AUGUST 2019

NEPS

SYSTEM DESIGN OUTLINE

NEPS SYSTEM DESIGN OUTLINE

Executive Summary

This document is an early outline for the System Design for the National Environmental Prediction System (NEPS) proposed under the 2016 National Research Infrastructure (NRI) Roadmap[1] and included within the 2018 Research Infrastructure Investment Plan[2]. The material presented here will be further refined and formally submitted as a System Design by 31 October 2019.

NEPS is conceived as a networked or federated form of national research infrastructure. The resulting capability enables integration of environmental observations with predictive modelling to produce data and information products and services to enhance Australian research capability and to support decision-makers and the economy with improved environmental knowledge.

The System Design for NEPS therefore needs to address the mechanisms required to support the necessary networking or federation across existing NRIs and other significant national and State and Territory environmental data assets and to deliver the complementary capability required to facilitate integrated access and modelling based on these infrastructures and assets. NEPS will make significant use of existing capabilities and as far as possible reinforce current NRIs to deliver components that are currently absent or insufficient. As such, existing investments in the component parts are foundational for NEPS, with opportunities for future funding addressing capability gaps identified during consultations undertaken in the NEPS Scoping Study.

The central need in developing this design is an **information architecture** that supports the access, management, integration, use and citation of services and digital resources to deliver integrative understanding of the Australian environment. This architecture must address the handling of all spatiotemporal data assets and of a wide range of other digital resources relevant to modelling the environment. The essential capabilities required include support for integrated access to existing data resources as a spatiotemporal hypercube and robust mechanisms for accessing and using diverse models and datasets to refine, analyse and enrich environmental data and to predict environmental states under different scenarios. The high-level presentation of an information architecture within this document will serve as the basis for ongoing consultation to refine and prioritise requirements.

As the information architecture is refined, it will be possible to develop a **technical architecture** that supports the required information flows and data management and a **social architecture** that enables contributing NRIs to participate in NEPS and to benefit from this federated capability.

Researchers and operational users of environmental data are expected to benefit from simplified access to rich cross-domain data on the Australian environment, with greater transparency, reproducibility and reuse for results. Contributing NRIs are expected to benefit through greater and more sophisticated use of their digital assets and from improved understanding of priorities for new data capture and enrichment.

This document serves two primary purposes. First, it offers an outline for the Department of Education (DoE) of the expected scope and direction for further work in developing the NEPS scoping study. Secondly, it will serve as the basis for the next stage of community consultation to develop the necessary national consensus around a NEPS proposal. Annex A summarised findings from the first stage of stakeholder consultation in support of the NEPS scoping study. Annex B describes the planned activities and timeline for the remainder of the scoping study period.

1 https://docs.education.gov.au/documents/2016-national-research-infrastructure-roadmap
2 https://docs.education.gov.au/documents/research-infrastructure-investment-plan

CONTENTS

BACKGROUND

The 2016 National Research Infrastructure Roadmap identified that investment is needed to establish a National Environmental Prediction System. The proponents for a NEPS argued that the integration of environmental observations with predictive modelling would ultimately lead to improved environmental management and knowledge and consequent benefits for the nation.

Informed by and in response to the 2016 Roadmap, the Australian Government released the 2018 Research Infrastructure Investment Plan that outlined future research infrastructure projects against current emerging Government priorities. The 2018 Investment Plan recommended the undertaking of a scoping study to articulate a value proposition and establishment plan for the proposed National Environmental Prediction System.

The Australian Government Department of Education and Training has commissioned the NEPS Scoping Study to provide technical assessments and requirements analysis for a NEPS, and to define implementation costs and timeframes to establish and manage a NEPS as national research infrastructure to meet researcher and operational user needs. The NEPS Scoping Study involves undertaking targeted consultations with key experts and stakeholders, including relevant areas of the existing National Collaborative Research Infrastructure Strategy (NCRIS) network.

The Australian Government has established an Expert Panel to conduct the NEPS Scoping Study. The Chair of the Panel is Professor Rob Vertessy and the members are Professor Bronwyn Harch, Dr Andrea Hinwood, Dr Adam Lewis, Dr Phil McFadden AO, Mr Warwick McDonald and Dr Steve Morton. The Terrestrial Ecosystem Research Network (TERN), an NCRIS-funded initiative headquartered at the University of Queensland, provides support to the Expert Panel.

The NEPS Scoping Study has two key objectives, namely to:

- obtain broad agreement from key stakeholders regarding the focus of a NEPS; and
- develop a detailed establishment plan, including identification of stakeholder co-investments and actions necessary to support the development and maintenance of a NEPS.

BASIC PRINCIPLES FOR DEVELOPING NEPS SYSTEM DESIGN

The outline presented here incorporates the thinking of the Expert Panel (EP) and the inputs received to date from stakeholder consultations. A key aspect of early discussions has been to clarify the scope under consideration for possible implementation as NEPS. The following principles are considered foundational for development of the System Design.

1. The primary focus for NEPS will be to deliver world-class research infrastructure. However, the work of environmental researchers and the expected outputs from NEPS have significant value for decision-making and regulatory uses. As a national capability, it is appropriate for these operational uses to be considered key use cases that the system should ideally support. Likewise, commercial users are likely to benefit from the capabilities foreseen for NEPS and to offer scope for long-term funding.
2. In the context of NEPS, “environment” is taken to encompass all biotic and abiotic

factors that may vary over time and space, in both natural and artificial systems (cities, agriculture, etc.) and across terrestrial, freshwater and marine areas, with a focus on how these factors affect the ability of people, crops, livestock and biodiversity to survive and exploit these systems. Relevant factors include (but are not limited to) climate, geology, soils, biodiversity, land cover, land use, hydrology, topography, infrastructure, air quality and pollution, at all scales from global through continental to local.

3. "Prediction" is commonly understood to imply a forecasting ability. A national research infrastructure that can offer forecasts regard the future state of the Australian environment would be highly valuable. However, delivering such capability will depend on NEPS having a prior and more general capability to offer modelled predictions of the state of environmental variables in the present or recent past. Such a capability, spanning multiple environmental domains and operating across a range of spatial and temporal scales would in itself be a major asset for Australian researchers and for use in operational decisions. The scope for NEPS is accordingly considered to encompass this broader capability.

4. NEPS should build on, rather than duplicate, existing data services offered by NCRIS or other national capabilities, including TERN, ALA, IMOS, AuScope, AURIN, BOM, GA, etc. These capabilities already deal with standards for primary data and with delivering aggregated and (usually) modelled data for their domains. In the same way, NEPS should as far as possible exploit the resources and models offered by ARDC and NCI rather than developing new compute resources or standards.

5. NEPS must show a clear value proposition with demonstrated benefits for the Australian research community and with collateral benefits for operational users and for Australia's positioning as an international leader in digital environmental research. It is impossible to determine the extent of these benefits in the absence of a straw-person design that can support concrete discussions around detailed scope and priorities and around possible modules that build on the core deliverables. This outline, to be followed by the System Design, will serve this purpose and support the next round of NEPS consultations.

ELEMENTS OF NEPS SYSTEM DESIGN

Any data infrastructure that is developed through collaboration between multiple stakeholders requires a design that provides clarity and facilitates cooperation on at least three architectural levels, as represented by the following figure.

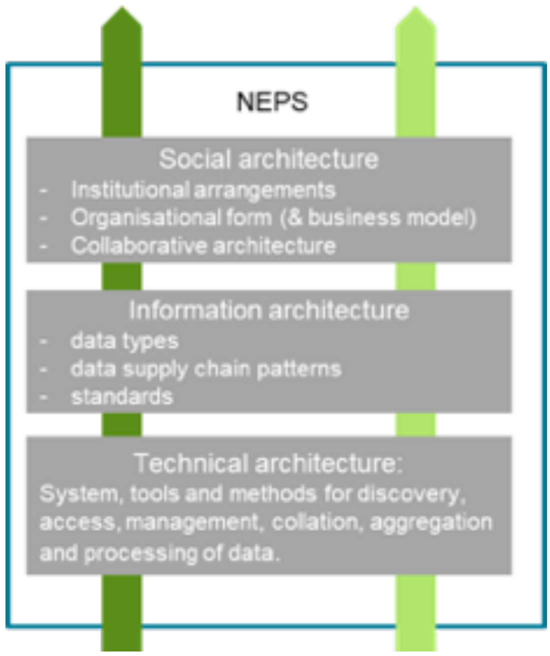

Figure 1 - Architectural levels (adapted from a figure by Paul Box & David Lemon, CSIRO L&W)

The technical, information and social architectures for NEPS each need to be appropriate and supportive for the involvement of all relevant stakeholders, particularly the existing NCRIS environmental capabilities and governmental data infrastructures. The consultation activities under the NEPS scoping study aim to clarify expectations and develop an agreed architecture at each of these levels.

Although these three architecture levels are interdependent, the primary focus for initial design must be on the information architecture. As a national research infrastructure, NEPS must facilitate access to information assets that expand the capabilities of the Australian research community and that reinforce the interconnectedness of the NCRIS landscape. This outline therefore focuses primarily on this level.

If the information architecture for NEPS can be defined and agreed and the benefits from this architecture can be shown, this will provide the foundation for detailed discussion both of the necessary social architecture to provide the delivery framework for NEPS and of the technical architecture that will make optimal use of the resources and strengths of existing infrastructures.

The following sections therefore begin with the requirements for the NEPS information architecture and then identify some of the areas that should be explored to develop associated social and technical architectures.

INFORMATION ARCHITECTURE

A system of systems

The capabilities expected from NEPS centre on the ability to integrate, organise and analyse data from a wide range of sources to understand the patterns and dynamics of different components of the environment and the interactions between these components. Most environmental data sets represent attempts to measure aspects of the environment (a set of variables) at a particular time and place or to model these aspects at particular times and places (usually as continuous modelled surfaces).

In recent years, there have been significant efforts globally to develop standards that can deliver an information architecture for major components of environmental data. The success of the Essential Climate Variables (ECVs) has driven other efforts to define and document sets of essential variables, e.g. Essential Ocean Variables (EOVs) and Essential Biodiversity Variables (EBVs). The Essential Environmental Measures for Australia program[3] was a national effort to explore needs at the national level for similar standardisation. In all cases, these efforts have sought to develop clear but flexible models to guide and prioritise in situ and remote-sensed earth observation activity, to structure efforts to integrate data from multiple sources, and to support modelling efforts around complex Earth systems. Such effort by multiple research communities is a prerequisite for delivering large-scale cross-domain integration of environmental data, for example as proposed for GEO's Global Earth Observing System of Systems (GEOSS)[4].

All of these initiatives seek to characterise a dynamic system through repeated collection of standard observations and measurements in space and time and through modelling to remove errors and bias and to create consistent data products. The primary focus is usually on representing past and present states of the environment at the best possible scale and resolution, both spatial and temporal. However, the same variables and models are also fundamental for modelling future states of the environment under diverse scenarios.

3 https://doi.org/10.25919/5b7f04377bbfd
4 https://www.earthobservations.org/geoss.php

It should be clear that, for any environmental variable, a continuum may exist from 1) primary observations and measurements using particular methods and devices, through 2) systematically normalised, aggregated and cleaned observations and measurements, to 3) modelled estimates of the most likely values for the variable across space and/or time. It is important to register and track data sets created at each stage in this process. Primary observations remain the evidence on which all subsequent modelling depends. Research infrastructures must document the provenance and interdependence of these digital assets and the models that are used to produce more derived assets.

Australia via Commonwealth, State and other public research agencies has made significant investments in data infrastructures that are each responsible for data standards, data aggregation and in many cases modelling for particular environmental subsystems, including climate, oceans, geology, soils, hydrology, terrestrial ecosystems, biodiversity, land use and urban environments. These investments are foundational for NEPS and simplify the task of delivering an integrated environmental information and prediction system. The appropriate model will be for each of these existing infrastructures to serve as a hub to stimulate standardised observing efforts and to aggregate, normalise and clean data representing a subsystem. NEPS will be a collaborative activity to provide cross-domain integration and services across all these subsystems and to facilitate interoperability and modelling that depends on enhancements to the deliverables from multiple hubs.

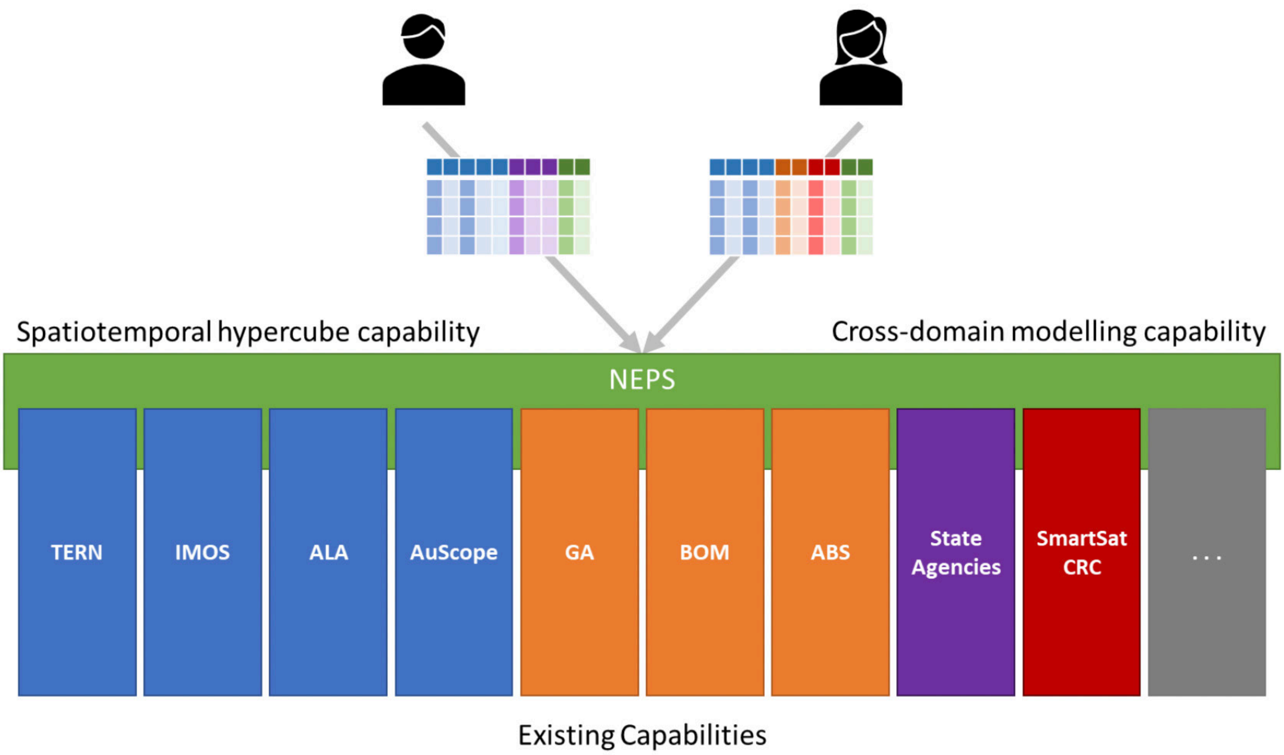

Figure 2 – the opportunity for NEPS as a cross-domain data integration and modelling platform for Australian environmental data based on existing Commonwealth, State, NCRIS NRI and other research agency capabilities

An environmental data hypercube

A key challenge for environmental data infrastructures is the immense range of scales (both spatial and temporal) for which data are collected and organised. This challenge increases as data from different methods and sensors is combined and as models need to incorporate datasets from different domains and infrastructures. There is a fundamental and highly general need for tools that can reliably upscale and downscale data according to application needs and that can assess whether shifts in scale reduce information to unacceptable levels.

The integration of data for all environmental variables can be modelled as a space-time hypercube with a set of aggregated or modelled variables for each cell (i.e. for each unit of space within a given time interval). Efforts such as the ECVs, EOVs and EBVs exploit this model of stackable spatiotemporal layers.

Developing NEPS as a generalised environmental information and prediction system will require the ability to deliver (whether centrally or via federation) such a hypercube with efficient capabilities to align, rescale, interpolate and extrapolate data and hence to offer estimates for a suite of environmental variables at any point in, or for any portion of, time and space (within appropriate limits).

Such a hypercube would have enormous value for many researchers and regulatory users and would be a valuable extension to existing NCRIS capabilities. It would be a prediction system in that it would predict the values of environmental variables for different times and places even in the absence of known measurements. It may be considered an extended version of the core that underlies many of the individual NCRIS or Federal capabilities. Existing virtual laboratories relevant to implementing this hypercube include Ecocloud[5] and the Biodiversity and Climate Change Virtual Laboratory (BCCVL)[6].

Other digital assets

Developing true predictive capability will require extensions that proceed beyond the hypercube to offer modelling capabilities that exploit multiple variables to improve predictive power, either to address research questions or to support regulatory decisions that require additional analysis.

To make this possible, NEPS must support access to additional digital assets beyond those that are included within the spatiotemporal data hypercube. Some or all of these may be managed directly by one of the contributing infrastructures, but it is likely that NEPS will nevertheless need to include services that support consistent and integrated access to these resources.

An ideal modelling and prediction system for the environment should be able to exploit evidence from observed properties of the classes of entity within the environment, e.g. through access to field or lab measurements of thermal tolerance for a given species, life tables for populations of a species at well-studied sites, or the hydrological characteristics of different soil groups. Similarly, NEPS should be able to exploit evidence from field and lab studies on functional relationships between different variables in the system (response curves, etc.).

Non-spatiotemporal assets of relevance to NEPS include at least:

1. Vocabularies, ontologies, gazetteers and directories relating to environmental data
2. Attributes of entities that are independent of spatial locations but required to parameterise models

5 https://ecocloud.org.au/
6 http://bccvl.org.au/

3. Process models, equations and other modular elements for modelling complex environmental systems

It is not possible at this stage to determine the full scope of such assets required to implement NEPS. A modelling framework would assist with setting an agenda and priorities for collection of the traits that make most difference (and for phylogenetically informed use of default estimates for different taxa). Since the potential scope is enormous, NEPS should catalogue these assets based on actual need as part of defined solutions. Nevertheless, the need for access to diverse classes of non-spatiotemporal assets must be recognised from the beginning and addressed as part of the NEPS information architecture.

Metadata, provenance and attribution

The emphasis above has been on the data assets required to deliver environmental information and predictions. It is essential that NEPS follow good contemporary practices for documenting, publishing, referencing and reusing both spatiotemporal and non-spatiotemporal assets. The same principles will apply across all these assets. ARDC (and more broadly RDA[7]) provide the leadership and models that NEPS should follow.

NEPS, along with its contributing infrastructures, must align where applicable with guidance offered by ANZLIC[8] in regard to spatial data standards and metadata. Domain-specific alignments (e.g. with the EOVs or EBVs) should be coordinated by the relevant contributing infrastructure.

The FAIR Data Principles[9] directly or indirectly address the requirements for NEPS to maximise the discoverability and reuse of data assets, in particular the need for robust and stable identifier schemes, clear and comprehensive metadata, machine-readable licensing, and clear attribution and credit. NEPS must follow ARDC recommendations on preferred mechanisms to implement these principles. As far as possible, data within the NEPS framework should also be licensed as freely as possible to maximise reuse. NEPS partners must evaluate the need for the system to support secure access for authorised users to sensitive or restricted data assets and to enable use of these within modelling tools. The extent and complexity of these needs may significantly influence the NEPS architecture at all levels.

Clear tracing of provenance for all digital assets and consistent practice around citation and reuse will encourage and facilitate world-class cross-domain research. By serving as an integration point for all Australian environmental data, NEPS is expected to enhance the use and value of the contributing infrastructures.

Information access

Stakeholder consultations during the remaining period of the NEPS scoping study will refine expectations around the information access required through the infrastructure. However, the following major classes of information access are considered important.

1. Cross-domain access to all primary observations and measurements for any location (point, grid cell or shape) within any time period.
2. Access to best-available modelled representations of key environmental variables at different scales in space and time.
3. Hypercube functionality to retrieve modelled representations of a set of key environmental variables across multiple space-time units at different scales – including grid cells, cadastral units, and other arbitrary divisions

7 https://www.rd-alliance.org/
8 https://www.anzlic.gov.au/
9 https://www.ands.org.au/working-with-data/fairdata

4. Ability to schedule models and analyses using arbitrary combinations of spatiotemporal and non-spatiotemporal assets
5. Tracing provenance, source data, contributing institutions and users for any data asset or data product

TECHNICAL ARCHITECTURE

Many of the components that are necessary to build NEPS already exist within current NCRIS capabilities or federal or state data infrastructures. The tools and systems offered by ARDC and NCI provide the technological foundations for any additional NEPS developments.

As already noted, NEPS will as far as possible simply adopt and adapt the products of these other infrastructures. The scope for the NEPS technical architecture will therefore be defined by identifying the gaps between these infrastructures. Some elements identified this way may best be delivered by extending an existing infrastructure. Others may best be delivered as new independent NEPS investments. Determining which approach is best will depend on the social architecture, particularly the governance and funding models, adopted by NEPS.

The following diagram is an indicative outline of the major component areas to be addressed within the NEPS technical architecture. This does not represent a formal architecture. It is intended to represent the major areas around which coordinated effort and delivery are required to integrate the services and capabilities of the existing national research infrastructures. Implementation of these components may be provided by one or more of these existing infrastructures rather than being totally new systems.

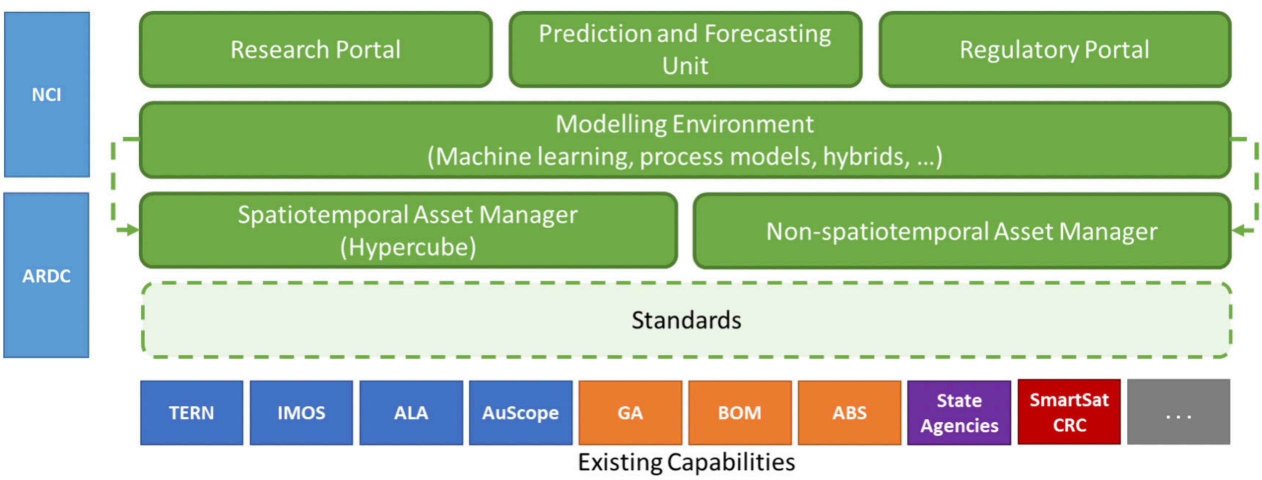

Figure 3 - Indicative component areas for NEPS implementation based on existing Commonwealth, State, NCRIS NRI and other research agency capabilities

Some of the upper components could be delivered as services that independently build on core NEPS functionality. Consultations during the remainder of the scoping study period will contribute to evaluation of alternative models for delivering the necessary range of functionality.

Standards

NEPS will work with existing infrastructures to standardise metadata, data formats, APIs, etc. and to implement connectors to ensure that relevant national environmental data assets are accessible and useful for the NEPS. This is likely to require some workshops and decisions on preferred representations for some classes of information and on preferred approaches to spatiotemporal organisation of data (units, scales, partitions, etc.).

Spatiotemporal Asset Manager

As discussed above under information architecture, NEPS requires a unified access mechanism for applications to align and stack all spatiotemporal environmental data assets. This could include development of a centralised data store or a federated solution, depending on priorities derived from application needs and efficiency considerations.

Non-spatiotemporal Asset Manager

NEPS will also require an architectural approach and application platforms for organising and accessing other, non-spatiotemporal data assets (class properties such as species traits, functional relationships, model workflows and modular algorithms, etc.). The scope of this component is much less clear than the previous two, but the detail can be enriched over time.

Modelling Environment

An engine or engines that use the first three components to model the state of a set of environmental variables at a given scale/grain (both space and time) for a particular time and place, with estimates of uncertainty for all aspects. This capability should ultimately support both predefined model workflows/algorithms using standard inputs and custom composition of bespoke models. Some standard model outputs using well-documented settings should probably become assets for further reuse through the Spatiotemporal Asset Manager component above.

This modelling capability will require support at least for:

1. Repeatable workflows based on spatiotemporal variables and optionally on parameters derived from other data (e.g. species trait information)
2. Machine learning via neural networks, etc.
3. Process models driven by more sophisticated use of semantic data and modelled functions processing data inputs

Research Portal

NEPS research users will require a generalised virtual laboratory interface allowing them to schedule and run either standard or bespoke models using the capabilities offered through the components listed above. Some commercial uses may be supported through this portal.

Prediction and Forecasting Unit

If NEPS is to offer predictive capabilities, a coordination unit should be staffed to work with research communities to develop and validate models to represent cross-domain dynamics and forecast the state of environmental variables under different scenarios. The outputs from such activity can be captured as new spatiotemporal data assets or as new functionality within the modelling environment.

Regulatory Portal

Agencies requiring access to environmental information, analyses and reports will benefit from improved coverage, completeness, accuracy and transparency resulting from the NEPS infrastructure. The return on investment from NEPS is likely to be significant for such uses. Accordingly, there would be value in NEPS aiming to deliver simplified access to standard reports and assessments that implement existing workflows and requirements used by state and federal regulatory agencies. This should incorporate clear documentation on the origins, quality and adequacy of data sources used and estimates of uncertainty arising from these. It is likely that commercial users may also be supported through standardised reporting tools offered by this portal.

SOCIAL ARCHITECTURE

The immediate requirement is to develop a clear information architecture for NEPS, from which the associated technical architecture can be derived. However, this architecture can only be successfully implemented if the existing environmental infrastructures are able to collaborate and contribute the required data assets and services.

Social architecture is about the conscious design of an environment within which information infrastructure can evolve. The social architecture comprises the formal decisions making process and structures together with the policies, standards and other rules that are created through governance. It also comprises the informal networks, collaborations, and numerous communities of practice involved in building, using and driving evolution of NEPS.

The social architecture for NEPS will encompass governance concerns spanning strategic and business decisions through to the technical science and data governance decision scopes. It will be developed based on an understanding of the social, institutional and economic dynamics of the landscape in which NEPS is being implemented - i.e. the political economy/context that shapes and within which, NEPS exists. Wherever possible attempts will be made to leverage and wire NEPS social architecture into, existing institutional arrangements. This may mean for example delegating standards development to pre-existing governance mechanisms such as the ecological or biodiversity science information communities.

Stakeholders with responsibility for existing infrastructure investments will be engaged through the next phase of the scoping study so that an appropriate social architecture can be developed and refined in conjunction with the development of the technical architecture.

ANNEX A:

NEPS Scoping Study Stage 1 Consultation

Stage 1 of the consultation process, undertaken in Q1 of 2019, involved the Expert Panel consulting with an initial representative group of stakeholders to refine the Panel's consultation approach.

Both potential end-users and potential providers of environmental and supporting information were consulted. Table 1 shows the individuals and groups that were consulted during Stage 1.

Table 1: NEPS Stage 1 Consultation list

Stage 1 Consultation Organisation/Individual	**Contact Point**	**NEPS Expert Panel Interviewer/s**
Threatened Species Research Hub (NESP)	Brendan Wintle	Steve Morton
NT Environment Protection Authority	Paul Vogel	
WA Environmental Protection Authority	Tom Hatton	Rob Vertessy & Warwick McDonald
Northern Australian Research Hub	Michael Douglas	Steve Morton
Centre for Air Pollution, Energy and Health Research	Guy Marks	Andrea Hinwood
Commissioner for Environmental Sustainability Victoria	Gillian Sparkes	Andrea Hinwood
Environmental Health Grouping of national health departments and agencies	Sophie Dwyer	Andrea Hinwood
NRM Regions Australia	Kate Andrews	Adam Lewis & Warwick McDonald
National Earth and Environmental Science Facilities Forum	Tim Rawlings	Adam Lewis & Warwick McDonald

Stage 1 consultation questions for potential users of a NEPS

The focus of our engagement with potential users will be to ascertain where the demand for and expectation of a NEPS might lie. In governments, industries and communities, decisions are made regularly regarding the way we use, protect and remediate our natural and managed environments. We seek to identify where better environmental, social and economic outcomes can result from the stronger use of information about past, present and future state(s) in decision making. Questions we will test with this group in the Stage 1 consultation include:

Purposes

1. How often do you make decisions that affect environmental outcomes, or that are dependent on the state of the environment, and what are the consequences of those decisions?
2. What are the most important environmental management or policy

questions you are challenged by that urgently demand better information?

3. What, if any, expectations would you have of a NEPS? What would your priorities be for developing a NEPS? Is there 'low hanging fruit' for a NEPS?

Information Priorities

4. In making those decisions, what environmental variables are of most interest to you and how satisfied are you with the present availability of information on them?
5. Thinking about the information you need most or would be most beneficial to your decision making, what proportion is historic data, very recent data, short-term forecasts or long-term predictions?
6. At what level of spatial and temporal detail (granularity) do you require that information?

Use and Adoption

7. What are the factors that lead you to trust and use that information?
8. Thinking about a trusted environmental information source that you currently use in decision making, tell us about its positive and negative attributes.
9. What could be done to improve the connection between end-users and providers of environmental information?

Consultation

10. Thinking about the NEPS consultation strategy, what engagement modalities do you favour?
11. Who are the other important potential end-users of environmental information that we should consult?

Stage 1 consultation questions for potential creators of a NEPS

The key goal of our engagement with potential creators will be to ascertain where the state-of-the-art environmental science, monitoring, prediction and informatics lies, with a view to identifying the challenges and opportunities of developing a system, the potential roles of the providers, and areas where more effort will be required. Our level of scientific understanding in environmental processes is strong in some areas and weak in others. Also, the availability of environmental data of different kinds varies significantly. Recent technological developments are rapidly changing our ability to capture data and improve understanding through modelling to support better decision making. Questions we will test with this group in the Stage 1 consultation include:

Priority Applications

1. Reflecting on your experiences with end-users of environmental information, where do you think they need more support? Do you see areas of particular expectation from end-users for a prediction system?
2. In what areas do you feel that we have useful environmental information that is yet to be harnessed in decision making?
3. In what areas do you see a need to build information?

Information Base and Infrastructure

4. Thinking about trusted existing environmental information sources being used in decision making, what do you see as their strengths and weaknesses?
5. What new data sources, analytic methods or tools do you see arriving in the next five years that are potential game changers for environmental management?

6. What environmental information infrastructure do you have (or plan to have) that would be necessary to implement the NEPS?

Use and Adoption

7. What are the issues involved in getting end-users to trust and use that information?
8. What more needs to be done to evolve that information into a state that satisfies end-user requirements?

Consultation

9. Thinking about the NEPS consultation strategy, what engagement modalities do you favour?
10. Who are the other important potential providers of environmental information that we should consult?

Key findings from Stage 1 consultations

1. Users of environmental intelligence were very keen to have access to better information to support their decision making but found it challenging to define their requirements. We concluded that deep dialogue is necessary to elicit user requirements.
2. Researchers who create tools and data sets for environmental analysis are eager to increase their impact by getting closer to users of environmental intelligence but struggle to identify points of entry. The large number of users and their segmentation across jurisdictions makes it hard for the research community to engage in a meaningful way. They see contributing to the building and maintenance of national research infrastructure as an ideal way to engage with user communities.
3. The users and creators of environmental intelligence who we consulted highlighted three promising user communities that we have deemed worthy of closer examination.
    a. Environmental Regulators regularly make highly consequential decisions that affect the state of our natural environment. Their decisions are subject to high levels of scrutiny, often expected within tight timelines and need to give regard to cumulative effects. Comprehensive, timely and reliable environmental intelligence is thus a highly sought-after commodity for environmental regulators.
    b. State of Environment (SoE) reports play a vital role in informing the Australian public about the current state and trend in environmental conditions across our country. SoE reporting is undertaken in all Australian jurisdictions but on different schedules and based on different methods. Several SoE reporting teams have highlighted the difficulties they face in getting access to quality data sets and methods and are seeking help from the science community.
    c. Australia’s 56 regional Natural Resource Management bodies have a huge task; to deliver positive environmental outcomes relating to water, soils, vegetation, biodiversity, climate change and other important facets of environmental management and so their information needs are extremely broad. Whilst their environmental management remit is wide, their capability is modest and they rely on a range of institutions to provide the vital environmental intelligence they need to perform their mission.

ANNEX B:

NEPS Scoping Study Stage 2 Consultation

Stage 2 of the consultation process commences in towards the end of Q3 of 2019 and will be conducted over the rest of the year. The Expert Panel's Discussion paper, which is available on the NEPS web site (www.science.uq.edu.au/neps), will be widely promoted through a wide range of mainstream and social media. The NEPS web page will invite participation in the consultation process via a number of mechanisms (see Consultation Methods and Tools). The Expert Panel will consult with a wide range of stakeholders with a potential interest in the NEPS. Both potential end-users and potential providers will be consulted.

Stakeholder Identification/ Categories

Consultations will be held with key Australian informants, being either individuals or small groups representing particular organisations, who have an interest in the development of the NEPS, particularly including representatives from:

- relevant Commonwealth, State and Territory government departments;
- current NRI staff; and
- researchers at universities.

Key domain conferences will also be leveraged to gain an understanding of the views of the broader ecological science community.

At a minimum the study should engage with:

- Atlas of Living Australia;
- AuScope;
- Australian Research Council (ARC);
- ARC Centres of Excellence;
- Australian Research Data Commons (ARDC) – including the National Research Data Cloud;
- Australian Urban Research Infrastructure Network (AURIN);
- Australia's Tier 1 High Performance Computing (HPC) facilities – including National Computational Infrastructure (NCI) and Pawsey Supercomputing Centre;
- Bureau of Meteorology (BoM);
- Commonwealth Scientific and Industrial Research Organisation (CSIRO);
- Department of the Environment and Energy, including groups associated with its environmental economic accounting agenda;
- Department of Agriculture and Water Resources;
- Ecosystem Science Council;
- Integrated Marine Observing System (IMOS);
- National Environmental Science Program; and
- Terrestrial Ecosystem Research Network (TERN).

Discussions, but not overseas travel, will occur with relevant international stakeholders, such as overseas environmental and climate monitoring facilities and any institutions offering environmental prediction services in other countries.

Consultation Methods and Tools

The NEPS Expert Panel will use a range of consultation methods and tools as appropriate, including written submissions, surveys, interviews, roundtables and workshops.

Method of consultation	Possible Advantages	Possible Disadvantages
Written submissions	Opportunity for in-depth information exchange, including detailed use cases Input for those who may not attend workshops/roundtables	Reviewing submissions can be labour intensive time consuming Hard to target specific stakeholders
Telephone interviews	Input from those who may not attend a public meeting Higher response rate than mailed surveys	More expensive and labour intensive than mailed surveys.
Face-to-face interviews	Opportunity for in-depth information exchange in non-threatening forum Opportunity to gain feedback from all stakeholders Can be used to evaluate potential citizen committee members	Time consuming Expensive
E-surveys	Input from those who may not attend a workshop or roundtable Provides a mechanism for extending a mailing list Provides information from a cross section of the community not only activists Statistics are valuable in determining a decision	Response rate can be low To get statistically valid results, can be labour intensive and expensive Level of detail may be limited
Meetings with existing groups	In-depth information exchange in a non-threatening forum	May be too selective and can leave out important groups
Workshops/Roundtables	Promotes community involvement Excellent for discussions Maximizes feedback obtained from participants Capitalises on existing networks Enhances credibility Fosters public ownership in solving the problem	Can be difficult to control information flow Can build false expectations Can be expensive and time consuming (professional facilitators)

adapted from IAP2 Toolbox

Consultation communication objectives

- To ensure that the ecosystem science community and broader NEPS stakeholders are engaged throughout the various consultation and planning activities of the NEPS Scoping Study.
- To engage the relevant sections of the Australian ecosystem science and management communities for producing the NEPS Investment Plan.
- To produce the highest quality consultation summaries and resultant NEPS Investment plan to address why a NEPS is necessary, what it is to produce, where to focus effort, and who should be involved in building and maintenance.
- To positively position the NEPS Investment Plan as an exciting and unique opportunity for the ecosystem science community to set the foundations for building and delivering a sustainable and effective environmental prediction system for Australia.

Consultation Questions

The NEPS Expert Panel will use a pre-defined set of questions in all consultations with stakeholders. These questions have been refined based on feedback from the Expert Panel following Stage 1 consultations. In the case of written submissions, Instructions on the NEPS web site will encourage those making a submission to address the Discussion paper and System Design Document.

Example text and consultation questions to capture use cases

As part of the NEPS Scoping Study, we wish to understand current and expected needs for access to integrated information on aspects of the Australian environment, past, present and predicted.

In this context, "environment" is taken to encompass all biotic and abiotic factors that may vary over time and space, both in natural and artificial systems (cities, agriculture, etc.) and across terrestrial, freshwater and marine areas, with a focus on how these factors affect the ability of people, crops, livestock and biodiversity to survive and exploit these systems. Relevant factors include (but are not limited to) climate, geology, soils, biodiversity, land cover, land use, hydrology, topography, infrastructure, air quality and pollution, at all scales from global through continental to local.

In order to clarify requirements and to understand the need across Australia for a National Environmental Prediction System, we ask you to describe your information needs in support of your research or applied decisions.

These questions are to help with development of broad requirements and needs for environmental prediction. We do not expect all needs to be addressed within an initial proposal for a NEPS, but this information will help to clarify the ideal ultimate scope for such a system.

Please use the following questions to describe a typical inquiry (research question or decision) that you might carry out based on one or more environmental factors. If your research or work includes multiple classes of inquiry with different characteristics and needs, we welcome separate descriptions of each. We also welcome descriptions of situations where your information needs relating to the Australian environment are difficult or impossible to address with existing resources.

1. Briefly describe the context and purpose for the inquiry

2. Define the core question to be addressed in the inquiry
3. Explain the spatial (continent, state/territory, local, site, 20km2, 1m2, etc.) and temporal (decade, year, week, day, hour, etc.) scales at which this question needs to be addressed
4. Explain the importance or significance of being able to address the question, including financial aspects, future expenditure of effort, regulatory or conservation outcomes, role within a larger research agenda, etc.
5. Identify any time-critical aspects around addressing the question (e.g. within 5 working days)
6. Are you able properly to address this question today?
    a. If so, please describe how you source and use information as inputs to address the question
    b. Otherwise, please identify gaps or constraints around existing information and tools that limit capacity in this regard, and describe any processes you currently follow to approximate an answer
7. Please list categories and sources (where applicable) of environmental information that you use, or need, to address the question

Here include a table to document information types – needs some more refinement, but should probably include at least the following elements:

- Picklist of broad categories (climate, biodiversity, land use/cover, marine, freshwater, air, infrastructure)
- Specific data inputs (mean annual rainfall, vegetation class, human population per km2, species distributions, CO2 concentration ppm, etc.)
- Spatial precision required
- Temporal precision required
- Availability (Existing satisfactory, Existing deficient, Lacking, …)
- Notes on specific requirements for use of these data

Consultation Timeline

Activity	Time (start date)
Stage 1 Consultation	February to March 2019
Planning began for Stage 2 Consultation	February 2019
NEPS Scoping Study Expert Panel meeting to discuss Stage 1 Consultation outcomes and Stage 2 Consultation strategy	March 2019
Stage 2 Consultation (see table below for more detail)	August to December 2019
Expert Panel to collate and analyse consultation responses and develop the first draft of the Investment Plan.	January to March 2020
Further consultation (at this time the Expert Panel may want to seek advice/guidance from DET regarding the content, detail and proposed direction).	April 2020
Redraft of Investment Plan based on further consultation.	May 2020
Approval of the Investment Plan by DET.	May 2020

Method of consultation	Consultation Period
Written submissions	Q2 to Q4 2019
Telephone interviews	Q3 & Q4 2019
Face-to-face interviews	Q3 & Q4 2019
E-surveys	Q3 & Q4 2019
Meetings with existing groups	Q3 & Q4 2019 – additional reviews in Q1 2020
Workshops/Roundtables	Q4 2019

All forms of consultation will be completed by 25 December 2019 to allow sufficient time for the Expert Panel to collate and analyse responses and develop the draft Investment Plan. The draft Investment Plan is to be submitted to DET by 30 May 2020.