998) and 3D Studio MAX Release 2.5 Educational (Kinetix, a division of Autodesk, Inc., 1998) were discovered within the School of Art, Architecture and Design, along with a number of other products.[54] AutoCAD and 3D Studio MAX were found in original packaging with manuals, installation CD-ROMs, serial numbers and CD keys. After some searching, hardware locks (which had been stored separately) were located within the school's IT department. However, since PCs are no longer supplied with parallel ports, running this software is impossible on modern machines.

[54] See Appendix 13.

4. Discussion

The case studies represent two ends of a spectrum of use for digital technology in the early 1990s. The Ridgway born-digital archive mainly contains what Greg Lynn, curator of the CCA *Archaeology of the Digital* exhibition at CCA, might describe as 'the rote requirements of realising a building,'[55] while within the Storey Hall born-digital archive can be found 'evidence of critical moments in the design process.'[56]

ARM Architecture used in their office sophisticated 3D CAD software from the beginning of the design process on Storey Hall to realise geometries that could not be achieved with traditional methods. Woods Bagot, on the other hand, employed computer aided *drafting* to automate some aspects of labour intensive manual drafting processes during the design documentation phase. CAD software was used to generate presentation floor plans and some title blocks for manual renderings, while sections, elevations and details were all drafted manually.

Our investigation has found that, at least in the case of the practices concerned, individual firms took quite different approaches toward archiving born digital records. It is, however, interesting to note that both firms archived the working directories of their respective projects.

Records from the case study era present a variety of (not insurmountable) challenges. Obsolescence of carrying media may mean that files stored are no longer accessible, let alone readable; for example, Woods Bagot retains 9-track open reel and CompacTape magnetic tape media from the late 1980s for which hardware (minicomputers) no longer exists.

Migration (where possible) to new carrying media is not a foolproof solution. Digital records are increasingly archived 'online,' either on a server or through a cloud-based storage provider, subjecting them to the possibility of accidental, or purposeful, modification or erasure. So long as original 'offline' carrying media remain viable, as in the case of the CD-ROM containing project files from Ridgway, a clear provenance can be established for born digital records. Meanwhile, if original media are discarded when files are migrated online, as in the case of floppy disks from RMIT Storey Hall, provenance becomes more difficult to verify.

Provenance can be maintained and original order kept intact by creating a disk image when records are migrated from original carrying media to new. Disk imaging, together with files duplicated through an ordinary copy/paste process are complementary methods of migration that address issues of provenance and file accessibility respectively.

[55] Lynn, Greg (ed) *Archaeology of the Digital,* Montreal (Canadian Centre for Architecture and Sternberg Press 2013) p. 13
[56] ibid p. 12

While most of the case study CAD files can be opened in more recent versions of software, for example 3D AutoCAD files created for Storey Hall, the authenticity of the interactive experience is brought into doubt as a result of new tools and enhanced graphics capabilities that would not have been available to the original designers. Emulation of archaic hardware to run obsolete software offers one solution to this problem, but is only (legally) possible when the original software installation files, product keys, and hardware locks can be obtained.

Consistent with the findings of the Archaeology of the Digital project,[57] the hardcopy archives of both case studies also demonstrate the prevalent use of analogue electronic technology, including fax machines and in particular photocopiers, which were used to scale, distort and transform images. Records demonstrate multiple and clearly distinguishable iterations of markup, correction, rescaling and electrostatic reproduction. This "layeredness" is not always present in the corresponding digital archives.

We have identified three broad categories of stakeholders who have interests in digital building archives: **creators** (including architecture firms and subcontractors), **collectors** (including libraries, archives and museums) and **users**. Potential use cases for building archives may include lay curiosity, academic research, legal cases, work to existing structures, teaching and operation/maintenance.

[57] ibid p. 18

5. Preliminary Recommendations for Practitioners

5.1 For architectural practitioners

5.1.1 Born digital archives

- Develop a strategy for the long-term survival of born digital archives, with a succession plan in place to ensure that records held will remain intact and accessible if and when the practice no longer exists.
- Born digital archives should be backed up with multiple redundancies. Options include offline hard drives and delegation to cloud-based storage providers.
- Archives should be insured.

5.1.2 Software, Hardware and Media

- Identify surviving legacy software (including operating systems such as Windows NT), and ensure that copies are either 1) retained permanently or 2) donated to an appropriate collecting institution (for example the Computer Archaeology Lab at Flinders University). Legacy software may include installation media, product keys and hardware locks as well as manuals and product packaging.
- Identify surviving legacy hardware. Working tape and disk drives for legacy formats should be retained or donated to an appropriate collecting institution
- Identify and retain legacy physical carrying media (for example floppy disks, zip disks, magnetic tapes and optical disks).
- Ensure that records stored on obsolete or at-risk carrying media (including floppy disks writable CDs and DVDs) are migrated onto active servers, using a combination of disk imaging and the more usual file copy/paste process to ensure chain of provenance and ease of accessibility to files, respectively. This operation should be carried out 1) before physical media fails and 2) while hardware necessary to access the contents of physical media remains functional. It is not necessary to disk image files stored on flash media.
- Legacy physical carrying media should be retained, even after stored data has been transferred to active servers.

5.1.3 Digital files and naming conventions

- Retain all digital files – including virtual CAD models, PDF drawings, renderings, correspondence (including emails), photographs, specifications and contracts – on the basis that their possible value in the future cannot be predicted.

- For past projects (already archived) retain the original folder structure as archived.
- For future projects (yet to be archived), develop a set of consistent file and folder naming conventions that work within the context of the office. Ensure that conventions are documented, accessible and archived with each project.

5.1.4 Specific recommendations for Woods Bagot (Adelaide office)

- Given the historical and cultural significance of the archives, it is vital that Woods Bagot (Adelaide office) develops a strategy for their long-term survival, with a succession plan in place to ensure that records held will remain intact and accessible if and when Woods Bagot no longer exists as an organisation.
- The hardcopy archive in particular is a significant financial burden on the Adelaide office. Woods Bagot may wish to consider financial incentives for cultural collecting institutions willing to take on (some or all of) the hardcopy archive in particular, on the basis that the long-term cost of maintaining records potentially outweighs the cost of sponsoring an institution to secure their preservation.
- A large box of magnetic tapes is held in a storeroom in the Woods Bagot Adelaide Office. As the tapes in question are outside of the main archive, they may be in danger of being lost. Steps should be taken to secure these artefacts to enable their future accessibility.
- While archival CD-ROM disks have since been transferred to the archive server, it has become apparent that there are noticeable discrepancies between the original data held on extant optical media and data that has been transferred to the server. Since there are a relatively small number of optical disks (for example, all of the projects from 1996 were archived on a single disc), creating images of surviving discs in the Adelaide office seems an appropriate and advisable course of action.

5.2 For archival practitioners

5.2.1 Born digital archives

- Archives should develop an appropriate collection policy for the long term preservation born-digital objects, reflecting the capabilities of the archive in terms of resources, expertise and funding.
- Born-digital archives should be backed up with multiple redundancies. Options include offline hard drives and delegation to cloud-based storage providers.
- Born-digital archives should be insured.

5.1.2 Software, Hardware and Media

- Archives should, if possible, collect the legacy software that was used to create digital files, including operating systems where necessary. Legacy software may include installation media, product keys and hardware locks as well as manuals and product packaging.
- If a collection ingest includes legacy physical carrying media, archives should collect appropriate hardware (for example working tape and disk drives) where available. Such hardware should be retained permanently or donated to an appropriate collecting institution (for example the Computer Archaeology Lab at Flinders University).
- Ensure that records stored on obsolete or at-risk carrying media (including floppy disks writable CDs and DVDs) are migrated onto active servers, employing a disk imaging process, and appropriate error mitigation (e.g. checksums). This operation should be carried out 1) before physical media fails and 2) while hardware necessary to access the contents of physical media remains functional. It is not necessary to disk image files stored on flash media, however error mitigation techniques should be employed.

5.1.3 Digital files and naming conventions

- Retain all digital files – including virtual CAD models, PDF drawings, renderings, correspondence (including emails), photographs, specifications and contracts – on the basis that their possible value in the future cannot be predicted.
- Maintain or record the original folder structure of digital objects
- 3D CAD files should be retained in with their original bit streams intact. Normalisation of formats may be acceptable in the short term to generate access copies of born-digital records.

Original files should however be retained, as the current obstacles surrounding proprietary 3D CAD formats may not exist in the future.

6. Directions for Future Research

6.1 *In-depth analysis of Ridgeway and Storey Hall born-digital project files*

Born digital files already collected from Ridgway and RMIT Storey Hall during the pilot project suggest a number of possibilities for future research, for example:

- modifications to Siegfried/Brunnhilde software to extract more precise metadata from files, in particular for dates created and modified, down to hours, minutes and seconds
- developing a script to restore file extensions to a large number of Microsoft Word for Macintosh documents from the RMIT Storey Hall corpus missing file extensions
- extracting data from backup files in the RMIT Storey Hall corpus
- hardware emulation to allow interaction with CAD files in their original software environments
- data visualisation (for example, interactive project timelines)

6.2 *Possible Collaborations*

- Paul Minifie from Minifie van Schaik Architects has offered to share legacy physical carrying media with the research team in order to recover inaccessible data, possibly including records from RMIT Storey Hall.
- Denise de Vries from the Flinders University Computer Archaeology Lab[58] has expressed interest in future collaborations. The Computer Archaeology Lab holds a large collection of operating hardware and software, including some tape drives which are currently in the process of being tested and accessioned. The apparent existence of mainframe operating system software, CAD software (in particular CADG + FM) and born-digital files from the mid- to late-1980s (stored on magnetic tape at Woods Bagot Adelaide office) suggests an opportunity for an experiment in emulation in conjunction with the Computer Archaeology Lab.

6.3 Other directions

Including:

- The possibility of approaching a major CAD software vendor (eg Autodesk, Dassault Systèmes, Robert McNeel & Associates) with the intention of securing an industry partner. Such an

[58] See Appendix 19.

arrangement could potentially provide access to technical support and assistance with digital rights management or licencing issues.

- An attempt to capture the tacit knowledge of experienced CAD operators through software walkthroughs (accomplished through a combination of traditional interviewing techniques and screen-capture software) along the lines of similar work already undertaken by CCA. While architectural firms may have difficulty resourcing such a project on their own due to time or financial constraints, this form of data collection could be more feasibly accomplished within the context of a research project, with in-kind cooperation from partner firms.
- Investigating the feasibility of establishing a born-digital collection within the Architecture Museum at the University of South Australia, including the development of a born-digital collection policy, reflecting the capabilities of the Museum in terms of resources, expertise and funding.