Australian Antarctic Program Partnership

Two-year Workplan

1 July 2021 – 30 June 2023

Summary of proposed two-year workplan (1 July 2021 – 30 June 2023)

The Australian Antarctic Program Partnership (AAPP) is a partnership of Australia's leading Antarctic research institutions supported by the Australian Government Antarctic Science Collaboration Initiative (ASCI) through the Department of Industry, Science, Energy and Resources (DISER). The objectives of the program are:

- to support research that aims to understand the role of the Antarctic region in the global climate system and its implications on marine ecosystems.
- to enable the AAPP to undertake collaborative science, research and innovation activities under the Australian Antarctic Science Strategic Plan and Australian Antarctic Strategy and 20 Year Action Plan.
- to secure Antarctic science jobs in Hobart.

The two-year workplan for 1 July 2021 – 30 June 2023 is described below. This workplan is delivered across three themes in seven projects and managed by a Science Management Team. It is supported by a more detailed 10-year plan that includes activities, participants, alignment, project objectives and outcomes, and methodology over the full ten years of the AAPP.

This two-year workplan is derived from this ten-year workplan agreed between the partners (and revised annually). The new workplan takes into account the changes since the first two-year workplan was lodged with DISER. The main changes are in response to changes in the availability of resources for the completion of fieldwork (e.g. delays due to COVID-19, delays in the delivery of *RSV Nuyina* and scheduling for the MNF *RV Investigator*). The two new Australian Research Council funded Special Research Initiatives (ACEAS and SAEF) and their work have also been taken into account and also potential new investments by the AAPP partners. The revised fieldwork plans were completed in collaboration with the Australian Antarctic Division (AAD), ACEAS and SAEF and are reflected in the 21-23 AAPP workplan.

The release of the Australian Antarctic Science Strategic Plan (April 2020), the Australian Antarctic Strategy and 20-year action plan have also been taken into account in the AAPP

workplan for years 3 and 4. The workplan for years 3 and 4 also addresses national strategic research priorities.

The focus of the Australian Antarctic Program Partnership remains firmly unchanged in direction and scope from the original application.

Guidance for the two-year workplan for years 3 and 4 has been sought from the Australian Antarctic Science Council. The guidance was based on the workplan for years 3 and 4 (this document), a two-page summary, and a presentation provided to the council by the Chair of the AAPP Management Committee and AAPP Program Leader for the Council's 25th of June 2021 meeting in Hobart. The workplan for years 3 and 4 is complementary and coordinated with the two SRI's and the AAD's own approved research plans.

The two-year workplan for years 3 and 4 was approved by the AAPP Management Committee (subject to guidance from the AASC) on the 5th of May 2021 and will be submitted along with the biennial progress report due 30 July 2021.

Risks remain in the overall program. Fieldwork using the CSIRO *RV Investigator* are not approved (although proposals have been lodged under the new MNF strategic plan and led by AAPP staff). The plans for the Antarctic field programs in 2023/24 and 2024/2025 have some dependency on the commissioning of the *RSV Nuyina* in 2021/2022 and 2022/2023 years, including access to bases and helicopters. The AAD has yet to commit to the underlying logistics for the AAPP field programs. Many of the other risks discussed in the 6-monthly progress reports to DISER have been mitigated by active engagement and coordination by AAPP staff with the two SRI's, the AAD and with the development of the new AASC strategic plan.

Theme 1: Antarctica's influence on climate and sea level

Summary Theme 1

The workplan the three projects in Theme 1 are given below. Theme 1 has completed recruitment in years 1 and 2 and will not have any more recruitments until year 6.

Project 1 – Atmosphere

The key science questions for this project are:

- What are the most important deficiencies in weather and climate models that hinder the accurate representation of cloud, radiation and precipitation over the Southern Ocean and Antarctic regions and how are these processes likely to change in a warming climate?
- What are the fundamental properties of aerosols over the Southern Ocean, how do emissions from ocean biota lead to aerosol formation and modification, and how do these properties subsequently affect the properties of clouds, precipitation and the surface energy balance?
- What is the role of ubiquitous super-cooled liquid water clouds in driving the surface radiation biases over the Southern Ocean, and how can we improve their representation in models?

Activities and deliverables for years 3 and 4 are:

- Full quality control and analysis of existing ship observations near the coast of Antarctica, allowing us to begin understanding the respective role of phytoplankton and sea spray emissions on aerosol and cloud properties.
- Evaluation of current version of the Australian Community Climate and Earth System Simulator (ACCESS) climate model (ACCESS-CM2) using satellite observations and of the regional ACCESS weather forecast model using ship observations.
- Implementation of parameterization to represent the MSA cycle.
- Start development of parameterization to resolve the link between aerosol and ice nucleating particles in the CASIM aerosol-cloud scheme.
- New ship deployments to address observational gaps identified in Years 1-2 (including the *RV Investigator* voyage early 2023; MIZ voyage Sept-Oct 2023).

Although an extensive set of observations has been collected during recent field campaigns, some key data gaps have already been identified around the production of biogenic cloud condensation nuclei and ice nucleating particles from the upper ocean and its role in cloud life cycle. The need for a more statistically significant characterization of the latitudinal and seasonal variability of the atmospheric properties has also been identified. Our plan is to address these known observational gaps during the lifetime of this project.

The years 3 and 4 plan are as follows:

- *RV Investigator* voyage in Austral Summer 2023 focussing on the interaction between biological productivity of the upper ocean and resulting aerosol and cloud properties (proposal will be submitted in June 2021).

- *RSV Nuyina* Marginal Ice Zone (MIZ) voyage in Sept – Oct 2023 to investigate why aerosol, cloud properties and surface shortwave radiation biases in ACCESS are different north and south of the Polar Front, and to determine the respective roles of phytoplankton, sea ice, and the Antarctic land mass emissions in aerosol production and resulting cloud and precipitation properties (confirmation of AAS support and timing 2021 calendar year).

Project 2 – Ice Cores

The key science questions for this project are:

- What does the ice core record of past climate and carbon dioxide concentrations spanning more than 800,000 years reveal about climate and climate-carbon feedbacks?
- How did the partitioning of carbon between different sinks (ocean, terrestrial, atmosphere) change (in volumes and rates) in the past (as resolved by isotopes of CO_2 and CH_4)?
- What are the implications for future climate, sea-level and ice sheet stability that emerge from the oldest ice record, and what do past interglacial conditions indicate as potential analogues of future warming?
- What does the late Holocene record of Antarctic climate reveal about links between high latitude climate and the dominant climate modes that influence Australia? What does this show about the range of natural variability of Australian hydroclimate and other variables, and how does present climate compare to long-term pre-industrial climate?
- What does the record of recent millennia show for key environmental parameters and climate forcings? (e.g. snow accumulation, sea-ice, aerosols, dust, volcanism, solar activity and greenhouse gases)

Activities and deliverables for years 3 and 4 are:

- Development of records of climate and climate drivers spanning the past 2,000 years from East Antarctic ice cores.
- New methods and validation studies developed to combine airborne radar data with volcanic horizons to derive spatial maps of the accumulation of snowfall over East Antarctica.
- Detailed process studies, analysis of back-trajectories and development of proxies to elucidate the links between Antarctic and Australian climate, including the influence of climate modes and teleconnections (and also years 5 and 6).
- Traverse for the Million Year Ice Core (MYIC) begins, with upper sections of the core available for evaluation against Dome C and Dome Fuji records and for study of the Last Interglacial period.

Project 3 – Ice Shelves

The key science questions for this project are:

- How susceptible are East Antarctic Ice Shelves to changes in climate forcing, from both the ocean and atmosphere?
- What is the ocean-driven and cryosphere-driven mass loss from East Antarctic ice shelves?

- How do dynamical processes in ice shelves, such as calving and fracturing, ice flow and firn compaction, influence ice shelf thickness and buttressing?
- When do we expect to see changes in ice shelf mass budget due to long-term climate forcing emerge from the variability of the system?

Activities and deliverables for years 3 and 4 are:

- Design, testing and analysis of instrumented platforms for englacial, subglacial and ice shelf cavity observations.
- Identify mechanisms for the differences in ice shelf calving behaviour between Antarctic ice shelves.
- Assess the impact of ocean cavity model behaviour on predictions of ice shelf mass loss through ocean-driven melt.

Theme 2: The nature and impacts of Southern Ocean change

Summary Theme 2

The workplan the two projects in Theme 2 are given below. Theme 2 has two recruitments in this period, both Postdoctoral Research Associates: a Trace Element Biogeochemist and a Physical Oceanographer.

Project 4 – Oceanography

The key science questions for this project are:

- How will changes in ocean circulation and temperature affect East Antarctic ice shelves? The project will determine where and how ocean heat reaches East Antarctic ice shelves and provide improved understanding of the factors that regulate poleward ocean heat transport across the Southern Ocean to the ice shelf cavity.
- How will Southern Ocean feedbacks (e.g. changes in ocean heat & carbon uptake, sea ice and freshwater) alter the pace of climate change? The project will assess how and why the ocean is changing with time, identify the processes responsible for heat and carbon uptake and their sensitivity to change in ocean circulation/stratification, and work with the sea ice team to assess the contribution of changes in ocean circulation to change in sea ice.
- What processes and teleconnections link the climates of Australia and Antarctica, and what do they tell us about future change? We will explore the role of teleconnections in driving variations in ocean circulation and water mass formation, and provide measurements of ocean heat content for assessment of SO influence on Australian climate.
- How will the changing physics and chemistry of the Southern Ocean and Antarctica influence marine life? The project will deliver assessments of change in the physical environment (temperature, salinity, currents, stratification, upwelling) of the Southern Ocean, as needed by other AAPP projects.
- What is the cause of persistent biases in climate models (e.g. clouds, sea ice) and how can these processes be better represented in climate models? The project will provide

better understanding of how the surface ocean influences the lower atmosphere and sea ice.

Activities and deliverables for years 3 and 4 are:

- New understanding of the local dynamics of the standing meander in the Macquarie Ridge region and assessment of its role for the ACC and overturning circulation gained from observations and regional and global ocean models.
- New insights into the local circulation and processes regulating ocean heat transport to ice shelves and basal melt, water mass formation and biogeochemistry.
    - in the Denman glacier region using available observations and newly developed high-resolution regional model.
    - In the Amery ice shelf region using opportunistic cruise observations.

Timeline of major field programs and logistics required for years 3 and 4:

- Prydz Bay/Amery Ice Shelf multidisciplinary expedition (RV Investigator).
- I9S repeat hydrography (RV Investigator), including deployment of Autonomous Lagrangian Air-Sea Interaction Array (ALASIA).
- Float deployments to quantify time and space evolution of ocean heat content, including under ice.

Project 5 – Biogeochemistry

The key science questions for this project are:

- What drives the unexpectedly large multi-year and decadal changes in the magnitude of Southern Ocean CO2 uptake, and how do they affect our understanding of probable future ocean CO2 uptake?
- What is the specific progress of ocean acidification impacts (lowered pH, reduced carbonate saturation, and higher CO2 availability) and accordingly which regions in the Southern Ocean and Antarctic coastal waters are likely to be more resilient to ocean acidification?
- Is iron supply or its bioavailability, as key controllers of Southern Ocean productivity, likely to increase over the coming century, and what processes will control this?
- What will be the expected magnitude of change in Southern Ocean primary productivity this century, and what controls this (with Theme 3. Future of Sea Ice, Krill and Ecosystems)?
- How will the transfer of energy from phytoplankton to higher levels in the food web be affected by the impact of biogeochemical change on phytoplankton community structure (with Theme 3. Future of Sea Ice, Krill and Ecosystems)?

Activities and deliverables for years 3 and 4 are:

- Improved understanding of the drivers of interannual to decadal variability in CO_2 uptake, including identification of regional pathways and assessment of the importance of mesoscale processes.

- Assessment of importance of the deep Southern Ocean iron reservoir for surface productivity.
- Resolution of iron and carbon cycles during a full year time series in Antarctic fast ice.

The tentative calendar for fieldwork efforts in years 3 and 4 is as follows*:*

Year	Voyage	CSIRO BGC Staff	CSIRO Voyage operating, k$	UTAS BGC Staff	UTAS Voyage operating, k$*
3	GOSHIP/GEOTRACES I9S	4	50	4	50
3	SOTS	1			
3	SWOT				
4	Prydz/Amery	2	100	3	50
4	SOTS	1			
4	Shackleton Ice Shelf	1		3	

*These funds are not currently allocated in the AAPP Project Plan budget.

Theme 2 recruitment to be completed in years 3 and 4

- **Postdoctoral Research Associate – Trace Element Biogeochemist** Will study the sources, sinks, and recycling of iron as the controlling element of Southern Ocean productivity, working closely with Theme 3.
- **Postdoctoral Research Associate — Physical Oceanographer** With expertise in the physics of subduction and water mass formation and their connection to sub-mesoscale dynamics and flow-topography interaction, including analysis of the swath altimeter satellite SWOT.

Theme 3: The future of sea ice, krill and ecosystems

Summary Theme 3

The workplan for the two projects in Theme 3 are given below. Theme 3 has one further recruitment in this period, a Postdoctoral Research Associate in remote sensing zooplankton and krill**.**

Project 6 – Sea Ice

The key science questions for this project are:

- How and why is the Antarctic sea-ice environment changing (especially the East Antarctic), how and why will it change in the future, and what are the local and global impacts of that change?
- Where within the Antarctic sea-ice system are the most important changes, both horizontally (i.e., Marginal Ice Zone [MIZ], polynyas) and vertically (e.g., snow cover)?

- How do sea-ice processes and change interact with and affect Southern Ocean water masses, waves, and the (East) Antarctic coastal system (including ice shelves)?
- What are the effects of sea-ice change on primary productivity and biogeochemical processes in the Southern Ocean?

Activities and deliverables for years 3 and 4 are:

- Conduct field program on East Antarctic fast ice (originally planned for Yr 2).
- Characterise krill under-ice habitat quality in the pack-ice zone using existing observations.
- Implement biogeochemical parameters in a 1D sea-ice physics model as means of identifying critical links in the coupled physical-biological sea-ice system and how these may be affected in a changing environment.
- Explore satellite-derived climatological patterns of coastal Antarctic fast ice using atmospheric reanalysis to identify the determinants (with view to investigate the drivers) of observed change and variability since 2000.
- Conduct a multi-variable analysis using observations and numerical simulation to identify the processes driving observed sea-ice change (extent, concentration, advance, retreat and duration) across Antarctica.

Focus of years 3 to 4:

- Conduct coupled fast ice physics-biology-biogeochemistry seasonal measurements at Antarctic coastal location (AAS #4546) including sample and data analyses, and write up.
- Derive spatio-temporal variability of pack-ice and fast-ice characteristics using relevant satellite imagery and auxiliary data to derive, identify, test and verify multi-variable algorithms for satellite sensors.
- Use existing observational data and model output to characterize and quantify under-ice habitat quality for Antarctic krill.
- Synthesize project findings from the first 2 years and communicate to the climate modelling community.

Planned fieldwork for years 3 to 4:

- Oct-Nov 2021 [TBC]: Davis integrated fast-ice physical and biological process study (AAA4546); autonomous instruments deployed the previous autumn (potentially delayed by another year to Oct-Nov 22).
- Sep-Nov 2021 [TBC]: Davis Airborne sea-ice thickness assessment (AAS4496) or Scott Base in Oct 2021 and Davis Sep-Nov 2022 – TBC.
- Continued operation of multi-disciplinary fast-ice observatories (AAS4506).

Project 7 – Krill and Ecosystems

The key science questions for this project are:

- How will complex environmental change, driven by alteration of cryospheric and oceanic properties, impact the base of the food web from microbes to krill?

- Will there be winners and losers in response to climate change and what are the ecological ramifications of such shifts for East Antarctica?
- What will be the cumulative effect on sea-ice and water column ecosystems of altered biological performance within the trophic levels of food webs in East Antarctica?
- What is the relationship between krill distributions and sea ice in East Antarctica, and how will it be altered in light of current/projected climate change?

Activities and deliverables for years 3 and 4 are:

- Assess a range of remote sensing approaches to zooplankton e.g., bio-optics (BGC-Argo and satellite LIDAR), bioacoustics (AAD moorings), and image analysis (zoo-scan on gliders) during a marginal sea-ice zone (MIZ) voyage.
- Perform an inter-comparison on a polar voyage of remote sensing approaches to zooplankton (from copepods to krill) including bio-optics (BGC-Argo and satellite LIDAR) and bioacoustics (AAD moorings), along with image analysis (zoo-scope and its deployment on gliders).
- Validate the multi-trophic trait-based model (developed in years 1-3), and the nested suite of ecosystem models developed at AAD.
- Revised krill biomass estimates for the Prydz Bay region from voyage proposed for 2021 (RV Investigator). (Note: Initial stages are complete based on TEMPO voyage).
- 4D full-life cycle energetics/habitat model developed for krill in East Antarctica; possible deployment and recovery of Prydz Bay bio-acoustic observing system for krill and other organisms.
- Determine experimentally the present-day physiological capacity of Southern Ocean and sea ice biota and whether this reflects the environmental heterogeneity of their habitats and makes them resilient to change.

Theme 3 recruitment to be completed in years 3 and 4

- **Postdoctoral Research Associate — Remote sensing zooplankton and krill** (previously called Spatial/Systems Ecologist) This position will lead research effort to develop innovative methods for combining zooplankton remote sensing, field observation and experimental data to provide broad-scale responses of the biological component of the sea-ice ecosystem to climate change in the region.

Data model for Antarctica (Digital Antarctica)

The AAPP is developing a roadmap to achieve the goal of a digital model of the Australian Antarctic Territory, as envisioned by Recommendation 2.2 of the 2017 Antarctic Science Governance Review by Drew Clarke:

The Strategic Plan to explicitly task the Australian National Antarctic Research Institute with developing a comprehensive digital model of the Australian Antarctic Territory, building on the Australian Antarctic Data Centre capability and that of the current Cooperative Research Centre participants.

This Recommendation was supported in principle:

The Australian Government supports in principle the establishment of a comprehensive digital model of the Australian Antarctic Territory that furthers Australia's Antarctic national interests and builds on the capability of the Australian Antarctic Data Centre, and Australia's Antarctic scientists.

The design, location, funding and maintenance of such a model will require further consideration, particularly by the Australian Antarctic Science Council. Options for the most appropriate model will be determined through consultation with relevant portfolios including Education and Jobs and Innovation and other stakeholders across Government, universities and the broader Antarctic sector. Prospective models will be assessed against the Australian Government's Digital Service Standard.

The Australian Government's response made clear that further consideration of "the design, location, funding and maintenance of such a model" was needed and that responsibility for this action rested with the Australian Antarctic Science Council. While the issue is much broader than the AAPP, and involves many stakeholders beyond the AAPP core partners, the AAPP plays a facilitating role in the development of a data model for the AAT. In particular, the AAPP appointed a Business Analyst (1FTE) for two years to be responsible for gap analysis of existing Antarctic and Southern Ocean data infrastructure and development of options for design, location, funding and maintenance of a 'data model' for Antarctica, now dubbed *Digital Antarctica*.

The first phase of the *Digital Antarctica* initiative, which commenced in Year 2 and continues into Year 3, is an analysis and design phase, delivering a series of documents defining various aspects of the initiative and culminating in a paper presenting options and recommendations for the delivery of *Digital Antarctica*. Over the course of this analysis phase, the Business Analyst has held (and will continue to hold) a number of meetings and workshops bringing together representation from multiple portfolios and stakeholders (as envisaged in the Government's response to the 2017 Antarctic Science Governance Review by Drew Clarke), the outputs of which are reflected in the documentation.

As part of this analysis a prototype is planned, which will also require a scope and definition document. The Business Analyst is engaging with Professor Kang of UTAS School of Information Technology, via the CAST initiative, to explore emerging technologies to assist with *Digital Antarctica.*

Planning for years 3 and 4 includes:

- Further work on above document deliverables
- Workshops and presentations to support the deliverables
- Workshops and presentations to engage the wider community regarding *Digital Antarctica*
- A prototype to be designed and built, demonstrating potential features and testing design concepts.
- Options paper, with budgets, to be presented to stakeholders
- Once agreement has been reached, the next phase of *Digital Antarctica*, planning and implementation, will begin in year 4 and continue beyond. The exact nature of this will be determined by the option or options decided, however it is likely to involve:

- Budget
    - Further defining and securing budget for implementation of digital Antarctica
- Standards
    - Developing standards for data management, integration, and interoperability
    - Coordination of participating institutions to work with those standards
- Product
    - Defining and designing features of associated product/s
    - Creating a product team
    - Infrastructure preparation
    - Developing a roadmap of product deliverables
    - Building and delivering to the roadmap
- Communications
    - Developing marketing and training materials
    - Ongoing stakeholder engagement

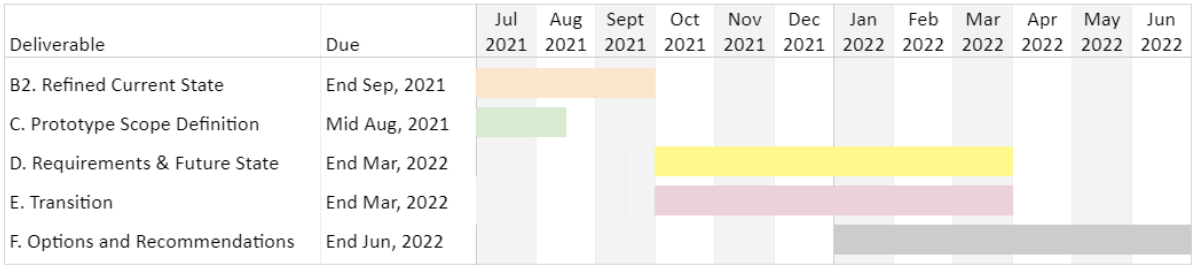

Figure 1 - Gantt chart for Year 3, showing remaining deliverables for analysis and design phase

Project Management

The AAPP is led and managed by a small team consisting of a Program Leader (0.6FTE), an Administration Manager (1FTE) and an Administration Officer (0.4FTE).

Together with the six co-Theme Leaders of the AAPP, the AAPP Program Leader manages the Science Management Program budget.

The activities of the Science Management team since the development of first workplan have been extended considerably. The recruitment of the Science Management Team has been completed. Processes around the operation of the Management Committee, Theme and Project Leaders, and contractual arrangements have all been established along with the seven Project Plans.

Activities and deliverables for years 3 and 4 are (on the basis that COVID-19 is suppressed for the second half of year 3 and fully for year 4):

- Travel and accommodation:
    - Recommence national travel in year 3, international travel in year 4

- Research Training: increasing research higher degree PhD students at a rate of 5 per annum for years 3 and 4 for a total of 15; and provide AAPP top-up scholarships stipends to elite level on a merit basis.
- Staff Training:
    - Provision of training and workshops in Machine Learning, Data Management, and any other staff training identified that directly supports the achievement of project outcomes.
- Science Conference sponsorship:
    - AAPP symposium, two-day workshop (October 2021, year 3)
    - SOOS Southern Ocean Open Conference
- Publications
    - Continued support of publications of high quality and high impact research articles, publication is about $3-5k per full publication.
- Visiting Fellowship Program
    - Commence the visiting fellowship program (after COVID-19) to create a vibrant exchange of scientists.
- Communications:
    - Continuation of the webinar series: Antarctic Policy & Research Forum (~6 per year)
    - Engagement with Worley
        - Knowledge Exchange (seminar series on Antarctic Science, with audiences reaching 300-500 people).
        - Research projects continued at 2 per year.
    - AAPP Impacts, KPI's and outcomes (new).
        - Establishment of reporting tool to support tracking of research publications and their use in policy related documents (year 3).
        - First AAPP impact narratives (year 4).

Budget – Years 3 and 4

ELIGIBLE EXPENDITURE SUMMARY BY RESEARCH THEME		Year 3 Budget	Year 4 Budget
Theme 1: Antarctica's influence on climate and sea level			
Labour - Research		1,327,568	1,356,112
Plant and Equipment			
Research Operating		333,251	239,844
	Total	**1,660,819**	**1,570,956**
Theme 2: Nature and impacts of Southern Ocean change			
Labour - Research		1,507,559	1,748,498
Plant and Equipment		450,000	450,000
Research Operating		149,680	147,488
	Total	**2,107,239**	**2,345,986**
Theme 3: Future of sea ice, krill and ecosystems			
Labour - Research		756,755	943,738
Plant and Equipment			
Research Operating		119,444	181,732
	Total	**876,199**	**1,125,470**
Total All Research Themes			
Labour - Research		3,591,883	4,048,348
Plant and Equipment		450,000	450,000
Research Operating		602,375	544,064
	Total	**4,644,258**	**5,042,412**
Project Management			
Labour - Project Management		264,136	148,812
Operating - Project Management		31,500	32,130
	Total	**295,636**	**180,942**
Travel and Accommodation			
	Total	**140,454**	**143,263**
Administration			
	Total	**254,700**	**251,754**
Audit cost			
	Total	**5,000**	**0**
Other Eligible Expenditure (Ex Research Operating)			
	Total	**370,931**	**396,228**
	TOTAL	**5,710,978**	**6,039,598**