A general framework for Australian environmental accounting

Limited Distribution Draft

Version 0.03a September 2012

This document describes a general environmental accounting framework for defining and applying environmental accounting at a range of scales. It also describes the *Joint Perspectives Model* as the conceptual underpinning to the framework.

[Author's note: Steps for finalisation of Framework

1. Internal BoM review (completed)
2. Limited Distribution Australian Government and expert review (underway for **2 months – til end November 2012 – including review meeting on 21st November 2012**). **Please get comments back to Richard as soon as you are able before the end of November.**

   Additional work for limited draft version:

   a) The 'Accounting for nature' (ecological perspective) section needs refining
   b) The Prototype Ecosystem Accounts Case Study needs to be written
   c) Framework Step 8 needs to be expanded
   d) Glossary and some table content need to be written and refined
   e) Diagrams need to be refined and added where appropriate e.g. statistical units section
   f) Appendices not included – if you want to see them, please get in touch]

3. Public release of Exposure Draft (later this year)
4. Final release of Framework (March/April 2013, as part of NPEI deliverables)

Citation (please do not cite yet)

Australian Government (2013) *A general framework for Australian environmental accounting.* Prepared by the Bureau of Meteorology, Australian Government.

Publication details

[ISBN etc]

NPEI publication Series

This document was prepared for the *National Plan for Environmental Information* (NPEI) by the Environmental Information Services Branch, Climate and Water Division, Bureau of Meteorology. It is part of the NPEI Publication Series [?series name?]:

[listing of other titles in the series]

1. Statement of Australian Government Environmental Information Requirements
2. Environmental Accounting Landscape Paper

Acknowledgements

Thanks to the Australian environmental accounting community-of-practice, particularly: Carl Obst; Jayne Godfrey, ANU; Michael Vardon, Mark Lound and Andrew Cadogan-Cowper, ABS; Mark Eigenraam and Joselito Chua, DSE, Victoria; Peter Cosier and Carla Sbrocchi, Wentworth Group of Concerned Scientists; NRM Regional Chairs; Jane McDonald, QUT; Simone Maynard; Steve Cork, Australia 21; Judith Ajani, ANU; Jean Chesson, ABARES; Fraser McLeod, Jim Donaldson and John Purcell, MDBA; plus many more.

Others who have contributed significantly are: Carolyn Raine, Central West CMA; Maria van de Gract and Mike Ronan, Queensland government; plus many more..

Thanks also to our international colleagues, particularly Michael Bordt, Canada; Jean-Louis Weber and Jock Martin, European Environment Agency; Roy Haines-Young, Nottingham University, UK; Rocky Harris, Defra, UK; and all the members of the SEEA Ecosystems Accounting Expert Group and London Group.

Disclaimers

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Summary

[Author's note: to be completed]

Document owner, purpose and description

Framework owner

Australian Government

Document Owner

Environmental Information Advisory Group

Purpose of document

1. To describe a general environmental accounting framework and its underpinning conceptual model
2. To assist potential account users to decide if they need an environmental account
3. To outline a process for creating an environmental account

Structure of document

[Author's note: Something here – this is important – needs to help readers 'dip into' the document rather than expect them to read cover to cover]

Authorship of document

BoM for the *National Plan for Environmental Information* (NPEI)

NPEI vision: "...to equip all Australians with environmental intelligence for safety, sustainability, well-being and prosperity."

The call for Australian environmental accounts

Australians live in a unique and rich continent surrounded by a vast marine estate; these are the living and non-living environments we depend upon and that form the basis of our common and collective wealth. There are opportunities and challenges associated with living here, not least the challenge of providing sound stewardship for our natural sources of wealth, our natural capital. It is this natural capital, together with human, social and economic capital, that provides the basis for the wellbeing of all Australians, now and into the future.

Our policy makers and land managers are in constant need of better tools for evaluating the impact of their decisions as they grapple with improving human wellbeing today, while maintaining the capital base necessary for a sustainable future. In addition, the Australian people[1] and the highest levels of the Australian Government[2] have called for improvements in the way environmental information is organised to meet this need, including a call for enhanced environmental accounts for nature[3].

Organising environmental information is challenging, not least due to the high levels of complexity in living systems themselves. As well, there are many different interactions between people and the natural environment, ranging from 'non-material' interactions (such as a sense of identity and place), to direct physical interactions (such as the production of food and timber). Some interactions are measurable in monetary terms while others are not or only partially so. Environmental accounting requires that, despite this complexity, we find comparable ways to measure different aspects of living systems and the different kinds of human–environment interactions. Such comparability is necessary if we are to use environmental accounts to inform policy and decision making.

Box 1 What are environmental accounts?

Environmental accounts provide organised information for a clearly defined decision-making purpose. They are systematic and comparable, and use standard definitions based on accepted measurement and accounting theory.

Environmental accounts use physical measures (e.g. area, volume, weight), derived or composite measures, such as an index, or, where appropriate, monetary measures. Specific types of accounts can be developed depending on the perspective and requirements of the account user.

Environmental accounts can be viewed from different perspectives:

- From an **economic** perspective, they can measure natural inputs to the economy and how the economy impacts on the environment (e.g. pollution and waste).
- From a **social** perspective, they can contribute to measuring human well-being.
- From an **environmental** perspective, they can be used to ascertain changes in the environment, ecosystems and their functioning.

Terminology associated with environmental accounts includes ecosystem goods and services and natural capital.

Ecosystem goods and services are benefits that flow to people from the environment, for example, clean water, timber, habitat for fisheries, ingredients for medicines and pollination of agricultural crops. Other ecosystem goods and services include carbon sequestration, flood mitigation, educational opportunities and a sense of identity and well-being associated with natural places (e.g. the bush or the coast) and the existence of life forms (e.g. blue whales).

Natural capital is the productive natural resource base, such as ecosystems, land, air, water and living organisms, with the capacity to maintain itself and supply ecosystem services to people, now and into the future.

[1] 2020 Summit

[2] Cabinet decision <date>

[3] Wentworth Group of Concerned Scientists

Any efforts to better organise environmental information, including environmental accounts, need to be built on a sound theoretical foundation. A parallel can be made with the economic theory underpinning economic accounts. The choice of conceptual model is a crucial step as it can enable, or disable, solutions and progress; for example, the tackling of 'wicked problems', such as climate change, requires an approach that enables us to see the linkages between environmental, societal and economic perspectives.

New support for our environmental stewards and policy makers

Improved access to environmental information

With improved knowledge of the natural environment's contribution to our wellbeing and better environmental information, new forms of support are emerging for the stewards of Australia's natural capital. The Australian Government has funded the National Plan for Environmental Information (NPEI) initiative to improve the quality and accessibility of environmental information for decision-making. This initiative is being jointly implemented by the Bureau of Meteorology and the Department of Sustainability, Environment, Water, Population and Communities. The Bureau's role focuses on operational elements and implementation of technical components of an environmental information infrastructure, including the development of a framework for environmental accounting.

Why the Bureau of Meteorology?

The Bureau has a long history of serving the people of Australia through excellence in science and a focus on delivering high quality information about fundamental physical processes in the environment. Drawing on this expertise, the Bureau has developed a conceptual model for environmental accounting based on first principles. The *Joint Perspectives Model* is grounded on the idea that our decisions and interactions with the wider world are informed by the fundamental physical and biological processes operating all around us. At the same time, it recognises that complex and powerful human systems have emerged that reflect our response to the physical and living world; these include social, scientific, legal, political and economic systems.

A fresh way to look at environmental systems, people and place

This document sets out the *Joint Perspectives Model* (Model) and its value as a foundation for environmental accounting. It is a model that shares many characteristics with existing approaches and is highly compatible with them, yet it has new characteristics that illuminate the task of developing environmental accounts. For example, it recognises that human systems emerge from natural systems and demonstrates that accounting in terms of monetary units is not always achievable, even in theory. Based on the foundations of the Model, a general framework for environmental accounting is presented that is flexible enough to be consistent with existing approaches yet offers a generic structure to any future environmental accounting effort. The *Australian Environmental Accounting Framework* (Framework) is designed to be applied at any scale and is primarily a guide to those deciding whether an environmental account will be of benefit, and if so, how to go about creating it.

Before explaining the Model and Framework further it is useful first to describe the basics of accounts and then of environmental accounts themselves.

"The Australian Environmental Accounting Framework is … primarily a guide to those deciding whether an environmental account will be of benefit, and if so, how to go about creating it."

What are environmental accounts?

Accounts

Accounts are a structured, systematic way to organise information for a clearly defined decision-making purpose. They track flows and stores of value via transactions that take place within a set period of time. Accounts present comparable information in a systematic fashion, using standard definitions based on consistent theory and a sound conceptual framework. They encourage the development of comprehensive and consistent data and provide a platform for producing a range of accounting reports and analyses.

There are two main forms of accounting, business (or financial) accounting and national accounting. The first generally deals with business assets, liabilities, income, expenses and equity while the second deals with the economic activity of a nation and is based on macroeconomic concepts such as national income, investment, consumption, inflation and international trade. National accounts measure stocks and flows using double-entry bookkeeping methods to ensure that changes in flow accounts are equal to the change in the related stock account.

Both types of accounts depend on clear definitions of the account subject (e.g. water, widgets or energy) and of the statistical 'units' for accounting, also called 'entities' (e.g. a business or household). As accounts are strongly concerned with changes in the account subject over time, much attention is paid to when transactions and measurements take place and which unit made them. An account is not a forecasting system; rather it is focussed on what is happening and reveals the trends to the present. An account can be used as a platform upon which to develop scenarios and other future-oriented assessments.

Measurement of the account subject is central to any accounting and necessitates the application of standard measurement methods and classifications. When it is not possible to record every transaction, as for many national accounting purposes, changes in the subject of the account are estimated using robust statistical sampling methods, such as surveys. The account is an organised way of reporting the measures and estimates of the account subject to allow comparisons to be made across time and space and between entities. This is powerfully enabled when a common currency is available, such as money.

Accounting systems are built on ethical foundations, designed to provide information to interested parties beyond the accounting system. Accounting information must be generated in an open and transparent manner and may be subject to independent auditing and quality assurance methods.

Environmental accounts

Environmental accounts take many forms, though most are variations on the national accounting approach. There are exceptions, for example, the Bureau of Meteorology's National Water Account has taken a financial accounting approach. To date, environmental accounts are generally extensions to the System of National Accounts (SNA), designed to track transactions between the economy and the environment.

The methods for extending the SNA are defined in the System of Environmental-Economic Accounts (SEEA), the Central Framework of which is now an international standard (SEEA2012). Focussing on aggregated measures of stocks and flows, the SEEA is designed to account for natural resources (such as water, timber and fish), environmental degradation, depletion and 'defensive' expenditures (e.g. environmental protection or restoration spending). For more on how the SEEA is, and can be, applied in practice in Australia, see *Completing the Picture* (ABS, 2012).

Where monetary valuation methods are available, typical national accounting aggregate measures can also be adjusted for depletion or damage to the environment; for example Gross Domestic Product (GDP) can become 'Green GDP'. Examples of this type of application include the OECD

Green Growth initiative[4].

There is also national and international effort being made to go beyond standard measures of economic activity (such as GDP) and establish robust assessments of national wealth that include measures of natural capital and ecosystem services[5]. Examples of these efforts—mostly focussed on monetary valuation—include The Economics of Ecosystems and Biodiversity (TEEB[6]), an assessment that focuses on the relationship between ecosystem services and biodiversity and attempts to value ecosystem services in monetary terms, and the Wealth Accounting and the Valuation of Ecosystem Services (WAVES[7]) project, a World Bank project that aims to incorporate natural capital into national accounts so the value of natural resources and ecosystems can be considered in government policy decisions.

With improved environmental information, many environmental costs and benefits that are currently excluded from the System of National Accounts, and classed as externalities, will be subject to accounting using money; however there are fundamental limits to the monetary valuation of environmental account subjects[8] so other forms of measurement must also be used to produce accounts. Environmental accounts generally use physical measures (e.g. area, volume, weight) and derived or composite measures, such as an index. Using these various measurement methods, specific types of accounts can be developed depending on the perspective and requirements of the account user. New forms of accounts, such as ecosystem capital and ecosystem service accounts, are under rapid development and are showing promise (see next sections below).

Current environmental accounting activity

A number of environmental accounts are being produced both in Australia and internationally. Various types of accounts are differentiated on their perspective (economic or environmental perspective), scale (regional or national), measurement units (monetary or physical) and statistical units (grid cell, catchment, ecosystem). Table 1 lists examples of operational and experimental environmental accounts.

Table 1 Comparison of environmental accounts existing or under development

Account	Agency	Account subject	Scale	Units	Statistical units
Water Account Australia	ABS	Water use within the economy	National	Gigalitres (?)	Industries
National Water	Bureau of Meteorology	Available water resource	Regional, National	Gigalitres (?)	Water management regions
Land	ABS	Land use and cover	Regional	Area, dollars	Cadastral parcels, NRM regions
National Greenhouse	DCCEE	Greenhouse gas emissions	National	Tonnes of carbon equiv.	Land-based industry sectors
Land and Ecosystem	DSE, Victoria	Ecosystem functioning	Local - Statewide	Environmental Benefits Index	Spatiotemporal; hectares per year
Regional Environmental Accounts Trials	Wentworth Group	Environmental asset condition	Local Regional National?	Econd	Environmental asset
Land; Ecosystem	European	Land use, land cover;	Continental (?)	Area; ECU,	Social-Ecological

[4] [Reference to OECD Green Growth initiative]

[5] see Stiglitz, Sen and Fitoussi (2010) for a thorough discussion of these ideas

[6] http://www.teebweb.org/

[7] http://www.wavespartnership.org/waves/

[8] see Stiglitz, Sen and Fitoussi (2010) for a synopsis

Capital	Environment Agency (EEA)	Ecosystem capability		Ecosystem Capability Unit	Land Cover Units; 1 km grids
WAVES	World Bank	Monetary valuation of ecosystem services	National (?)	Monetary (?)	various

The *Australian Environmental Accounting Framework* (see section 3) aims to provide an overarching framework that encompasses all well-founded environmental accounting methodologies already being applied and to further clarify the basis for both monetary and non-monetary forms of environmental accounting. Its real value lies in providing a cohesive conceptual structure for linking the various perspectives at play (i.e. economic, social and environmental) when growing the well-being of the Australian people. It is intended as a bridging guide to policy makers, scientists and accounting practitioners alike.

Natural capital and ecosystem goods and services

Natural capital, including ecosystem capital and ecosystem goods and services, are central concepts in environmental accounting. The concepts have been translated from economic theory and provide a bridge between the economic, social and environmental domains. For example, economic, social, human and natural capital form the basis for assessing sustainability and human well-being in Australia[9] as well as a measure of the wealth of nations[10].

Environmental accounting is concerned with measuring changes in natural capital, including 'consumption of natural capital', through degradation or depletion. Economic methods for measuring change in capital value are based on measuring the flow of value produced by the capital over its expected life span, for example, using net present value methods. These methods generally depend on establishing a price for goods and services and an estimate of the expected life span of the flow.

In environmental accounting, there are few markets for flows of environmental goods and services with which to establish a price; further estimation of the expected life span is difficult for self-regenerating (renewable) systems, so innovative methods must be developed that allow accounting to take place in spite of those challenges. There are some promising methods emerging that directly measure the condition[11] and extent of natural capital and its capacity to provide ecosystem services, or that use economic instruments to create new forms of markets[12]. Valuable progress is being made on methods for measuring gains or losses (e.g. 'depreciation' or degradation) of ecosystem capital; that is, measuring ecological sustainability.[13] Significant work is also being conducted around the world in identifying and valuing ecosystem goods and services.

Ecosystem accounts

Ecosystem accounts focus on ecosystems as an integrated whole, rather than treating them as a number of disconnected components such as water, food or timber. For example, while the SNA and the SEEA Central Framework (SEEA2012) deal with timber as a product of native forest ecosystems, an ecosystem account would measure and track benefits that flow to people from the forest as an integrated, functioning ecosystem. Regulation of the water supply to streams and erosion protection are examples of such benefits. A second strand of the SEEA, the *Experimental*[14] *Ecosystem Accounts* (SEEA-EEA) addresses ecosystem accounting.

[9] The Treasury's Well-Being Framework <> and the associated Sustainability Indicators <>

[10] World Bank *Changing Wealth of Nations (20??)*

[11] For example, the Wentworth Group's NRM Environmental Accounting Trials

[12] For example, the Victorian DSE work on BushTender and EcoTender

[13] Jean-Louis Weber, European Environment Agency [ref to Simplified Ecosystem Capital Accounting (2012) and ECU]

[14] It is known as 'experimental' to reflect the relatively new approach of bringing together ecosystem science, economic knowledge and accounting practice.

Further, there is the potential to account for ecosystems in physical terms without reference to the economic system or monetary valuation, which opens a pathway to accounting for ecosystems from an ecological rather than economic perspective. The approach offers significant opportunity for a very wide range of environmental and ecosystem accounting while maintaining a bridge to SNA approaches.

A key requirement when accounting from an ecological perspective is to establish and maintain a credible and legitimate knowledge base of ecosystem functioning. This is required in the absence of a functioning market that provides a monetary price (i.e. a 'revealed preference') encapsulating the value of the goods or services of interest. Typically, a conceptual model and evidence base is needed to enable effective accounting practice (see the *Australian Framework for Environmental Accounting* Steps 3 and 4), particularly for complex systems, such as ecosystems. Where feasible, a conceptual model endorsed or accredited by broad consensus by experts in ecosystem functioning will add considerably to the credibility and stability of the accounting system.

Box 2 Distinguishing environment, ecosystems, biodiversity and nature

Term	Common meaning	Comment	Technical meaning (within the Framework)
Biodiversity	[CBD definition]	Biodiversity is a way of looking at living systems.	Biodiversity is a series of emergent properties of living systems.
Ecosystem	[SEEA and Wikipedia definition]	Ecosystems are a way of looking at living systems.	Ecosystems are a range of emergent property of living systems.
Environment	1. Living and non-living physical objects and phenomena of Earth e.g. plants, animals, rivers, seas, sky, wind, rain, sun. Sometimes, the "non-human" aspects of the world. 2. A more technical meaning is "everything that impinges on the object or phenomena of interest" e.g. the air within a building. The object of interest can include people e.g. "environmental air quality".	1. The Framework uses this meaning, though usually in a colloquial, everyday sense. The Framework includes people as part of the environment. 2. This meaning is not used in the Framework.	1. The living and non-living systems with which people interact. The living systems include the physical, biological aspects of people.
Nature, natural	Difficult to define precisely, but, in broad general usage it means the non-human world and includes the sun, moon, earth, and all living things. If people are included, it generally has a pre-industrial feel.	Due to definitional vagueness, this meaning is only used colloquially in the Framework.	The Framework is based on a split between living and non-living systems (or 'biophysical' systems), with physical, biological aspects of people included in the living systems.
Natural capital	One of the forms of capital defined in the Changing Wealth for Nations approach.	Using the economic definition, it is considered to be separate from other forms of capital, i.e. human, social and fixed capital. The Framework draws on the JPM and includes the physical and biological aspects	Is the contribution of the living and non-living systems (including those aspects of humans) to the production of value for the human cultural and economic systems

of humans in natural capital.

Why is an account not an assessment?

Environmental accounts share many characteristics with environmental assessment. Data and information are marshalled, analysed and then reported in ways designed to inform policy and practice. Examples range from *State of the Environment* reports to assessments of specific risks posed by introduced marine pests. So what is the difference between an environmental account and an environmental assessment?

In a general sense, accounts are a specific form of organised information focussed on time series and are a relatively simple and robust presentation of environmental information upon which a variety of analyses can be built. The key differences are that, generally, accounts have a mechanism that ensures a cross-check, or reconciliation, of changes through time in a tightly defined account subject.

With the addition of a well-designed monitoring program, the environmental assessment process takes on further characteristics of an environmental account, especially the periodic gathering of data in a way that allows comparison from one cycle to the next, so changes in environmental variables can be tracked. Such an assessment would be a potential candidate to be translated into an account format if that was deemed beneficial.

An important difference between a monitoring program and an account is the maturity of the scientific evidence base behind the two processes. Monitoring programs are ideally carried out in the context of an adaptive management cycle, with the view to updating current understanding of the system being monitored once the monitoring data has been gathered. On the other hand, accounts are based on mature current understanding and largely settled science.

Another difference is the purpose of an account. With a monitoring program, the agency doing the monitoring will typically be the agency using the data to inform management, whereas an account is only generated when parties external to the agency producing the account are the main audience for the account.[15] In other words, only make an account when accountable to others.

Further comparisons between assessment and monitoring, and accounts are presented in Table 2.

[15] [ref to Australian Accounting Standards Board materials]

Table 2 Characteristics of environmental accounts compared with environmental assessment

Characteristic	Environmental Account	Environmental Assessment and monitoring
Purpose	Created when there are compelling reasons with strong consequences requiring a consistent flow of information that enable comparisons and change to be detected. Can be considered a relatively simple base upon which more complex analyses and scenarios can be built.	Multiple purposes including building the fundamental environmental information base to sophisticated targeted assessments. Multiple assessments with significant challenges in aggregating or synthesising the results.
Methods	Highly structured information using standards, statistical units, accounting periods, opening and closing balances and cross-checking (e.g. double entry methods). Data is often in the form of 'environmental statistics'[16]	A very large range of techniques including inventory, census, snapshot survey, degree of modification, vulnerability assessment, risk assessment, scenario and outlook assessments. Standards are emerging.
Coverage	Complete coverage of the account subject is required either as observations (e.g. census) or as estimates (e.g. via sample survey) for each accounting period.	Typically only partial coverage, particularly through time, but also across space. Very limited coverage of ecosystem characteristics such as functioning and processes.
Temporal	Focussed on the current accounting period (e.g. change over 1 year). Time series are expressed through a wide range of account types enabling reporting on change in rates (flows) and stores (stocks).	Ranges from single snapshot survey to use of mixed age data (e.g. catchment land use mapping); Monitoring methods and data sets are patchy, though considerable progress is being made in some sectors and on national standards.
Spatial	Tightly defined statistical units matched to management needs and the nature of the account subject.	Spatial characteristics vary depending on assessment purpose. Some national systems exist (e.g. bioregionalisations) though much is driven by the resolution of available data.
Interested parties	Usually focussed on reporting to an external party for accountability purposes.	Ranges from commercial in-confidence assessments to a very wide range of stakeholders.
Independence	Credibility and legitimacy derive from orthodox use of standards, accreditation procedures and independent assurance (verification and auditing).	Assessments may have a scientific peer review process or at least the methods used will be based on scientific peer reviewed methods. Some standards and accreditation procedures may be in use, though assurance is not common.
Economic linkages	Accounts are closely linked to economic theory and there are multiple existing pathways for bridging environmental and economic approaches (e.g. via the SEEA 2012). Economic theory has significant limitations when dealing with environmental subjects, so other perspectives are needed to gain a fuller understanding of the current status of natural capital.	Environmental assessments are usually conducted in environmental and ecological terms and have weak or limited meaning within economic domains.

[16] For example, as defined in the *Framework for the Development of Environmental Statistics* (UNSD, 1984) and the National Statistical Services' *Essential Statistical Assets*

Joint Perspectives Model: a systems approach

The Bureau has formulated the *Joint Perspectives Model* as a theoretical foundation for the development of environmental accounts. The Model, based on a systems approach, has the key features of clarifying both

- the perspective (i.e. world view) driving the creation of each specific account (e.g. economic, social or biophysical), and
- the linkages between different perspectives on each specific account subject.

For example, the *Joint Perspectives Model* may be used to identify the economic, social and environmental perspectives on a single specific economic transaction or activity. This is an important development in meeting the challenge of both simplifying and better organising environmental information.

Systems thinking offers powerful ways of simplifying the complexity of the world. Put simply, a system is something that is greater than the sum of its parts. For example, a car (vehicle system) becomes drivable when all the parts (e.g. wheels) are in place. Similarly, the economy (economic system) can have a rate of growth (e.g. GDP) when all the economic activity of the component enterprises, businesses and households are measured together. Likewise, ecosystems are living systems made up of many interacting living and non-living components.

Box 3 Systems thinking

System	A group of interacting, interrelated or interdependent elements forming a complex whole. Systems (a) have inputs, outputs and feedback mechanisms, (b) maintain an internal steady-state, (c) display properties peculiar to the whole (called emergent properties) that are not possessed by any of the individual elements and (d) have boundaries that are usually defined by the system observer.
Emergent properties	[defined and examples]
Scale	[Nested multiple speeds and sizes, a la resilience alliance diagrams and ideas]
Complexity thinking	[continuum from simple to complicated to complex to chaos]
Surprise	[note Steve Cork's excellent discussion in SoE Report]
Resilience	[idea of identity; flip concept of vulnerability] [applies to all systems – physical, living, human cultural and economic]
Irreversibility	[Hysteresis etc.]

The *Joint Perspectives Model* for environmental accounts consists of four nested systems: the 'physical earth system', the 'living system', the 'human cultural system' and the 'economic system'. Each system has 'emerged' from all the systems listed before it (see Figure 1). For example, the living system emerged from the physical earth system about 3.8 billion years ago. In turn, the living system gave rise to the human cultural system which gave rise to the economic system. A key concept of the *Joint Perspectives Model* is that emergent systems are also, at the same time, part of the systems from which they emerged, not separate to them. In other words, the economic system is also a part of the human cultural system, which is, in turn, also part of the living system. The living system is part of the physical earth system. These systems together can be thought of as the whole of the earth including nature, all the people and all their culture and activities.

Crucially, this means that any transaction in an emergent system can also be viewed from the perspective of the systems in which it is nested. For example, a business transaction, such as the sale of 30,000 tonnes of oranges, can be viewed from human cultural perspective and a living systems perspective and a physical earth perspective. A feature of this approach is that measures

useful in the base systems (e.g. fluxes of energy and matter in the physical earth system) are also informative, though with limitations, in the emergent systems (e.g. quantity of carbon emissions in the economic system).

There are many other systems that can be recognised in the world around us, for example, legal systems, political systems, climate systems, solar systems and so on; however, for the purposes of the *Joint Perspectives Model*, the foundational systems are physical earth, living, human cultural and economic.

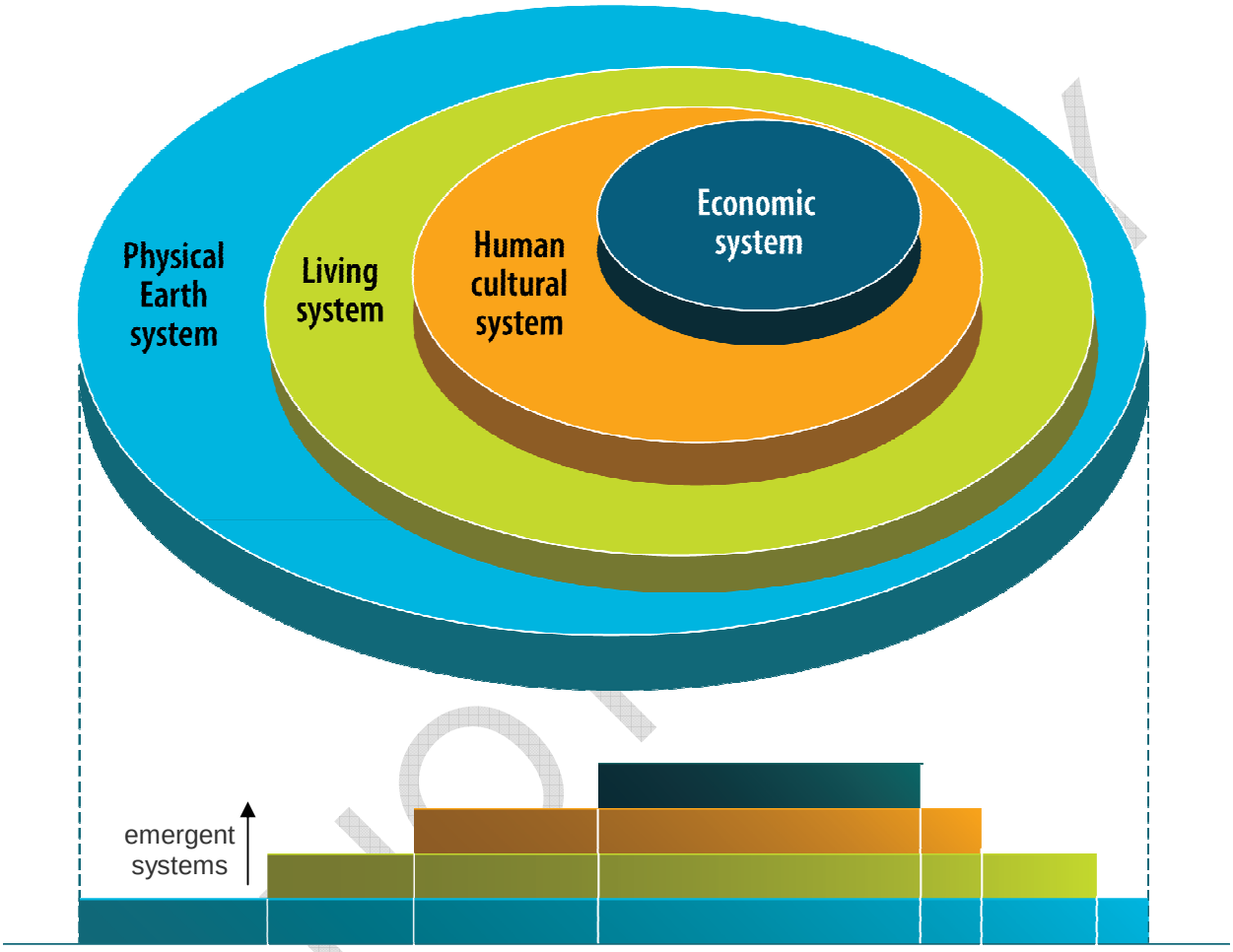


Figure 1 Joint Perspectives Model.

The following sections provide information about each system—what the system encompasses, what characterises the boundary delineating it from the systems from which it emerged and the knowledge domains (disciplines) focussing on that system. Also discussed are important emergent properties of each system—those characteristics that make the whole system greater than the sum of its constituent parts. Finally, potential subjects and statistical units for accounting are canvassed from the perspective of that system. The information in these sections is summarised in Table 3.

Physical earth perspective

The physical earth system consists of all non-living components of our planet, including inputs and influences from the sun and moon and other more distant parts of the universe that drive and regulate processes taking place on earth.

The basic material constituents and processes of chemistry and physics belong to the domain of the physical earth system and human attempts to describe and understand this system are based on those bodies of knowledge.

Accounting within the earth system involves being able to track the movements and changes of various forms of matter and energy between physically defined accounting units such as

geographical locations.

Living perspective

The living system emerged from the earth system with the advent of organisms that could capture and concentrate energy, either thermal energy from within the earth's interior or, later, energy from the sun. The ability to concentrate energy is an emergent property of living organisms and serves to define the boundary between the living system and the physical earth system. In the process of concentrating energy within the living system, dispersed energy, mostly in the form of heat, is exported across the boundary to the physical earth system.

The constituents upon which the living system is based are the same matter and energy components that drive the physical earth system. The laws of chemistry and physics still apply to living things. The primary chemical reaction that drives the living system (photosynthesis) takes place in plants that use the sun's energy to convert carbon dioxide from the atmosphere into food and oxygen, thus supporting all other components of the living system.

As well as being driven by chemical and physical processes, the living system has emergent biological processes related to its ability to concentrate energy. These emergent processes include evolution, homeostasis, metabolism, reproduction and responsiveness to the environmental stimuli.

Human attempts to describe and understand the living system have given rise to bodies of knowledge such as biology, genetics and ecology. Computer-based models have been developed to organise and capture the cause-effect relationships so that patterns of environmental change can be understood and projected.

Accounting within the living system involves being able to track the movements and changes of genes, organisms and life processes, as well as matter and energy, between biologically defined accounting units such as species and ecosystems.

Relevant to accounting within the living system is the dynamic responsiveness of ecosystems when compared with the physical earth system – a consequence of the emergent properties of life. The boundaries of ecosystems change over a range of time and spatial scales as the organisms that constitute them evolve, reproduce and respond to changing environmental conditions (for example, climate changes or asteroid impacts).

Human cultural perspective

Paramount among the emergent properties of the human cultural system is the social (i.e. collaborative) creation of knowledge and meaning, manifesting itself in activities such as science, healing, religion, the arts, the legal system and economics. Knowledge and meaning contribute to our adaptive advantage as a species and also our individual and collective well-being.

While socially created knowledge and meaning have opened astonishing vistas to humankind, we are still part of the living system, dependent on its processes of production and reproduction, and, at the same time, part of the physical earth system that provides the basic constituents of life such as carbon, oxygen, water, sunshine.

The boundary between the human cultural system and the living system is defined by the limits to our knowledge and meaning.

Accounting within the human cultural system involves being able to track movements and changes in components of the system that are relevant to human well-being and flourishing, including non-material things such as knowledge and happiness. Culturally defined accounting units are individuals or delineated human groups such as families, moieties, clans, tribes, associations, businesses, municipalities, communities, societies and nations.

Economic perspective

The economic system has emerged from the human cultural system; other systems to emerge include the legal system, the medical system and the education system.

Important emergent properties of the economic system include markets and the existence of a common (delocalised) currency in the form of money. From an economic perspective, all money is more or less equal but, in contrast, from an ecosystem perspective, all carbon, water, and energy (or other potential currencies for ecosystem accounting) are not equal; the value of these currencies is *local* as they depend on local conditions and context. For example, the value of a tonne of carbon in one form (wheat, timber or coal) is not equal to a tonne of carbon in another (humans, coral reef or rainforest).

From the national accounting perspective, the economic system is delineated by the production boundary. Defined under the System of National Accounts,[17] the production boundary includes those activities that contribute to the calculation of Gross Domestic Product (GDP). The GDP is the market value of all officially recognised final goods and services produced within a country in a given period. Excluded from the GDP and effectively outside the production boundary are many activities and processes that contribute to human well-being, including unpaid domestic work, voluntary work more generally and unmanaged natural processes such as the production of goods and services by ecosystems. These are not priced and are termed 'externalities'. The position of the production boundary can change; for example, water and carbon, previously classed as externalities are starting to be priced and markets are emerging for these commodities.

As an emergent system from the human cultural system, the economy is also part of that system, and, in turn, part of the living and physical earth systems.

In the economic system, the movements and changes of those components of the human cultural system that fall within the production boundary are tracked with economic statistical units (also called 'entities') of households, businesses and countries using money as a common currency.

Because the economic system is also part of the systems from which it emerged, transactions that take place within the production boundary can also be tracked by measuring changes in aspects of those systems. For example, accounts could report in physical terms on the basic constituents of life, especially carbon, water, nutrients and energy as well as in monetary terms. However, the local nature of these potential non-monetary currencies will constrain or challenge the comparison and aggregation of accounts using these units.

[17] The SNA is an internationally agreed, standard set of recommendations on how countries measure economic activity.

Joint Perspectives Model Summary Table

Table 3 Joint Perspectives Model Summary Table

System	System description and boundary	Emergent properties	Knowledge domains	Candidate environmental account subjects	Candidate measures	Candidate accounting units
Physical earth system	The non-living earth system. Non-living systems are all slowly dissipating energy (increasing entropy or 'running down'). The boundary is the top of the atmosphere	Emerged from coalescing star material during development of the solar system	chemistry, physics, geology, geography	solar inputs, wind, tides, geothermal, tectonics, geology, temperature, water cycle, ground water, climate, weather	Mass balances of basic elements (matter), energy fluxes (e.g. changes in entropy, exergy and emergy)	Primarily spatially defined using physical characteristics e.g. topography
Living system	The living system concentrates energy (use energy to decrease net entropy) within its boundary. Information is stored in genes. The boundary with the physical earth system is the living/non-living divide.	Use of energy (e.g. photosynthesis), evolution homeostasis, metabolism, reproduction, growth, accumulation, response to environmental stimuli	biology, evolutionary biology, genetics, ecology	natural capital, ecosystem functions and processes, biodiversity, biocarbon cycle	All above plus: counts of genes and organisms; composite indices (e.g. resilience, vulnerability).	Primarily spatially defined using living system properties e.g. land cover, habitat, ecosystems, environmental assets
Human cultural system	Socially created knowledge and meaning is used to predict outcomes, improving evolutionary fitness. The boundary is difficult to identify precisely as human culture is ubiquitous for humans; however, something may, at least, be considered inside the boundary when it has social meaning and has an active role in the cultural life of humans.	Socially created meaning. Cultural activities and markers; language, music, art, social institutions (family, community), legal systems, political systems, science, knowledge systems.	sociology, anthropology, psychology,	ecosystem services (benefits flowing directly to human cultural systems and outside economic production boundary e.g. non-material benefits such as sense of place as an inspiration for design)	All above plus: indices of human well-being (multiple), suffering and happiness	Individuals or delineated human groups e.g. families, moieties, clans, tribes, associations, businesses, enterprises, municipalities, communities, societies and nations
Economic system	Human social activity based on negotiated agreements about the value of goods and services, facilitating the flow of these within and among nations. This activity is largely captured by the System of National Accounts. Boundary is the economic production boundary.	Markets, economic production, the delocalisation of currency, accumulation, wealth	economics, psychology	ecosystem services and waste (those crossing the economic production boundary)	All the above plus: money	Individuals, households, businesses, enterprises, nations

Seeing with joint perspectives

Figure 1 (above) illustrates the four nested systems of the Joint Perspectives Model (JPM), showing the relationships between the different systems and how they emerge from each other. The vertical white lines in the side view delineate the boundaries of each system. These boundaries have depth because they include a part of all the systems below them in the stack (Figure 2).

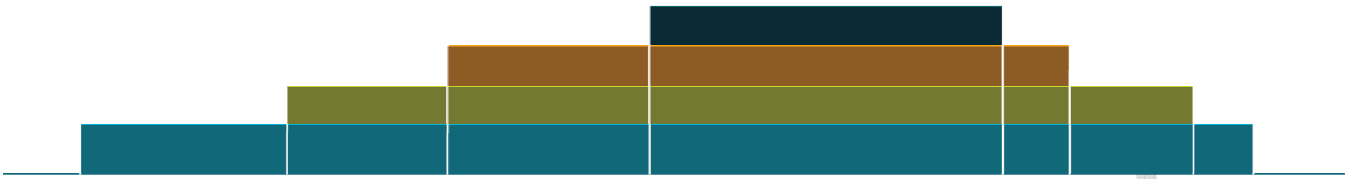


Figure 2 Side view of the Joint Perspectives Model, showing that the boundaries delineating each system also include parts of systems below.

The economic system, along with those parts of the human cultural, living and physical earth systems that are included within the production boundary, is highlighted in Figure 3.

Figure 3 The economic system and elements of the human cultural, living and physical earth systems within the production boundary are highlighted.

This means that most economic activities can also be looked at from the perspective of the other systems. For example, within the economic system boundary are elements such as paid labour, investment and overseas trade. These are also elements of the human cultural system, able to be viewed and interpreted from a cultural and social perspective. Similarly, from a physical systems perspective, they can be measured in terms of matter (mass) and energy (work) transfers.

Notice that parts of the living and physical earth systems are also included within the production boundary. As a result, food products, for example, can be considered, and measured, from economic, cultural, living and physical system perspectives. These measurements can be done from a single perspective or from many perspectives. If more than one perspective is used, there is an opportunity to jointly consider the perspectives. This is the essence of the Joint Perspectives Model.

One of the insights the JPM offers is that measurements made in the more fundamental systems (say, carbon and water fluxes in physical earth and living systems) will also have some meaning in the emergent systems (as food and drink in human cultural and economic systems) (Figure 4). However, the reverse case is more limited; that is, properties of an emergent system will carry less information about the characteristics of the fundamental systems, particularly outside of their system boundary. For example, dollar values will not capture all the available information about biodiversity or the cultural benefits of nature, especially those aspects that fall outside the production boundary. This is a useful insight in the search for measurements that are meaningful across all the systems.

Figure 4 Examples of the measurement units that could be applied in the different systems. Note that measurement or properties of fundamental systems are also relevant in their emergent systems, but measurements of properties of the emergent systems generally only apply within the emergent system's boundary.

Transfers across the economic boundary

There are transfers of matter and energy across the economic production boundary, variously known as natural resources, residuals (waste) and ecosystem services. The many services provided to managed production by *unmanaged* ecosystems (ecosystem services) such as pollination, natural pest control and water purification enter the economic system in the form of natural resources or ecosystem services. Impacts on natural ecosystems occur through the release of waste across the production boundary including loss of biodiversity and resilience by land clearing and the effects of pollution. Similarly flows of sunlight, geothermal energy, wind and water cycle through the physical Earth system, including across the economic boundary (see Figure 5).

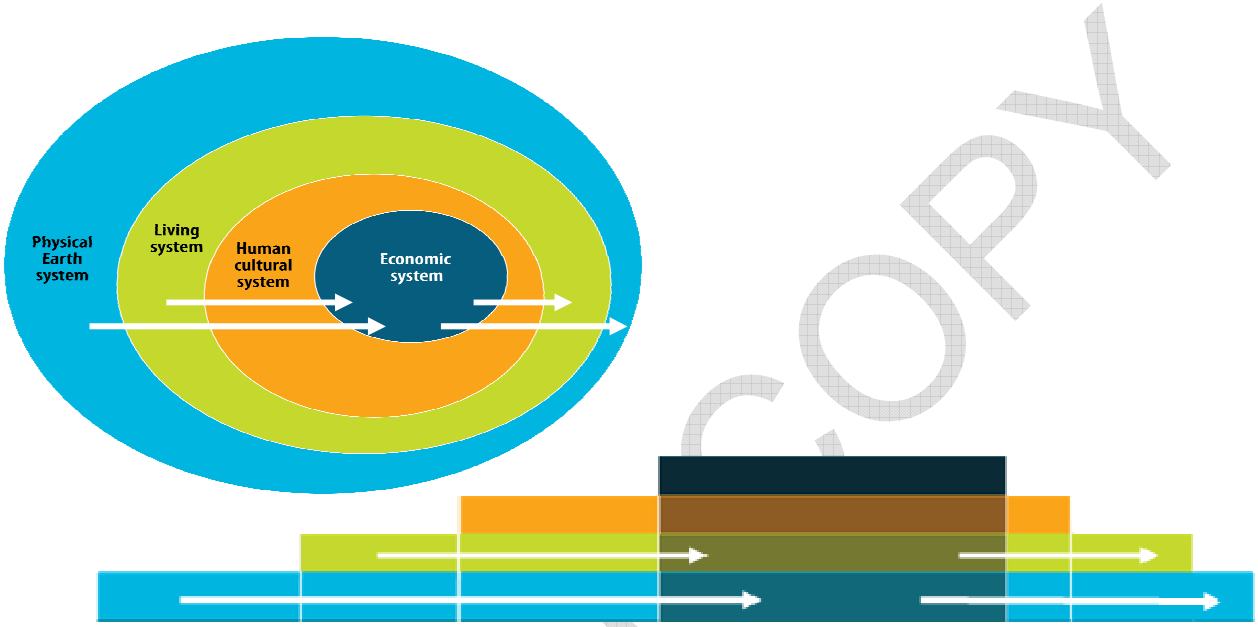


Figure 5 Many services and impacts flow (white arrows) across the production boundary into and from the economic system from the physical Earth and living systems (as seen from two JPM orientations).

Extending the production boundary

Gross Domestic Product is based on the market value of all goods and services produced by a country. In order to arrive at the market value of a good or service, it is necessary to know all the costs incurred in its production. So long as the cost of ecosystem services are left outside the production boundary, along with any loss (or 'consumption') of ecosystem capital involved in production, it is not possible to arrive at a realistic market value for the goods and services produced. One important task of environmental accounting is to extend the production boundary to include the many environmental costs that are currently not accounted for under the GDP but which could be (Figure 6).

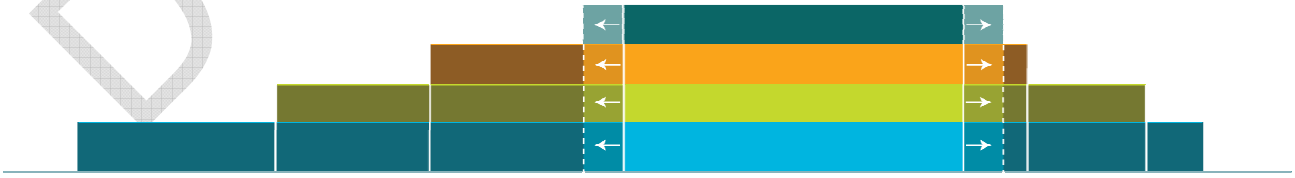


Figure 6 The production boundary can be expanded to include many social and environmental costs of production, giving a more realistic basis for arriving at a market value for goods and services.

It has long been recognised that the GDP has many deficiencies as an indicator of human well-being but it is also deficient as an economic indicator in failing to account for many environmental and human costs of production.

Beyond the production boundary

Extending the production boundary to include everything that *can* be costed to arrive at a market value does not, and cannot, cover all the services to human well-being provided by the human cultural, living or physical earth systems, as illustrated by the JPM in Figure 7 and Figure 8.

These are factors that cannot be costed, even in theory, and therefore can never be brought within the production boundary to be accounted for in monetary terms. Yet these factors do contribute to human well-being and thus support the economic system and other systems (legal, education, health etc.) that have emerged from the human cultural system.

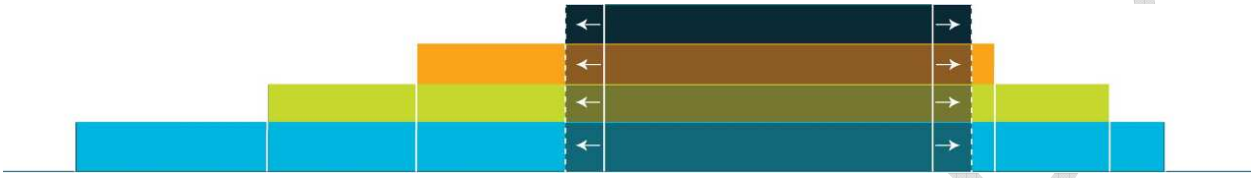


Figure 7 When the production boundary is extended to include all social and environmental costs of production, some services to human well-being (as indicated by the highlighted areas) remain outside the production boundary.

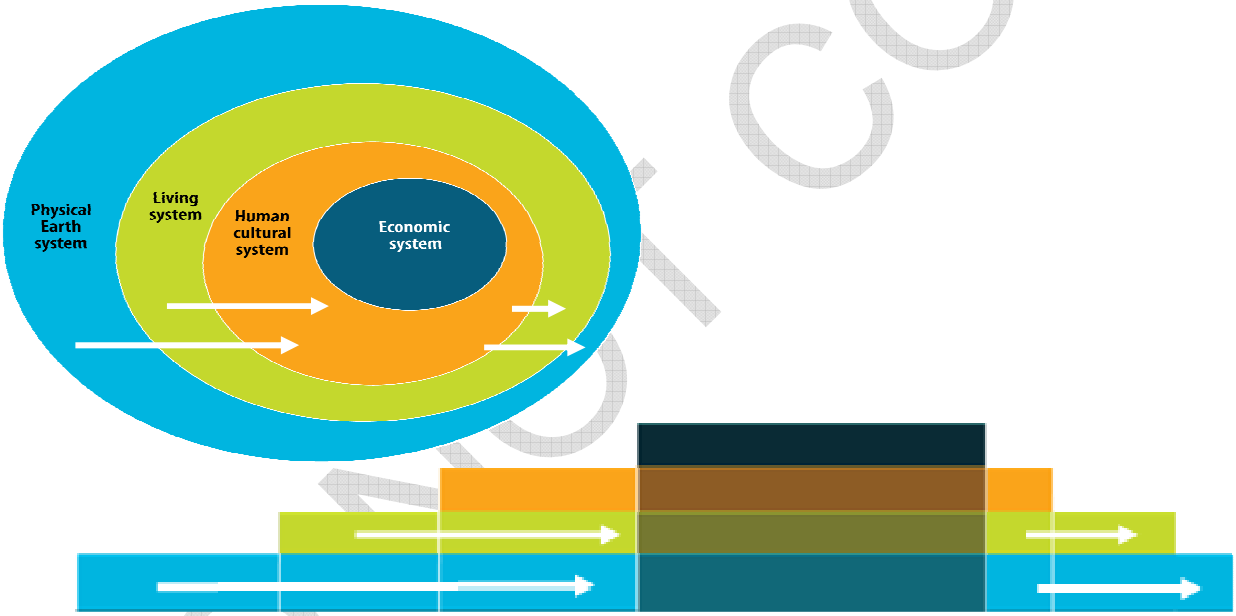


Figure 8 Some services to human well-being (white arrows), such as the sense of identity and meaning related to the landscape and nature, are directly experienced by people outside of the economic system (seen from two JPM orientations).

Examples include the contribution to cultural identity and meaning by the land and living systems, recreational and spiritual values of natural places (services provided by the living system and earth systems), inspiration for the design of human material culture (services provided by human cultural, living and earth systems) and the natural scientific resources provided by the pollen record, tree ring record and genetic patterns (services provided by the living system).

While the factors that contribute to the human cultural system, but fall outside the production boundary, cannot be measured in monetary terms, the Joint Perspectives Model offers a range of alternative options. Some candidate measures are:

- indices of human well-being, happiness, suffering or flourishing,
- measures that track stocks and flows of cultural ecosystem services[18]

[18] as defined by the Common International Classification of Ecosystem Services (CICES)

- measures of energy factors such as entropy and exergy
- measures of the mass balances of different chemicals and elements in natural ecosystems that correlate with the extent and health of those ecosystems.

Accounting for ecosystems

All the examples above are more or less responding to an economic perspective. It is time to turn to an ecological perspective. In the end, the use of economic terms and ideas has limitations when seeking to understand and measure the natural world. Concepts of capital, economic assets, markets and monetary valuation, while providing powerful analogies, begin to be limited by their theoretical basis and the knowledge base; for example, the lack of functioning markets in ecosystems makes monetary valuation impossible. The economic and cultural driving force of human intention is a more complex characteristic to those driving ecosystems, which is basic survival and reproduction. The knowledge developed around ecology and biology has more to offer in these circumstances.

It is worth pausing and considering the meaning of the term the 'natural world'. Many would consider that humans are separate from the natural world; however, as the JPM illustrates, humans and economic systems are, at the same time, also physical and living systems. In this sense, it is possible to consider that human activity from a living system perspective (e.g. reproduction, population dynamics and food production systems) is part of the natural world.

The JPM offers a way to remove the necessity to separate humans from nature while still recognising the unique characteristics of human culture[19]. This means that, in the JPM, people are considered part of nature and participate in ecosystems, such as urban and rural ecosystems. This approach enables much more comprehensive accounting for the stock and flows of ecosystems and physical matter and energy than the current economically focussed approach. For example, comprehensive water and carbon balances could be produced for the entire Australian continent, including cities and rural areas, giving us integrated insights in to our stewardship of the entire country including the ecosystems and wider landscape[20].

If it is accepted that Australians see value in maintaining the ecosystem's, then it may be useful to adopt an ecological-centric notion of 'ecological utility'[21] where the structure, function and processes of an ecosystem are assessed against a reference condition[22] that uses the natural state of the ecosystem as an ideal state as it "represent millions of years of natural ecological optimisation" (Eigenraam et al., 2012). The idea of ecological utility complements and to some extent mirrors the concept of 'ecosystem capital' in the SEEA-Ecosystems.

[Author's note: this section needs further work and development – all comments and contributions welcome]

JPM linkages to other conceptual models

[Author's note: this section needs further work and development – all comments and contributions welcome]

Typically, the models that underpin frameworks for environmental accounting and accountability are concerned with the conceptual relationship between the economy and the environment. Depending on the purposes of the model, the society is often introduced as a third domain to be considered.

For example, triple bottom line reporting (TBL), is an accountability framework that reports on the

[19] This approach could be considered in the 'capitals' paradigm as an extension of the idea of 'natural capital' to include the physical and living perspectives of humans in natural capital. Thus humans could be defined to participate in 'human capital' (knowledge and skills), 'social capital' (social cohesion etc) and 'natural capital' (physical and living aspects of being human); hence 'human natural capital' would be a subset of total 'natural capital'.

[20] For more on these challenges see PMSEIC (2010) Challenges at Energy-Water-Carbon Intersection

[21] See Eigenraam, Chua and Hasker (2012) Land and ecosystems services: measurement and accounting in practice

[22] See also the Wentworth Group's NRM Regional Environmental Accounting Trial

economic, environmental and social aspects of a business or organisation with the aim of assessing and communicating progress towards sustainability. It is based on the three pillars model (Figure 9). While this model emphasises the equal importance of the three 'pillars' in business or organisational sustainability, one or other pillar will typically be emphasised in the assessment, depending on its purpose or the perspective of those conducting it.

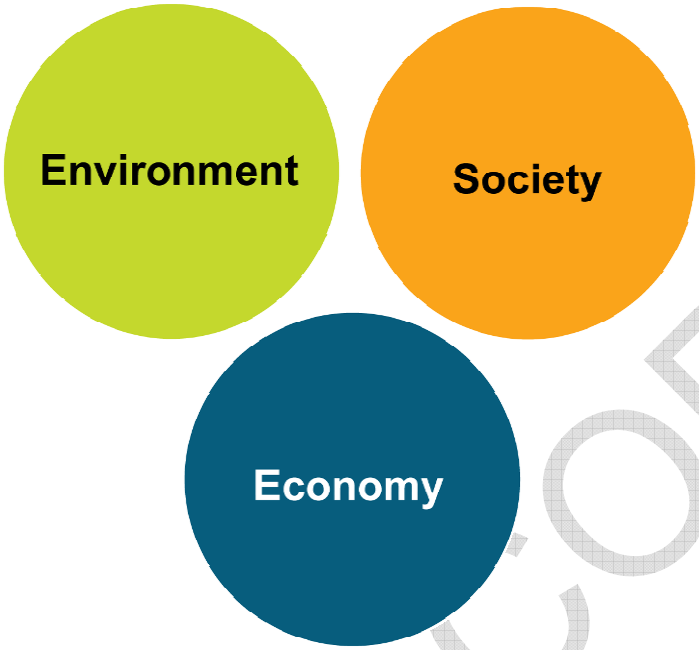


Figure 9 The three pillars of sustainability

The SEEA Central Accounts framework is based on a model that includes the economy, the environment and exchanges between these two domains (Figure 10).

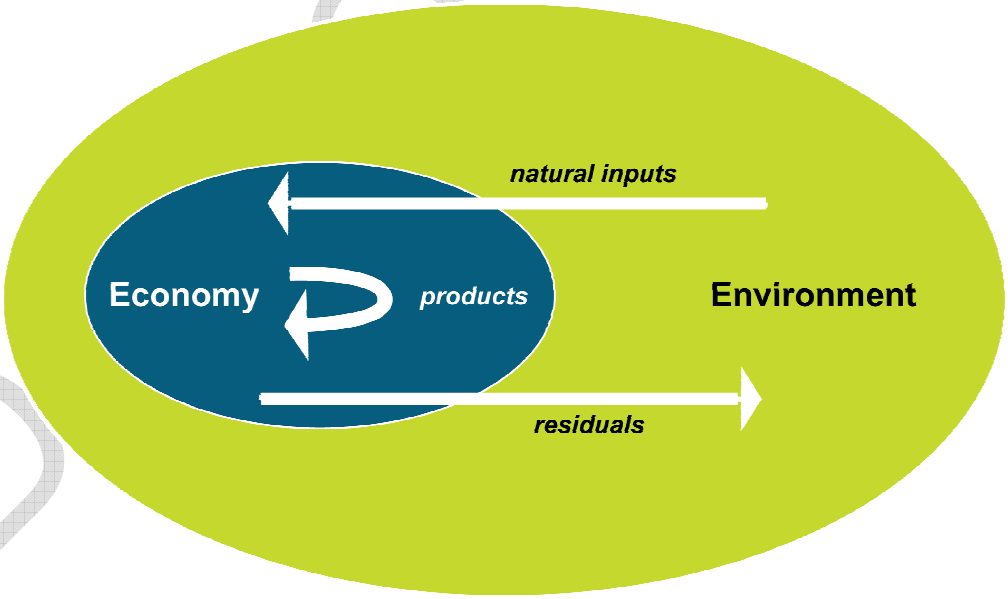


Figure 10 The SEEA Central accounts model of the relationship between the economy and the environment

By adding depth to the conceptual landscape, the Joint Perspectives Model (Figure 11) makes it possible to map the relationships among the three domains—environment, economy, society—more accurately. For example, in a flat model, such as the SEEA model, elements of the environment no longer appear to belong to that domain once they have passed the production boundary into the

economy. Further, natural elements of the economy that fall within the production boundary, such as the soil upon which crops are growing, may become invisible.

The Joint Perspectives Model clarifies the fact that everything within the production boundary remains part of the systems lower in the hierarchy of emergence. Crops and pastures are still part of ecosystems (elements of the living system) and *Homo economicus* is still *Homo sapiens*, dependent on life processes such as metabolism and reproduction and the elements of the physical earth—oxygen, water, carbon and so forth.

Similarly, inputs from living systems to the economic system (shown by a white arrow in the SEEA model) still have a value within the living system, aside from their function within the economy. Economic activity uses energy and resources from the living system to benefit human culture (including the economy). In the process, the ability of an ecosystem to provide services and to reproduce itself (supporting services) may be sustained or degraded. Whichever is the case; these natural processes that feed the economy are still enmeshed in the living system.

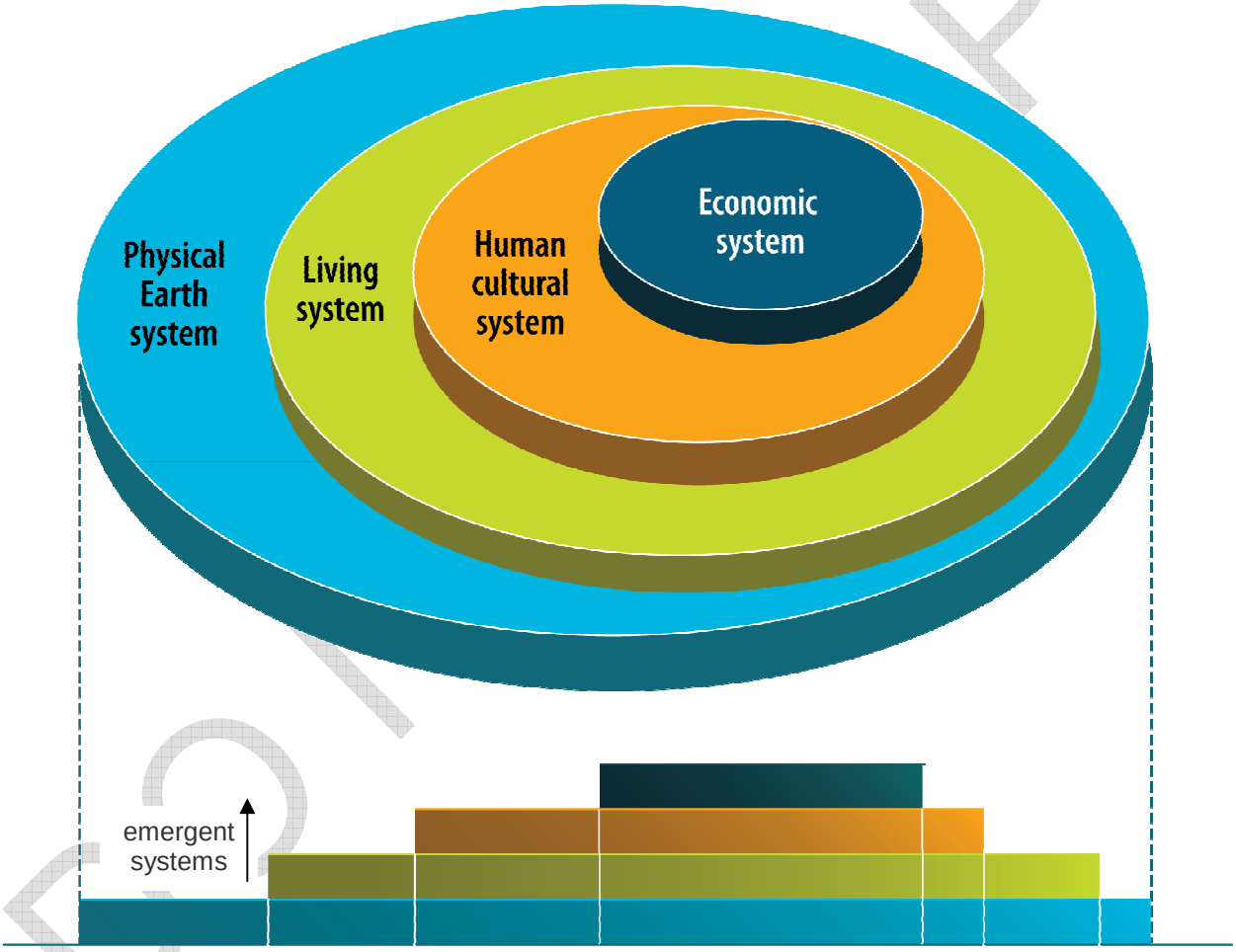


Figure 11 The Joint Perspectives model

Also evident from the Joint Perspectives Model is the possibility of measuring each emergent system using units from systems lower in the hierarchy of emergence. The health of the economy can be measured in money terms but also in terms of carbon, water and energy.

General environmental accounting framework

Introduction

Based on the *Joint Perspectives Model*, this section presents a general framework for environmental accounting that guides:

1. Assessment of whether an environmental account is the optimal form of organising environmental statistics and data sets to meet user requirements. Alternative ways of measuring and tracking environmental variables are environmental assessments and monitoring programs.
2. How to go about using the framework to frame the account; that is, identifying the information needed to meet the principles and practices of environmental accounting. Important framing questions include: the purpose of the account, who will be involved in the account, what will be measured (account subject) and the measuring units.

Given the broad range and complexity of environmental account subjects, the approach here is general and provides guidance and principles for account 'framers' rather than the technical detail needed for any specific account.

At a basic level, any person or agency considering the development of an account (the account framer) must ask a series of questions to determine the value of creating an account. These are organised into a framework by asking specific 'why, who, what and how' questions that cover the basic principles of environmental accounting.

In essence an account must be:

- purposeful and consequential for a party (the account user) who depends on the reported information and who is other than the account producer
- able to measure change in a defined phenomenon (subject) of interest through time
- organised in an internally consistent manner to enable comparisons and cross-checks
- comparable with other relevant accounts so it can provide the basis for more detailed or aggregated analyses.

The framing questions that flow from these core concepts are as follows:

1. Why have the account? What is its purpose?
2. Who are the parties to the account?
3. What is the account subject?
4. How will the account be structured and implemented in practice?

It is important to start by addressing the first three questions as the answers will drive the specification of any account and its implementation (i.e. the 'how'). Together, the questions provide a robust framework for tackling complex environmental information challenges. They are expanded upon in following sections. A specific set of example questions are also presented in Appendix 1 to illustrate the approach.

Guiding principles – relevance, credibility and legitimacy

Every account needs to address the fundamentals of relevance, credibility and legitimacy. These crucial characteristics play different roles in the development and value of the account. Clearly, the account must be **relevant** to the users and the intended use, so the selected account subject and the degree of match with user needs are important factors. The **credibility** of an account depends upon whether it is adequately representing the account subject and relates to questions of measurement and measurement accuracy. For example, questions are asked such as, 'How accurately do the identified measures reflect the environmental phenomena (subject) of interest?' 'Are the right phenomena of interest being measured?' 'Do the measures provide us with the

information we actually need to make decisions?' These questions are flavoured with issues arising from the perspectives bearing on the development of the account.

Legitimacy is a third dimension necessary for successful, effective implementation of environmental accounts. Legitimacy underpins the degree of acceptance of an account. 'Legitimacy reflects the perception that the production of information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests' (Cash et al. 2003). Even if they were available, well-founded relevant and credible measures of the environment are not enough for uptake and use; measures also need legitimacy.

In summary, to frame an account it is necessary to, firstly, identify the purpose, users and subject of an account and, secondly, to address its legitimacy, credibility and relevance. Once the account is framed, questions about how to produce and populate the account can be addressed.

Framing an environmental account: why, who, what and how?

The worldview, or perspectives, of those framing an environmental account will deeply influence the choice of subject, often without the account framer realising it. The framework presented here directly addresses the values and perspectives of the account framers and, by doing so, seeks to improve the value of the account. The process for framing an environmental account is to identify systematically the information needed to meet the principles and practice of environmental accounting.

The importance of the perspective of the account participants is a key characteristic of this framework; given this, the framework steps are summarised in the following table and related to the *Joint Perspectives Model* to assist with addressing the steps. While the process is presented here as a series of steps, it is not necessary to follow these rigidly in the order given. It may be necessary to revisit some steps in the light of what is revealed at other steps.

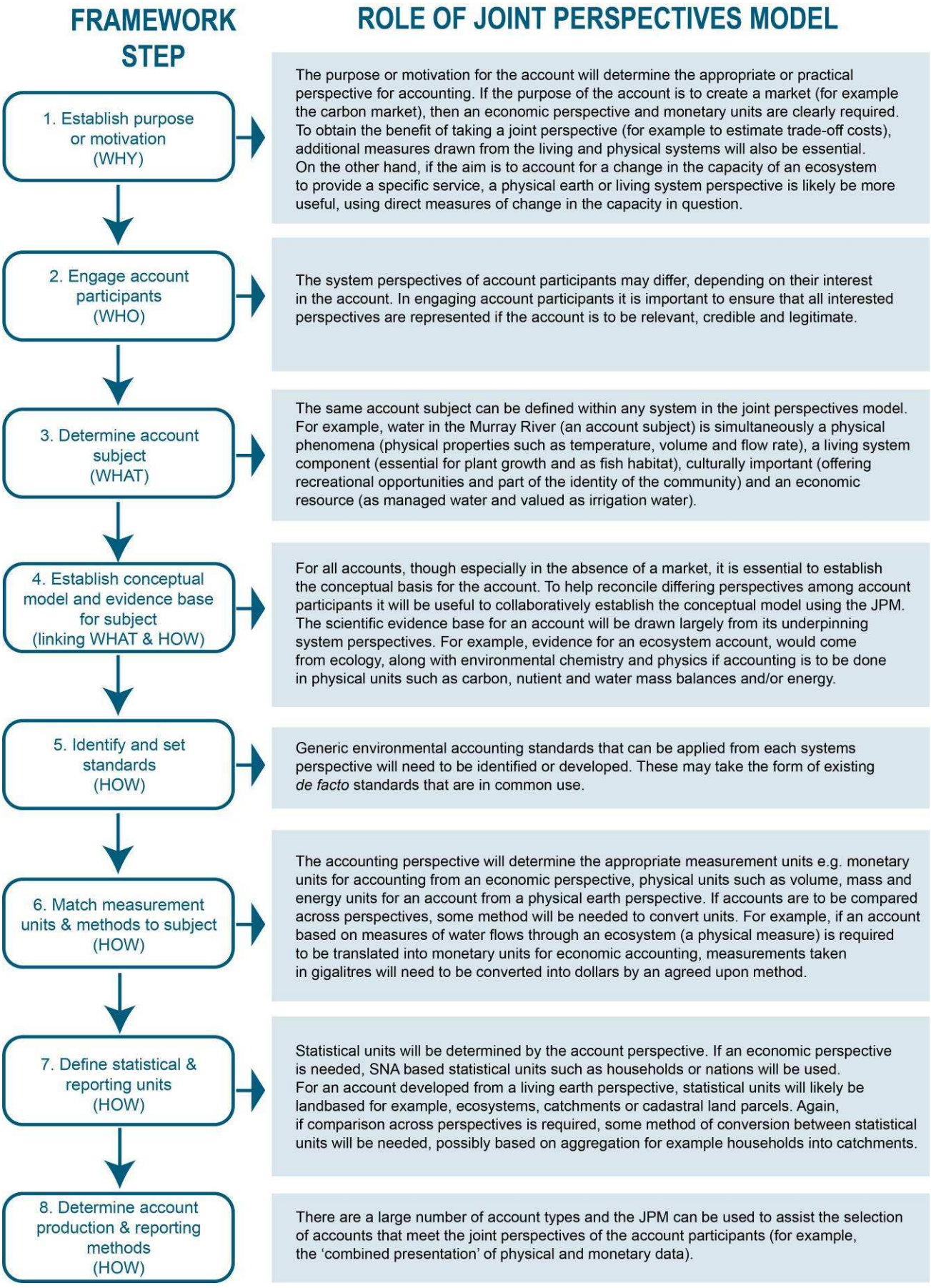


Figure 9 Relationships between steps in the Australian Environmental Accounting Framework and the systems perspectives in the Joint Perspectives Model

Step 1 – Establish purpose or motivation (why)

There are a number of reasons for creating an environmental account. Primarily the purpose will be to obtain timely, credible information about changes in the account subject (e.g. gains or losses in ecosystem capital) that are relevant to decision making. The aim is to 'know what is going on' through obtaining 'environmental intelligence' so consequences and opportunities for intervention may be identified. The purpose or motivation for an account is strongly influenced by the perspectives taken by the account users on the subject of the account (please refer to the *Joint Perspectives Model* for more on perspectives).

The perspectives of the account framer and the account users will inform their objectives, values, rights and responsibilities (see Table 4). For example, contrast the perspectives of an agency with objectives and values around conservation of ecosystems with a business concerned with mineral extraction. In turn, objectives, values, rights and responsibilities will shape the reason for the account, the interested parties and the account subject.

Table 4 Factors influencing the purpose and motivation for an environmental account

Perspectives	Multiple world views are always present - see the JPM for more
Responsibilities	Obligations, legislation, duty-of-care, commitments, future generations, neighbours
Rights	Ownership (private property), mandates, licences, entitlements
Values	Stewardship, existence value, dominion, utility extraction
Objectives	Business plan, management plan, conservation plan, including targets

Examples of environmental account purposes and motivations

- meeting economic requirements e.g. enabling market valuation to allow the buyer to judge value during due diligence
- meeting obligations to others e.g. as part of mandate, taxation purposes, legal requirement
- meeting social norms and values e.g. stewardship, reputation, positive regard and recognition as competent manager, equity, intergenerational equity
- meeting environmental management objectives e.g. managing ecosystem and biophysical structure, composition, function and processes, reducing the impact of waste, providing the feedback necessary for adaptive management and learning.

Action: the framer of an account needs to identify and document the purpose for the account.

Step 2 – Engage account participants (who)

Consistent with public sector accountability principles[23], the participants involved in an account should be identified and their roles and relationships defined and understood. This will provide clarity for the participants, align the account with the participants' needs and also underpin the legitimacy of the account. Interested parties to an account may be: individuals, organisations (government agency, corporation), entities (e.g. 'economic units' such as households, businesses or enterprises), owners, controllers and/or the wider society. A second category of account participants are independent parties including auditors or those providing accreditation. A more detailed listing of uses and users of environmental accounts is provided in Appendix 3.

Determining a process and schedule for reviewing the participants in the account is a further aspect of accountability.

Action: the framer of an account needs to identify and document the roles and relationships of participants in the account, within the context of the account purpose.

[23] See the Australasian Council of Auditors-General <http://www.acag.org.au/epsa.htm>

Step 3 – Determine subject of account (what)

The subject of an environmental account will depend on the purpose of the account and the identity and objectives of the interested parties. For example, an account may have the purpose of providing an overview of changes in natural capital for all Australians and the Australian Government to meet obligations to future generations and fulfil other stewardship requirements. Such an account will focus its subject at a national scale and on measures related to natural capital.

The subject of the account also depends on the current ability to understand and measure the phenomena of interest. For example, ecosystems and their boundaries are challenging to define as they are complex entities that operate at multiple and nested spatial and temporal scales. Advances in knowledge are defining new criteria for measuring these complex systems, such as condition, resilience and safe operating ranges.

Subjects of an account may also have meaning from multiple perspectives. For example, a mega litre of water in the Murray River is simultaneously a physical phenomena (H_20 with physical properties such as temperature, mass and flow direction), a living system component (essential for plant growth and as habitat for fish), culturally important (representing recreational opportunities and part of the identity of the community) as well as an economic resource (as managed water and valued as irrigation water).

At this step the type of account or account framework is usefully considered. For example, most environmental accounts in Australia are based on the System of Environmental-Economic Accounts (SEEA), though the BoM *National Water Account* uses a financial accounting approach. More concrete and detailed decisions about he account type or types will need to be made at Step 8.

Action: the framer of an account needs to identify and document the subject of the account and consider the accounting approach, within the context of the account purpose and participants.

Step 4 – Establish a conceptual model & evidence base for the account subject (linking what & how)

For any account subject, though particularly when dealing with complex phenomena, it is necessary first to develop a conceptual model (description) using the best available current knowledge to provide the basis for measurement and subsequent policy and activity. The approach is to identify the key structures, functions and processes (e.g. habitats, carbon and water cycles, biodiversity) in the account subject of interest from each relevant perspective and also the characteristics of the human interactions with the system (e.g. extraction, waste impacts, management).

This approach is well recognised within environmental management practice; for example, the Framework for the Assessment of River and Wetland Health (FARWH) uses conceptual models to underpin selection of indices of aquatic ecosystem functioning. If the development of the conceptual model is conducted collaboratively, it is more likely to capture the various perspectives of the account subject.

Though there are many operational approaches to conceptual modelling, generic guidelines to conceptual modelling for environmental accounting are not currently available. Conceptual models are defined here to include a range of descriptions of system characteristics, from simple descriptions, through sophisticated diagrammatic science communication models to fully-specified mathematical process models.

Action: the framer of an account needs to collaboratively identify, document and maintain the conceptual model of the subject of the account, within the context of the account purpose and participants.

Building an evidence base

The conceptual model will contribute to the development of an evidence base for each account subject. The evidence base is the body of scientific knowledge summarising assumptions upon

which the account is based. For environmental accounting, the evidence base would typically be drawn from the disciplines relating to the physical earth and living systems which might include ecology, hydrology, chemistry and geomorphology among many others. The evidence base will provide credibility and legitimacy that the account is adequately measuring the value of the account subject, particularly when price signals (from a well-functioning market) are absent.

When establishing a conceptual model and evidence base for environmental accounting, the framer should ensure that the following principles are applied[24]:

- An adequate amount of evidence is available from multiple independent sources (scientific literature, expert opinion, community knowledge/values)
- Multiple independent peer reviews of the evidence are available
- A high maturity of understanding is needed for all model elements in the account
- A high level of consistency is required between conclusions drawn from the multiple lines of evidence
- At least one high quality synthesis/review relevant to the account subject is required
- No conflict of interest should exist (that is, none of the participants in developing the conceptual model and evidence base have a vested interest in the production of the account).

Action: the framer of an account needs to develop and maintain an evidence base by applying the principles to underpin the conceptual model of the subject of the account, within the context of the account purpose and participants.

Step 5 – Identify and set standards

Standards could be produced at almost every step of the accounting pathway including standards about measurement, data management, analysis and reporting. Standards are powerful adjuncts to the production of accounts as they codify knowledge about well-defined cause and effect responses or phenomena with stable, measurable properties.

An intermediate step towards the production of environmental accounting standards is to document and publish the conceptual model of the account subject as a *de facto* standard. Conceptual models developed collaboratively using an accepted and codified methodology can confer relevance, credibility and legitimacy to accounts based upon them. The process of producing a conceptual model may or may not be able to be converted into a standard as this is generally only feasible for less complex phenomena. Many environmental subjects, particularly living system components and processes such as biodiversity, are not able to be specified precisely. Other codified forms of information, such as nationally accepted vegetation classification schemes, can also be used as *de facto* standards.

Because accredited standards ensure that a high quality, consistent and repeatable process is used to produce an account, meeting such a standard strengthens the evidence base and strongly supports the credibility of the account. Formally accredited standards are costly to establish and maintain; however, where they are feasible to produce, they provide a basis for independent auditing and assurance and thus strongly support the legitimacy of the account.

Action: referring to the conceptual model and evidence base, the framer of an account needs to identify and set standards and *de facto* standards relevant to the account subject and that meet accounting principles, within the context of the account purpose and participants.

[24] Acknowledgement: Carolyn Raine, Central West Catchment Management Authority, NSW

Step 6 – Match measurement units and methods to account subject (how)

Matching the account subject required by managers and policy makers with the scientific capability to measure it is a critical step towards specifying the account. Measures are also known as the properties, characteristics or attributes of a system. The account conceptual model and the *Joint Perspectives Model* can assist the process of identifying the relevant knowledge domains (disciplines, e.g. ecology, chemistry) and measures. Note that there are multiple perspectives that can be taken on any account subject and multiple measures or common measures may be required if there is a need to work across the systems of the *Joint Perspectives Model* (i.e. physical earth, living, human cultural and economic systems). For example, if an account based on measures of water flows through an ecosystem (a physical measure) is required to be translated into monetary units for economic accounting, measurements taken in gigalitres will need to be converted into dollars by some agreed upon method. At the same time it may be necessary to measure the ecological value (or utility) of the same gigalitres of water in terms of maintaining ecological processes and biodiversity.

Action: for each relevant perspective, the framer of an account needs to identify measurement units (attributes) and methods relevant to the account subject, within the context of the account purpose and participants.

Scale matching

Matching the scale (or resolution) of the account subject with the scale of management is an important part of account subject matching. The scale of the account subject can be considered in three ways; through time, across space and by theme (i.e. classes or attributes of the subject). This process will involve classification schemes and typical definitions are:

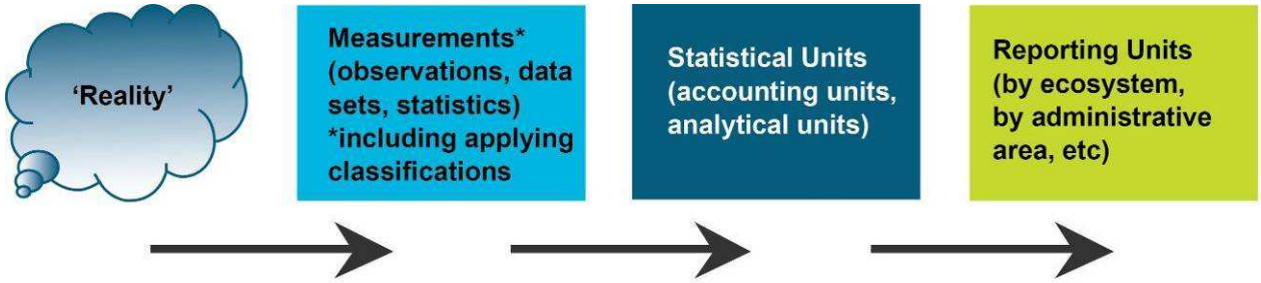
- Temporal (duration/cycling of phenomena, transaction and/or exchange event definition)
- Spatial (location and dimensions)
- Thematic (e.g. land cover classes; ecosystem services classes)

It is important to identify the definition and resolution of each of these dimensions to ensure they match the requirements of management and policy makers. Much of the environment-related management activity in Australia is at the regional and local scale so accounts populated with national scale data and information will have limited applicability. Alternatively, information relevant to specific local scale management may not aggregate well for national level reporting.

Action: the framer of an account needs to define and select a scale (resolution) in the spatial, temporal and thematic dimensions for measuring and reporting the account subject that is matched to the account purpose and participants' management needs.

Step 7 – Define statistical and reporting units (how)

Accounting practice requires a clear definition of a statistical unit (or accounting unit or analytical unit) at the core of any account as this is the base unit to which measurements and estimates are assigned. Statistical units provide the basis of analysis and aggregation for reporting purposes. As well, they may provide the common denominator among various forms of accounts that allow linkages to be made between those different accounts. This is a central challenge for any environmental account as the subjects of interest (such as ecosystems or environmental assets) are often difficult to define precisely.



The statistical units are the basis for organising measures, such as environmental statistics (data sets), into an accounting format that is as consistent as possible with the conceptual model for the account. As they must be a simplification of the real world they will necessarily contain reduced information. The key is to reduce the information content as little as possible and still meet the accounting principles.

As accounting is all about consistently identifying units of value (utility) that can be maintained and carried forward in time, it is important to characterise value in the physical earth and living systems. The perceived value of all physical earth and living system phenomena are highly dependent on their location and context. As a simple example, from almost any perspective, a cubic metre of water at the top of a mountain range has very different value from a cubic metre of water in a desert or the ocean. It will both have different distributional and physical characteristics (e.g. form, temperature, salinity, kinetic energy) and different roles and value in the surrounding ecosystems, including to people. This reasoning – that location and context is critical to value – has implications for the selection of a statistical unit for accounting purposes.

Scope of statistical units

The Basic Statistical Units (BSU) must cover the full scope of the accounting subject (typically, area) (must be 'exhaustive') and must not overlap for any particular account ('mutually exclusive'). BSU must be able to adequately measure the account subject at specified accounting periods. Ideally, BSU are stable through time to support comparison and development of trends.

Base Statistical Units (BSU)

As location is a fundamental, though not exclusive, dimension of value, statistical units for environmental accounting, particularly ecosystem accounting, will usually be spatially defined. In general, a base statistical unit (BSU) is delineated using spatial properties, not ecological properties. This will usually take the form of a tessellation, such as a grid[25] (see figure 6), with dimensions relevant to the scale matching criteria (e.g. 1 ha, 1 km, 5 km or 10 km) (see Step 6). There is no reason why the tessellation could not be a volume (e.g. a cube or similar) to enable the inclusion of the air, sub-surface subjects or water column (also see figure 6).

Simple basic characteristics can then be attributed (recorded) to the BSU, such as elevation, rainfall, land cover and land use; enough to produce a unique register of the BSU. For specific accounting purposes, a wide range of other attributes can be assigned to the BSU, such as ecological classes, model results, observations, tenure and quality and condition measures.

An important type of attribute is the measures that capture the relationship of the individual BSU with the wider landscape and the interactions (flows) across its boundaries. For example, it may be important to know the degree of connectivity of a BSU to other BSU. Is it part of a large group of similar BSU, such as a forest or is it a small remnant?

Similarly, statistical units must be able to deal with is the dynamism of all natural environments on short and long time and spatial scales.[26] This may necessitate developing and assigning attributes

[25] Ideally using the National Data Grid <http://www.crcsi.com.au/Research/3-Spatial-Infrastructures/National-Data-Grid> or a similar standard

[26] Land cover has been investigated as a basis for generating terrestrial BSU (ref or example). While it can provide a

to BSU that capture interactions at scales (resolutions) above and below the defined account subject (phenomena of interest). For example, very long term 'time havens' or places where species have survived for millions of years (refugia) could be identified as such by assigning suitable attributes to BSUs.

Keeping in mind that common statistical units are needed if accounts are to be aggregated or compared, the units chosen must be adequate to deal with their environmental or ecological context. Important contextual features could include any or all of the following:

- Habitat dynamic on short time scales: 'hotspots' ; marine ('key ecological features'), estuaries/rivers, air
- Habitat dynamic on longer timescales: landuse change, migration of ecosystems or ecosystem components due to climate change
- Non-contiguous fixed habitat: groundwater dependent ecosystems (oases)
- Non-contiguous dynamic ecosystems: migratory bird habitat, ecosystems supporting pelagic fisheries
- Cross-habitat ecosystems: ecosystems supporting salmon, eels, rock lobster.

If the tessellation approach is taken, and if there is a need to link to economic units (i.e. households and businesses), the resolution of the tessellation should enable spatial linkages to be made with land parcels (i.e. cadastre). This is a scale matching issue.

The dimension of time is also a crucial attribute for defining statistical units as accounting is essentially a process of comparing the state of the account subject at one time to its state at another time via the accounting period. For many purposes an annual accounting period is a default, though, if necessary may be varied depending on the account purpose and the phenomena of interest. In combination, the basic spatiotemporal dimensions of a statistical unit are, for example, a hectare per year (ha/yr) or, if required, a 'cubic volume based on a hectare' per year (see figure 6).

Action: the framer of an account needs to define a statistical unit (BSU) for the account that is consistent with the account's conceptual model, accounting principles, the account purpose and that will remain stable through repeated accounting periods.

Reporting Units (RU)

Depending on the purpose and subject of the account, reporting units (RU) can be generated by attributing the BSU with relevant data and information and then aggregating them, including, where feasible, hierarchically at a number of reporting scales. Reporting units could be generated for many different purposes including reporting on specific ecosystem types (e.g. wetlands) or changes between ecosystem types (e.g. forested to urban). The reporting units can also be produced for administrative or management units, such as municipalities, regions or States. The ABS *Australian Statistical Geographical Standard* system provides a robust and tested spatial framework for many accounting purposes including reporting.

It is anticipated that specific ecosystem-based RU will be needed for some particular accounts (e.g. forest or wetland accounts) but that locations may emerge where RUs repeatedly overlap as the process is repeated for separate accounts across the landscape (i.e. ecological 'hot spots' may emerge). Particular methods for delineating and attributing reporting units will relate to the particular purpose and subject of the account.

Action: the framer of an account needs to define a reporting unit (RU) for the account that is consistent with the account's conceptual model, accounting principles, the account purpose and meets the participants' management needs.

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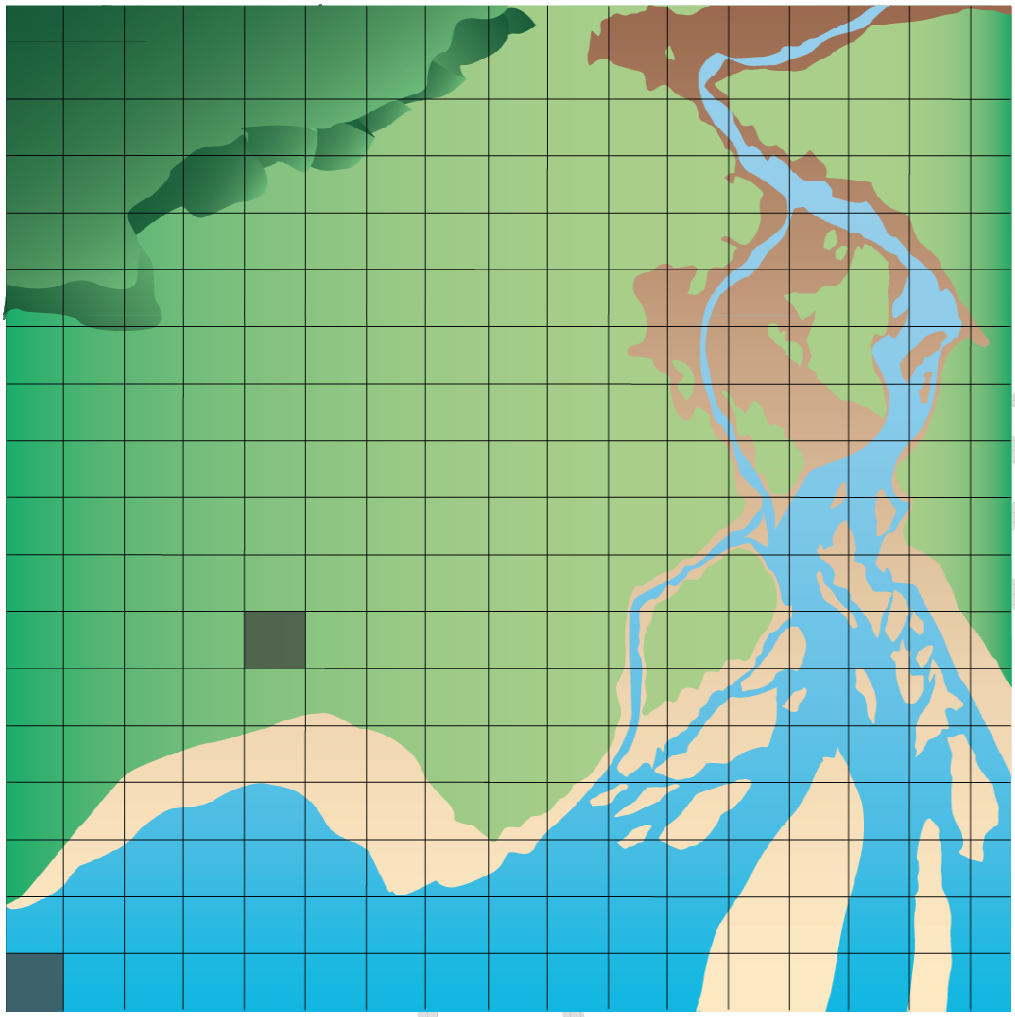
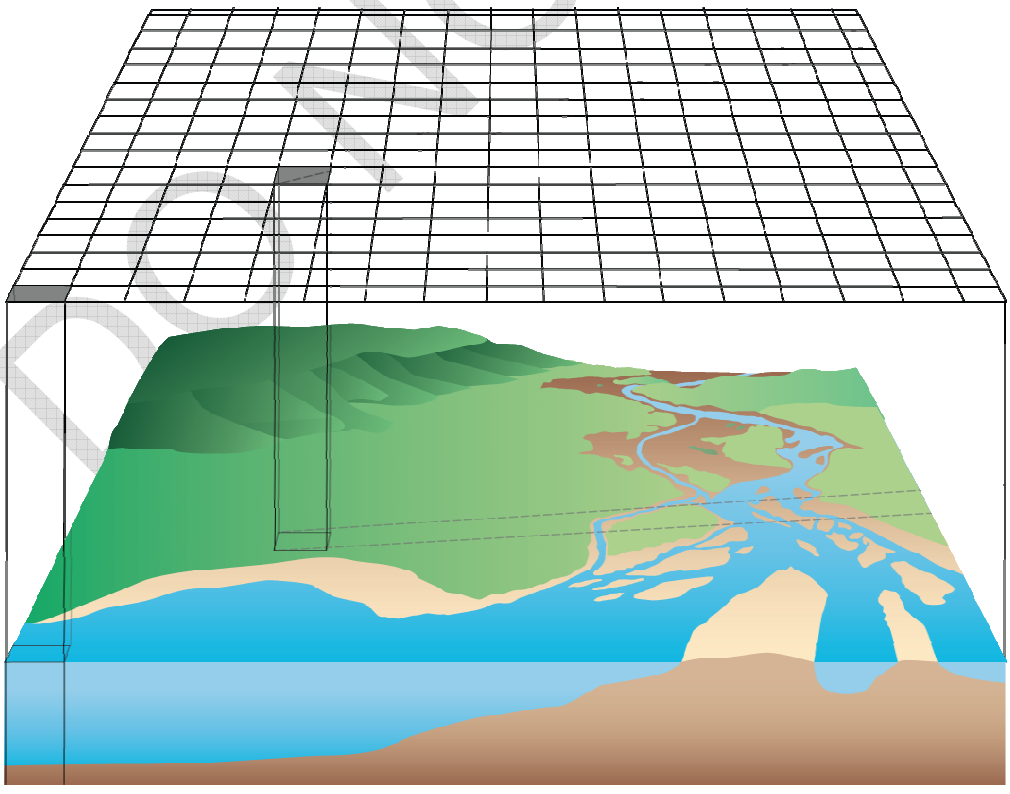
useful first pass at defining simple static statistical units all natural environments are dynamic at short or long time scales, so the use of land cover for defining statistical units is limited.





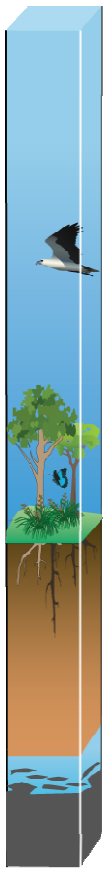


Figure 6 A grid of base statistical units (BSUs) overlaid on a landscape showing an estuary, shoreline, floodplain and elevated areas (plan and oblique views).

Step 8 – Determine account production and reporting methods (how)

Once all the preceding steps are completed and the account is thoroughly framed, there remains the practical job of producing the accounts. This will, by necessity, usually be a process of compromise as the reality of the accessible data sets and limited resources means ideal data and analytical methods are not generally available. These circumstances will mean that the production of the account will be constrained and that flexible methods are needed so that, as new data and analyses become available, they can be incorporated without major disruption to the account series. It may mean that the series will need to be rerun (backcast) with the improved methods; this is accepted practise in the statistical community.

The following tasks must be completed to produce an environmental account:

- Frame the account (Steps 1-7)
- Select the optimal accounting framework for the account (e.g. SEEA)
- Design the account tables
- Identify and access the required data
- Collate and extract the account measures and assign them as attributes to the statistical units
- Aggregate (or disaggregate) as required to the reporting units
- Produce tables, charts, maps and descriptive text to publication standards (including account methods documentation and metadata)
- Produce interpretive narratives of the account subject relevant to the account participants (this task is dependent on the requirements placed on the account producer)

Action: the producer of an account needs to complete the tasks defined in Step 8.

[Author's note: The tasks listed above will be described in more detail as the document is refined and completed. Any assistance in doing so would be gratefully received.]

Case Study: Prototype Ecosystem Accounts

[Author's note: whole section yet to written]

[Introduce SEEA-EEA interest in ecosystem accounts as integrated form of environmental accounting. Run through applying the Framework and thus Model to this example – i.e. define/specify Ecosystem Accounts with the general EA Framework.]

[Identify the different ways of measuring and accounting for ecosystems (fundamental constituents/mass balances vs. habitat vs. biodiversity vs. structure, composition and functioning vs. ecosystem services etc. etc.) – select SEEA-EEA approach and follow through with a (broad) plan for setting up an Ecosystem Account]

Box 4 Defining ecosystems

Ecosystem	
Ecosystem capital	
Capacity	
Ecosystem services	
Ecosystem goods and services	
Resilience	
Lag times	
Irreversibility	
Human ecology	[Humans are included as participants in ecosystems (i.e. urban ecosystems and rural ecosystems can be included)]
Socio-ecological systems	
Industrial ecology	

Ecosystem capital and ecosystem goods and services

Ecosystem capital

Ecosystem goods and services

Glossary

Account	1. An organised set of numerical information, often in the form of tables as defined by… 2. To recount a situation, provide a description of the situation from a particular perspective, "…to provide an account" 3. To be held accountable, "…to be called to account"
Accounting	The practice of creating accounts
Accountability	1. To be able to provide evidence of the conduct of business or activity to others of consequence 2. See definition from Australasian Council of Auditors-General *Effective Public Sector Accountability* at <http://www.acag.org.au/epsa.htm>
Accumulation	In economics, accumulation is the acquisition of tangible assets during a period of account minus the incurrence of liabilities. This is gross accumulation. Net accumulation is gross accumulation during a period reduced by the consumption of fixed capital. (OECD Glossary of statistical terms) In ecosystems, accumulation is variously called growth, biomass or a reservoir and the process of accumulation is known as sequestration. In principle, the concept of consumption of ecosystem capital can be applied, and is related to degradation and depletion.
Asset	Economic asset is "a store of value representing a series of benefits accruing to the economic owner by holding or using the entity over a period of time. It is a means of carrying forward value from one accounting period to another."[27] A definition for an ecosystem asset (proposed here as a variation on the economic definition) is "a store of value representing a series of benefits and opportunities accruing to all ecosystem participants by maintaining the processes of primary productivity, reproduction, growth (respiration), accumulation, release* and evolution (adaptation) over a period of time. It is a means of carrying forward value from one accounting period to another." *"release" is release of resources through decay, disturbance and disruption
Capital	A form of wealth owned by an individual or organisation and able to be used to produce goods and services. There is no agreed listing of the types of capital, however they generally include fixed (plant and machinery), human (knowledge and skills), social (social cohesion), natural (mineral, water, timber, fish) and ecosystem (living systems) capital. Some definitions also include financial capital. For accounting purposes, only fixed capital and some forms of natural capital are directly measured. Human and social capital is estimated as a residual.
Consumption	Consumption is an activity in which economic statistical units use up goods or services; consumption can be either intermediate or final. It is the use of goods and services for the satisfaction of individual or collective human needs or wants. (OECD Glossary of statistical terms)
Credibility	[validity, confidence]
Data collection	[census, sampling, survey…]
Emergy	
Entity	A statistical unit, as defined above. In order to ensure the accuracy of accounting, an entity, once defined, should be stable and not regularly changed.[28] This presents a challenge for environmental accounting where candidate entities, such as ecosystems, are hard to precisely define and provide multiple goods and services.
Entropy	
Environmental	[Note FDES and NSS Essential Statistical Assets]

[27] Standard National Accounts

[28] www.investopedia.com

statistics	[explain relationship between data sets and statistics]
Exergy	
Flow	Changes in the volume, composition or value of stocks. In ecosystem accounts, flows are the goods, services and benefits derived from ecosystems.
Legitimacy	[Authority, acceptance] "Legitimacy reflects the perception that the production of information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests" (Cash et al. 2003)
OECD	Organisation for Economic Co-operation and Development
Production	In economics, production is an activity carried out under the control and responsibility of an economic statistical unit (such as a business) that uses inputs of labour, capital, and goods and services to produce outputs of goods or services. (OECD Glossary of statistical terms). Gross Domestic Product: The market value of all officially recognised final goods and services produced within a country in a given period. In ecosystems, primary production is the creation of plant biomass via the function of photosynthesis.
Relevance	[salience]
Residual (waste)	Outflow from the economy to the environment (e.g. solid, liquid and gas waste) which uses the environment as a sink.
Stock	The amount of an asset (financial and non-financial) held at a particular time that has the capacity to produce goods or services.
Unit	1. Statistical Unit: Entity for which information is sought and for which statistics are compiled. For example, the SNA uses an industry classification of enterprises and economic activity to define the entity, while the statistical unit for ecosystem accounts is typically a spatially defined area of land. 2. Measurement Unit: The unit used to measure the subject of the account. The 'currency' in which the account is set. Can be a monetary unit such as dollars or yen or a physical unit such as mega litres (of water) or tonnes (of CO_2 equivalents). Reporting Unit: Aggregation of statistical units used for accounting purposes. Typically, in Australia, these are Statistical Areas or a management area (e.g. by municipality or a region).
Wealth	A measure of the value of all of the assets owned by a person, community, company or country. Economic wealth is the found by taking the total market value of all the physical and intangible assets of the entity and then subtracting all debts[29].

References

Cash et al 2003

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[something here?]

[29] www.investopedia.com