Opportunities for assessing the impact of the geosciences on the Australian economy via the system of national accounts

Background Paper prepared for the National Committee for the Development of a Strategic Plan for Australian Geosciences

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Summary

When it comes to demonstrating the economic impact of research and experimental development (R&D), the geosciences are in a very strong position compared with other research fields. This is because the R&D outcomes are monitored by a line-item in the national balance sheet. This line item covers Australia's 'sub-soil assets' of *economically demonstrated resources* awaiting future extraction. These assets were valued at $245.7 billion at the end of the 2002 financial year representing 6.5 % of Australia's total national assets and 8.4 percent of net worth.

Furthermore, there are elements of a useful chain of causality linking the annual flows of geoscience R&D spending to the value of Australia's sub-soil assets. This chain of causality exists because the value of the capital stock of accumulated minerals exploration investment is independently estimated. The exploration capital stock captures the value of the investment in the knowledge, experience and datasets that are proprietary to exploration companies and other organisations and is currently valued at $28.6 billion. Each year's annual flows of investment ($360.1 million in geosciences R&D in 2000-01 and $1.545 billion in minerals exploration investment in 2001-02) are tiny compared to the value of these assets generated by the year-on-year accumulation of scientific and technological knowledge. The pay-off to tax-payers' investment in geosciences lies in the yields obtained from these substantial stocks of knowledge-based assets accumulated over the decades as a result of geoscientific R&D. Although work still remains to be done to complete this chain of causality, at present no other field of research comes as close to this sort of formal relationship to a line item in the national balance sheet. This is no coincidence, geoscientists have made tremendous efforts to provide the data now used in the national accounts.

Looking towards the future, the geosciences also play a role in ensuring that our national balance sheet accurately reflects the underlying value of Australia's assets. This is because the value of our national assets, and land values in particular, may be over stated if the outputs from research on environmental degradation and natural hazards are not widely disseminated *and* taken on board when setting prices. The landscape-level data and analyses that the geosciences provide plays a key role in helping to facilitate the gradual market-based responses to environmental challenges sought by policy-makers. In this respect, the geosciences help to increase the effectiveness with which market processes assist in the adaptation of the economy and of society to environmental degradation, natural hazards and climate change. Given these advantages, a process of even more active engagement with the official statisticians over developments in the national accounts, including a greater role in the implementation of new environmental national accounting standards, may be a particularly fruitful means of demonstrating the overall value of the geoscience to Australia.

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Introduction

The purpose of this paper is to highlight the tremendous potential that exists for geo-scientists to demonstrate public returns on government investment in their R&D by using data contained in the system of national accounts.[2] These data relate to the national balance sheet and to related experimental estimates of the economic cost of environmental degradation and natural hazards.

The paper has been prepared as part of the process of developing a strategic plan for Australian geosciences. It is essentially a technical primer and 'road map' for future work designed to assist geoscientists in exploiting the data and 'profile-building' opportunities that exist in this area. These opportunities are not widely known about outside of the specialist national accounts community. The paper also aims to brief policy-makers on the unusually robust picture of geosciences' contribution to the Australian economy made possible by this use of the system of national accounts.

Geoscientists are already familiar with the key economic statistics relating to the contribution to national *income* made by the minerals, oil and gas industries (i.e. the contribution to the *flows* of economic activity that take place each year). They are also aware of the contribution to national *wealth* made by the resources sector (i.e. the additions to the *stocks* of mineral, oil and gas *assets* used to generate income over future years).[3] The technical details of how the relationships between *income* and *wealth* generation are handled in the system of national accounts may, understandably, be fairly opaque to geoscientists as these are complex national accounting issues. In the past, there has been little reason for geoscientists to seek to understand these technical details. However, such details are now becoming increasingly relevant to geoscientists because significant innovations are taking place in how the system of national accounts deals with the environmental dimension to economic growth and development. When the depletion and degradation of natural capital are factored into estimates of national income and wealth any additions to this natural capital must also be included in the analysis for consistency.

New international standards and guidelines have been developed in order to provide internationally consistent data on the environmental sustainability of economic growth.[4] Thanks to the efforts of the *Australian Bureau of Statistics* (ABS) Australia is at the cutting-edge of this work. The adjustments that can now be made to estimates of national income, and that could potentially be made to estimates of national wealth, attempt to factor-in the costs of environmental degradation. At present, the ABS has only provided experimental estimates of the impact of the depletion and

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[2] The national accounts are published in Australian Bureau of Statistics (2003a) and some data are available on the ABS web site.

[3] Stoeckel (1999), building upon path-breaking work done by the World Bank (1998) provides a very useful and well-known summary of the relationship between income and wealth from a minerals industry perspective.

[4] United Nations (2003) *Handbook of National Accounting: Integrated Environmental and Economic Accounting*. Guidelines issues by the United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development and the World Bank. Available on-line at: http://unstats.un.org/unsd/environment/seea2003.htm

degradation of Australia's natural capital on annual economic flows (via the metric: 'depletion adjusted net domestic product'). However, it is not difficult to use the published estimates to estimate the impact upon national wealth (i.e. Australia's net worth). Such adjustments would allow 'satellite accounts'[5] to be produced that indicate what our flows of annual income and stocks of wealth look like when we consider the damage being done to the environment by the very processes involved in generating this income and in maintaining this wealth.

The system of national accounts is a set of international standards and guidelines relating to how macro-economic performance is measured (SNA93). These standards are set under the auspices of the United Nations following extensive deliberations of experts nominated by governments. Academic research, and exploratory work carried out by government statistical and research agencies, plays an important role in influencing how these standards evolve. These international standards are intended to produce reliable comparisons of economic performance and to ensure probity and transparency in how governments present statistics on the effectiveness of their economic management. These standards have become increasingly sophisticated over time. The latest draft standards and guidelines represent a major step forward in the capacity to integrate data on economic performance and environmental management.[6]

This paper highlights the growing potential for geoscientists to use the evolving system of '*integrated economic and environmental national accounts'* to provide a chain of causality via which the geosciences' overall contributions to national income and wealth can be clearly presented.[7] This is an attractive approach for a long-term strategy because it covers both the 'upside' impact of the geosciences on Australia's income and wealth *and* the contribution of the geosciences to managing the 'downside' risks to this income and wealth posed by environmental degradation and natural hazards.

At present, although key elements of this chain of causality exist (in the form of geoscience R&D investment, exploration investment and additions to sub-soil assets) it is not possible to *link* these elements by defining the precise relationships *between* geoscience R&D, exploration investment and additions to sub-soil assets (i.e. economically demonstrated resources). Providing these analytical links would leverage the substantial existing efforts that have been made to capture the impact of geoscience R&D in the national accounts. The cost to the geoscience community and the minerals sector of providing these missing links would generate the major benefit of possessing a more transparent, verifiable and therefore robust means of demonstrating national benefits than is available

[5] Official estimates that complement more mainstream figures and that allow particular issues of importance to policy-making to be highlighted.

[6] UN Handbook of National Accounting: *Integrated Environmental and Economic Accounting*. Final draft circulated prior to official editing. Known as SEEA 2003. http://unstats.un.org/unsd/environment/seea2003.htm

[7] A chain of causality can be defined in this context as a transparent and verifiable chain of estimates that relate different sets of performance measures and thereby allow the relative role of different investments in generating outcomes to be determined.

to other industries and associated fields of research. Indeed, this could define a best practice methodology for assessing R&D outcomes.

The suggested approach has important implications for the strategic direction taken by Australian geosciences over the next decade. Some of the major productivity advances to be achieved in the minerals, oil and gas industries are now viewed as resting upon the *integration* of different disciplinary areas of knowledge and datasets. Similarly, some of the major advances in demonstrating the economic and social benefits to arise from geosciences R&D may stem from integrating scientific knowledge and data with knowledge and data from the social sciences. As the submission to the 2002 *National Research Priorities Task Force* from the *National Committee for the Geosciences* stressed:

> *it is not good enough just to understand the geological (including soil and water system): this knowledge must be thoroughly integrated with the social, political, and industrial systems and, in particular, with the agricultural system.*

This paper suggests that greater involvement by geoscientists in the process of developing these *integrated economic and environmental national accounts* by working more closely with the Australian Bureau of Statistics provides a timely opportunity to put the National Committee's 2002 recommendation into practice. As this paper goes on to suggest this could include developing a new geo-spatial data-set able to highlight the risks posed by environmental degradation and natural hazards to the economic value of Australian assets. Such a data-set could build upon the already substantial integration of data on geo-spatial variations in agricultural productivity carried out as part of the national Land and Water Audit, (Hajkowicz and Young, 2002*)*.

The Policy Context

Given the increased emphasis upon demonstrating a return on investment in public sector *research and experimental development* (R&D), cost-benefit analyses and forecasts might have been expected to become an increasingly important factor in determining the level of funding allocated to particular research fields. In practice however, political realities coupled with the important role played by popular perceptions over promising new research fields and the 'sunrise' industries that they are related to, means that formal cost-benefit forecasts play a weaker role than the emphasis on generating outputs and outcomes might suggest. Given the limitations of benefit-cost forecasts when there is much uncertainty over what the future may hold, the dominance of popular perceptions is an important safeguard against the risks of focusing too highly upon the most easily quantifiable research outcomes.

On the other hand, cases in which there exist clearly demonstrated, and very high, returns to public sector R&D investment, in parallel with uncertainty over future funding and even real *declines* in this R&D funding, may indicate that the balance between popular perceptions and the reality of numerically demonstrated yields on public investment may be out of balance. Of particular concern are cases in which the additional benefit to the nation of an *increase* in public sector R&D may be both *higher* and more *reliably demonstrated* than that of research fields that are receiving sustained real increases in public R&D support. The popular perception that geoscience is associated with the 'old economy', and that resource extraction is an old economy activity, is not supported by the evidence on patterns in economic and technological development (Wright and Czelusta, 2002).

Public sector geosciences R&D is a key enabler of private sector investment in minerals exploration that, in turn, generates substantial economic gains for Australia. Public sector geosciences R&D is also central to understanding many of the environmental challenges and natural hazards that Australia faces – and which can pose threats to our economic assets. Promoting these aspects of geosciences in the broader context of national economic, social and environmental security makes the wider impact of geosciences clear.

What is particularly striking about the geosciences in the context of government R&D allocation priorities is that the geosciences are particularly well positioned to provide a chain of causality in the system of official statistics linking public sector R&D investment to the strength of the national balance sheet. This is because the stocks of *economic demonstrated resources* (EDRs) of minerals, oil and gas discovered (hereafter referred to simply as 'minerals') are now included in the national balance sheet.[8] These estimates are only included in the national balance sheet because geosciences researchers in the public sector have been active in collating data on companies' discoveries of EDRs and in providing these data to the *Australian Bureau of Statistics* (ABS).

This potential for making a clear case for geoscience R&D was highlighted by Lambert (1999) and was re-iterated in the *Geoscience Australia* submission to the *House of Representatives Standing Committee inquiry into resources exploration impediments* (Geoscience Australia, 2002). As Lambert points out, over the period 1987 to 1996, federal and state governments' public investment in geoscience totalling approximately $2 billion, resulted in exploration expenditure of $10 billion, which in turn resulted in $360 billion in additions to sub-soil assets. *In other words, every dollar of exploration expenditure generated $36 of additional sub-soil assets and every dollar of geoscience R&D is associated with generating $180 of additional sub-soil assets.*

The value of sub-soil assets represents a 'tug of war' between the depletion of these assets via resource extraction and the addition of new assets via exploration activity. This exploration activity is, in turn, facilitated by geoscience R&D, and in particular the release of data-sets designed to reduce the investment risks faced by companies exploring for minerals. In Australia, these investment risks tend to be high relative to international norms because the geological structures are unusually old,

[8] The national balance sheet is published in the Australian System of National Accounts (ABS Catalogue 5204.0).

highly deformed, and buried by a deep regolith. In order to attract 'footloose' international exploration investment, the government needs to provide an incentive that reduces this risk premium.[9]

Given that the government imposes royalties and taxes upon these resources when they are extracted, multinational exploration companies carry out formal assessments of the trade-offs between the tax-take and the overall investment risks that they face when making exploration investments in different countries. 'Outlier' countries with relatively high political risks and/or complex and fragmented geological structures in which it is relatively costly to explore face a competitive disadvantage in attracting this footloose exploration investment. Although Australia's political risks are very low, the complexity of geological structures does impose a cost disadvantage.

Governments competing to attract exploration investment are able to utilise two major tools: the rate(s) of tax levied and the quantity, quality and cost of the data made available on the countries geological and geophysical structures. Too high a tax take coupled with too high a cost of acquiring basic data on geological and geophysical structures place a country at a competitive disadvantage. The costs imposed by the tax take and the cost of the subsidies to data provision tend to trade-off with each other. Australian policy is to provide free data on geological and geophysical structures in order to offset the comparative disadvantage imposed by the nation's old, fragmented, and largely buried geological and geophysical structures. The current tax take is substantially greater than the cost of providing these data free of charge.[10] In contrast, the United Kingdom has recently acted to reduce licence fees by 90 percent in order to simulate exploration investment in the North Sea as these resources become more costly to identify and extract.[11] Each nation will attempt to choose a trade-off between taxes and other costs imposed on the industry and the subsidies to data provision that best fits their combined economic, fiscal and geological circumstances.

Making comprehensive geoscientific data available also helps to secure Australia's long term capacity to achieve environmentally sustainable development. This capacity operates by reducing the risk that the market prices of assets are over-stated because the *risks* to these assets are under-stated. In the face of environmental challenges, governments use the premise that gradual adaptation is preferable to sudden adaptation via crises. Rapid adaptation can cause severe economic, social, political disruption, and can sometimes cause military tensions to arise at a regional level. The greater the resolution and accuracy of data pertinent to understanding the nature and extent of environmental

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[9] The role of geosciences R&D in reducing investment risks faced in hydrocarbon exploration, thereby releasing private sector exploration investment and additions to EDRs, was examined in Matthews (2001).

[10] This relationship is incidental when viewed from the perspective of the stated rationale for the royalties levied on resource extraction. This is because the royalties are designed to skim off the excess profit associated with the fact that the owner of the assets (the Australian community) would not otherwise be compensated for this loss of wealth. However, the reality of international competition for minerals industry investment is that the trade-off between the tax take and the reduced investment risk made possible by releasing geological data has a real impact upon investment levels – this issue cannot be viewed solely from within a national 'silo' based solely upon the stated rationale for the royalties.

[11] Dr Marita Bradshaw, Geoscience Australia, Personal Communication.

degradation and its causes, the lower the risk that the prices of assets such as land will fail to reflect these risks. Consequently, better and more widely available data on these risks reduces the possibility of delayed and possibly catastrophic rather than smooth adaptation to environmental pressures by increasing the efficiency with which market-based mechanisms are able to operate. Comprehensive geoscientific data pertinent to environmental degradation is a critical *input* to markets.

Geosciences and Strength of the National Balance Sheet

> The wealth of a nation is the value of its assets – the things that generate income. Most people think of income as money income. But it can also be intangible (non money benefits) such as safety and clean air. Wealth is a stock of assets while income is the flow of benefits generated by that stock…..To understand whether future generations will be as well off as the current generation it is necessary to appreciate how the balance of wealth creation and wealth reduction is changing – we need to know whether we are burning the outside walls of our house to stay warm. That in turn means appreciating where our wealth currently is and how the different forms of wealth in Australia are used or transformed into income. (Stoeckel, 1999)

At present, far more attention is paid both, in the media and by the policy-making community, to economic *flows* - the fluctuations in *gross domestic product* (GDP) and measures such as *national income* (NI) rather than to the assets that determine the health of the nation's *balance sheet*.[12] As concerns with the environmental sustainability of economic growth and development get translated into official statistics we are likely to see the health of a nation's balance sheet increasing in prominence as a measure of national well-being. Looking towards the future, when the reductions in the value of assets due to expected future environmental degradation may be included in an 'environmental version' of the balance sheet we will obtain a different view national wealth. Year-on-year changes in national *net worth* (our stocks of assets less our liabilities to the rest of the world) will provide a succinct summary of the *combined* impact of the economic *and* environmental sustainability of the economy. If an insufficient proportion of national income is devoted to investing in assets for use in generating *future* income in an economically and environmentally sustainable manner, then the value of these assets will start to fall over time. This will mean that economic growth is not economically and environmentally sustainable, even if the annual increases in GDP appear to indicate that all is well.

Table 1 shows the current official estimates of Australia's national balance sheet in current prices and in terms of the percentage changes in real terms between 1993 and 2002. It also shows the percentage shares of both total assets and overall net worth accounted for by each type of asset. These particular official figures have not been explicitly adjusted for the impact of environmental degradation. However, market-processes are already factoring-in these impacts by holding back price

[12] A useful discussion of the growing use of national balance sheets can be found in Thompson (2000). According to Thompson the 'balance sheet revolution' is partly the result of the revisions to the national

increases or even reducing the prices of assets such as land for which salinity and acidification problems are anticipated to reduce future streams of income. One of the most critical questions in environmental policy is whether these price impacts are an effective reflection of the risks faced by these assets.

On the 30th June 2002, Australia's overall net worth (that is to say the total assets both produced and natural, less total liabilities to the rest of the world) stood at $2,934.2bn at current prices. This was 4.1 times GDP in that year.[13] Of this, $1,362.8bn (or 46.4% of net worth and 36% of total national assets) lay in the 'non-produced' assets of land, economically viable minerals and energy reserves and native standing timber[14]. This contrasts with $335bn for machinery and equipment and $14.8bn for (breeding) livestock. The total stock of Australian land available for economic exploitation was valued at $1107.8bn (37.8% of net worth and 29% of total national assets).

The stock of minerals and energy supplies (referred to by the ABS as 'sub-soil assets') was valued at $245.7bn, or 8.4% of net worth and 6.5% of total national assets). The value of the sub-soil assets has been estimated by the ABS on the basis of their net present value (i.e. the sum of all forecasted future revenues less costs discounted by the prevailing corporate discount rate). These are forward-looking valuations that attempt to estimate what these assets are worth by using established principles of investment appraisal. Although official statisticians prefer to value assets on the basis of market prices, sub-soil assets have no direct market price. It is, therefore, necessary to use these estimation techniques.[15]

The estimated NPV of sub-soil assets is sensitive to the discount rate used to place the future stream of net revenue onto a present value basis. The NPV of sub-soil assets with several decades of profitable extraction potential is particularly sensitive to the discount rate used. This is because the value of a profit margin in the distant future is very low using commercially-based discount rates. ABS estimates of the sensitivity of sub-soil asset NPVs published for 1992 (ABS, 1992) indicate that the move from a 10 percent to a 5 percent discount rate results in a 73 percent increase in the NPV of total sub-soil assets. The current discount rate used is 6 percent, which is low by historical standards (the average rate used since 1985 is 8 percent, with a minimum of 6 and a maximum of 10 percent).

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accounting standards introduced in the 1993 update of the System of National Accounts (SNA93). SNA93 recommended that countries start to compile national and sectoral balance sheets.

[13] GDP was $712.98bn at current prices.

[14] ABS 5204.0 2003

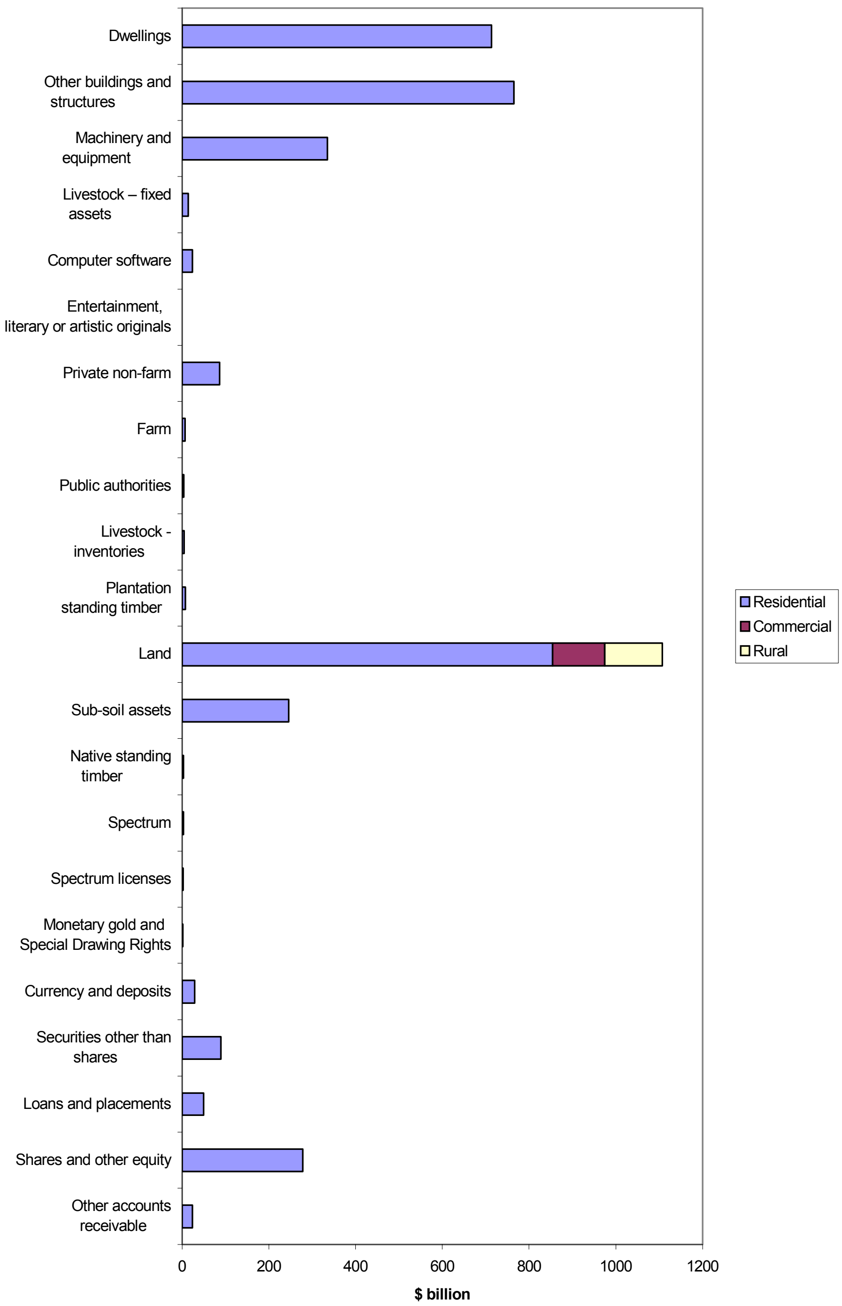
[15] In theory, the net present value (NPV) of the future income stream of an asset will be the same as the market price of that asset. The use of NPV estimates by the ABS is therefore theoretically robust and a practical necessity given that there is no market price for these assets. In practice, the estimated NPV/market price of an asset may not adequately reflect the risks to the value of this asset if there is a pervasive 'institutional failure' in the process of identifying and reacting to information on these risks and/or a failure to disseminate information on these risks in a form that can be assimilated.

Table 1: Structure and Trends in Australia's National Balance Sheet 1993 to 2002

	Value in current prices, 30th June 2002 ($bn)	Real terms 1993/94 ($bn)	Real terms 2001/02 ($bn)	Percentage change in real terms between 1993 and 2001 (%)	Percent of total assets at 30th June 2002 at current prices (%)	Percent of Net Worth 30th June 2002 at current prices (%)
Total Assets	**3,797.0**	**2,746.9**	**3,539.5**	**128.9%**	**100.00%**	**129.4%**
Non-financial assets	3,324.7	2,575.0	3,083.3	119.7%	87.56%	113.3%
Produced assets	**1,961.9**	**1,533.3**	**1,930.0**	**125.9%**	**51.67%**	**66.9%**
Fixed assets	1,853.1	1,442.4	1,819.6	126.2%	48.80%	63.2%
Tangible fixed assets	1,828.5	1,437.9	1,792.7	124.7%	48.16%	62.3%
Dwellings	713.3	537.5	694.1	129.1%	18.79%	24.3%
Other buildings and structures	765.3	654.1	754.6	115.4%	20.16%	26.1%
Machinery and equipment	335.0	246.8	331.3	134.2%	8.82%	11.4%
Livestock – fixed assets	14.8	18.6	12.6	67.7%	0.39%	0.5%
Intangible fixed assets	24.7	7.9	26.9	340.5%	0.65%	0.8%
Computer software	24.0	7.3	26.3	360.3%	0.63%	0.8%
Entertainment, literary or artistic originals	0.6	0.5	0.6	120.0%	0.02%	0.0%
Inventories	108.8	90.9	110.4	121.5%	2.87%	3.7%
Private non-farm	86.2	74.3	87.3	117.5%	2.27%	2.9%
Farm	6.9	4.4	8.4	190.9%	0.18%	0.2%
Public authorities	3.8	4.7	3.3	70.2%	0.10%	0.1%
Livestock - inventories	4.4	3.5	3.6	102.9%	0.12%	0.1%
Plantation standing timber	7.5	6.3	7.9	125.4%	0.20%	0.3%
Non-produced assets	**1,362.8**	**1,049.3**	**1,153.4**	**109.9%**	**35.89%**	**46.4%**
Tangible non-produced assets	1,360.3	1,049.3	1,150.9	109.7%	35.83%	46.4%
Land	1,107.8	912.2	954.1	104.6%	29.18%	37.8%
Sub-soil assets	245.7	129.1	190.2	147.3%	6.47%	8.4%
Native standing timber	3.1	2.8	3.0	107.1%	0.08%	0.1%
Spectrum	3.7	0.0	3.5		0.10%	0.1%
Intangible non-produced assets	2.5	0.0	2.5		0.07%	0.1%
Spectrum licenses	2.5	0.0	2.5		0.07%	0.1%
Financial assets with the rest of the world	**472.3**	**189.1**	**456.2**	**241.2%**	**12.44%**	**16.1%**
Monetary gold and Special Drawing Rights	1.7	4.8	1.6	33.3%	0.04%	0.1%
Currency and deposits	28.6	4.7	27.6	587.2%	0.75%	1.0%
Securities other than shares	90.0	43.1	87.0	201.9%	2.37%	3.1%
Loans and placements	49.4	23.3	47.7	204.7%	1.30%	1.7%
Shares and other equity	278.4	104.8	268.9	256.6%	7.33%	9.5%
Other accounts receivable	24.3	8.3	23.4	281.9%	0.64%	0.8%
Liabilities to the rest of the world	**862.8**	**453.7**	**833.5**	**183.7%**		**29.4%**
Currency and deposits	56.6	17.1	54.7	319.9%		1.9%
Securities other than shares	355.8	181.8	343.7	189.1%		12.1%
Loans and placements	102.0	71.6	98.5	137.6%		3.5%
Shares and other equity	339.1	177.4	327.6	184.7%		11.6%
Other accounts receivable	9.3	5.8	9.0	155.2%		0.3%
Net Worth	**2,934.2**	**2,315.0**	**2,706.0**	**116.9%**		**100.0%**

Source: Calculated from ABS 5204.0.2003

Figure 1: Australia's National Assets in 2002



Source: Calculated from ABS 5204.0.2003

The distribution of these asset values is more clearly grasped in the figure 1. The dominance of land values in general, and residential land in particular clearly stands out. Table 2 provides a more detailed breakdown of land values by state and type of land.

Two points are worth noting about the national balance sheet. First, these asset values are linked by complex inter-dependencies of the type captured in input-output data.[16] Consequently, each type of asset's value is partly determined by these inter-dependencies. Although each type of asset is by definition productive, some types of asset have a more pervasive impact on the national balance sheet than others by virtue of the knock-on effects of economic activity associated with exploiting that asset. Sub-soil assets have this characteristic. Scope therefore exists to use input-output data to assess these inter-dependencies in the national balance sheet.[17] Second, a large proportion of total assets are subject to environmental/natural hazards. 87 percent of total assets are tangible and in theory are subject to the risks and hazards associated with landscape-based processes (earthquakes, fires, droughts, floods etc). Again, the application of input-output methods provides a means of assessing the direct and indirect consequences for the national balance sheet of the manifestation of these risks and hazards.

Table 2: Details of Australian land values, 2002

$ billion (current prices)

	Residential	Commercial	Rural	Total
NSW	367.8	47.6	61.2	476.6
Vic.	239.7	31.5	27.7	298.9
Qld	104	16	15.5	135.5
SA	42	6.4	11.7	60.1
WA	76.9	13.7	14.3	104.9
Tas.	6.6	1.3	2.8	10.7
NT	3.8	1.5	0.3	5.6
ACT	14.1	1.4	0	15.5
Total	854.9	119.4	133.5	1107.8

Source: Calculated from ABS 5204.0.2003

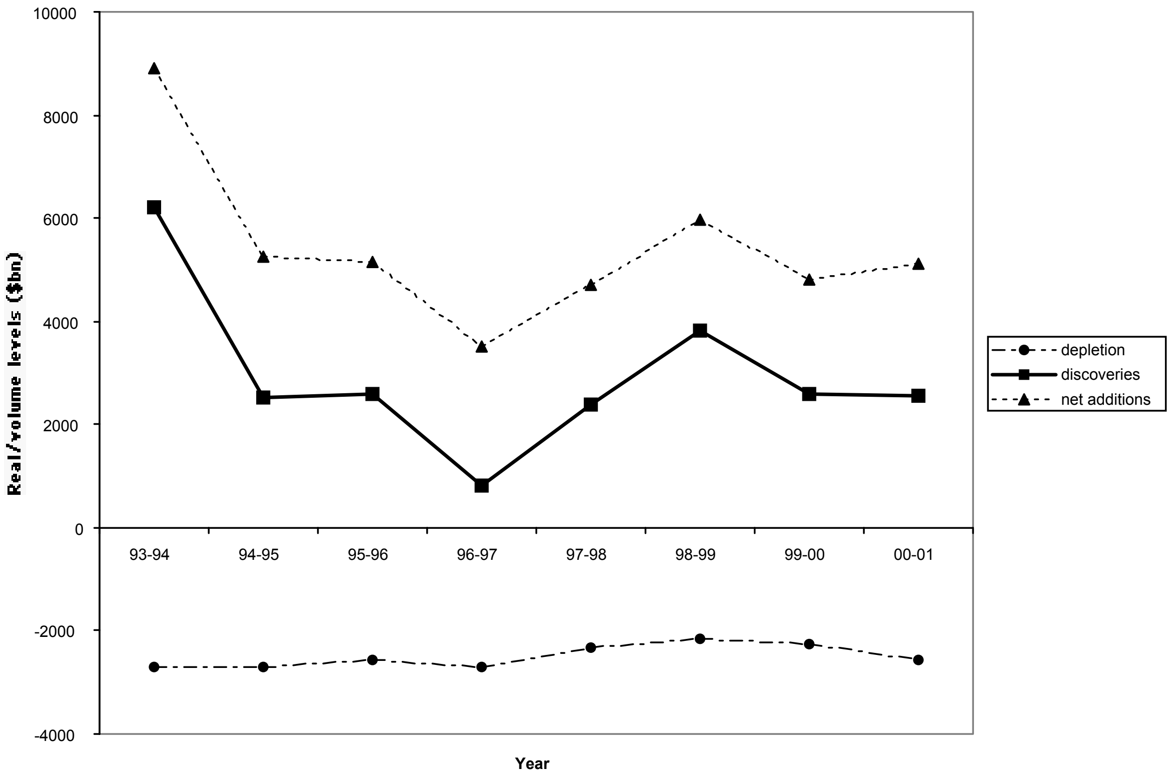
Turning to the minerals industry, the historical behaviour of minerals discoveries and depletions since 1993-94 can be observed in figure 2. This shows that discoveries have out-paced the depletion of these assets over this period. The large fluctuations in the size of discoveries are also evident. The sustained and significant contribution to the national balance sheet by discoveries of sub-soil assets

[16] Data on inter-industry sales that allows these inter-connections to be mapped and their consequences analysed.

[17] As economies become more developed the complexity of these economic inter-dependencies increases. This tends to result in a levelling-out of the indirect impacts of expansion or contraction in any particular sector. The economy becomes less reliant upon a particular group of sectors for generating value added and more reliant upon the overall *system* of inter-industry relationships. Consequently, input-output analyses generate broadly similar output 'multipliers' for economic activity in different sectors.

that results from these net increases is made clear in table 3, which shows that sub-soil assets in *real terms*[18] have stood at around 5 percent of total Australian assets.

Figure 2: Sub-Soil Assets - Real Changes in Discoveries Relative to Depletions



Source: adapted from data provided in ABS 4617.0 2003 (Chapter 25).

Table 3: Sub-soil Assets as a Percentage of Total National Assets

Real/volume terms ($bn)	1994	1995	1996	1997	1998	1999	2000	2001	2002
Total national assets	2746.9	2845.6	2887.5	2986.7	3124.6	3210.2	3358.2	3497.6	3539.5
Sub-soil assets	129.1	153.9	148.9	162.4	171.6	174.9	176.2	182.9	190.2
Percent sub-soil	*4.70%*	*5.41%*	*5.16%*	*5.44%*	*5.49%*	*5.45%*	*5.25%*	*5.23%*	*5.37%*

Source: Calculated from ABS 5204.0.2003

The Special Case of Minerals Exploration Investment

In both the minerals industry company accounts and in the national accounts the annual investment in exploration for minerals is treated as part of capital formation rather than as an expense. This is because the return on exploration investment takes the form of increased knowledge about sub-soil assets for exploitation in future years and not, in general, in the year in which the exploration investment was made. The result of capitalising exploration investment is that the national accounts contain a capital stock called 'mineral exploration'. This capital stock does not appear in the national

[18] 'Real/volume terms' refers to estimates that adjust for inflation in order to allow more accurate historical

balance sheet because the eventual 'yield' on the knowledge represented by the minerals exploration capital stock is manifested in additions to the stock of sub-soil assets (ie. EDRs). To put both stocks on the national balance sheet would be a form of double counting, although there is a debate over how best to deal with the mineral exploration capital stock.[19]

Although, the mineral exploration capital stock is hidden away in the detailed tables in the national accounts, it provides a useful source of data for geoscientists.[20] This is because it provides an estimate of the accumulated investment in minerals exploration in Australia that, in turn, reflects the value of the accumulated knowledge and data-sets gained from the exploration process. Although much of the expenditure may go on field-based activity (surveying, drilling etc), this exploration activity generates new data that adds to existing datasets and allows improved analysis and pattern recognition to be carried out in the future. The larger and more comprehensive these proprietary data-sets, the greater an organisation's capability to explore effectively (i.e. knowing where to look, what to look for and how to look for it). This stock of intellectual and data resources is large, valuable and has been built up over many years by the companies that carry out exploration activity. The fact that the ABS uses a capital stock measure to track the value of this accumulated investment therefore mirrors the real scientific and technological processes involved in minerals exploration.

This capital stock aspect of minerals exploration must be born in mind when considering fluctuations and underlying trends in the real level of exploration investment by the minerals industry. In principle, the existence of these intangible assets improves the efficiency and the effectiveness of the process of minerals exploration. This means that exploration companies should be able to improve their forecasts of the investment risks faced when exploring particular geological structures via pattern recognition. This benefit from accumulated knowledge, data and sophisticated statistical analyses helps to offset the problems associated with prospecting in more difficult geological structures (allowing real levels of exploration investments to be maintained) or, alternatively, may allow real levels of exploration investment to be *reduced*.

Consequently, reductions in the underlying level of investment in minerals exploration may not necessarily be an indication of a problem. Indeed, a sustained decline in real investment spanning successive business cycles may be a consequence of the *success* in building-up the technical capacity to carry out exploration investment more effectively due to accumulated knowledge, data and

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comparisons of values to be produced.

[19] Prior to sub-soil assets being placed on the national balance sheet, the mineral exploration capital stock was used as a proxy measure. The minerals exploration capital stock estimates were developed when the Australian System of National Accounts (ASNA) adopted the UN System of National Accounts 1993 standards (SNA93).

[20] The figures can be found in Table 66 of ABS Catalogue 5204.0 'Australian System of National Accounts'.

analytical techniques. This knowledge, data and the analytical methods used do not constitute R&D but they do represent a major knowledge-based asset.[21]

Reductions in mineral exploration investment should only be a matter of concern if the yield on the minerals exploration capital stock captured by additions to sub-soil assets exhibits a sustained drop. This highlights the importance of possessing the capability to *link* geoscience R&D, exploration investment and sub-soil additions in a formal economic model that allows the impact of changes in investment and capital stock values to be quantified. In systems engineering terms we need to understand how closely each part of the system coupled together.

In FY 2001-02, on a current price basis, gross fixed capital formation via exploration investment was $1,545m, the end of year net capital stock was $28,631m and the consumption of fixed capital (effectively the depreciation charge) was $1,543m.[22] By way of a comparison the *overall* value of the capital stock in the mining industry in FY 2001-02 was $125.953 billion (this does not include the value of sub-soil assets), so 22.7 percent of the total mining industry capital stock consisted of the knowledge-based exploration capital stock (both figures are expressed in current prices).

In previous years the consumption of fixed capital charge has been far lower than the actual investment in exploration. For example, in FY 1988-89 (again in current price terms) exploration investment was $1,334m whilst the consumption of fixed capital was $853m. (some 64 percent of annual investment). These fluctuations are a natural part of the mineral sector's dynamics, and highlight the importance of using capital stock measures to capture the economic rationale for these investments.

The following graphs provide an overview of the stock of mineral exploration capital and of the flows in and out of this stock (these are *Gross Fixed Capital Formation* in minerals exploration and *Capital Consumption*). All these estimates are in real terms. Figure 3 shows what has been happening to the overall value of the minerals exploration capital stock and allows the size of the flows in and out of this stock to be compared to the size of the capital stock. Figure 4 allows the inward and outward flows from this capital stock to be judged in relation to each other by excluding the overall size of the capital stock.

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[21] The only element of minerals exploration investment that is classed as R&D is that associated with developing new exploration processes and methods.

[22] ABS Catalogue 5204.0 2001-02 table 67, page 79.

Figure 3: Behaviour of the Minerals Exploration Capital Stock

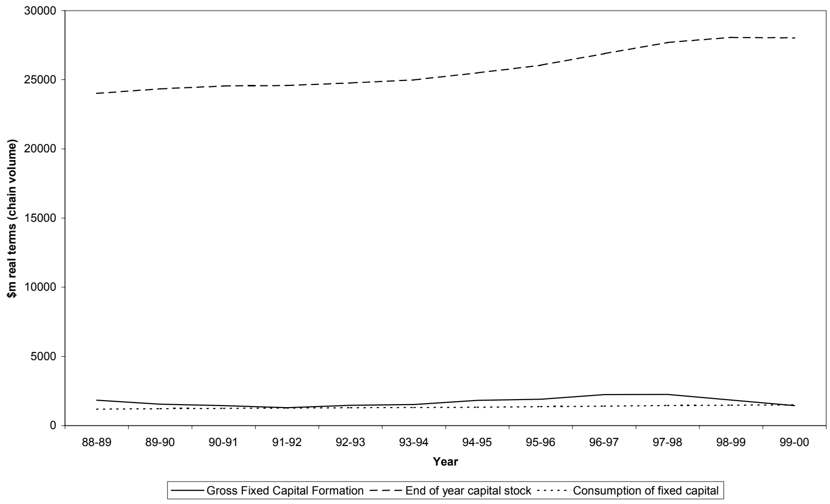
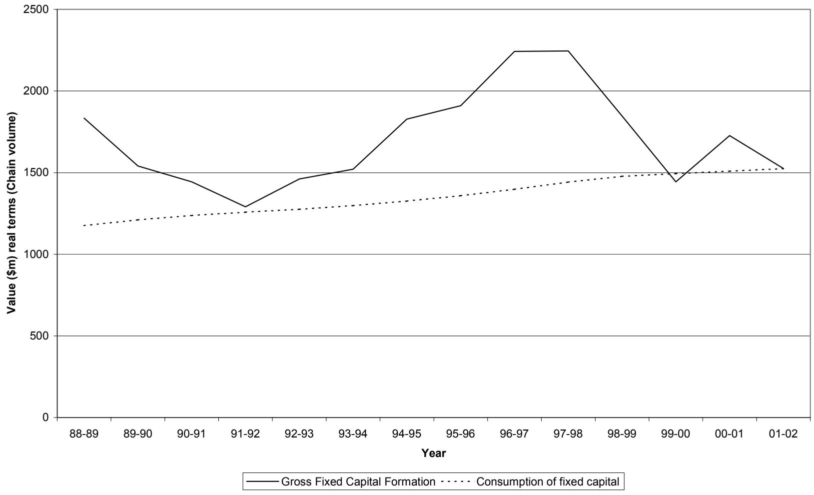


Figure 4: Additions to and Deductions from the Minerals Exploration Capital Stock



Source: data taken from ABS 5204.0 2003 for both diagrams

It is noteworthy that the minerals exploration capital stock is large compared to annual expenditure on minerals exploration. The cyclical nature of minerals exploration expenditure results in phases of marked expansion in the minerals exploration capital stock – the benefits from which are recouped over future years via exploitation of the knowledge reflected in the minerals exploration capital stock as a whole. The ABS also estimates the average age of the mineral exploration capital stock (see figure 5). The trend is upwards, in FY 2001-02 the age stood at 16 years (11.3 years in FY 1988-89). In comparison, the average age of the overall capital stock in the mining industry is 11.6 years, increasing from 9.8 years in FY 1988-89. Figure 6 contains a comparison of the relative levels of the minerals exploration capital stock and the stock of sub-soil assets.

Figure 5: Average Age of the Minerals Exploration Capital Stock

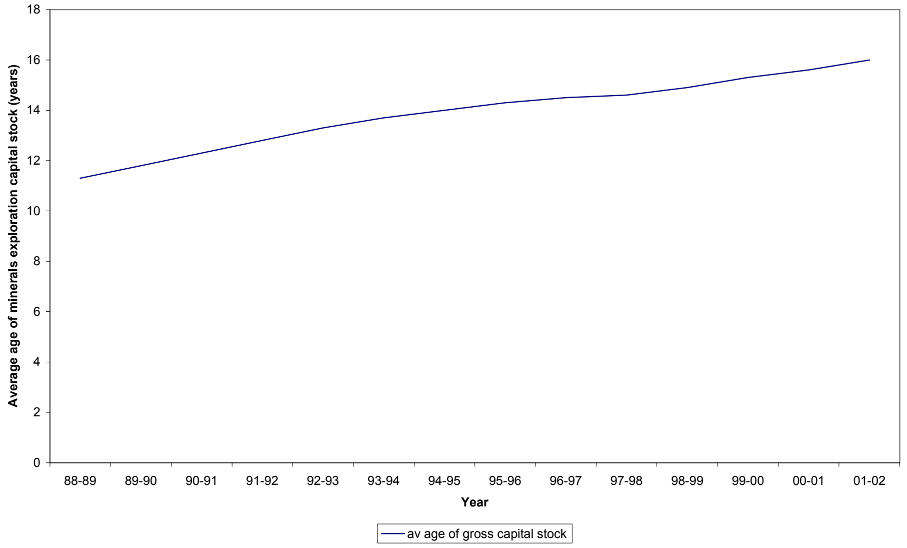
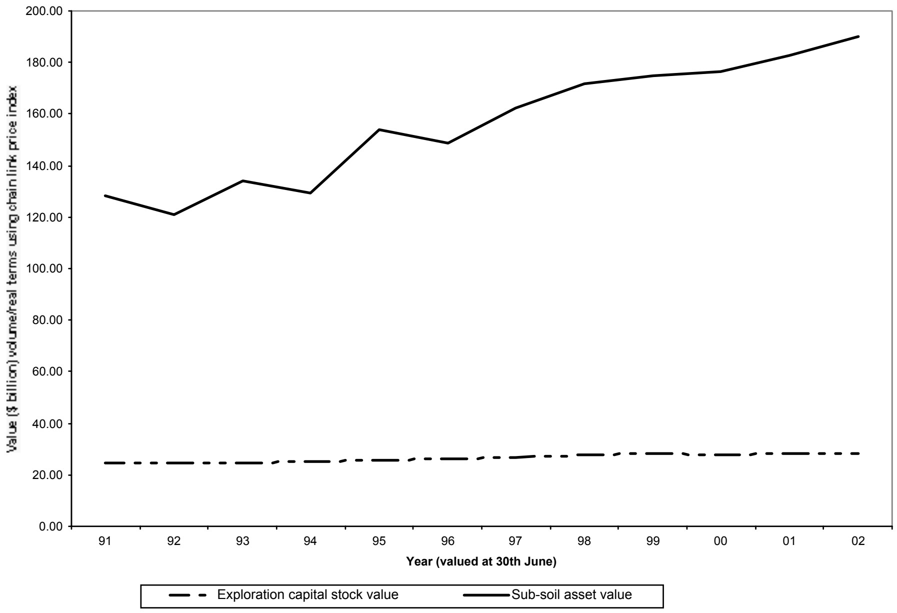


Figure 6: Minerals Exploration Capital Stock and Stock of Sub-Soil Assets Compared



Source: from ABS 5204.0 2003 for both diagrams

These estimates of the value of the mineral exploration capital stock provide geoscientists with parts of the set of stepping stones that link annual flows of public sector investment in geosciences R&D to additions to sub-soil assets that take place due to this stock of accumulated minerals exploration investment.

Why is this important?

One of the conceptual challenges in science and innovation policy is to demonstrate that each year's public sector funding of R&D is not simply an *expense*, it is an *investment* in an accumulating stock of knowledge, experience and data. Although the principle that R&D should be treated as a stock rather than a flow is accepted, it is notoriously difficult to produce convincing estimates of the value of R&D stocks per se. The geosciences possess the advantage that they have a non-R&D knowledge-based capital stock estimate that exists, in a large part, due to their R&D. In the United States, the Whitehouse Office of the Management of the Budget (OMB) uses estimates of the value of the intangible element of the federally funded R&D capital stock to make the *policy-based* point that each year's R&D expenditure is only partly responsible for each year's R&D outcomes.[23] Geoscientists have no need to pursue such an approach.

What is not clear at present is the precise relationship between levels of investment in geoscience R&D, levels of minerals exploration (and the value of the capital stock) and levels of sub-soil assets. Completing these links in the chain would provide the chain of causality that demonstrates the extent to which an increase or decrease in geoscience R&D (and associated data releases) will result in changes in exploration investment. These changes in exploration investment and the value of the exploration capital stock will, in turn, lead to changes in the level of annual additions to sub-soil assets and the value of these assets in the national balance sheet. The capital stock nature of minerals exploration implies that this system linking geoscience R&D to sub-soil assets is not closely coupled. Year-on-year fluctuations matter less than sustained changes in capital stock values. Consequently, models of these inter-relationships need to focus primarily upon the *stocks* (the knowledge-based and tangible assets) and treat annual flows of investment and discoveries as one influence on the value of these stocks.

The existence of a capital stock estimate covering minerals exploration does not necessarily mean that the assumptions made about the rate of depreciation of this capital stock (and hence its overall value and average age) reflect the economic obsolescence of the knowledge, data and experience associated with this capital stock. The opportunity therefore exists for geoscientists and the minerals industry to liaise with the ABS in order to ensure that changes in the value of this capital stock does actually track technical and commercial realities. This paper concludes with recommendations on how to achieve this.

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[23] In 2002 the intangible element of this capital stock was valued by the OMB at US$1,116.6bn in 2002 dollars. US$511.9bn (46%) of this lay in basic research and US$604.7bn (54%) in applied research and development. This is 10.8 percent of US GDP in 2002.[23] In producing these estimates the OMB has decided that the stock of *basic research* capital should not be subjected to a depreciation charge because the future value this fundamental knowledge does not decay over time. Applied research and experimental development capital stocks are depreciated at a rate of 10 percent per annum.

Another important aspect of the mineral exploration capital stock is that corporate reporting requirements on the outcomes from prospecting in particular areas eventually feed-back into the public domain data-sets that inform *future* exploration activity. As a result, aspects of the proprietary data become incorporated into the public domain data – to the collective benefit of the minerals industry as a whole.

No other field of research has the advantage of *both* a line-item in the national balance sheet that exists partly because of public sector R&D investment *and* an estimate of the *intangible knowledge-based asset* (the mineral exploration capital stock) that links this flow of R&D investment to the stock of assets on the national balance sheet. It is, therefore, in the interests of the community of geo-scientists that they stress the size and *nature* of the mineral exploration capital stock together with the 'feed-back' effect upon public domain data-sets when demonstrating the economic impact of their R&D on Australia. Arguably, insufficient effort has gone into communicating this message to policy-makers. Completing the links in the R&D outcome 'chain of causality' highlighted in this paper would provide a particularly compelling and robust means of communicating this message.

Geoscience and the Costs of Environmental Degradation

The process of adjusting estimates of income and wealth in order to capture the impact of the environmental consequences of the processes that generate this income and build this wealth are extremely complex. The guidelines produced collectively by the United Nations, World Bank, OECD, IMF and the European Commission (referred to in brief as SEEA 2003) run to several hundred pages.[24] They deal with the treatment of the physical flows in an economy, including flows of waste products and the treatment of ecosystems and 'sinks', the valuation of natural resource stocks, the valuation of environmental degradation and other technical matters concerning how these different types of data can be integrated. A useful discussion of environmental accounting issues can be found in Lange (2003).

The discussion in this paper focuses upon the experimental estimates of 'environmental national accounts' produced by the ABS. These adopt a particular, limited, interpretation of SEEA 2003 that conforms to Australian government priorities concerning the production of official statistics. It is important to note that the current SEEA-related efforts to produce official environmental national accounts data are limited in scope and are essentially experimental.[25] There is still a long way to go to fully integrate such experimental estimates into existing sets of measures such as the national balance sheet. Consequently, the following discussion is forward-looking in the sense that it covers opportunities for future work in this area of relevance to geoscientists over the next decade. The major

[24] UN Handbook of National Accounting: *Integrated Environmental and Economic Accounting*. Final draft circulated prior to official editing. Known as SEEA 2003. http://unstats.un.org/unsd/environment/seea2003.htm
[25] At present, the Australian national accounts are still based upon the older SNA93 standard. Neither Australia, or any other country has proceeded very far in implementing the environmental aspects of the new SEEA guidelines.

opportunities for geoscientists lie in the fact that much work still has to be done to refine and implement environmental national accounting.

Broadly speaking, the process of adjusting conventional national accounts in order to factor in environmental factors involves estimating the impact of the depletion and degradation on the value of natural assets that have an identifiable owner who is able in principle to derive an economic benefit from that asset. Thus, natural assets (such as the atmosphere) that do not have an identifiable owner are excluded from the analysis. In Australia three classes of assets on the national balance sheet are currently treated as environmental assets. These are: land; sub-soil assets (e.g. minerals, oil and gas); and, native standing timber. Both the value of sub-soil assets and land are of relevance to capturing the impact of geosciences R&D.

The ABS has drawn upon work carried out on agricultural land values by Kemp and Connell (2001) and by the *National Land and Water Audit* in order to try to estimate the economic losses due to land degradation (increasing salinity, sodicity and acidity). Kemp and Connell used farm survey data in 2001 to estimate the difference between the capital value of farms with and without degradation. This yielded an estimate of $14.2 billion for 1999 in terms of accumulated losses due to lost future land productivity. In 2002 the *National Land and Water Audit* estimated the difference between farm profits with and without soil degradation as $2.6 billion in 1996-97 (National Land and Water Audit, 2002a). As one estimate is framed in terms of the capital value of farms and the other in terms of a lost profit stream the ABS turned the lost profit estimate into a 'capitalised' value of lost returns on exploiting the land. This yields an accumulated lost 'resource rent' due to agricultural degradation by 1996-97 of $16.4 billion. Once framed in capital value terms the two estimates from different sources are reasonably close ($14.3 billion and $16.4 billion) respectively.

The annual losses due to landscape degradation have been estimated by the ABS using these base-line accumulated loss figures. In 2000-01 these annual losses amounted to only $344m. One interpretation of this might be that this is because the land affected is not especially productive anyway. The analysis of productivity carried out as part of the national Land and Water Audit also lends some support for this point. 80 percent of the total profit obtained from all agricultural activity (assessed on the basis of the combined returns from land, water, capital and managerial skill) comes from just 0.8 percent of the area used for agriculture in Australia, (Hajkowicz and Young, 2002*)*. In comparison, rural land was valued at $133.5 billion in 2002 (based on market prices). So, very broadly the annual cost of degradation only amounts to 0.25 percent of the current asset value.[26]

Some observers argue that market prices for farm land are not fully factoring in the future impacts of land degradation and that consequently the annual losses are under-stated. This risks increasing the inventory of future economic threats in agriculture yet to be factored into asset prices.

[26] The official data are however subject to the problem that, in some jurisdictions, 'urban-rural' land is included with rural land. Consequently, degradation may account for more than 0.25 percent of land asset value.

Shortages and shortcomings in data may be one factor in this. However, here are other factors such as cultural attitudes. In addition, these ABS estimates only relate to the cost of degradation to rural land, and this is only part of the story. The *National Land and Water Audit* in 2002 also estimated that the public cost of risks to infrastructure (676,400 km of roads, 5,100 km of railways, 41,300 km of streams, 2m hectares of native vegetation and urban infrastructure in 200 towns at risk) would approach $500m annually over the next 20 years (National Land and Water Audit, 2002b). The Land and Water Audit stresses that planning and implementing public works in priority areas sooner rather than later is preferable.

The current state of the official but *experimental* estimates of the economic cost of the depletion and degradation of Australia's natural resources is expressed in terms of *depletion adjusted* Net Domestic Product (NDP) (i.e. GDP less the consumption of fixed capital and the net depletion of natural capital). To date, land degradation estimates have only been prepared for agricultural land and the impact of factoring this into NDP is barely noticeable (see the estimates in Annex A). It is not clear what the impact of salinity on urban land prices will be.[27] Also, given that these adjustments are based upon the analysis of market price responses to expected future environmental degradation, the possibility exists that 'myopic' market responses to these risks mean that some types of land and other assets are currently over-valued in the face of these risks.

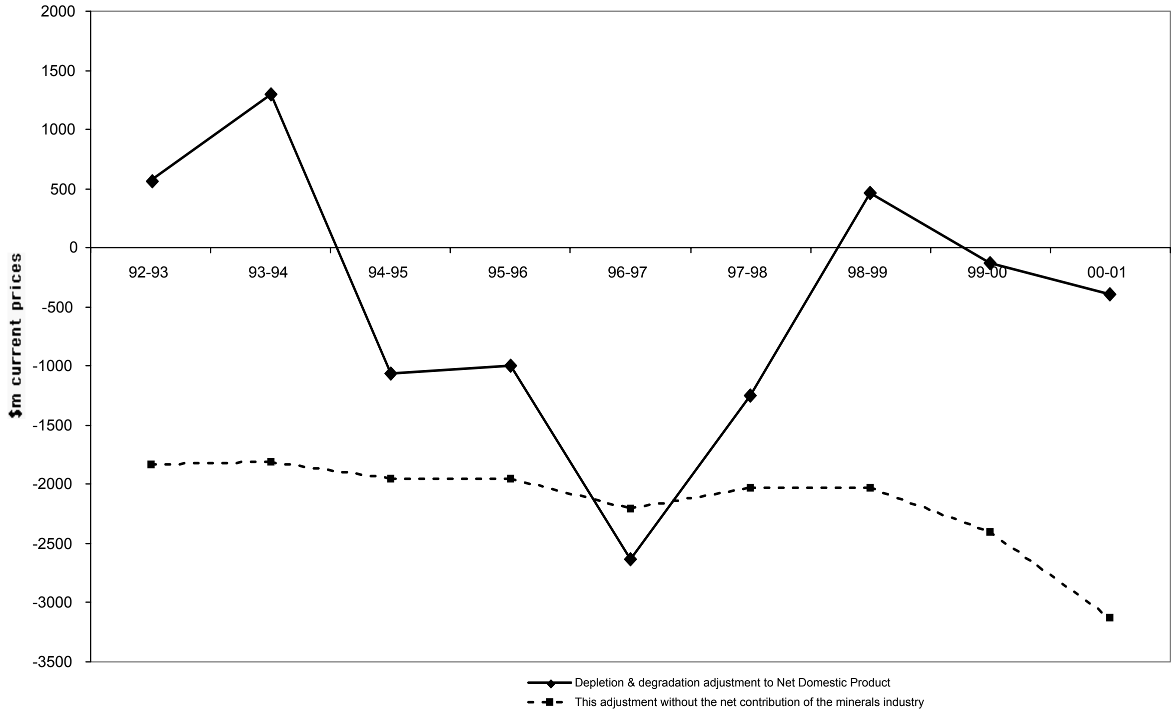
One reason for this may be that geoscientific and other scientific data on these risks to the future productivity of land are not connecting effectively with community and market awareness because of the manner in which the data are presented. It is plausible that the more that scientific data is translated into 'visualisable' economic variables (e.g. maps showing the contours of economic risk faced in different geographic locations) the greater the reaction of market prices for land and other assets in response to these risks.

The experimental results on the economic impact of the degradation and depletion of Australia's natural resources produced to date by the ABS provide a highly summarised picture. This picture is not intended to generate this 'connection' to price-setting and other aspects of economic behaviour. That said, the current estimates do clearly demonstrate that the discoveries of mineral resources are sufficient to more than offset the cost of the depletion and degradation of Australia's natural resources. Figure 7 illustrates this. The continuous line shows the official experimental estimate of the adjustment that must be made to Australia's Net Domestic Product in order to factor-in the net impact of the degradation and depletion of natural assets and the additions to these assets arising from mineral discoveries. The broken line takes out the positive impact of new mineral discoveries, thus highlighting the underlying trend associated with resource depletion and degradation. Although, when natural assets are considered, in a 'good' year new minerals discoveries can result in an increase

[27] Salinity poses a threat to the foundations of buildings in some urban areas, however this could further increase urban land values rather than decrease them as supply may become even more restricted.

in Depletion-adjusted Net Domestic Product it is important not to under-estimate the growing problem of degradation by only reporting the combined estimate indicated in the solid line. Changes in the value of natural capital should ideally separate-out the net depletion in sub-soil assets and the impact of the degradation of this natural capital. Otherwise, there is a risk of masking two different sets of relationships in a single measure.

Figure 7: The Adjustment to Net Domestic Product to Account for Changes to the Value of Natural Capital with and without the Impact of Mineral Discoveries



Source: adapted from data provided in ABS 4617.0 2003 (Chapter 25).

Re-thinking the Treatment of Minerals Investment and Discovery

The issue of how to value sub-soil mineral assets in the national accounts is currently the subject of significant debate (see Nordhaus and Kokkenlenberg, 1999). This debate is not restricted to the technicalities of estimation methods, it runs to the heart of theorising about the role of R&D and exploration investment, advances in knowledge and the rate of economic growth. The core of this debate relates to whether sub-soil assets should be treated as a gift of nature or, alternatively, as the product of investment. In short, are sub-soil assets 'non-produced' or 'produced' assets?

The case in favour of treating sub-soil assets as 'produced assets' rests upon the role of investment in advances in scientific and technological knowledge, together with investment in accumulating exploration expertise and data, in 'creating' these assets. From a business perspective, minerals companies tend to invest in maintaining an 'inventory' of economically proven resources sufficient only for their short to medium term production requirements. They do not seek to determine the *overall* level of economically useful resources as this would be irrationally costly relative to the commercial benefits obtained over business planning horizons. Thus, the volume and the value of sub-soil assets reflected in a national balance sheet does not reflect a finite resource, rather, it reflects economically demonstrated resources (EDRs) created by investment with a limited time-horizon in mind. Further investment and advances in scientific and technological knowledge will add to these EDRs by discovering new deposits and finding ways of economically extracting previously known but un-economic deposits. This process differs little from any other process of producing assets.

If this 'produced asset' perspective were to be adopted (sub-soil assets are currently treated as 'non-produced assets') then minerals exploration investment would be treated as an intermediate input into the production of sub-soil assets. Sub-soil assets would not be treated as a gift of nature, they would treated as the product of investment. This would mean that *both* the minerals investment capital stock and the stock of sub-soil assets would appear on the national balance sheet (Thompson, 2000). History shows that advances in science and technology can transform an apparently resource poor or resource depleted economy into a resource rich economy. This lends support to the notion that sub-soil assets are 'produced assets'. Australia's experience is one example of this (see Wright and Czelusta, 2002).

Given these dilemmas in national accounting, it makes sense to seek to improve our understanding of the inter-related dynamics of R&D investment, exploration investment and additions to sub-soil assets from an investment risk-based perspective. As has been argued, particular attention should be paid to understanding the generic value of the location-specific knowledge and data generated by the exploration process.

The fact that exploration companies carry out advanced pattern recognition analysis in order to manage *location-specific* investment risks suggests that minerals exploration at a specific site has a value irrespective of whether or not this particular prospecting is successful. This in turn suggests that the generic, knowledge-based, component of the minerals exploration capital stock as a key enabler of 'producing' sub-soil assets should be treated as an asset class and should be included in a national balance sheet. The value of this asset lies in its capacity to translate *uncertainty* into *risk* and then to seek to minimise this risk anywhere in the world. Advances in pattern recognition methods applied to complex geological systems coupled with advances in the theoretical understanding of the formation and distribution of minerals are a primary means of managing these uncertainties and risks.[28]

[28] In Matthews (2001) an attempt was made to highlight the importance of minerals R&D outcomes in terms of uncertainty and risk reduction. This included the notion that academic research, in providing improved theories about statistical patterns in the distribution of hydrocarbon deposits, helps to address a 'wrong theory' aspect of market expectations. Theoretical assumptions made about the statistical distribution of deposits (e.g. fractal

Consequently, greater clarity in understanding how these factors inter-relate from the perspective of the impact of advances in knowledge upon uncertainty and risk may help to resolve this dilemma in national accounting.

Conclusions and Recommendations

Policy-makers should take note of the strong contribution of the geosciences to the Australian economy. Geosciences R&D strengthens the national balance sheet and helps to manage the risks to this balance sheet. Policy-makers should also note the unusually robust, if still incomplete, nature of the chain of causality via which the geosciences are able to demonstrate their impact on Australia's net worth. This chain of causality would be completed if geoscientists developed a formal quantification of the relationships between the level of expenditure on geoscience R&D, the level of expenditure on exploration investment and the additions to sub-soil assets generated by this knowledge. It is difficult to find any other research fields that has such potential strength for demonstrating R&D outcomes in this robust manner using the system of national accounts.

Given that the current provision of data on geological and geophysical structures already has a strong positive impact on Australia's net worth, it is worth examining whether this impact would be greater if freely available data were further improved. One way of thinking about this is to consider what we know about the balance of opportunities and risks to the national balance sheet. We know far more about the ways in which comprehensive geoscientific data strengthen the balance sheet, and eventually add to government revenue, than we do about the fragility of the national balance sheet in the face of environmental challenges. These environmental challenges may eventually increase costs and lead to fiscal pressures. The information we have on opportunities and risks relating to Australia's net worth is therefore not balanced.

Governments play *the* key role as stewards of the environment. Uncertainties over the long-term economic, social and political consequences of environmental degradation in Australia are high. At present, the extent to which policy-makers can be re-assured that markets are operating effectively in reacting to environmental risks is uncertain. Whilst some of this uncertainty can be reduced by further economic research on this issue, better and more integrated scientific data relating to landscape degradation and the economic impact of climate change would provide more favourable conditions for markets to operate effectively.

One mechanism for helping to ensure that geosciences knowledge gets translated into effective price adjustments would be to create a national geo-spatial database of risks in relation to economic asset values. The aim would be to integrate geo-spatial data on the inter-dependent risks posed by

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versus non-fractal distributions for oil) influence exploration decisions. If the theory is wrong then prospecting may overlook potential resources.

natural hazards, climate change[29] and environmental degradation with the economic data on the value of the assets similarly organised upon geo-spatial lines. Much progress has already been made to integrate data on agricultural land using a 1km resolution grid as part of the national land and water audit. A more comprehensive geo-spatial model could be used to generate contours of risks to economic assets, similar to the contours generated for hazards such as earthquake risks. The widely disseminated mapping of the co-variances and causal inter-relationships between these different risk factors and their translation into the economic dimension could play an important role in ensuring that market-prices factor-in such combined risks. The existing work on the analysis of risks in complex closely coupled systems in which human decision-making plays a causal role provides a useful input to such a project (Perrow, 1984).[30] This, in turn, would help to insure that both markets and policy-makers are able to respond earlier rather than later to these challenges.

A geo-spatial database and model of this type could be created via a collaborative program led by *Geoscience Australia*, together with the *Australian Bureau of Statistics Environment Australia*, *CSIRO*, and the *Australian Greenhouse Office*. Dedicated resources would have to be provided to these agencies to carry out such work.

The following recommendations emerge from the above discussion.

(1) Public sector geoscientists and minerals industry personnel should liase with the Australian Bureau of Statistics over the value of the minerals exploration capital stock used in the National Accounts. The aim should be to ensure that this capital stock estimate accurately reflects the underlying commercial value of the proprietary accumulations of knowledge and data used to improve the economic efficiency of the minerals exploration process. Particular attention should be paid to the rate at which this capital stock is depreciated. An industry-led working group would provide a suitable mechanism for doing this – coordinated perhaps by the Australian Minerals Industry Research Association (AMIRA International).

(2) Greater efforts are needed to understand the impact of the accumulation of knowledge, data and techniques associated with the exploration capital stock on the investment risks faced, and investment levels required, when prospecting for minerals. It would also be useful to seek to quantify the additional investment risk reduction benefits that originate from improvements to public domain data-sets made on the basis of corporate reports on exploration outcomes. These aims could be met by initiating a research project aimed at quantifying:

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[29] Although the atmosphere does not have an identifiable owner, and is not therefore treated as an economic asset in the System of National Accounts the impact of climate change and other atmosphere-related processes does impact upon asset values.

[30] I am grateful to Andrew Davies for suggesting this link.

a. how geoscience R&D and the release of geological data-sets, in combination with other factors such as tax/royalty rates affects minerals exploration investment levels and the value of the exploration capital stock

b. how the knowledge embodied in the minerals exploration capital stock influences the productivity of the exploration and development process (as reflected in the cost of adding to sub-soil assets)

c. how the 'feed-back' from these minerals exploration outcomes in turn improves the public domain data-sets and reduces the investment risks faced in future exploration activity.

A formal investment risk-based model of these inter-relationships would provide the missing links in the chain of causality via which the geoscience community and the minerals industry are able to translate expenditure on geoscience R&D into the strength of the national balance sheet. An industry-led and financed project with participation by academic geoscientists and economists would provide a suitable mechanism for completing this chain of causality. Again, this could be led by AMIRA International.

(3) Public sector geoscientists should also establish stronger links with the Australian Bureau of Statistics over the production of 'integrated economic and environmental national accounts' in line with new international guidelines (SEEA). The aim of these links would be to ensure that full use is made by the ABS of all available geo-scientific data and knowledge. Particular emphasis should be placed upon extending the scope of the advances in the national accounts to include the economic impacts of natural hazards and to understanding how they relate to the process involved in environmental degradation and the impact of climate change. Geoscience Australia could coordinate this liaison on behalf of the Australian geoscience community. This liaison would need to balance the ABS' priorities for developing environmental national accounting with the specific interests of the geoscience community by identifying areas of common interest. The ABS has limited resources available for developing environmental accounting and it would therefore be useful to identify the areas in which external resources would complement internal ABS resources.

(4) Consideration should be given to exploring the attractiveness and the feasibility of producing an integrated geo-spatial map of the risks posed to Australia's economic assets by the *combined* impact of environmental degradation, climate change and natural hazards. A national map of *economic risk contours* could play an important role in ensuring that both the general community and markets have access to the best possible information on the risks that influence the price of location-specific assets such as land and buildings. Widespread dissemination of this information would help to ensure that

markets operate efficiently in driving adjustments to the inter-dependent challenges posed by environmental degradation, climate change and natural hazards. A publicly financed scoping study would provide the necessary assessment of the attractiveness and the feasibility of this concept.

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Annex A: Explanation of how economic growth is adjusted to take into account the net depletion and degradation of natural resources

The following account of the process of adjusting Gross Domestic Product (GDP) in order to factor-in the depletion and degradation of natural resources is based upon the article published in the ABS 2002 Year Book (ABS 1301.0 2002) and re-printed with some small changes in ABS 4617.0 2003 'Environment by numbers'. The table in the following page details the stages in these adjustments. This exposition differs from that provided by the ABS in order to make the process more understandable to someone without a detailed knowledge of the National Accounts.

The process starts with the conventional GDP measure (A), and working downwards, deducts the consumption of fixed capital (broadly equivalent to depreciation of the nation's produced fixed assets) in order to arrive at Net Domestic Product (C). The total value of subsoil depletion (the reduction in *economically demonstrated resources* due to extraction as distinct from price changes)[31] and the cost of land degradation is then calculated (G). The total value of depletion and degradation is then deduced from Net Domestic Product in order to produce an estimate of NDP taking the depletion and degradation of the nation's natural assets into account. The net gains from sub-soil asset additions are then calculated by subtracting the cost of mineral exploration from these discoveries. It is necessary to add the Consumption of Fixed Capital in minerals exploration because this figure has already been deducted in the process of producing the conventional figures – in these estimates the cost of mineral exploration provides an alternative means of handling this issue. Depletion adjusted Net Domestic Product in then calculated by adding the net contribution of mineral exploration (L) to the NDP that includes the estimate of depletion and degradation (G). Rows N and O pull-out the impact of the overall net depletion adjustment on Net Domestic Product and indicate what this adjustment looks like when the net gains from sub-soil asset discoveries are *excluded*. The final row therefore tells us what the underlying downward adjustment to NDP is *without* the benefit of new mineral discoveries.

[31] The estimated reduction in the value of EDRs due solely to extraction is based upon modelling work.

Table A.1: Calculation Depletion Adjusted Net Domestic Product

	$m (current prices)	Year								
		92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
A	Gross Domestic Product (GDP)	425,706	446,480	471,348	502,828	529,886	561,229	591,592	629,212	670,029
B	Consumption of Fixed Capital	69,775	73,773	76,264	78,617	80,376	86,160	91,316	97,663	104,292
C=A-B	Net Domestic Product (NDP)	355,931	372,707	395,084	424,211	449,510	475,069	500,276	531,549	565,737
E	Subsoil depletion	1,531	1,509	1,650	1,640	1,892	1,703	1,710	2,073	2,785
F	Land degradation	299	301	306	313	318	322	322	329	344
G=E+F	Total depletion & degradation	1,830	1,810	1,956	1,953	2,210	2,025	2,032	2,402	3,129
H=C-G	Net Domestic Product less depletion and degradation	354,101	370,897	393,128	422,258	447,300	473,044	498,244	529,147	562,608
I	Subsoil resource additions	2,737	3,470	1,542	1,664	583	1,762	3,050	2,383	2,785
J	Cost of mineral exploration	1,418	1,471	1,791	1,905	2,257	2,300	1,916	1,562	1,563
K	Consumption of fixed capital on mineral exploration	1,086	1,109	1,147	1,199	1,248	1,316	1,364	1,448	1,517
L=I-J+K	Net contribution of mineral exploration	2,405	3,108	898	958	-426	778	2,498	2,269	2,739
M=H+L	Depletion adjusted Net Domestic Product	356,506	374,005	394,026	423,216	446,874	473,822	500,742	531,416	565,347
N=M-C	Net depletion adjustment	575	1,298	-1,058	-995	-2,636	-1,247	466	-133	-390
O=N-L	Net depletion adjustment if new net gains from sub-soil asset discoveries are excluded	-1,830	-1,810	-1,956	-1,953	-2,210	-2,025	-2,032	-2,402	-3,129

Source: adapted from data provided in ABS 4617.0 2003