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I. Precis

The economic activities of agents give rise to environmental externalities. These externalities vary in extent by type of activity, by specific impact of environmental damage, and by severity and coverage. The externalities introduce distortions in the economy which result in a change in the distribution of welfare. The objective of this paper is to provide a framework for explicitly examining the impact that environmental externalities have on the level and distribution of income, production, and ultimately, welfare. The analysis will consider the distributional impact of environmental distortions on economic activity and welfare within the current economy and between the current economy and the future economy.

In the analysis presented here, we propose to evaluate the impact that environmental externalities have on welfare using changes in the levels of consumer and producer surpluses which accrue to different activities and agents in both the current and future economies. By associating these surpluses with externality costs in a Social Accounting Matrix (SAM), the method proposed here provides an operational framework for quantifying the magnitude of these environmental distortions and tracing the distribution of the resultant rents among all the sectors and institutional actors in the current economy. The analysis of externality distortions in the current economy is strengthened by estimation of the impact of the currently generated externalities on the future economy. Three types of

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future damage categories are identified and an estimation approach is developed for each category. The estimation techniques include the construction of a future externality SAM, the construction of a multiplier matrix model, and direct allocation of welfare changes.

In the final step of the analysis, the "externality SAM" and the present-value results of the future damage estimates are subtracted from the original SAM to arrive at an environmentally corrected representation of the flows generated by the activities of the economy.

Making environmental distortions explicit is an important step in deriving a correct evaluation of the true value-added in each sector and in making clear the impact of pollution on the per-capita income of households, and hence, on distribution. In this way, the environmentally corrected SAM and SAM multiplier results can be used to derive an environmentally corrected Net National Product (NNP) measure. This environmentally correct NNP measure is an improvement over standard measures in that it accounts for current distortions in value-added due to environmental externalities and accounts for environmental damage that is "debited" to future generations.

The environmentally corrected NNP measure derived with the environmental SAM and multiplier results takes into account both intergenerational and current distortions in production, consumption and welfare that arise from environmental externalities. However, the environmental prices used in the analysis are not derived from an optimal growth path and do not represent optimal prices. Instead, these prices reflect estimates of surplus changes that occur because of the damage sustained by current and projected victims of the externality. The damage and surplus-change estimates, and hence the environmental prices, are agent and sector specific. The environmentally corrected NNP number is not more or less sustainable than unadjusted NNP.

The analysis recognizes the constraints inherent in empirical valuation techniques and differentiates between environmental valuation methods that utilize actual market-based techniques and those that utilize non-market techniques.

The methodology proposed here is analogous to that used in the analysis of international trade to quantify the rents arising from quantitative restrictions in international trade (Buchanan and Tullock [1965], Baghwati and Srinivasan [1981], and Krueger [1983]). However, in this research, we are more concerned than these authors with making explicit how the rents are distributed among firms, consumers, and the government and among wages, profits, consumption and savings. There are also elements of our approach in the Little-Mirrelees [1974] project evaluation methodology. Our analysis is more general-equilibrium than the actual (though not conceptual) Little-Mirrelees project analysis methodology and entails the quantification of the distributive consequences arising from the use of market prices instead of environmental prices.

In Section II, economic accounting for environmental externalities is discussed. Section III gives a discussion of environmental externalities and welfare distortions. In Section IV, the changes in consumer and producer welfare that arise from environmental distortions are examined. In Section V, environmental accounting within the context of a Social Accounting Matrix is discussed and a brief literature review is given. In Section VI, a schematic externality SAM is used to trace through the distributional effects of environmental distortions. Section VII presents the calculations for an environmentally corrected Net National Product. In Section VIII, the methodology developed in Sections V-VII, is applied to the construction of an agriculturally oriented SAM for California which is used to examine the welfare impacts of groundwater contamination generated by the California cotton sector. The conclusion is presented in Section IX.

II. Environmental Distortions and the Accounting System

Throughout the 70's and 80's, environmentalists sparked public awareness (or vice versa) of the interconnectedness of the economy and the environment. Growing awareness in the developed countries concerning pollution, resource degradation and irreversible depletion of natural resources was matched by a concern in developing countries that economic programs that encouraged rapid, unsustainable exploitation of natural resources were at best shortsighted and at worst destructive. In both developed and developing countries, there is continuing recognition that natural resources and environmental amenities are important determinants of the growth, stability and welfare of a socio-economic system.

Efforts to quantify concerns about the economy's impact on the environment, and to illustrate different policy scenarios have been hindered by the standard System of National Accounts (SNA). In the framework detailed in the 1968 SNA, there is only a limited accounting of the contribution of the environment to the economy, and even a more limited accounting of the impact of the economy on the environment. The 1990 SNA and its Satellite System for Integrated Environmental and Economic Accounting (SEEA), attempt to redress many of the shortcomings of the earlier SNA. (Appendix 1 gives an outline of the 1990 SNA and the SEEA.) Inspite of the progress made in revising the standard system of accounts, the debate concerning economic accounting and the environment continues.

At the very heart of the debate on environmental accounting is the concern that the benefits and costs of environmental exploitation are unfairly distributed, whether between industry and consumers, between rich and poor, or between today and tomorrow. Though the focus of this concern has been on intergenerational equity in the enjoyment of the earth's natural resources, it has been accompanied by renewed concern that the management and exploitation of natural resources often results in an inequity in the *current* distribution of the costs and benefits of resource use. At the extreme, environmental exploitation and environmental externalities can lead to the impoverishment of certain sectors of an economy while other sectors prosper.

Much of concern about the distribution of natural resource and environmental use arises from the observation that incomplete prices (and incomplete property rights) can lead to environmental externalities in which all of the costs and benefits of resource use do not accrue to a single agent. Examples of environmental externalities are abundant. They range from the classic negative example of the smoke from a factory blackening the drying clothes of a neighboring laundry to the classic positive example of the benefits to an apple orchard from the cross-pollinating services provided free of charge by a neighboring apiary. Other examples include a factory that dumps waste into a stream that is used for fishing and swimming, and a hillside lumber operation that results in soil erosion which reduces the profitability of farms located at the base of the hill. The examples can be inter-regional or global as in the case of ivory embargoes and the livelihoods of elephant hunters and their families, or in the case of fluorocarbons and the destruction of the earth's ozone. The examples can also be intergenerational, as in the case of economic production today that results in irreparable damage to the environment.

Even more importantly, environmental externalities and incorrect valuation of the costs and benefits of natural resource use can lead to a misallocation of research and development funds, government subsidies and defensive expenditures. This misallocation can trigger structural change in the economy that further encourages inappropriate resource use.

Though we restrict our discussion to the distribution of the costs and benefits associated with environmental externalities, the distinction between externalities and exclusivity, particularly when considering intergenerational distortions, tends to become blurred. An externality produced by the current economy could have such devastating effects on the environment that future economies could not use or enjoy certain aspects of the environment. Through the externality, the current economy precludes use by future generations of a non-degraded environment. The current economy essentially assumes exclusive use-rights over certain aspects of the environment through the production of the externality.

III. Environmental Externalities and Welfare Distortions

The concept of an "externality" was introduced by Marshall and has been widely applied in the environmental economics literature. In general, there are two conditions necessary for an externality to exist (the definition presented here is Baumol and Oates' [1988]). First, an externality exists whenever some individual's (say A's) utility or production function includes real variables whose values are chosen by others without particular attention to the effects on A's welfare. Second, the decision maker, whose activity affects the utility levels of others or enters the production functions of others, does not receive (pay) compensation equal in value to the resulting benefits (or costs).

As a result of an externality of the sort described above, a wedge is introduced between the marginal private product (or cost) and the marginal social product (or cost). This is illustrated in Figure 1 below.

Figure 1
Private vs. Social Cost

In Figure 1, the demand for the good produced by the polluting firm is shown by the demand curve D, and the private marginal cost of producing the good is shown by curve MCp. The cost to society of the production of the good includes the negative effects of the pollution produced in the production of the good and is shown by curve MCs. The polluting industry maximizes profit by producing Qp at Pp. From society's point of view, however, production should take place at Qs and Ps. The fact that the producer does not include social marginal cost in his profit-calculus results in over-production of the good by (Qp - Qs), over-production of pollution, and a larger producer surplus than would be achieved if the producer had paid all the costs of production including pollution costs.

Analysis of environmental externalities from the point of view of the deviation between private and social costs and benefits situates the discussion within the framework of the theoretical welfare analysis of Pigou (1920). The Pigouvian approach to externalities involves calculating the dollar-compensation that must be paid in order to compensate for the reallocation of welfare that results from the deviation between social and private costs and benefits. The change in welfare that results from the externality is measured by the change in consumer or producer surplus, where consumer surplus is defined as the area under the ordinary (Marshallian) demand curve and above the price line, and producer surplus is defined as the area above the supply curve and below the price line. Consumer and producer surplus are money measures of welfare changes.

The use of consumer and producer surplus to measure consumer and producer benefits was proposed by Dupuit and further developed by Marshall. Producer surplus and its sister measurement "quasi rent" have been generally recognized as accurate money measures of changes in producer welfare, but consumer surplus has been deemed to be an unsatisfactory measure of consumer well being (see Just et al. [1982] for a detailed analysis of consumer surplus and welfare measures).

The basic criticism of consumer surplus arises from the fact that this measure is based on the Marshallian demand curve, which holds *income* rather than *utility* constant as one moves along the curve. This fact poses a number of problems when assessing the welfare change arising from price or quantity changes. It has been demonstrated that the conditions under which consumer surplus actually measure a true, unique "surplus of utility" are restrictive. These conditions include that 1) the marginal utility of income must be constant with respect to price and or income change and 2) income elasticities must be the same for all goods for which prices change and zero if income changes. Strict satisfaction of these conditions poses unrealistic restrictions on preference schedules, and as a result, consumer surplus measures have been discredited on theoretical grounds. Other measures, namely Hicksian willingness-to-pay measures, which hold *utility* rather than *income* constant, are preferred by welfare economists.

However, applied economists are, more often than not, unable to generate willingness-to-pay measures, or the expenditure curves which can serve as the basis for their construction. As a result, welfare economists have developed guidelines to express the margin of error that should be expected in using consumer surplus rather than "true" willingness-to-pay measures, as expressed by compensating and equivalent variation (Willig [1976]). In his work, Willig found that consumer surplus can be used for approximating compensating and equivalent variation in single-price-change cases where the change in consumer surplus is a very small fraction of total income. In this case, less than a 5% error may be made by using consumer surplus as an estimate for compensating or equivalent variation.

The study presented here adheres to the conditions for using consumer surplus "without apology." In the examples we consider it is reasonable to assume that for most consumers, the magnitude of the changes in consumer surplus in relation to income will be quite small . In addition, each price change will be examined individually.

IV. Surplus Measures of Environmental Externalities

The manner in which environmental externalities translate into positive or negative incremental changes in consumer or producer surplus is examined next. A change in surplus can arise from unregulated externalities as well as from economic policy designed to control externalities. Surplus measures of distortions in unregulated and regulated economies are both examined below.

IV.1. Environmental Distortions in Unregulated Economies

In principle, the prices generated by economies which do not take account of environmental externalities can lead to four types of rents. First, are those rents which are enjoyed by the externality-causing industry and its clients. Second are those negative rents which are suffered by industries that are negatively affected by the externality. Third, are those rents that accrue to industries that supply goods or services that provide some defense against the externality. Fourth, are those rents suffered by households and individuals who are affected directly by the negative externality. Each of these four types of externality rents is examined.

The first type of rent involves the externality-generating industry. For the pollution-originating sector, not taking account of the negative externalities which they generate or of the environmental services which they enjoy free of charge (or at less than full price) is equivalent to a producer-subsidy; their subsidized supply curve is to the right of the "environmentally correct" supply curve and they are the beneficiaries of producer rents. As a result, these producers generate more employment and the purchasers of their products, both other producers and final-demand users, benefit from lower market prices, which give rise to a positive incremental purchaser-surplus. In addition, increased production on the part of the polluting firm leads to increased demand for inputs (derived demand), thus increasing the producer surplus of those industries which supply these inputs. (Note that the accompanying rise in input price will eventually lead to a dampening of production in the original polluting industry.) The positive increments to producer and purchaser surpluses are illustrated in Figures 2-4.

Figure 2
Positive Incremental Producer Surplus

Figure 3
Positive Incremental Purchaser Surplus

Figure 4
Positive Incremental Derived Producer Surplus

The second type of rents are those negative rents which are suffered by industries that are perversely affected by the externality. Producers on whom environmental damage is inflicted are, in effect, taxed. Their supply curve is to the left of the supply curve that would obtain in the absence of externalities: they employ fewer workers; the users of their products pay too high a price, and incur negative purchaser surplus. Those industries which supply inputs to the pollution-damaged producers also experience a fall in demand for their goods and a corresponding decrease in their producer surplus. The negative increments to producer and purchaser surpluses are illustrated in Figures 5-7.

Figure 5
Negative Incremental Producer Surplus

Figure 6
Negative Incremental Purchaser Surplus

Figure 7
Negative Incremental Derived Producer Surplus

In addition to the upward shift in their marginal cost curves, certain industries that are affected by the externality could experience a direct fall in demand. Household valuation of polluted goods and services versus unpolluted goods and services could result in a direct downward shift in demand. For example, demand for recreation areas or attractions that are degraded by an externality will go down as will demand for housing in polluted areas.

The third type of rent is a result of an increase in demand for goods and services that provide defense against the externality. Industries that provide these goods and services experience an upward shift in demand as shown in Figure 8. This shift results in an increase in producer surplus.

Figure 8
Demand Shift

With the fourth type of negative rents, those agents that are directly affected by negative externalities from the pollution-generating sector (for example, households living near an air-polluting factory) are also, in essence, taxed. They incur negative consumer rents from the pollution, which must be subtracted from the positive consumer rents they get as purchasers of the polluter's output. For consumers, the negative rents induced by pollution arise from a decline in health and life expectancy, and from a decrease in the general quality of life. As a result of the pollution, households might spend more on defensive goods and services. This could result in a redistribution of expenditure and savings.

IV.2 Distortions Through Environmental Regulation

The manner in which environmental regulations compensate or correct for the distortions introduced into the system by environmental externalities can itself introduce a whole set of distortions into the system. For our discussion, three types of environmental regulation will be examined: one type which specifies commodity-controls (conservation policy, product-bans or restrictions, etc.), one type which specifies input-controls (pesticide bans, toxic chemical restrictions, etc.), and one type which directly regulates the production or management of externalities (restriction of fluorocarbon emissions, carbon dioxide emissions, etc.). In each case, the regulations themselves result in distortions and in the creation or redistribution of rents.

Quantity Controls

In the case of regulation through quantity controls, firms directly affected by the regulation have a kinked supply curve. Unlike regulation through input restrictions, there is no incentive for a change in relative input-demand with quantity controls. Figure 9 illustrates the case of binding quantity controls.

Figure 9
Quantity Control

To the extent that the regulation is effective, suppliers are off their non-kinked supply curve and both suppliers and demanders are rationed. In this case, the producers that are directly affected experience a negative incremental producer surplus and the purchasers of their products experience a negative incremental purchaser surplus. This negative effect extends to industries that supply the controlled firm and to depressed employment levels in all negatively impacted industries. By contrast, the firms and agents that purchase commodities that were negatively affected by the environmental effect experience a positive producer or purchaser surplus due to the regulation. This is also true of firms that supply these industries. Employment levels in industries that benefit from the externality will go up.

Input Restrictions

In the case of environmental regulation through input restrictions, the producer cost curve and hence the supply curve shifts up to the left, at least in the short run, in reaction to higher-priced inputs which must be used instead of the banned or restricted input. The extent and duration of the shift depends on the existence or development of non-polluting substitute inputs or of technologies which reduce the use of polluting inputs. The change in producer surplus is indicated by the difference between areas B and A in Figure 10.

Figure 10
Input Restrictions, Direct Pollution Control, and Defensive Expenditures

Again, the producers that are directly affected experience a negative incremental producer surplus and the purchasers of their products experience a negative incremental purchaser surplus. Firms that supply these industries will also be negatively affected. And, by contrast, the firms and agents that purchase commodities that are negatively affected by the environmental effect experience a positive producer or purchaser surplus due to the regulation. Firms that supply these industries will be positively affected. The level of employment will be redistributed from industries that are negatively impacted by the restrictions to those that are positively impacted.

Environmental Defensive Expenditures

Another type of environmental expenditure, though it does not involve regulation, can be added to the list above. These expenditures include defensive expenditures, or clean-up costs undertaken by the government to compensate for environmental distortions which have remained unchecked. Expenditures on the part of the government which are not accompanied by a taxation scheme which taxes environmental users in proportion to the environmental damage they inflict will continue to "subsidize" the polluting industries. Where taxation is proportional to environmental damage, the polluting firms will experience a shift in their cost curves of the sort illustrated in Figure 2.

The shift in government expenditure toward environmental defensive goods and services generates surplus and new employment in industries producing these goods and services. If government expenditure is curtailed in other areas in order to compensate for the increase in defensive expenditure, then surplus and employment in these areas could decrease.

V. Environmental Distortions and the Social Accounting Matrix

The distribution of the costs and benefits of an externality can have an important impact on an economy's distribution of welfare. As illustrated above, distributional impacts occur between agents that are directly affected by the externality and those that are only indirectly affected; between workers in pollution-generating industries and workers in pollution-suffering industries; and between purchasers of environmentally subsidized products, and purchasers of products which are more expensive or of lesser quality because of the externalities. A partial equilibrium evaluation of the incidence of these externalities will not suffice since the net impact of the environmental distortions is often unpredictable and hard to evaluate without an economy-wide quantitative framework. Every change in externality or pollution control has an impact on all other prices and quantities. One must capture the direct and indirect percolation of rents throughout the system to understand the real extent to which particular activities or enterprises benefit or suffer from the externality and the extent to which different consumers or types of consumption benefit from the externality. For this reason, a general equilibrium framework such as a SAM is essential for understanding the extent of the impact of environmental distortions on the economy.

The SAM was developed by Stone, and has been used to model a wide array of economies for policy analysis and economic planning. (See Pyatt and Round [1977] and Pyatt and Roe [1977] for bibliographies and examples). The Social Accounting Matrix is a form of double entry accounting in which the accounting entities in national income and product accounts and in input-output production accounts are presented as debit (expenditures) and credit (receipts) in balance sheets of institutions and activities. Activities may include agricultural and non-agricultural production (or any disaggregation of the two). Institutions include households, firms, government, and the rest of the world. Entries in the SAM include intermediate input demands between production sectors, income (value added) paid by production sectors to different types of labor or capital, the distribution of wages across different household groups, and the distribution of household-group expenditures across savings, consumption of domestically produced goods and services and imports. A government account collects income from activities and households and allocates it to government consumption, investment, transfers to production activities and households, savings and payments to foreigners (for imports and debt service and repayment).

The total product of each activity in the SAM must be earmarked for some use, inside or outside the economy (intermediate demand, consumption, investment, government demand or exports). Total gross receipts of each activity must be allocated to some entity inside or outside the economy (purchases of inputs from other activities, payment to labor and capital, imports, taxes, and savings).

By convention, columns of the SAM represent expenditures while rows indicate receipts. The salient characteristic of SAMs, derived from double entry accounting, is that the sum of receipts (row sums) and the sum of expenditures (column sums) must be equal for each and every account in the system. The SAM accounting framework thus guarantees that there are no unaccounted for leakages. Another salient feature of the SAM is that the SAM categories to which incomes and expenditures are assigned are the same on the revenue and expenditure sides, so that the SAM is a square matrix.

The great strengths of the SAM are its comprehensiveness and its flexibility in portraying diverse institutional settings and economic structures and in providing a framework for addressing different policy issues. The SAM is superior to the National Accounts Framework in that it includes a portrayal of interactions within a particular account (e.g., production, enterprises or households). Each of the accounts in the National Accounts is expanded from a scalar into a matrix. The Social Accounting Matrix is also superior to the Input Output framework in that it endogenizes incomes and consumption and thereby permits accurate appraisal of the full ultimate effects of specific changes.

In the economic/accounting literature, the interest in a SAM accounting framework was motivated by a number of issues, two of which will be touched on here. First, a SAM, unlike the National Income Accounts (NIA), provides a flexible framework for data organization that is compatible with alternative analytical uses; the SAM framework is capable of integrating an accounting framework and modeling applications (Hanson and Robinson [1991] give a good examination of the role of SAMs in linking data and modeling requirements). The SAM framework and the general equilibrium models which are built upon it are of particular interest when a partial equilibrium approach is not sufficient.

The second motivating factor behind the introduction of the SAM framework was the refocusing of interest on the part of economists from macro to micro issues. R. Stone describes this motivation in the following way. Stone (1961) pg. 110

> The term social accounting, as opposed to national accounting, is used to denote the activity of designing and constructing a system of accounts which will embrace all the ramification of an economy, as far as these are measurable....The transition from national accounts to social accounts involves .... the replacement of a simple structure by a more elaborate one..

In the economic literature, the shift from NIA to SAMs, and the desire to examine all of the "ramifications" in an economy gave rise to the resurgence of interest in issues involving micro or structural analysis such as the extent and incidence of poverty, income distribution and industrial structural change. A SAM provides a vehicle for this research by reconciling micro accounts with macro accounts thus providing a framework to examine not just the interplay of micro elements in the economy, but also the impact of micro shocks on structural change, income distribution, etc.

In the environmental accounting literature, the reasons for the use of the SAM framework have tended to mirror the reasons for its inception, though most of the current work involving SAMs and the environment has tended to focus on the role of the SAM in providing a link between environmental accounting and general equilibrium modeling. Bojo et al. [1990], Dasgupta and Mäler [1991], Mäler [1991], and Weale [1992] use the SAM framework to examine the general equilibrium consequences of different environmental accounting approaches. Bojo et al. use the SAM framework to illustrate the types of modifications which should be made to the accounting system to better reflect defensive expenditures, damage to individuals from environmental degradation, and the depreciation of natural stocks. Mäler develops a Net Welfare Measure, and then uses the SAM framework to illustrate how environmental resources should be included in national accounting systems, and how the conventional Net National Product measure should be adjusted to reflect sustainable income. Weale develops an environmental SAM for

Indonesia (where the social accounting matrix is taken from Khan and Thorbecke [1985] and the environmental linkages are taken from Repetto et al. [1989]) to examine accounting techniques used to measure the decumulation of natural resources and the cost of repairing environmental damage. Through the development of the environmental Indonesian SAM, Weale also describes the role that the SAM framework can play in linking environmental national accounts to an environmental/economic model. The system of statistics he presents with his SAM is consistent with the structure of the SNA, and can be consolidated to the tables in the System of Environmental and Economic Accounting described by Bartelmus, Stahmer and van Tongeren [1991]. The framework he develops in his SAM is also consistent with the modeling needs of environmental economists. In Weale's SAM he identifies three types of environmental/economic linkages: land degradation, deforestation, and depletion of oil reserves, and he is able to derive a set of environmental multipliers for these three resource issues. Weale is able to demonstrate that the modeling of environmental effects is possible with only a slight adjustment of a "typical" social accounting matrix.

Resosudarmo and Thorbecke (1995), develop a SAM of Indonesia that incorporates the linkages between economic production, air pollution and health costs. Their analysis utilizes the strengths of the SAM in differentiating between socio-economic groups, and they examine the impact of environmental management on household incomes for different socio-economic classes. Unfortunately the linkage between the economy, air pollution, and income is not complete in that morbidity is not linked back to employment and income.

In the work of Bergman (1991), the SAM framework (in this instance, a computable general equilibrium model), is used to examine the general equilibrium effects of emission control programs of SOx, NOx, and CO2 on input and output prices and the allocation of resources in the Swedish economy. Bergman (1991) develops a computable general equilibrium (CGE) model that includes markets for both emission permits and technologies for emission control, and examines the general equilibrium effects of emission reduction policies. His objective is to highlight the necessity of using general equilibrium analysis as opposed to partial equilibrium analysis, as is standard practice, to examine emission controls for major pollutants. His findings suggest that

> ...under certain conditions environmental policy measures have general equilibrium effects. Unless these general equilibrium effects are taken into account, policy analyses might give a distorted picture of a set of proposed environmental policies. The reported results also suggest that the implementation of reasonably large computable general equilibrium models is a feasible undertaking, and that models of this type can be useful as a device for ex ante policy evaluation.

Aside from the work by Resosudarmo and Thorbecke (1995), the use of the SAM for environmental accounting and modeling has not extended to distributional or structural change issues. And yet, the very nature of environmental externalities, and the corresponding distortions which they create in the economy, calls for an examination of the welfare-distribution impacts. Through the creation of an environmental externality SAM, we will attempt to provide a framework for examining the welfare distribution consequences of environmental externalities.

VI. The Externality SAM

Each environmental externality gives rise to a set of interconnected flows that can be portrayed in an "externality SAM" due to that particular distortion. The measured flows in market economies capture only the rectangles circumscribed by the observed market prices and the observed quantities sold. But, in the presence of environmental externalities, the observed prices and quantities are very poor indications of the real values and costs of the commodities exchanged in the market. The externality SAM indicates the changes in the values of the flows arising from specific environmental externalities.

Production forms the core of economic activities and generates direct environmental consequences which trickle through from one sector to another, through the purchase of intermediate inputs. Production also generates value added which is distributed to economic institutions as income. As a result, households, enterprises, government and the rest of the world all experience externalities from the environmental effects generated by production. In addition, institutions themselves generate direct environmental effects, which impact on each other as well as on production (e.g. air pollution from cars may reduce agricultural yields). Institutions also purchase the net output of production. These purchases are another path through which externalities from production are transmitted. They also offer a mechanism through which changes in consumption patterns can affect the structure of output and, hence, the degree of pollution.

The purpose of the externality SAM is to provide a relief-map of the distribution of environmental distortions in the economy. The externality SAM separates those flows in the economy which are generated by environmental externalities from other flows in the economy and in this way, provides a sharp evaluation of those who benefit from the environmental distortion, and those who are made worse off because of the distortion. The externality SAM provides a mapping of the negative or positive increments to producer or consumer welfare in the economy. The externality SAMs also indicate the taxes and lump sum transfers that must be added to the market-price based SAM economy to induce the same behavior and income for all institutions and sectors as would have obtained in the absence of the externality under the existing non-market regulations.

The general equilibrium nature of the SAM provides a more accurate picture of who benefits and who loses from pollution once higher round interactions are evaluated than a partial equilibrium approach. As a result, the SAM framework enables one to trace through the ultimate incidence of any particular type of economic intervention to reduce pollution. It can therefore also be used to anticipate where the strongest political resistance to environmental legislation or environmental taxes is going to come from and where the strongest support for such measures can be mobilized.

The methods used to derive the externality SAMs are analogous to those discussed in Adelman, Berck and Vujovic (1990). We illustrate these procedures by reference to rents and externalities arising from water pollution in agriculture. The derivation of externality SAMs due to air pollution and land degradation and for other sectors of the economy is conceptually similar. The actual estimation of the environmental distortions is done in two steps. First, we estimate the price-equivalents of the environmental distortions in each sector of the economy. Second, we use information contained in a SAM plus information on elasticities to evaluate the direct and indirect rents received by each activity and agent and to distribute these rents to factors, enterprises, households and government; and between current consumption, investment and the public deficit.

VI.1. Ecological Prices in an Accounting Matrix

The estimation of ecological or environmental prices is an important and controversial element in green accounting. The ultimate meshing of environmental and economic accounting depends on generating the cost of the externality or of the "corrected" versus the "uncorrected" price of the environmental good or service.

Much of the literature on environmental pricing and economic accounting is concerned with computing environmental prices that are associated with an optimal growth path. By contrast, the corrected prices computed here do not represent optimal prices, in the sense that they are not derived from an economy on an optimal growth path. The prices computed here do not represent sustainable prices any more than do market-generated prices. Rather, these prices are an economic valuation of environmental services in cases where these services are not traded in the market.

The economic literature on resource and environmental valuation is growing at a great pace and a methodology for estimating the value of non-marketed environmental services is quickly being established (See Navrud [1994] for a comprehensive review). Resource and environmental economists have conducted studies to estimate the value of a wide range of environmental services; from the value of fishable, swimmable and boatable water, to the value of clean air in residential areas; from the value of bio-diversity, to the value of the western spotted owl; and from the value to residents of Nebraska of clean water in Alaska, to the value today of a forest tomorrow. The array of methodologies which economists use to derive money-value amounts includes the contingent-valuation method, the travel-cost method, the hedonic-pricing method, and the cost-of-illness method. For the construction of the externality SAM, we rely on the fairly extensive research that has been conducted in California on environmental valuation. To convey the extent of work done in this area, a 1985 bibliography on the effects of air pollution and acid rain on agriculture [Barse et al. (1985)], includes 21 entries concerning the economic effects on crop producers and consumers.

The manner in which the cost of the externality is estimated has important philosophical and methodological implications for incorporating environmental externalities into an accounting system. Costs that are calculated from market transactions (such as the tabulation of defensive expenditures, travel cost method, cost-of-illness method, and the hedonic price method) are fundamentally different from those calculated using non-market valuation techniques (such as the contingent valuation method and any method where preferences are not translated into actual money transactions). Costs that are calculated from actual market transactions are firmly linked to the rest of the economy and can have reverberations on the rest of the system. The SAM, or any accounting system, registers these costs in the current account as changes in the allocation of expenditure and production. Damage estimates of this sort could also be forwarded for payment by future economies.

By contrast, though non-market money measures of the value of environmental amenities might accurately translate environmentally derived welfare into money terms for comparison with other money measures, these non-market estimates impact differently on the rest of the economy because, though incurred, they are not paid. Estimates which rely on non-market measures of externality costs provide an indication of welfare loss that is not translated into economic activity. The benefits of the externality resonate throughout the economic accounts, but the effects of these unpaid *costs* are not measurably linked to the economy. Nevertheless, these estimates mirror a decline in welfare. In the analysis presented here, we have chosen to allocate damages of this sort to the future economy and discussion of their incorporation into the economic accounts follows the development of the current account schematic SAM.

VI.2. The Current Account Water-Externality SAM

In this section, we locate the rents which arise from water pollution on a schematic externality SAM. Conceptually, each entry in the schematic SAM reflects the changes in producer and purchaser surpluses for each sector or agent that generates water pollution or uses water.

We begin unraveling the effects of environmental distortions on the economy by calculating the cost of the environmental externality. The cost of the environmental externality is used to derive the change in consumer and producer surplus that accrues to the victims of the externality. This calculation is pivotal, in that the change in the victims' producer and consumer surplus serves to determine the benefit of the externality that accrues to the polluting industry. The change in producer and consumer surplus that accrues to the downstream industries and consumers represents the amount of the subsidy that is paid to the polluting industry. This subsidy to the polluting firm has an impact throughout the economy in that it redirects production and consumption. In this analysis, "environmental prices" are derived by calculating the pre-subsidy equilibrium prices.

The first step in calculating the externality SAM is to identify the defensive or other compensatory expenditure flows in the original SAM, i.e., the amount that is paid by the victims of the externality to those industries or services that provide some defense or alternative against the externality. For each sector and each industry, it is then necessary to establish the change in producer and consumer surplus for the sufferers of the externality. The next step is to determine the negative change in consumer and producer surplus that results from the externality but is not registered in the current accounts (i.e. changes measured by non-market methods). The total negative change in surplus represents the benefit to the polluting industry; it is the subsidy that is enjoyed by the polluting industry.

The types of flows that are generated by the externality are illustrated below in Figure 11, The Schematic Externality SAM. In the discussion that follows, the change in flows that arise from the externality are examined for each block of the schematic SAM.

Block A

The first effect registered in Block A is that the polluting industry enjoys lower input prices due to the "environmental subsidy." The environmental subsidy shifts the producer's marginal cost curve, resulting in a new equilibrium price and quantity (where the exact change in price, quantity and revenue depends on the elasticities of supply and demand). In Block A, this increase in production is allocated according to share coefficients to those activities producing an input for the polluting industry.

The second effect registered in Block A is that intermediate demand enjoys lower cost inputs from the freely polluting industry. The environmental subsidy leads to a reduced selling price for the output of the subsidized industry and this is passed on to both intermediate and final demand. As a result, the marginal cost curve of industries that use cotton as an input shifts downward generating a new equilibrium price, quantity and revenue. Block A allocates the change in revenue among inputs according to the share coefficients.

Industries that supply goods or services that defend against the externality also enjoy a positive change in surplus. As a result of the externality these industries experience an increase in demand. Block A records the increase in the production of environmentally defensive goods and services as well as the increase in demand (and production) for inputs to environmentally defensive industries.

Block A also records the negative impacts of the externality on the production of "down-stream" industries. Due to the externality, these industries experience an upward shift in their marginal cost curves and a reduction in production. This upward shift in marginal cost arises because of the increase in defensive expenditures. The resulting decrease in production causes a decrease in other inputs. Both the increase in defensive inputs, and the decrease in other inputs is registered in Block A.

For producers, the change in water-rent directly due to environmental damage is also registered in Block A. The quantity element of this rent consists of the change in productivity due to pollution, if any, applied to the base quantities of resources used; the price equivalent is valued at the non-polluted price.

Block B

The rents in the activity rows cascade down through the SAM to the value-added accounts. The change in value-added that is induced by the externality is divided between the wage bill and profits. Since the rents recorded in the activity rows imply changes in the "true" intermediate costs, they affect value added and its components. To allocate the change in value added between wages and profits requires a theory of how the labor market operates in each sector. In sectors in which labor has substantial market power, one would assume that workers can protect the purchasing power of their real wages. In these sectors, one must add to the wage rates of each labor skill the increased cost of the re-priced direct and indirect water component of their consumption bundle. In sectors with an elastic supply of labor at a fixed money wage, and a largely non-unionized or weak labor force, such as agriculture, no adjustment to the wage rate is made, though there is an increase in the wage bill due to increased levels of hiring. The change in the wage bill due to water pollution includes both the effect of purchaser surplus and the effect of productivity change. The overall change in rent flows to labor in each sector is the difference between the wage bill with and without water pollution.

The changes in rents which accrue to capital as profits and investment funds are the residual account. The residual must be calculated from the new value added minus the change in the wage bill, the change in the price of inventories, and the change in depreciation. The change in value added is the change in the rent from intermediates and is the column sum of the rent entries in the activity rows for each sector. The inventory rent is calculated by multiplying the inventory vector of final demands by $(I-A)^{-1}$, where A is the input-output table of the water-externality SAM.

Block B also records the change in capital equipment use and depreciation. The change in depreciation reflects two effects of the externality: first, those industries which use water as an input in the production process incur increased depreciation due to lower quality water inputs; and second, those industries which enjoy increased (decreased) production due to the externality also incur increased (decreased) depreciation, this time because of higher (lower) use-rates for capital.

Block C

The entries in Block C that accrue to government are the change in taxes. The entries in the activity columns of this row include the change in value-added taxes, computed on the change in value added that arises as a result of the externality, and the change in tariff revenue computed on the change in imported inputs that arises as a result of the externality.

Block C also records the impact of the externality on the importation of inputs from the rest of the world (ROW). Imports will experience an increase in demand from those industries which benefit from the externality (the polluting industry, inputs to the polluting industry and pollution-defense industries), and a decrease in demand from those industries which are harmed by the externality (downstream industries and their input industries). The size of the change will depend on the shift in demand due to the externality, and on the elasticities of supply and demand for each imported input.

Block D

In Block D, we examine institutions as the final repositories of rent. Enterprises absorb the change in returns to capital for incorporated businesses, while households absorb both the change in returns to labor and the change in returns to capital for unincorporated businesses. Block D registers the increase in the return to capital and labor enjoyed by subsidized enterprises, and the decrease in the return to capital and labor suffered by the activities which are harmed by the externality. The change in the return to capital considered here is already net of any change in depreciation or change in the price of inventories.

Block E

In the government row, Block E records the change in social security tax that results from the net change in household income as a result of the externality. It also records the change in profit-tax revenue from unincorporated businesses that results from the externality. In the capital account row, Block E records the change in savings net of depreciation on the part of unincorporated businesses. In the rest-of world accounts, Block E records the change in foreign investment in unincorporated businesses. The SAM holds investment proportionate to income.

Block F

Moving across the activity row, Block F records both the change in surplus due to the fact that final demand enjoys lower cost goods from the pollution industry, and the change in surplus due to the fact that final demand faces higher cost goods from those industries that are negatively effected by the externality. Block F also registers the increased expenditure by households for goods and services that provide some defense against the externality. This increase is matched by a decrease in other consumption goods which is also registered in Block F.

Block F also records the direct health and quality-of-life changes experienced by households as a result of the externality. Total damages of this sort consists of the price equivalent of the change in utility of the decrease in the quality of water multiplied by the consumption of water in the base, plus the value of change in health, morbidity and life expectancy due to lower water quality, plus the value of the decrease in quality of life due to water pollution. The health and morbidity can be estimated from the increase in health expenditures due to water pollution; the life expectancy component can be evaluated from the present value of the earnings stream due to shorter working life, if any, induced by water pollution. The quality of life component can only be estimated using a non-market valuation method. These values are reflected in a decrease in final demand proportionate to the change in welfare generated by the externality and the income elasticity of each good in the consumption basket.

Block G

In Block G the change in corporate earnings that results from the externality is allocated among households (distributed earnings) down the enterprise column.

Block H

In Block H, the change in corporate earnings that results from the externality is allocated between the capital account (investment/savings) and the government (business profit tax). For computational purposes, it can be assumed that the marginal rate of investment is the same as the average rate. These changes are recorded in the enterprise column. The ROW accounts in the enterprise column record the change in foreign investment in incorporated businesses that results from the externality. In the household column, Block H records the change in income tax paid by households due to changes in the wage bill and distributed earnings. The household column in Block H also records the change in savings by households that results from the externality.

Block I

The first entries in Block I are the changes in government expenditure that result from externality-induced changes in relative prices. Government expenditure also changes to include an increase in environmentally defensive expenditures as a result of the externality.

The second entries in Block I allocate the change in gross investment among the activity rows, where the change in gross investment is a result of changes in productivity and capital use that result from the externality.

The third entries in Block H record the fact that, just like agents in the domestic accounts, ROW purchasers benefit from the externality when purchasing goods or services from the polluting industry, and the reverse when purchasing goods or services from industries that are harmed by the externality.

VI.3 Future Damages

The current account externality SAM records both the cost and benefits of environmental externalities in those cases where the damages are realized in the current economy. However, in many instances, the costs of an environmental externality are not borne by the current economy, but are passed on to a future generation. In these cases, the future generation does not enjoy the benefits of the externality but pays the residual damages. Not only do future generations pay a price for current externalities, but there is often a cumulative or time element involved with environmental degradation so that the future consequences of environmental mismanagement could be more severe than those manifested in the current economy. For example, the siltation of waterways that poses only a minor inconvenience today could lead to a decrease in the fish population and habitat that could severely restrict commercial and recreational fishing activities in the future. Or, the beauty of a natural lake could be destroyed to such an extent that future generations can no longer enjoy it. Or, the health consequences of contaminated groundwater might only become evident after years of water consumption.

Not only does the future economy inherit the cost of environmental externalities, but it also inherits the direction of growth that was established in the previous economy. In the presence of environmental externalities, particularly "unpaid" externalities, the direction of growth is established on the basis of incomplete environmental prices that provide faulty signals for the direction of growth and development.

The impact of externality damages on the future economy could be estimated in a number of ways depending on the type of damage. The type of damages we will consider are environmental defensive expenditures or other damages that trigger a redistribution of economic activity; damages that entail a decline in productivity due to a degraded resource base; and damages that reflect a direct fall in welfare due to the externality. The types of analyses that we describe for examining the impact of these damages on the future economy can also be used for examining the impact of these types of damages on the current economy.

Damages that involve defensive expenditure or any damage that results in a direct reallocation of production and consumption in the future economy could be estimated through the construction of a future SAM. In the same way that the current externality SAM traces the distributional changes that arise in the current economy, the future SAM traces the distributional changes in the future economy that result from externalities generated and enjoyed in the current economy. The costs of the externality trickle through the future economy in the same way that they trickle through the current economy except that in the future economy they are not offset by the positive change in welfare that were generated by the current externality. In the future economy, no industries receive and externality "subsidy", which means that the first set of positive entries in Block A of the schematic SAM do not take place in the future economy (unless the future economy generates its own set of externalities in which case a whole new set of damages and benefits must be calculated).

In order to trace the impact on the future economy of damages that result from a decrease in productivity due to a degraded resource base, a multiplier matrix is generated from the original SAM. Damages of the sort generated by decreases in productivity are, in essence, an "exogenous shock" to the future economy, and though they could be incorporated in a future externality SAM, the SAM multiplier framework is a more expeditious framework for estimating the general-equilibrium impacts that this type of damage will have on the future economy.

The multiplier matrix illustrates the relationship between exogenous injections and endogenous income and production levels, and through the construction of the multiplier matrix, it is possible to trace the impact of exogenous change on every endogenous account in the future economy. The construction of the SAM model is easily understood by considering the decomposition of a SAM presented in Table VI.1.

Table VI.1
Decomposition of a SAM

	Endogenous Accounts	Exogenous Accounts
Endogenous Accounts	Endogenous 1 Y11 Y12 Y13 Y21 Y22 Y23 Y31 Y32 Y33	Exogenous 1 X14 X15 X24 X25 X34 X35
Exogenous Accounts	Endogenous 2 Y41 Y42 Y43 Y51 Y52 Y53	Exogenous 2 X44 X45 X54 X55

Define "Y" as the vector of column totals of endogenous accounts, i.e., the column totals of block Endogenous 1 plus block Exogenous 2. Define "N" as the vector of row totals of block Endogenous 1 and "X" as the vector of row totals of block Exogenous 2. Recall that a basic feature of any SAM is that the row and column sums must balance. This means that:

$$Y = N + X$$

Noting that N equals BY, where B is the matrix of coefficients for block Endogenous 1 (from the normalized SAM), equation 1 can be rewritten as:

$$Y = BY + X$$

Solving for Y:

$$Y = (I - B)^{-1}X$$

where $(I - B)^{-1}$ is the SAM multiplier, M. Element Mij in M represents the effect on sector (account) i of an increase in exogenous demand for sector (account) j. With the multiplier matrix, the damage caused by the externality can be traced through the future economy to calculate the change in the incidence and distribution of future economic activity.

The third type of damage involves direct changes in welfare that are not translated into economic activity. This type of damage indicates the direct decline in well-being that results from the externality. Damages of this sort include the decrease in enjoyment of natural sites due to pollution (both use and non-use values). The benefits of the externality resonate throughout the economic accounts, but the effects of these unpaid *costs* are not measurably linked to the economy. Nevertheless, these estimates mirror a decline in welfare which we reflect with a drop in real future income.

VI.4 From Externality SAM to Environmentally Adjusted SAM

Examination of the externality SAM and the results of the future-damage analyses gives a picture of the distortions that arise as a result of environmental externalities in the distribution of production, consumption, income and welfare in both the current and future economies. To arrive at an environmentally adjusted portrayal of the current economy in which the distortions caused by the environmental externalities are removed, the current externality SAM is added to the actual SAM. To arrive at an environmentally adjusted

SAM that includes natural resource depletion and degradation as it impacts future activities, the present value of the results of the future-damage analyses are added to the current environmentally adjusted SAM. Together, the environmentally adjusted SAM and the present-value future-damage estimates, provide a description of the true costs and benefits of the externality to each sector of the economy.

On the basis of the calculations described above, we can calculate a Net National Product (NNP). This is done in the next section.

VII. Green Accounting and the Externality SAM

At its strongest, the quest for a more accurate economic accounting of the environment has been a quest for economic indicators that more truly measure a society's welfare. This approach is taken by Dasgupta and Mäler (1991), who reaffirm both the need and possibility of generating Net National Product (NNP) measures which can be used to evaluate well-being. (pg. 106)

> What we are after are present and future well-being and methods of determining how well-being is affected by policy. And it is not an accident that the index which, when properly computed, can be used toward this end is net national product.

We are in sympathy with the desire to interpret NNP as a measure of welfare, and the NNP number that we derive is a more accurate reflection of welfare. Nevertheless, we recognize that in the current calculations of the SNA there are many elements of welfare that are not correctly included thereby reducing the effectiveness of NNP as a measure of welfare. In our NNP calculations we only correct for distortions caused by the specific environmental distortions under investigation.

The outline presented in Figure 12 provides a guide to the way in which NNP is presented in the SAM framework (for a detailed discussion of SAM's and National Income Accounts see Hanson and Robinson [1991].). By definition, GNP equals value-added plus indirect taxes. NNP equals GNP minus depreciation.

Through incorporation of the economic effects of environmental externalities in the current account externality SAM and the current environmentally adjusted (CEA) SAM, it is shown that environmental externalities trigger changes to value-added and depreciation throughout the current economy. These changes result in changes in GNP and NNP. Through calculation of the impact of externality damages on the future economy with the methods described above, the impact of environmental damages on future value-added is estimated. By combining the NNP number calculated with the environmentally adjusted SAM with the discounted future damage estimates, an environmentally adjusted NNP that accounts for future and current externality distortions can be derived.

The approach we have outlined for accounting for environmental externalities is substantially different from most approaches outlined in the literature. Our treatment of the major issues in environmental accounting is clarified in the next section.

VII.1 Green Accounting Issues

In broad terms, the debates surrounding the generation of environmentally adjusted national statistics can be organized into three concerns: 1) Economic accounts that do not incorporate the environment are inadequate for planning and present a distorted picture of economic activity; 2) Environmentally defensive expenditures are treated inconsistently in standard accounts and often overstate economic performance and; 3) Due to neglect of environmental depletion or degradation, GDP and NDP measures calculated from the standard SNA accounts do not represent sustainable income. Each of these concerns is examined below.

Distortion of the Economic Information System

In the 1968 SNA, natural resources and the environment are not included in balance sheets or assessed by environmental quality indicators. Through its failure to adequately register the economic services rendered by the environment and natural resources, the 1968 system does not fulfill its role as an information system. Specifically, neglecting environmental and natural resources distorts the accounts in two ways. First, these accounts overlook the production of some undesirable outputs (e.g. pollution), and secondly, they overlook or undervalue a number of environmental inputs to production. Through its distorted or incomplete accounting, it is argued that the 1968 SNA or any similar system cannot serve as a data base or information system for policy makers, researchers or economic modelers.

Through the development of the CEA SAM and the future-damage analyses, we account for environmental externalities such as pollution and provide a valuation for environmental goods or services that are unpriced. The CEA SAM and the future-damage analyses provide a thorough mapping of the impacts of environmental distortions on the incidence and distribution of economic activity in both the current and future economies. The CEA SAM and the future-damage analyses provide a picture of economic activity that is undistorted by environmental externalities.

Defensive Expenditures

The 1968 SNA offers a poor indication of a society's efforts to defend against environmental degradation. On the one hand, economic growth that results in pollution, the congestion of parks, and the irreversible depletion of natural resources is mirrored by a positive change in GNP, while on the other hand, efforts to preserve a healthy environment and a sustainable natural resource base often result in a negative change in GNP. The perversity of this situation is further complicated by the fact that the 1968 SNA treats certain defensive expenditures (measures to reduce or avoid environmental damage) incurred by industry as intermediate expenditures which are netted out of final value added, while those defensive expenditures undertaken by households and governments are generally treated as final goods, and are therefore included as productive contributions to national output.

There is much debate in the literature as to whether defensive expenditures should be deducted from GDP in order to provide a better estimate of sustainable income and whether estimates of damages to the environment as a result of economic activity should be accounted for. There is also a certain amount of contention concerning just what type of expenditure qualifies as a "defensive" expenditure.

On one side of the debate is the argument that the purchase of goods or services for protection against environmental degradation improves well-being, and that in this respect, there is nothing different about defensive expenditures from other expenditures. This point is argued by Bojo et al. (1990), who contend that if defensive expenditures are deducted from final demand, the NNP calculation that results will be absurd because increases in welfare could trigger a fall in NNP. The other side of the debate argues that defensive expenditures are not indications of improvements in human well-being, that they are instead indications of environmental degradation. Beckerman (1972) supports this point and argues that defensive expenditures are "anti-bads" and represent a drop in real income.

In the development of the environmentally adjusted SAM and the future-damage analyses, we take a middle ground between the two sides of the argument presented above. We do not deduct environmental defense expenditure from national income, but we do expose the distortions that result in the economy as a result of externalities and defensive expenditures in order to reveal the direction of economic activity that might have obtained in the absence of these distortions. In keeping with the SEEA, exposure of environmental distortions allows for identification of the part of economic activity which reflects defensive expenditures.

Depreciation

The first step on the road to recognizing the inconsistencies in the SNA with regard to depreciation, was to establish or rather reestablish the notion of the "environment as capital." El Serafy (1992), traces the notion of natural capital back to the classical and early neo-classical economists. In particular, he claims that Alfred Marshall viewed the distinction between land and capital in their capacity as factors of production as rather artificial. Stressing the capital quality of land (which El Serafy equates with Nature in this instance), Marshall is quoted,

> ....all that lies just below the surface has in it a large element of capital, the produce of man's past labor. Those free gifts of nature which Ricardo classed as the "inherent" and "indestructible" properties of the soil, have been largely modified; partly impoverished and partly enriched by the work of many generations of men. (Alfred Marshall, Principles of Economics, p.147.)

The case put by modern environmentalist and environmental economists is that the decision to husband, maintain or deplete natural resources is strictly analogous to the decision to create, maintain or deplete man-made capital. This being the case, the SNA should record environmental and natural resources as alternative forms of capital, and register the depletion or degradation of these resources, part of which represents the depreciation of natural capital.

The issues of natural capital depreciation and the degradation or depletion of natural resources have generated a lot of debate in the environmental accounting literature, but these issues generate even more debate when taken in tandem with the issue of sustainability. The recognition of nature as capital is an integral part in defining sustainable income. The notion of true, or "sustainable income" can be traced to Sir John Hicks' definition of income. In fact, on the basis of Hicks' definition, Daly (1989) asserts that the term "sustainable income" is redundant. Hicks' definition of income is as follows,

> The purpose of income calculation in practical affairs is to give people an indication of the amount which they can consume without impoverishing themselves. Following out this idea, it would mean that we ought to define a man's income as the maximum value which he can consume during a week, and still expect to be as well off at the end of the week as he was at the beginning. Thus, when a person saves, he plans to be better off in the future; when he lives beyond his income, he plans to be worse off. Remembering

> that the practical purpose of income is to serve as a guide for prudent conduct, I think it is fairly clear that this is what the central meaning must be. (Value and Capital, pg. 172)

Clearly, it is argued, any definition of income, including GDP or even NDP as defined by the 1968 SNA, which does not allow for the depreciation of all capital or production assets, including environmental and natural resources does not give a true indication of how much a nation can consume and "still expect to be as well off at the end of the week." Such measures of income are not true measures of income in the Hicksian sense of the term. Hence, the current SNA overstates income because it does not account for the consumption or degradation of natural resources.

Of course, differences exist among experts on how to adjust national accounts to reflect sustainability goals, or even whether conventional GDP measures should be adjusted. Many economists insist that both GDP and NDP in the SNA must be corrected according to the Hicksian definition of income [El Serafy (1989)]. While others insist that the core accounts of the SNA and the traditional measures of GDP and NDP must remain intact and that sustainability concerns should be addressed through the computation of new measures of "sustainable social net national product," "sustainable income," or environmentally adjusted net domestic product "EDP" and environmentally adjusted net income "ENI" [Bartelmus (1989), Daly (1989), Pearce (1989), Harrison (1989a,b), Stahmer (1992), Lutz (1992)]. The UNEP\World Bank approach to this issue was decided at an expert meeting on Environmental Accounting and the SNA in November 1988, At this meeting it was decided that it is currently impossible to value, in monetary terms, all of the functions provided by the environment and that "replacing GDP with a more sustainable measure of income is not yet feasible". In addition, though the Hicksian definition of income was adopted by an SNA expert group meeting in 1989, GDP will continue to be defined in the revised SNA without adjustment for the degradation of natural capital. Allowance for an environmentally adjusted GNP will be made through a system of satellite accounts.

Whether incorporated directly into the core accounts, or included in satellite accounts, the mode of accounting for natural capital depreciation or environmental depletion or degradation must be determined, and a number of different approaches have been adopted. In one approach, the value of the amount of the resource which has been used up is simply deducted from national income and any new resource discoveries are credited to national income [Repetto et al. (1989); Pearce et al. (1989)]. In another approach, capital gains are included [Eisner (1985, 1988)]. In the approach proposed by El Serafy (1989), the value of the extracted natural resources is deducted, but in addition, a permanent component is calculated for the revenue generated by the exploitation of an exhaustible resource, and this permanent component is added back to national income. This permanent component is calculated by multiplying an estimate of the opening value of the stock of the resource by the real interest rate.

In our development of the environmentally adjusted SAM and the future-damage analyses, we have not attempted to define or calculate sustainable income, sustainable growth, sustainable development, or sustainable NNP. The environmental prices that we use in the analysis are not derived from an optimal growth path and do not represent optimal prices. Though we do include future damage payments in the current accounts, the inclusion of these costs in current economic calculations does not necessarily make them sustainable.

Our hesitancy to embrace a sustainable interpretation of environmentally adjusted NNP stems from discomfort with the notion that there is a basis for defining "sustainability." While a lot has been written about sustainable development, the concept is not well defined. The most appropriate definition would appear to be in welfare terms. Sustainable development would consist of a development process which allows for some non-negative rate of long-term increase in per capita welfare accompanied by some non-negative rate of population growth. But this definition begs many important issues: What rates of welfare growth and population growth should be stipulated? Is the distribution of welfare to be taken as given at the initial distribution or can it be changed to achieve increases in welfare? Are institutions for access to labor markets, education, international trade and resources to be assumed as given? Are changes in the composition of consumption possible? Can there be changes in consumer tastes which allow for less resource-intensive growth paths? What changes in technology are to be taken into account? What role is international trade to play in this process? Clearly the definition of sustainable development does not require the maintenance of the stock of each resource ad infinitum. Substitution among resources in the production of individual commodities, substitution among commodities in the composition of output, conservation, changes in the distribution of income, defensive expenditures, and international trade can all contribute to save particular types of resources at the national level without lowering the rate of growth of welfare.

For all of these reasons, we consider the environmental NNP measure derived with the CEA SAM and the future-damage analyses to be a better representation of economic activity and welfare, but not necessarily of sustainable welfare. In the next section, as a pedagogical exercise, we apply the SAM framework to the California cotton sector and water-pollution externalities.

VIII. The California Cotton Water-Externality SAM

California, one of the largest and most diverse agricultural states in the nation, serves as an ideal database with which to examine issues of agricultural pollution. Agriculture in California is a rich and varied industry. California farmers produce more than 250 crops, and for the past 45 consecutive years, California has led the nation in farm production and farm income. On just 3% of US. farmland, California farmers produce more than half of the country's fruits, vegetables and nuts, and approximately 10% of all US. agricultural exports are shipped by California farmers.

The 83,000 farms in California comprise 17.1 million acres of pasture and range land, and 10.89 million acres of cropland, which includes 8.5 million acres of irrigated land. California farm real estate (land and buildings) is valued at $60 billion. Total net income for California agriculture exceeded $7 billion in 1990, which corresponds to an average of $82,710 per farming operation, or $228 per acre. In 1992 California farmers sold an estimated $18.1 billion of farm products. California farm population is less than 1% of the state's total population, but one in ten jobs in California are generated by farming activities. It is estimated that California agriculture directly or indirectly contributes $63 billion, more than 9% of the gross state product.

Agriculture clearly plays an important role in California, and the question as to the role of agriculture in creating environmental externalities and welfare distortions in the Californian economy is certainly worth investigating. For the presentation of the methodology which we have developed here, we have chosen to focus on California cotton cultivation and its contribution to groundwater and surface water degradation. We chose cotton and water externalities as our example because of the richness of the supporting research and because of the relative importance of the cotton crop. California is the second largest cotton producer in the country, and with a value of 930 million dollars (1994), cotton is the fifth most important crop in California. In addition, all cotton fields in California are irrigated.

In the empirical example presented here, we examine the redistribution of welfare in the economy of California due to water contamination (both surface and groundwater) from cotton cultivation. This example calculates the distortions arising in the allocation of resources, production, consumption, income and ultimately welfare due to the fact that cotton cultivation does not bear the total cost of water degradation and soil erosion. In the first step, we develop an agriculturally oriented SAM for California. Next, we estimate the damages to groundwater and surface water that are attributable to cotton cultivation, and allocate the current costs and benefits of the cotton water-externality among the sectors and agents in the economy. Third, we present a current externality SAM for groundwater contamination due to cotton cultivation. The difference between the current externality SAM and the original SAM gives us an current environmentally adjusted SAM. We use a multiplier matrix derived from the original SAM to analyze the impact of productivity damages from the current cotton water-externality that are passed to future generations. We deduct future damages that result in a direct drop in welfare from real income. In the last step we combine the information supplied by the current environmentally adjusted SAM and the present-value results of the multiplier analysis and the direct drop in welfare to evaluate the distortions (current and future) caused by the cotton water-externality.

VIII.1. The California Agriculture SAM

The SAM for California was constructed from output files supplied by IMPLAN (Impact Analysis for Planning). IMPLAN is a modeling system designed for constructing regional accounts and input-output tables. The 1982[2] version of IMPLAN produces a SAM summarizing macroeconomic flows, i.e., a SAM with a set of single commodity and activity accounts in lieu of an input-output table. To build a complete California SAM with a disaggregated set of production activities, the transactions, regional, institutional demands, and factor income matrices were grafted onto the summary SAM.

The California SAM is disaggregated into 22 production accounts, 5 institutional accounts, 2 factor income accounts, 2 "rest-of-the-world" accounts, and a capital account. There are nine agricultural activities: livestock, cotton, food grains, feed grains, hay and grass seed, fruits, tree nuts, vegetables, and miscellaneous crops. The twelve nonagricultural production activities are: forest products, food processing, nonagricultural industries, oil-gas and refining, agricultural chemicals, textiles, wood and paper products, nonagricultural chemicals, rail, trucking, air transport, utilities, and services. Production

[2]For the analysis presented here, the 1982 database is used because output from the 1990 IMPLAN database does not permit construction of a macro summary SAM.

activities pay for factor services to the capital and labor accounts. Institutions comprise low, medium, and high-income households, as well as government and enterprise accounts. The domestic trade account records flows of exports, imports, and income transfers between California and the rest of the United States. The foreign trade account records these flows between California and foreign countries. The California SAM is presented in Table I of Appendix 2.

VIII.2. Groundwater Contamination due to California Cotton - Damage Estimates

In recent years, concern over the extent of pollution generated by agriculture, particularly groundwater pollution, has grown rapidly. As observed by Crutchfield (1988), several factors have contributed to this development. First, is the increased use of agricultural chemicals; application rates of fertilizers tripled between 1960 and 1985. This increase is combined with a decrease of point pollution sources due to the construction of municipal and industrial treatment plants. Hence, not just the absolute, but also the relative importance of agricultural nonpoint pollution has grown. In addition, continuing studies by the EPA and USDA have highlighted the extent of groundwater contamination.

The damages due to groundwater contamination are primarily sustained by household consumers of groundwater for drinking purposes. In the terminology developed earlier, they are subsidizing cotton (and all agriculture) by the amount of the "cost" of the externality. Determining the cost of the externality to household groundwater consumers, or conversely the level of the subsidy that is paid to cotton producers, is a crucial element in the construction of the externality SAM.

As a first step in estimating the cost of contaminated groundwater, we estimate the extent of potential groundwater contamination from agricultural chemicals. Under the auspices of USDA, Nielsen and Lee (1987) conducted a comprehensive nationwide survey of water pollution due to agriculture. In their study, Nielsen and Lee combined information about agricultural chemicals with data on pesticide and fertilizer use by region and by crop and incorporated into a model (DRASTIC) which rates an area's relative vulnerability to groundwater contamination based on the area's hydrogeologic characteristics. Combining the DRASTIC index with information on population use of groundwater for drinking purposes, yields estimates of the percentage of the population at risk from agricultural groundwater contamination. For California, Nielsen and Lee find that 4,736,915 people with private wells are at risk from agricultural groundwater contamination and that 4,115 people who use public water systems that depend on groundwater are at risk from groundwater contamination.

For the purposes of this study, we need to further specify the at-risk population to indicate those at risk from contamination due to cotton cultivation. The first step of this task was undertaken by Crutchfield et al. (1991) in their survey of cotton agricultural chemical use and farming practices in 1989. In this study, Crutchfield et al. use a DRASTIC-type model to derive estimates of groundwater vulnerability due to cotton cultivation. Their results for California are presented in Tables VIII.1 and VIII.2.

Table VIII.1. Estimated Groundwater vulnerability potential: Pesticide Leaching

	Potential 1	Potential 2	Potential 3	Potential 4	Unknown
1,000 acres	15	36	66	177	756
Percent	1	3	6	17	72

Potential 1 and Potential 4 signify the most vulnerable and least vulnerable classifications respectively. The "Unknown" category accounts for uses of agricultural chemicals that were not included in the assessment procedure.

Table VIII.2. Estimated Groundwater vulnerability potential: Nitrate Leaching

	High Vulnerability	Medium Vulnerability	Low Vulnerability
1,000 acres	792	257	0
Percent	75	24	0

Combining the estimates of groundwater vulnerability due to cotton with those on the at-risk population generated by Neilsen and Lee (1987), produces a rough estimate of the population that is at risk from groundwater contamination due to cotton cultivation; it is estimated that 44,200 households in California are at risk from groundwater contamination due to cotton cultivation.

Identification of the population at risk and the activities that contribute to creating the risk, still leaves the difficult task of assessing exactly what the risk is, and even more difficult, of assessing the cost of the risk. The potential effects of groundwater contaminated by agricultural chemicals are given in Table VIII.3.

Table VIII.3. Potential Effects of Groundwater Contaminated by Agricultural Chemicals

Effects	Documented incidents	Costs incurred
Agricultural:		
Livestock poisoning and health problems	Nitrate/nitrite poisoning of livestock	Unknown
Crop quality or quantity declines	Salts leached from fertilizers can be concentrated through irrigation. Total contribution to salinity though to be minor	Unknown
Heath risks:		
Methemoglobinemia from nitrites	Infant death and illness. Infant death in South Dakota, June 1986 tentatively linked with nitrogen fertilizer application (18).	Unknown
Cancer	Herbicide use in Kansas linked with non-Hodgkin's lymphomas (33). Relationship between herbicides, groundwater contamination, and cancer unknown.	Unknown
Miscellaneous health problems from pesticides and nitrates	No conclusive documentation.	Unknown
Environmental:		
Damage to vegetation, waterfowl, and aquatic life in recharge areas and in surface water contaminated by agricultural chemicals in the groundwater.	No conclusive documentation.	Unknown

Source: Nielsen and Lee (1987)

As is readily ascertained from Table VIII.3, not only has the difficult step of estimating economic costs of morbidity, death and quality of life yet to be taken, but in most cases, even documenting the extent of the effect has yet to be accomplished. In the absence of this type of data, economists have turned to a number of other techniques to derive estimates of the cost of groundwater contamination. Raucher (1986) takes a damages-avoided approach to analyze the cost and benefits of landfill containment. Nielsen and Lee (1987) propose using the cost of household remedial options (such as filters, and other water treatment systems) as an estimate of damages. In order to go beyond use - value estimates, and to evaluate option or existence value, Carson et al. (1991) developed a contingent valuation study to estimate the value of protecting groundwater resources from possible contamination even when they are not needed for drinking water. For our analysis, we will remain within the realm of use-values, more because of data constraints than because of philosophical stance, and will use the estimates of filtration cost generated by Neilsen and Lee (1987).

In order to generate the total and per household costs of cotton chemical contamination of groundwater, we start with an average filtration installation cost estimate of \$200 which we depreciate over five years to yield a yearly cost of \$40. This amount is added to the yearly maintenance estimate of \$200 bringing total yearly filtration cost to \$240 per household. Adding an average household's yearly expenditure on water, which is \$243, to the costs of filtration yields a yearly household water bill of \$483. This means that a household that is at risk from groundwater contamination would need to pay almost double that paid by a risk-free household in order to assure itself of uncontaminated water. The per gallon water price for these households jumps from \$1 per 570 gallons, to \$1.98 per 570 gallons. Assuming a price elasticity of water of -0.4 [Schmidt and Plaut (1993)], the decrease in consumer surplus per year for each at-risk households is estimated at \$237. The total decrease in the welfare of all household consumers of groundwater due to the groundwater externality generated by cotton cultivation is \$10,475,400 (1980 dollars). Expressed in 1982 dollars, the total cost of groundwater damage due to California cotton cultivation is \$12,267,913.

The total groundwater cost estimate represents the subsidy that California cotton receives from households due to the fact that it does not assume the full cost of groundwater damages that result from cotton cultivation. However, in the current-account SAM, this externality benefit or subsidy is not "funded." The majority of groundwater consumers have not modified their behavior in response to the potential health danger posed by contaminated groundwater. The available data suggests that most groundwater consumers have not installed filters, experienced more sick-days or incurred higher medical bills. Though the cost of the cotton externality does not manifest itself in the current accounts, the quality of the nations groundwater reserves is being degraded. The current economy is passing the potential cost of groundwater contamination to some future date. In the externality SAM, the benefits of the cotton externality are allocated among the various agents in the current economy, but the costs are allocated to future households.

VIII.3. Surface Water Contamination and California Cotton - Damage Estimates

Surface water contamination from agricultural cultivation arises through soil erosion and pesticide and chemical runoff. Downstream activities such as fishing, recreation, utilities, industries and navigation all suffer damages and increased operating costs due to soil erosion and agricultural chemicals in surface water. In addition, the long-term productive capacity of the land can be compromised by the erosion caused by cultivation. The on-site and off-site damages caused by soil erosion and runoff from California cotton cultivation are examined below.

On-Site Damages

The agricultural productive capacity of the land is weakened by soil erosion from cultivation. As a result of this erosion, soil fertility and crop yields decline. According to Strohbehn and Alt (1987), if present levels of erosion continue for the next 100 years, the decline in crop yields that are not enhanced by yield-increasing technologies could translate into average annual losses of over $1 billion (this number includes annual fertilizer losses). On the national level, it is estimated that cotton yields would fall by 4.5 percent over the next 100 years. Extrapolating from the national estimates supplied by Strohbehn and Alt (1987), we estimate that the annual yield loss to California cotton due to soil erosion is approximately $549,400 (1982 dollars).

Off-Site Damages

The estimates for the off-site monetary damages imposed by erosion from agricultural land that will be used here were derived by Ribaudo and Young and are reported in the appendix of Strohbehm (1986) and in Ribaudo (1987). The major source for the Ribaudo and Young estimates was a comprehensive report on off-farm damages from soil erosion compiled by Edwin Clark and his colleagues for the Conservation Foundation [Clark et al. (1985)]. In this report, Clark reviewed and extrapolated from available data sources to arrive at estimates of the monetary value of erosion damage to six primary in-stream activities and seven primary off-stream activities. Ribaudo and Young built on the best estimates reported by Clark to arrive at their own best estimate of annual off-site damage from agricultural soil erosion. Their estimate of three billion dollars per year (1983 dollars) is almost three times larger than Clark's estimate of 1.3 billion dollars per year (1980 dollars). Adjusting for inflation still leaves a difference of more than one billion dollars between the two estimates.

The discrepancy between the two best estimates reported above makes clear an observation that both sets of authors freely acknowledge; the nature of the available data, which relies both on extrapolation from small geographic areas to national levels and on extrapolations based on uncertain assumptions about physical relationships and resource valuations, means that researchers can only hope to produce very approximate estimates. In addition, as observed by Clark, some potentially significant impacts of soil erosion, both positive and negative, have been excluded from these estimates meaning that the full costs of agricultural soil erosion could differ substantially. The estimates reported by Young, Ribaudo, and Clark are all subject to a wide margin of error. Nevertheless, despite the shortcomings of the damage estimates currently available, these are the best estimates and represent an enormous outlay of time and effort. These damage estimates also represent a significant improvement over the common practice of setting the cost of environmental externalities at zero.

For the analysis here, we will use the estimates reported by Strohbehn (1986). Table VIII.4 presents the estimates of the *total* damage from soil erosion by activity as reported by Strohbehn. To arrive at a national estimate of damage due to *agricultural* erosion, Ribaudo and Young [Strohbehn (1986)] estimate that erosion damage due to agriculture accounts for approximately half of all erosion damage or 3.5 billion dollars per year.

Table VIII.4. National off-site damage from all soil erosion by type of damage (1,000 dollars*)

Activity	Total Erosion Damage	%
Freshwater Recreation	1,889,000	27%
Marine Recreation	544,000	7.6%
Commercial Freshwater Fishing	55,000	.77%
Commercial Marine Fishing	353,000	4.9%
Water Storage	1,097,200	15.13%
Navigation	680,300	9.5%
Flooding	887,400	12.4%
Drainage Ditches	214,400	3.4%
Irrigation Ditches	106,500	1.5%
Irrigated Agriculture (Salinity)	27,700	.4%
Municipal Water Treatment	121,000	1.7%
Municipal and Industrial Users	1,086,300	15.0%
Steam Electric Power plants	54,300	.7%
Total	7,116,000	100%

*1983 dollars

Making the leap from national estimates to California cotton estimates requires further extrapolation from the regional to the national and back to the regional. California agricultural land represents 3.06 % of national agricultural land and a proportional amount of the national damage figure is used to approximate California damages. California erosion damage due to agriculture is estimated at 3.06% of the national damage amount or 108 million dollars. Comparisons of the incidence and distribution of erosion damages by region, as supplied by Strohbehn and Alt (1991), indicates that the distribution of off-farm damages in California approximates national, average distribution except for water-storage and water-use expenses. The damage incurred by water storage facilities is much larger in California than in other regions of the country while water-use damages are a lower percentage of California total damages. In extrapolating from the national damage numbers in Table VIII.4 to California damage numbers included in Table VIII.8, we modified the allocation of damages to mirror this fact. The modification is a very rough estimate.

The next step is to determine what percentage of California agricultural damages can be attributed to erosion from cotton cultivation. Cotton cultivation accounts for 3.68% of total California cultivation, or 1,105 thousand acres, but not all of this acreage is particularly susceptible to erosion. The first step in estimating the contribution of cotton to erosion damage expense in California is to examine the physical vulnerability of California cotton acreage to erosion. Crutchfield et al. (1991) use a model developed by Ribaudo (1989) to estimated soil erosion and sediment delivery to surface water for cotton cropland. Of the fourteen states surveyed by Crutchfield, California had the lowest erosion rates due to cotton cultivation. In Table VIII.5 , California cotton soil erosion totals and regional averages are presented.

Table VIII.5.
Estimated soil erosion and sediment delivery to surface waters from cotton cropland

State/Region	Erosion rate	Total gross erosion	Total Sediment Delivered
	Tons/acre/year	--------------------Tons	------------------------------
California	.4	448	205
Delta	10.1	30,030	16,793
Southeast	8.3	7,037	3,323
Southern Plains	3.2	16,046	7,761
West	.8	1,062	483

Because off-site damage is due to both the amount of sediment in the water and the amount of agricultural pollutants, that find their way into surface water, the information on pure erosion rates must be augmented with information on the potential of chemicals used in cotton cultivation to end up in surface water. Building on a screening procedure for calculating the delivery of pesticides to surface water (Goss and Wauchope [1990]), Crutchfield et al. (1991) categorize cotton cropland according to its potential for pesticide losses attached to dissolved sediment and according to its potential for losses of pesticides dissolved in runoff. Potential 1 indicates cropland that is most vulnerable to pesticide losses, while potential 3 indicates cropland that has little or no likelihood of pesticide loss. A fourth category called "unknown" is included in the Crutchfield(1991) categorization to account for uses of agricultural chemicals that were not included in the Goss and Wauchope (1990) assessment procedure. The California estimates from the Crutchfield report are presented in Tables VIII.6 and VIII.7 below.

Table VIII.6. Estimated surface water vulnerability potential: Pesticides attached to sediment.(units = 1,000 acres)

State/Region	Potential 1		Potential 2		Potential 3		Unknown	
California	183	17%	100	10%	25	2%	742	71%

Table VIII.7. Estimated surface water vulnerability potential: Pesticides dissolved in run-off. (units = 1,000 acres)

State/Region	Potential 1		Potential 2		Potential 3		Unknown	
California	139	13%	140	13%	49	5%	722	69%

The information presented in Tables VIII.5 - VIII.7 seems to indicate that California cotton cultivation is not a major source of erosion or of surface water pollution. Cross-referencing between the two tables, and allowing for the fact that they are not mutually exclusive, we estimate that less than half (40%) of California cotton acreage contributes to surface water erosion damage costs. We estimate that 4.47% or approximately $1,500,000 of California erosion damages due to agriculture are attributable to cotton cultivation. Table VIII.8 presents our estimates of damage by activity. Because the California SAM is in 1982 dollars, the dollar amounts in Table VIII.8 have been converted from 1983 dollars to 1982 dollars by using the Consumer Price Index.

Table VIII.8. Off-site damage from California cotton soil erosion by type of damage ($1982)

Activity	Total Erosion Damage	%
Freshwater Recreation	392,400	27%
Marine Recreation	110,500	7.6%
Commercial Freshwater Fishing	11,200	.8%
Commercial Marine Fishing	71,200	4.9%
Water Storage	263,500	18.13%
Navigation	138,100	9.5%
Flooding	180,200	12.4%
Drainage Ditches	49,400	3.4%
Irrigation Ditches	21,800	1.5%
Irrigated Agriculture (Salinity)	5,800	.4%
Municipal Water Treatment	24,700	1.7%
Municipal and Industrial Users	174,400	12.0%
Steam Electric Power plants	10,200	.7%
Total	1,453,400	100%

In order to trace the flow of damage expenses in the California SAM, those activities that sustained damage were first grouped into categories that correspond to the sectors included in the California SAM. Second, the exact nature of the damage sustained by each sector was examined in order to correctly allocate the increased expenditure in the SAM. For example, the raw data gave estimates on water-treatment costs. We determined that the sector in the SAM that sustains this type of damage is utilities. The raw data described the process involved in water treatment (chemical treatment) as well as the inputs to the process (cleaning agents, materials and labor). We used this information to allocate the damage payments to non-agricultural chemicals, non-agricultural industry and labor. The precise allocation of damage expenses for each sector is described below.

In determining the allocation of expenditure, we often needed to develop rough estimates as the data sources were not always explicit about expenditure. In particular, we needed to develop rules-of-thumb in allocating increased capital expenses. In cases where damage expenditure included increased capital costs, we allocated part of the increase to capital depreciation in order to account for increased wear and tear of existing equipment and the remainder to investment in new equipment. Determining the break-down between increased depreciation and investment depends on the amount of excess capacity in the sector under investigation. We do not have this information and therefore relied on a best-guess rule; in each case we allocated 25% of the increase in capital cost to depreciation and 75% to new investment. The type of damage payments by sector are described below.

1. Utilities - $298,400

Water treatment costs -$24,700. Agricultural soil-erosion deposits sediment and other contaminants in waterbodies and reservoirs that supply drinking water. The increase in water-treatment costs corresponds to the costs of removing suspended solids and other contaminants from municipal water supplies. In the SAM, we allocated $2,470 (10%) to non-agricultural chemicals for the purchase of cleaning agents; $7,410 (30%) to non-agricultural industry for the purchase of other materials; and $14,820 (60%) to labor.

Water storage costs - $263,500. The increase in water storage costs corresponds to the cost of dredging existing reservoirs or constructing new or extra capacity reservoirs to compensate for the loss in capacity due to soil erosion. In the SAM, $184,450 (70%.) of the increased cost was allocated to increased capital expense; $26,350 (10%) to non-agricultural industry; and $52,700 (20%) to labor. Capital expenses were allocated between depreciation $47,430 (25%) and investment in new machines $137,020 (75%).

Steam electric power plants - $10,200. For steam power plants and other water cooling facilities, soil erosion increases the amount of sediment and algae in the water thus decreasing the efficiency of the plant. Removal of algae from condensers requires increased purchase of chemicals for chlorination treatments and increased labor costs. In the SAM, $4,080 (40%) was allocated to non-agricultural chemicals and $6,120 (60%) to labor.

2. Government Services - $246,966

Navigation - $138,100. Damage to navigation consists of the increased dredging costs that must be sustained in order to keep channels and harbors clear of erosion-caused siltation. The Army Corps of Engineers performs approximately half of the dredging activities while state and local authorities perform the other half. In the SAM we allocated these increased costs to labor $96,670 (70%) and equipment $41,430 (30%). Equipment costs were distributed between depreciation $10,358 (25%) and investment $31,072 (75%).

Flooding - $59,466. This amount represents the damages to government property and structures and the clean-up cost incurred by the government as a direct result of flood sedimentation and increased flood heights due to stream aggradation. This amount is the result of a rough division of the total flood damage amount presented by Strohbehn (1986) between government, households, agriculture and non-agricultural industries. In the SAM, we allocated the flood damages incurred by government services between capital expenses $14,866 (25%) and labor $44,600 (75%). Capital expenses are distributed between depreciation $3,716 (25%) and investment $11,150 (75%).

Drainage Ditches - $49,400. Some of the soil eroded from agricultural fields is deposited in drainage ditches where it can cause localized flooding. To prevent this, state and local highway departments must remove the sediment form drainage ditches. In the SAM we allocated the increased between labor $34,580 (70%) and capital $14,820 (30%). Capital expenses are distributed between depreciation $3,705 (25%) and investment $11,115 (75%).

3. Agriculture - $51,026

Flooding - $23,426. This damage amount represents the long-term loss of productivity associated with sedimentation due to flooding of relatively fertile agricultural land. This amount is lost *potential* production.

Irrigation ditches - $21,800. Soil erosion clogs irrigation canals and substantially increases costs for sediment-removal and weed-control in irrigation canals. In the SAM we allocated half of the increased cost, or $10,900, to labor and the other half to non-agricultural industry for the purchase of materials.

Salinization - $5,800. In addition, salt which enters irrigation water through irrigation return flows or through erosion of saline soils can reduce crop yields. These damages are also a measure of *potential* forgone production.

4. Households $111,612

Flooding - $54,060. This amount represents the damages to household property and structures directly due to sedimentation and increased flood heights due to stream aggradation. In the SAM, 20% or $10,812 of this amount was allocated to non-agricultural industry for the direct purchase of materials and new structures; and 80% or $43,248 was allocated to construction and other services. It should be noted that household labor is not accounted for in most accounting systems.

Municipal and Industrial Users - $57,552. Even after water is treated for suspended sediment and harmful contaminants, dissolved minerals, salts and other materials can still reduce the efficient operation and durability of water-using equipment in industries and homes. The amount included here represents the estimated annual costs to households of demineralizing water and repairing or replacing scaled or corroded machinery. In the SAM we allocated $11,510 (20%) to non-agricultural chemicals; $17,266 (30%) to non-agricultural industry; and $28,776 (50%) to services for professional repairs and replacements.

5. Services - $502,900

Freshwater Recreation - $392,400 and Marine Recreation - $110,500. Soil-erosion damages water recreation industries through the destruction of fish habitat, siltation of recreation facilities and eutrophication of waterways. The basis for the national estimates of damages sustained by the water-recreation sector used by Clark (1985) is a number of site-specific studies conducted by different researchers. The environmental amenities that contribute to the value of a recreation site usually do not have market prices and efforts to generate money values must depend on techniques such as the contingent-valuation method, hedonic pricing, the travel-cost method, etc. These estimates of damages to recreation depend to a large extent on non-market valuation of fishable, boatable and swimmable water. Though it is difficult to determine exactly what percentage of the final estimate measures "lost enjoyment," we hazard that a large portion, say 60% ($301,740) of the estimated damages to recreation depends on non-market valuation of enjoyment while another 20% ($100,580) depends on non-market valuations of forgone income. Probably only a very small percent of the damages corresponds to expenditures that the industry has actually incurred in order to compensate for agricultural soil erosion. For the SAM we allocated $100,580 (20%) to services for the construction of improved recreation facilities.

6. Non-agricultural industry - $242,496

Commercial Freshwater Fishing - $11,200 and Commercial Marine Fishing - $71,200. The damage assessment method used to estimate the cost to marine fishing from soil erosion is based on a model of biological productivity functions to estimate the impact on productivity of changes in water quality [Bell and Canterberg (1975)]. These predictions are then combined with an economic model of supply and demand to determine the economic losses due to productivity changes. Freeman (1982) extrapolated from Bell and Canterberg's estimates to derive freshwater fishing damages. Ribaudo and Young [Strohbehn (1986)] use the relationship between the damages to recreation fishing (freshwater) from agricultural soil erosion as reported by Clark (1986) to determine the percent of marine and freshwater commercial productivity losses that can be attributed to agricultural soil erosion. The amount of damage attributed to marine and freshwater commercial fishing does not represent costs that these industries actually incurred, but forgone *potential* output.

Flooding $43,248. This amount represents the damages to industrial property and structures directly attributable to sedimentation and increased flood heights due to stream aggradation. In the SAM, 80% or $34,598 of this amount was allocated to services for construction and repair, while 20% or $8,650 of the damage amount was allocated to labor.

Municipal and Industrial Users $116,848. Even after water is treated for suspended sediment and harmful contaminants, dissolved minerals, salts and other materials can still reduce the efficient operation and durability of water-using equipment in industries and homes. The amount included here represents the estimated annual costs to industry of demineralizing water and repairing or replacing scaled or corroded machinery.

In the SAM we allocated $23,370 (20%) to non-agricultural chemicals; $35,054 (30%) to non-agricultural industry; $23,370 (20%) to labor; and $35,054 (30%) to services for professional repairs and replacements.

VIII.4. The Cotton Water-Externality SAM

The first step in creating the cotton water-externality SAM is to allocate the benefits of the externality to the cotton industry and to cotton consumers. In this example, cotton enjoys a subsidy of $14,270,713. This subsidy includes both potential unpaid damage amounts and damage amounts that have been paid in the current year. It represents the difference between the private cost and the public (both current and future) cost of the externality. Because of this difference, the marginal cost curve of the cotton industry is lower than it should be, and the equilibrium price of cotton is lower and the equilibrium quantity greater.

In order to estimate the change in cotton price and quantity that results from the externality and the shift in cotton's marginal cost curve, we rely on supporting studies. Lichtenberg et al. (1988), estimate that a 1% increase in the cost of producing cotton in California reduces cotton production by 0.36%. Howitt (1991) estimates that a 1% increase in production in California would lead to a decrease in farm price of 0.154%. Applying these two estimates to the environmental subsidy received by cotton in this example indicates an increase in cotton revenue of approximately $4,500,000. The increase in production results in an increase in input use in cotton production that is allocated down the cotton column according to input shares. The increase in input use by cotton cultivation translates into increased demand for inputs. These increases are allocated by shares down all cotton direct and indirect input columns.

Cotton consumers also enjoy a benefit from the externality in the form of lower cotton prices; this fact is mirrored in row 2 which records the increase in cotton expenditure across demand. For final demand, an increase in cotton expenditure that was not matched by an increase in income or revenue was set against a decrease in other expenditure to meet budget restrictions.

Industries that supply defensive goods or services to the victims of the externality also realize an increase in demand because of the externality. This increase is allocated by shares among the inputs to the industry, and then again among the inputs to the inputs of the industry.

Industries that are victims of the externality, and must pay to offset the damage caused by the externality, experience an upward shift in their marginal cost curve. This shift translates into a higher equilibrium price and a lower equilibrium quantity than would have obtained without the externality. The relative shifts in price and quantity, and the resulting increase or decrease in revenue depend on the elasticities of supply and demand for the industries and services in question. In the example examined here, only utilities, whose demand is inelastic experience an increase in revenue as a result of the increase in marginal cost. In the Externality SAM, the fall in revenue and production for the victimized industries is allocated among the inputs to each industry according to the input coefficients for the industry. The fall in expenditure (or increase in the case of utilities) on the externality-ridden good or service that results from the increase in price is allocated proportionately among the purchasing sectors. It is assumed that households decrease other consumption and savings activities in order to offset the increase in defensive expenditures. This decrease is allocated according to household expenditure coefficients.

To summarize, the steps in creating the externality SAM are delineated below. First, the initial winners and losers from the externality are identified, i.e., who generates the externality and who suffers from the externality. In some cases there will be numerous agents that benefit or lose, and an individual agent could simultaneously benefit and lose from an externality.

The second step is to derive the cost of the externality to the losers. Focusing on the cost of the externality to the losers keeps the analysis consistent with analyses involving a compensation principle; the cost of the externality becomes the compensation that winners would have to pay losers in order to justify the continuance of the externality. For this analysis, this externality cost represents the "subsidy" that is paid by the sufferers of the externality to the generators of the externality.

In the third step, the "payers" of the subsidy decrease consumption (in the case of households) or production (in the case of activities) in reaction to the subsidy. The distribution of the decrease in consumption depends on the income elasticity of each good and service in the consumption basket. The decrease in production depends on the elasticity of supply and demand for the good in question. The distribution of the decrease in production among the factors and inputs to production depends on the elasticity of demand for these inputs, and on the bargaining position of labor and capital.

In the fourth step, the increase in production in the polluting industry is calculated according to the interaction between the subsidy-augmented supply curve, and the demand curve for cotton. The resulting increase in production or in revenue is distributed among the factors and inputs in production according to the elasticities of cottons demand for these inputs, and to the bargaining position of labor and capital.

The California cotton water-externality SAM is presented in Appendix 2. The externality SAM presented in the appendix has not been balanced; this step is taken when the environmentally adjusted SAM is calculated.

VIII.5 Future Damages

With the cotton water-externality a large portion of the damages caused by the externality are debited to the future economy. Some of these damage amounts reflect losses in productivity, and some reflect a direct loss in welfare due to environmental degradation. The impact of damages that measure losses in productivity are analyzed with a multiplier matrix, as described below. Analysis of the direct welfare damages follows the multiplier discussion.

In order to trace the impact that unpaid productivity damages incurred in the current economy might have on the future economy, we generate a SAM multiplier model from the original California SAM. Productivity damage amounts that are forwarded for payment to the future economy are fed through the SAM multiplier matrix so as to yield the impact of these damages on the future economy. Thus, it is possible to trace the impact of exogenous change on every endogenous account in the future economy.

In the cotton-water example, $1,063,346 of the externality damages measure productivity losses that are passed directly to the future economy. This amount represents 7% of the total damages caused by the combined water externalities. Of this amount, $29,226 represents the expected decline in agricultural production due to salinization and sedimentation. Commercial fishing is projected to experience a fall in production of $82,400, and recreational fishing and water recreation services are expected to experience a fall in income of $402,320. The cotton industry is projected to sustain a fall in production of $549,400 due to soil erosion. These numbers are fed through a multiplier matrix that is based on the original California SAM. The direct impact of the degradation of the resource base will be a drop in productivity in the sectors directly dependent on the resource in question. The decrease in productivity triggers changes throughout the economy as indicated by the multiplier. The structure of the multiplier matrix also reflects the pattern of development established with incomplete environmental prices thereby further indicating misdirected growth.

In addition to the productivity damages sustained by the future economy as a result of the surface water externalities, the future economy also inherits a degraded groundwater resource. As a result of the low quality groundwater available to future households, it can be argued that future groundwater consumers are less well-off than current groundwater consumers. Even if they do not incur higher medical expenses or experience more sick-days as a result of the contaminated water, they nevertheless consume lower quality water than their current-day counterparts. The reduction in welfare due to lower quality water that was established in Section VIII.2 is equivalent to $12,267,913. This amount represents 86% of the total damages caused by the cotton water-externalities. In our analysis, this amount is deducted directly from future household real income in order to reflect the change in real welfare. This fall in welfare is allocated among the household income groups on the basis of each income group's portion of total household utility expenditures. In the absence of information on water consumption by income group, we used utility expenditures as a proxy for the distribution of water consumption among the income groups. Since households do not actually alter their purchases as a result of this drop in welfare, we do not feed this portion of the future damage through the multiplier analysis.

In order to incorporate future damage amounts into the current accounts, the present-values of the results of the multiplier analysis and of the direct drop in welfare are calculated. The discount rate is set at 3%, an approximation to the "natural" rate of growth of California, which is selected to be at a midpoint between the rate of population growth for California (2.2%) and the rate of GDP growth for California (3.4). The present-value results of the multiplier analysis and of the direct fall in welfare are presented in Table VIII.9.

Table VIII.9. Present Value of Future Damages (1982 dollars)

	Reductions due to: Fall in Productivity -	Direct Fall in Welfare
Livestock	16693	
Cotton	539057	
Food Grains	2938	
Feed Grains	5335	
Hay and Grass	4974	
Fruits	14008	
Tree Nuts	2501	
Vegetables	14161	
Misc. Crops	1849	
Forest Products	93778	
Food Processing	66937	
Nonag. Ind.	261189	
Oil, Gas and Ref.	120791	
Ag. Chemicals	17471	
Textiles	15937	
Wood and Paper	12098	
Nonag Chemicals	19131	
Rail	4978	
Services	1234998	
Trucking	19331	
Air Trans	23132	
Utilities	48131	
Labor	730971	
Capital	519988	
Enterprises	323698	
Low Income HH	68387	2,382,119
Med. Income HH	468542	5,955,298
High Income HH	378355	3,573,178
Government	exogenous	
Investment	exogenous	
ROW Domestic	exogenous	
ROW	exogenous	

VIII.6. The Environmentally Adjusted SAM and NNP Calculations

In order to examine the environmental distortions as summarized by the externality SAM in relationship to the complete economy, the externality SAM is subtracted from the original SAM to yield a Current Environmentally Adjusted (CEA) SAM. The CEA SAM is presented in Appendix 2[3]. The flows of the CEA SAM are adjusted by the value of the flows which are generated by the environmental externality. The CEA SAM illustrates the reduction in cotton cultivation and consumption and in defensive industries that would occur if the externality was assumed by the cotton industry. It also illustrates the increase in production and consumption of goods and services provided by industries that are currently harmed by the externality that would occur if the externality were removed.

In order to expand the analysis of the impact of the externality to include future damages, the present value results of the multiplier analysis and the direct decrease in welfare are presented alongside the current results. In the first three columns of Table VIII.10, the sector totals for the original SAM and the CEA SAM are compared. In the last two columns, the results of the future damage estimates are compared with the current account estimates.

[3]The method used to balance the CEA SAM is the generalized cross-entropy method developed by Golan, Judge and Robinson (1994).

Table VIII.10. Matrix Totals ($1,000,000)

	Original SAM	Current Env. Change	Current Env %Change	Future Damage	Total %Change
Livestock	4644.2	0	0	-	0
Cotton	1126.0	-4.6	-.4	-0.5	-.45
Food Grains	609.3	-0.3	-.05	-	-0.5
Feed Grains	896.0	-0.1	-.01	-	-.01
Hay and Grass	651.6	-0.2	-.03	-	-.03
Fruits	2748.9	-	0	-	0
Tree Nuts	616.4	+0.1	+.02	-	+.02
Vegetables	2794.7	-	0	-	0
Misc. Crops	379.8	+0.1	+.03	-	+.03
Forest Products	4794.2	-0.6	-.012	-0.1	-.0146
Food Processing	30360.9	-	0	-0.1	-.0003
Nonag. Ind.	166854.7	-0.2	-.0001	-0.3	-.0003
Oil, Gas and Ref.	33406.4	-0.1	-.0003	-0.1	-.0006
Ag. Chemicals	528.7	-0.2	-.04	-	-.04
Textiles	6165.4	-	0	-	0
Wood and Paper	6255.4	-0.1	-.002	-	-.002
Nonag Chemicals	7168.2	-0.1	-.002	-	-.002
Rail	1858.1	+0.2	+.01	-	+.01
Services	343348.8	-1.2	-.0003	-1.2	-.0007
Trucking	7470.3	+0.1	+.001	-	+.001
Air Trans	9202.5	-0.1	-.001	-	-.001
Utilities	12538.4	-0.1	-.0008	-	-.0008
Labor	229311.2	-0.5	-.0002	-0.7	-.0005
Capital	120726.1	-0.4	-.0003	-0.5	-.0007
Enterprises	88838.6	-0.6	-.0007	-0.3	-.001
Low Income HH	41589.4	-	0	-2.5	-.006
Med. Income HH	158971.2	-.01	-.00006	-6.4	-.004
High Income HH	115955.5	-.01	-.00008	-4.0	-.0035
Government	199767.2	-0.1	-.00005	na	-.00005
Investment	102082.4	-0.1	-.00009	na	-.00009
ROW Domestic	137539.0	-0.5	-.0004	na	-.0004
ROW	40668.8	-	0	na	0

It should be noted that, as in the original California SAM, the effects in Table VIII.10 are in millions of dollars. Because of this, many of the lesser effects simply drop out; this does not indicate zero change in these sectors. In the CEA SAM and in the multiplier analysis, changes due to the environmental externality percolate throughout the economy and every account experiences some change. A dashed entry in Table VIII.10 indicates a change that rounds to less than $100,000.

Table VIII.10 summarizes the incidence of distortions generated by the California cotton industry's water use. The third column of the Table reflects the impact of cotton's water externalities on California's current activities and incomes. In the current period, the effect of the externalities on the economic activity is to overstate "true" gross economic activity by 8.9 million dollars in the unadjusted SAM.

In the agricultural sector, the largest effect is in cotton, where gross output is overstated by about 4.6 million dollars in the unadjusted SAM. The combined output of other agricultural activities is overstated by $400,000, with miscellaneous crops and tree-nut crops the only agricultural activities to be understated in the unadjusted SAM. Because of their linkage to those activities that are directly affected by the externalities, these crops benefit through reduction of the externality.

Non-agricultural output is overstated in the unadjusted SAM by 2.4 million dollars. In the non-agricultural sector, the largest effect is in services where output is overstated by 1.2 million dollars. This is explained by the fact that both cotton and environmental defensive industries are heavy users of services in their production.

In the non-agricultural sector, only rail and trucking are understated in the unadjusted SAM and hence experience an increase in output with the reduction of the externality. The direction of change for rail and trucking is difficult to explain as cotton is an important client for both of these forms of transportation. Increased rail or trucking use by tree-crops or miscellaneous crops after the externality is not large enough to explain the direction of change. Secondary and third round effects must combine to explain the change.

Another puzzling observation is the small net impact that the externalities have on food processing and textiles. These two industries are the largest users of cotton and one would expect larger benefits from the cotton "subsidy" to trickle down to input demand. Examination of both the magnitude of the cotton-price change that results from the externalities, and of the input coefficients for cotton in textile and food processing, highlights the observation that throughout the SAM, the second and third round effects of the externality are small. In food processing, which is the largest industrial user of cotton, the input coefficient on cotton is .0027. The change in cotton price as a result of the externality is .07%. Assuming an elasticity of 1.5 for calculating the change in quantity produced due to a change in input price, it is possible to estimate the change in food-processing output due to the change in cotton price. In this case, the increase is approximately equivalent to $81,000. Taken alone, a change of this magnitude is negligible in an economy that is described in units of millions of dollars. For this reason, many, if not most of the secondary effects of the externality are negligible.

Due to the overstatement of output in both the agricultural and non-agricultural sectors, the total current account impact of the water externalities generated by cotton on value-added is overstated by about one million dollars. As a result, incomes are overstated in the unadjusted SAM, with enterprise income the most overstated.

In the exogenous accounts, economic activity is overstated by $700,000 in the unadjusted SAM. The largest overstatement occurs in ROW domestic which is the largest consumer of cotton. Investment is overstated by about $100,000 in the unadjusted accounts which is explained both by increased investment in industries bolstered by the eternality and also by the fact that some of the defensive expenditures (such as additional water-storage facilities) generate investment.

The fourth column of Table VIII.10 reflects the impact of cotton's water externalities on California's future activities and incomes. When future damages are considered, current economic activity is overstated to an even greater extent than illustrated in columns two and three. Inclusion of future damages indicates that economic activity, as measured by the unadjusted current SAM, overstates "true" gross economic activity by an additional 16.7 million dollars. This overstatement is almost twice as large as the overstatement due to the current account adjustments. It is noteworthy that all the externalities generated by cotton affect future generations negatively. While there are current costs and benefits, the major impact of the externalities is to shift the costs of current externality damages to future generations.

The major industries injured by the externality in the future are cotton, non-agricultural industries (commercial fishing), and services (recreational fishing and water recreation). Inclusion of future damages indicates that total productive output is overstated by an additional 2.3 million dollars in the unadjusted SAM.

The overstatement of output in the production sectors due to future damages results in an overstatement in value-added of 1.2 million dollars. As a result, incomes are overstated in the unadjusted SAM, with enterprise income the most overstated. In addition to the impact of value-added on income, incomes are further overstated due to the direct drop in real welfare and real income that results from the externality. Because of this direct drop, future households bear the brunt of currently generated externalities. In absolute terms, middle incomes households are most affected, with an overstatement of 6.4 million dollars. High income households follow with an overstatement of 4 million dollars, and low income households are least affected in absolute terms with an overstatement of 2.5 million dollars. In relative terms, the percent overstatement is the largest for low income households and lowest for high income households.

Calculation of the current environmentally adjusted SAM and of the future-damage estimates provides an indication of the changes in the level and distribution of economic activity that arises from the environmental externality. The current environmentally adjusted SAM and the future-damage estimates also provide a basis with which to calculate an environmentally adjusted NNP. The overstatement of value-added described by the externality adjustments is reflected in the NNP calculations. In the unadjusted accounting system, NNP is overstated by 2.2 million dollars. Of this amount, adjustment for only current externality distortions results in an overstatement of one million dollars. The multiplier analysis adds another 1.2 million dollars to the overstatement of value-added in the unadjusted SAM due to future distortions[4].

Future damages that result in a direct drop in welfare do not affect NNP calculations. These damages do change real income, and in the cotton water-externality example, real income is overstated by 14 million dollars in the unadjusted SAM. This overstatement is larger than the overstatement in NNP by an order of magnitude. In most analyses, NNP and National Income would be the same. In our case, they are not, since there is a change in household welfare that does not flow through value-added because it is not reflected in a change in expenditures. This change in household welfare is directly due to the externality. In many ways, this direct change in welfare is like an increase in the price of a "util." Due to this price change, the correspondence between NNP and *real* income shifts downward despite the fact that the correspondence between NNP and money income remains the same.

In interpreting the results it is important to bear in mind that cotton uses only 3.68% of California's agricultural land, and is not one of the heaviest polluters. Nevertheless, the distortions caused by the cotton water-externalities affect NNP, real welfare and both the incidence and allocation of economic activity .

[4]It should be noted that the multiplier analysis does not provide information on the exogenous accounts, including government (indirect taxes) and investment (depreciation). As a result, a full adjustment to NNP cannot be calculated on the basis of these future damages.

IX Conclusion

With the SAM framework, the information conveyed by the environmentally adjusted NNP measure is expanded to present distributional ramification of the externality. The SAM analysis gives a better accounting of the true costs and benefits of environmental externalities. The general equilibrium nature of the SAM provides a more accurate picture of who benefits and who loses from pollution once higher round interactions are incorporated. This represents a major improvement over the partial equilibrium approach. The SAM framework, combined with the economic valuation of environmental externalities, provides a method for analyzing the distribution and incidence of the costs and benefits of environmental exploitation, whether between industry and consumers, between rich and poor, or between today and tomorrow. Through the creation of the environmentally adjusted SAM and the future-damage analyses, it is possible to account for the impact of environmental distortions.

Moving from the unadjusted accounting system to the environmentally adjusted system is equivalent to removing the distortions imposed by the environmental externality. Piercing the veil of incorrect externality prices reveals that society is worse off that it realizes. The level of economic activity portrayed in the unadjusted accounts is higher than would have occurred with the correct environmental prices, which is reflected in the environmentally adjusted NNP measure. Current activity triggered by the externalities occurs at the expense of both current and future resource users. Through our pedagogical exercise we observe that the major burden of the cost of the externality is borne by the future economy.

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APPENDIX ONE

The 1990 SNA and the SNA Satellite System for Integrated Environmental and Economic Accounting (SEEA) of the United Nations Statistical Office

Much of the theoretical debate concerning the development of a system of environmental and resource accounting to supplement or replace the 1968 SNA has taken place under the auspices of the UN and the World Bank. The UN effort began in 1983 when the UNEP convened a meeting to "ascertain whether environmental accounting could be developed as a public policy tool" [Ahmed et al. (1989)]. This meeting led to a series of workshops, convened in collaboration with the World Bank (CIDIE gives a good chronology). The major papers and conclusions which resulted from these workshops were published in "Environmental Accounting for Sustainable Development" edited by Ahmed et al.(1989).

In 1991, the UN and World Bank efforts were officially joined by the International Association for Research on Income and Wealth (IARIW), when IARIW organized a "Special Conference on Environmental Accounting" in Baden, Austria, May 27 - 29, 1991 (Carsten Stahmer and Alfred Franz were the conference organizers). The proceedings of this conference were published by the Austrian Statistical Society and several of the papers were included in the World Bank 1992 volume entitled "Toward Improved Accounting for the Environment" Ernst Lutz, editor. The remaining papers in the volume arose from formal and informal gathering, international meetings, meetings of experts responsible for the review of the SNA, and preparatory meetings for the UN conference on Environment and Development (Lutz 1993). The volume also includes reporting on the two UNSO-World Bank case studies (Mexico and Papua New Guinea) which attempt to apply the general approach outlined in the UNSO framework and the Draft Handbook.

In conjunction with these efforts, a revision of the SNA was mandated by the UN Statistical Commission in the early 80's. Through a series of expert group meetings which spanned the decade, it was decided that the core of the SNA system would remain intact and that adjustment to the core would take place through a system of satellite accounts. The joint UNEP\WB expert meeting on Environmental Accounting and the SNA in November 1988 recommended that the revised volume on the SNA should have a section on satellite accounts for environmental accounting. This decision was mirrored by that taken at the twenty-fifth session of the Statistical Commission of the United Nations (1989) where it was decided that the 1990 revision of the SNA should include satellite accounts for environmental and resource accounting. This system of satellite accounts is described in the Handbook on Integrated Environmental and Economic Accounts [UNSO (Interim version, May, 1992)]. This handbook details the environmental satellite accounts known as the System for Integrated Environmental and Economic Accounting (SEEA).

Carsten Stahmer, the principle author of the SEEA Handbook contends that there are two preconditions for the successful construction of the environmental satellite system. These preconditions are described in the somewhat lengthy quotes that follow. These quotes serve to give a feeling for the philosophy behind the environmental satellite accounts.

> The concept of a satellite system should have higher degrees of freedom than those of national accounts. They should be chosen in such a way that they can both give a comprehensive picture of the environmental-economic interrelationship and take into account the ecological point of view. It should also be possible to use valuation methods which might have a weaker data basis than the traditional national accounts. Furthermore, the possibility should be offered to test different methods and to describe different options. The complex problems of the use of the environment for economic activities can not be reduced to one specific approach. The most comprehensive measures of economic-environmental relations represent at the same time concepts which have the weakest data basis. The experimental character of possible environmental accounting systems should, therefore, be stressed. A satellite system should certainly present a consistent framework. But such framework should as far as possible take into account different schools of thinking. (Stahmer [1992],pg. 10)

> The aim of the accounting system con not be restricted to describing environmental deterioration caused by economic activities. The system should become a data basis for integrated environmental and economic policies. This aim can only be achieved if both the direct and indirect impacts of the economic use of the environment on economic activities can be analyzed. This implies close connections between the traditional economic accounting system and the new satellite system. The links between the two data systems could be used to establish comprehensive economic models which comprise not only economic but also environmental data. (Stahmer [1992], pg. 11)

With these preconditions in mind, the SEEA framework developed by Stahmer and his crew is comprised of modules or building blocks which are linked to the traditional accounting system in differing degrees. Four types of building blocks are included in the framework for the SEEA (description given by Stahmer [1992]. The interconnectedness of the building blocks is outlined in Tables A1 and A2. Building block A is the production part of the SNA which describes production and consumption activities and the accounts of non-financial assets. The production part or input-output part of the SNA is a good framework for incorporating flows between the environmental and the economy. The starting point for the natural asset accounts of the SEEA are the non-financial asset accounts of the SNA which also comprise non-produced natural assets in the revised version.

Building block B of the SEEA comprises a description of the interrelationship between the natural environment and the economy in physical terms. This part of the SEEA draws on the theoretical and empirical experiences of natural resource accounting, material/energy balances, and input-output compilation. It is closely linked to the monetary flows and assets of the SEEA as derived from the production component of the SNA.

Building block C represents the estimation of imputed, non-market costs of natural resource use. In the SEEA context, three different valuation methods are used:

1) Market valuation according to the non-financial asset accounts in the SNA,

2) Maintenance valuation which estimated the costs of maintaining the present state of the natural asset and,

3) Contingent valuation or willingness-to-pay estimates.

Building block D contains additional information which could be obtained through extension of the production boundary of the SNA. Possible extensions include first, the case of household activities and their impact on the natural environment and the welfare aspects of environmental degradation, second the case of treating economic functions of the natural environment as the production of environmental services and third, the case of treating both internal and external environmental protection activities as production activities.

These four building blocks fit together to comprise the satellite system of environmental and natural resource accounts. The following are the main features of the SEEA [United Nations (1991b)].

<u>Segregation and elaboration of all environment-related flows and stocks of traditional accounts.</u> Segregation and elaboration of environmental flows and stocks will increase the value of the SNA as a data base and information system. An additional objective of this segregation is to allow for the identification of the part of GDP which reflects defensive expenditures.

<u>Linkage of physical resource accounting with monetary environmental accounting and balance sheets.</u> Non-monetary data on physical accounts is an integral part of the SEEA, but the SEEA also proposes to account for environmental and natural resources thereby providing a "hinge" by which comprehensive physical accounts could be linked to the monetary balance sheet and flow accounts of the SNA.

Assessment of environmental costs and benefits. In particular, two major issues will be considered: (a) the use or depletion of natural resources in production and final demand, and (b) changes in environmental quality.

Accounting for the maintenance of tangible wealth. The SEEA will include the depreciation of natural capital. The SEEA will include additional costs for the depletion and degradation of natural assets thereby extending the concepts of capital formation to capital accumulation.

Elaboration and measurement of indicators of environmentally adjusted product and income. The consideration of the depletion of natural resources and changes in environmental quality will permit the calculation of an "Environmentally adjusted net Domestic Product" (EDP).

APPENDIX TWO
THE SAMS

Table 1. The California SAM

Table 2. The California Cotton Externality SAM

Table 3. The Current Environmentally Adjusted SAM

TABLE 1. CALIFORNIA SAM

SECTORS:	LIVE-STOCK	COTTON	FOOD GRAINS	FEED GRAINS	HAY & GRASS	FRUIT	TREE NUTS	VEGE-TABLES	MISC CROPS	FOREST PROD	FOOD PROC	NONAG INDUST	OIL, GAS, & REF	AG CHEM	TEX-TILES	WOOD & PAPER	NONAG CHEM
LIVESTOCK	555.3	10.6	11.1	32.5	14.3	5.8	1.3	9.5	1.3	58.2	2716.6	0.7	0	0	5.9	3.8	2.0
COTTON	1.3	11.3	0.1	0.1	0.1	1.6	0.4	0.8	0.1	0.6	81.6	0.2	0	0	12.0	0	0
FOOD GRAINS	6.1	0.6	20.4	0.1	0.1	0.8	0.2	0.4	0	0.3	211.5	0.4	0	0	0	0	0
FEED GRAINS	344.6	0	0	39.0	0	0	0	0	0	3.1	216.0	0	0	1.7	0	0	0
HAY & GRASS	564.2	1.1	0.1	2.4	2.8	1.4	0.3	0.7	0.1	10.0	0	0	0	0	0	0	0.9
FRUITS	2.8	2.5	0.3	0.3	0.2	3.3	0.8	1.7	0.2	1.2	934.4	0	0	0	0	0.1	0
TREE NUTS	0.6	0.6	0.1	0.1	0.1	0.7	0.2	0.4	0	0.3	34.1	0	0	0	0	0	0
VEGETABLES	2.5	1.7	0.2	0.2	0.2	2.3	0.5	60.9	0.1	0.8	530.1	0	0	0	0	0	0
MISC CROPS	0.4	0.3	0	1.5	1.2	0.4	0.1	0.2	14.3	0.2	173.1	0.8	0	0	0.3	2.2	14.3
FOREST PRODCTS	189.5	171.9	20.2	20.6	16.8	308.2	60.5	146.2	10.8	192.6	83.2	151.1	0.5	0.1	19.9	173.3	8.6
FOOD PROCESSING	872.9	0.4	0.3	0.6	0.5	0.8	0.1	0.8	0.1	21.4	3282.5	59.0	9.0	2.3	2.0	3.3	83.0
SERVICES	68.9	23.4	17.6	26.7	21.5	169.3	17.3	52.7	8.0	186.7	3766.4	39140.8	1293.7	48.7	186.1	424.2	915.9
NONAG INDUSTRY	66.3	52.0	62.0	77.4	63.8	205.9	45.7	92.8	17.1	260.7	277.1	2739.2	9931.8	45.5	42.7	155.6	663.9
OILGAS & REFINING	3.9	27.9	16.3	30.5	24.6	51.5	8.1	40.4	8.0	116.8	3.0	14.2	4.8	17.2	0.2	1.1	14.3
AG CHEMICALS	1.5	0	0	1.0	0.9	5.6	1.4	6.5	0	14.9	9.3	417.4	1.9	0.5	795.1	12.2	2.5
TEXTILES	8.7	0.4	0.2	0.4	0.4	8.2	1.5	7.4	0.1	4.2	184.8	2806.7	4.4	5.2	17.1	1120.3	29.1
WOOD & PAPER	17.2	4.8	2.6	6.0	4.8	9.5	1.7	7.8	1.5	42.0	137.7	1860.7	226.4	17.9	43.0	128.5	505.0
NONAG CHEMICALS	15.4	1.6	2.9	3.6	2.9	5.2	0.6	5.0	0.8	7.7	143.3	470.1	34.8	5.1	3.7	53.9	43.9
RAILROADS	307.7	205.1	126.1	142.6	116.9	171.0	41.2	229.6	52.9	586.1	1800.3	19200.9	3078.6	45.5	399.7	321.3	793.7
TRUCKING	64.1	5.0	4.0	8.1	6.6	13.6	1.9	21.2	2.5	27.9	562.4	1735.1	89.8	17.1	30.8	66.1	94.7
AIR TRANSPORT	2.1	1.1	0.1	0.2	0.2	6.3	1.1	12.5	0.1	61.2	116.4	1274.5	81.9	4.7	28.3	27.6	52.2
UTILITIES	25.3	23.3	6.7	16.3	13.7	39.5	0	30.8	15.5	48.3	304.0	1604.6	627.0	17.1	38.2	103.9	113.4
LABOR	279.9	148.3	30.7	30.2	21.8	588.3	132.0	374.5	33.3	1646.1	4308.6	57650.8	1535.6	60.9	1631.7	1465.6	1466.7
CAPITAL	401.9	283.1	176.3	265.9	196.4	812.3	244.0	1384.1	158.2	711.4	2947.5	5209.7	4571.9	78.8	437.0	456.4	901.6
ENTERPRISES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOW INCOME HH	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0	0	0	0
MED INCOME HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HIGH INCOME HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GOVERNMENT	117.7	14.8	12.7	22.6	13.6	47.9	11.1	37.2	5.2	110.7	947.4	2343.2	1696.3	8.6	48.5	52.6	120.8
CAPITAL ACCOUNT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM IMPORTS	715.2	128.2	93.1	158.6	120.7	277.5	42.6	259.3	47.5	651.1	5802.5	27464.2	6999.0	139.0	2257.0	1567.6	1205.6
ROW IMPORTS	8.1	6.2	5.0	8.6	6.9	11.9	2.0	11.0	2.1	29.6	787.0	2710.4	3219.1	12.7	166.4	115.7	136.1
TOTAL	4644.2	1126.0	609.3	896.0	651.6	2748.9	616.4	2794.7	379.8	4794.2	30360.9	166854.7	33406.4	528.7	6165.4	6255.4	7168.2

TABLE 1. CALIFORNIA SAM (continued)

RAIL	SERVICES	TRUCK	AIR TRANS	UTILITIES	LABOR	CAPITAL	ENTER-PRISES	HOUSEHOLDS LOW	HOUSEHOLDS MED	HOUSEHOLDS HIGH	GOVT	CAPITAL ACCOUNT	DOMESTIC EXPORTS	FOREIGN EXPORTS	TOTAL
0	147.2	0	0.3	0	0	0	0	94.2	267.6	167.3	1.4	21.6	504.2	11.5	4644.2
0	0.2	0	0	0	0	0	0	0.1	0.6	0.5	136.6	8.3	552.5	316.8	1126.0
0	0.3	0.2	0	0	0	0	0	0.1	0.4	0.4	41.6	11.1	5.6	308.4	609.3
0	87.0	0	0	0	0	0	0	1.6	5.7	4.8	0	2.7	0.1	189.6	896.0
0	0.4	0	0	0	0	0	0	3.2	19.8	18.8	0.1	0	14.5	10.6	651.6
0	30.5	0	0	0	0	0	0	76.4	208.0	147.9	0.2	0	1056.8	281.3	2748.9
0	0.1	0	0	0	0	0	0	3.5	12.2	10.4	0	0	362.3	190.8	616.4
0	163.1	0	0	0	0	0	0	95.8	283.9	184.2	0.7	0	1348.2	119.3	2794.7
0	3.5	0	0	0	0	0	0	0.1	0.5	0.4	5.0	0	156.8	4.3	379.8
0.3	557.2	0.3	0.5	1.0	0	0	0	43.3	175.2	193.2	14.1	0	2157.0	78.3	4794.3
0.3	4716.1	0.6	10.8	0.9	0	0	0	2152.1	6864.1	4516.0	129.9	4.0	5954.5	1672.6	30360.9
344.6	13973.5	131.9	320.6	675.1	0	0	0	963.8	4329.2	4034.1	12363.9	29941.2	38185.5	15223.2	166854.7
169.9	3338.4	543.9	2231.6	1998.9	0	0	0	683.6	2834.7	1959.2	215.4	29.3	141.1	4461.1	33406.4
0.9	29.2	0	0	0.4	0	0	0	2.9	10.0	8.5	6.4	1.8	1.3	84.4	528.7
0.4	353.4	4.6	3.8	0.8	0	0	0	436.3	1692.2	1770.7	392.2	100.3	45.7	94.3	6165.4
0.6	591.9	4.4	3.1	17.8	0	0	0	99.0	365.9	295.6	20.6	8.6	221.9	426.8	6255.4
1.2	1114.2	4.1	4.1	21.7	0	0	0	290.6	893.8	674.6	292.3	19.0	468.8	366.9	7168.2
57.7	214.0	26.7	4.8	80.6	0	0	0	52.5	133.5	158.9	124.0	40.9	1.5	162.7	1858.1
142.5	58323.8	944.4	1791.9	498.1	0	0	0	20549.8	70644.3	63019.4	30817.8	2957.9	54771.1	11268.4	343348.7
11.2	1198.8	999.9	82.8	39.5	0	0	0	198.9	506.4	438.9	763.7	106.6	147.8	225.0	7470.3
4.2	1708.5	15.1	651.7	18.3	0	0	0	548.1	1393.7	1658.8	560.9	41.8	415.2	515.6	9202.4
5.5	3468.9	18.0	28.2	1406.6	0	0	0	590.7	1819.9	1321.7	301.7	0.3	529.9	19.5	12538.4
820.8	133637.5	3112.7	2237.1	1519.5	0	0	0	0	0	0	0	0	16578.7	0	229311.2
114.0	83278.4	1138.9	339.8	2700.5	0	0	0	0	0	0	0	0	13918.2	0	120726.1
0	0	0	0	0	0	70209.4	0	3365.2	3835.6	1365.8	10062.5	0	0	0	88838.6
0	0	0	0	0	12239.4	-335.0	8457.2	0	0	0	17878.9	3348.9	0	0	41589.4
0	0.0	0	0	0	108599.0	4767.8	27946.4	0	0	0	17658.1	0	0	0	158971.3
0	0.0	0	0	0	77163.1	7717.7	27209.5	0	0	0	3865.3	0	0	0	115955.5
63.8	20580.3	196.8	331.8	461.9	31309.7	0	22143.3	6284.6	31131.3	10441.0	50711.7	20500.0	0	0	199767.2
0	0	0	0	0	0	37866.8	3082.2	71.7	12826.2	7588.3	39537.6	1109.7	0	0	102082.4
110.0	14113.4	307.5	411.1	3022.8	0	499.6	0	4350.7	16187.3	13816.7	10754.8	21399.1	0	4637.3	137539.0
10.3	1719.1	20.4	748.4	73.9	0	0	0	630.6	2529.2	2159.2	3109.7	22429.2	0	0	40668.8
1858.1	343348.8	7470.3	9202.5	12538.4	229311.2	120726.1	88838.6	41589.4	158971.2	115955.5	199767.2	102082.4	137539.0	40668.8	1879868.0

TABLE 2. THE CALIFORNIA COTTON EXTERNALITY SAM

SECTORS:	LVSTK	COTTON	FOOD GRAINS	FEED GRAINS	HAY & GRASS	FRUIT	TREE NUTS	VEGE-TABLES	MISC CROPS	FOREST PROD	FOOD PROC	NONAG INDUST	OIL, GAS & REF	AG CHEM	TEX-TILES
LIVESTOCK	277	3843	-12	-50	-15	-6	-2	-12	-2	727	-1046	0	0	0	-3
COTTON	397	7547	30	30	30	483	121	244	30	191	24821	61	0	0	3648
FOOD GRAINS	-5	217	-48	0	0	-1	0	0	0	4	-348	0	0	0	0
FEED GRAINS	-246	0	0	-111	0	0	0	0	0	35	-345	0	0	28	0
HAY & GRASS	-381	372	0	-7	-6	-5	0	-1	0	113	0	0	0	0	0
FRUITS	-2	905	0	0	0	-7	-2	-6	0	13	-1546	0	0	0	0
TREE NUTS	-1	217	0	0	0	-1	0	0	0	4	-53	0	0	0	0
VEGETABLES	-1	616	0	0	0	-5	-2	-165	0	9	-886	0	0	0	0
MISC CROPS	0	109	0	0	2	0	0	0	-38	3	-267	-1	0	0	0
FOREST PRODCTS	95	62448	-23	-33	-17	-387	-52	-206	-16	2406	-31	-89	0	2	-11
FOOD PROCESSING	435	145	0	1	0	0	0	0	0	268	-1264	-40	-7	41	-1
SERVICES	13	8492	738	1039	736	3223	742	3506	422	2277	-2578	710	-1335	866	-162
NONAG INDUSTRY	34	18891	-73	-124	-61	-261	-39	-131	-26	3256	-107	-1571	-7270	823	-24
OILGAS & REFINING	2	10136	-19	-48	-23	-66	-8	-55	-12	1459	-1	-8	-3	312	0
AG CHEMICALS	1	0	0	-1	-1	-7	-2	-8	0	185	-4	-180	-1	9	-451
TEXTILES	4	145	0	0	0	-9	-2	-12	0	52	-71	-1691	-3	94	-10
WOOD & PAPER	9	1744	-3	-10	-4	-11	-1	-12	-3	524	-53	22286	-166	325	-24
NONAG CHEMICALS	8	581	-3	-5	-3	-8	-1	-8	-1	96	-56	-303	-24	92	-2
RAILROADS	122	74463	-164	-243	-122	-233	-40	-348	-84	7260	-875	55180	-2561	818	-268
TRUCKING	33	1817	-5	-14	-7	-18	-1	-32	-4	349	-217	-977	-65	310	-18
AIR TRANSPORT	1	400	0	0	0	-7	-2	-16	0	765	-45	-803	-60	85	-17
UTILITIES	319	8743	72	169	150	426	0	326	162	1182	3502	18502	7066	515	437
LABOR	140	53876	727	1042	742	2747	647	3068	386	20559	-1659	-2790	-1123	1103	-926
CAPITAL	202	40326	-1735	-2604	-1714	-8001	-1739	-9157	-1109	8886	-1136	-79759	-3347	1427	-249
ENTERPRISES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOW INCOME HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MED INCOME HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HIGH INCOME HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GOVERNMENT	66	5381	-13	-31	-11	-53	-11	-47	-5	1394	-290	-1111	-876	158	-25
CAPITAL ACCOUNT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM IMPORTS	1444	46582	-87	-200	-111	-339	-35	-287	-56	8152	303	-15683	-5123	2518	-1281
ROW IMPORTS	14	2249	-6	-14	-7	-14	-1	-15	-4	370	-203	-1577	-2357	229	-94

TABLE 2. THE CALIFORNIA COTTON EXTERNALITY SAM (continued)

WOOD & PAPER	NONAG CHEM	RAIL	SERVICES	TRUCK	AIR TRANSP	UTILITIES	LABOR	CAPITAL	ENTER-PRISES	HOUSEHOLDS LOW	MED	HIGH	GOVT	CAPITAL ACCOUNT	DOMESTIC EXPORTS	FOREIGN EXPORTS
-3	60	0	35	0	0	0	0	0	0	-100	-196	-69	0	0	-135	-1
0	0	0	61	0	0	0	0	0	0	30	183	152	41388	2529	168185	96465
0	0	0	0	0	0	0	0	0	0	0	0	0	-117	-14	-9	-409
0	0	0	-91	0	0	0	0	0	0	-3	-9	-7	0	-3	0	-244
0	26	0	0	0	0	0	0	0	0	-7	-28	-24	0	0	-22	-12
0	0	0	-25	0	0	0	0	0	0	-184	-378	-255	0	0	-1623	-376
0	0	0	0	0	0	0	0	0	0	-7	-18	-14	0	0	-547	-2[illegible]
0	0	0	-173	0	0	0	0	0	0	-223	-566	-360	-1	0	-2100	-162
-3	414	0	-2	0	0	0	0	0	0	0	-1	0	-14	0	-224	-5
-116	258	0	129	0	0	-2	0	0	0	-45	-107	-123	-22	0	-579	-4
-2	2496	0	1060	0	-5	-2	0	0	0	-2353	-4466	-2485	-205	0	-1599	-113
-408	27268	-190	-1009	-80	-235	24347	0	0	0	1467	9092	8637	-23195	-9159	-21700	-5583
-102	19964	-41	746	-160	-969	-29058	0	0	0	-741	-1859	-1082	-339	1	-38	-300
0	430	0	12	0	0	-1	0	0	0	-3	-2	0	-10	0	0	-5
-8	76	0	83	-1	-2	-2	0	0	0	-468	-1127	-959	-619	-1	-13	-6
-744	874	0	118	-1	-2	-160	0	0	0	-102	-219	-186	-32	0	-59	-28
-87	15184	-1	684	-1	-2	6267	0	0	0	1523	4917	3764	175390	0	-126	-24
-36	1320	-14	51	-9	-2	-1103	0	0	0	-52	-97	-69	-195	0	0	-10
-246	23788	-49	106937	-372	-958	-7310	0	0	0	-15681	-21053	-12434	-29420	-314	-21197	-2382
-43	2848	-3	275	-294	-35	-551	0	0	0	-223	-319	-252	-1203	0	-40	-15
-19	1571	-1	390	-5	-285	-173	0	0	0	-597	-925	-895	-884	-1	-112	-35
1179	4771	65	42207	210	325	-3581	0	0	0	6361	20485	15054	3145	4	6167	233
-975	44106	-207	29919	-917	-971	51795	0	0	0	0	0	0	0	0	-4445	0
-304	27111	-28	-52809	-336	-147	145427	0	0	0	0	0	0	0	0	-3739	0
0	0	0	0	0	0	0	0	-9419	0	-1464	-230	57	-15861	0	0	0
0	0	0	0	0	0	0	3380	45	-1103	0	0	0	-28184	-20	0	0
0	0	0	0	0	0	0	29995	-639	-3643	0	0	0	-27835	0	0	0
0	0	0	0	0	0	0	21311	-1035	-3546	0	0	0	-6094	0	0	0
-25	3650	-18	7320	-56	-142	-6533	8648	0	-2886	-3294	-4220	-425	-81673	-1990	0	0
0	0	0	0	0	0	0	0	-5080	-402	-84	-8387	-4147	-13446	-6	0	0
-1039	36271	-28	3549	-90	-178	-43652	0	-67	0	-4568	-9969	-7187	-16895	-117	0	-311
-76	4094	-3	434	-7	-326	-1070	0	0	0	-657	-1580	-1141	-4901	-141	0	0

TABLE 3. THE CURRENT ENVIRONMENTALLY ADJUSTED SAM

SECTORS:	LIVE-STOCK	COTTON	FOOD GRAINS	FEED GRAINS	HAY & GRASS	FRUIT	TREE NUTS	VEGE-TABLES	MISC CROPS	FOREST PROD	FOOD PROC	NONAG INDUST	OIL, GAS, & REF	AG CHEM	TEX-TILES	WOOD & PAPER	NONAG CHEM
LIVESTOCK	555.3	10.5	11.1	32.5	14.3	5.8	1.3	9.5	1.3	58.2	2716.6	0	0	0	5.9	3.8	2.0
COTTON	1.3	11.2	0.1	0.1	0.1	1.6	0.4	0.8	0.1	0.6	81.5	0	0	0	12.0	0	0
FOOD GRAINS	6.1	0.6	20.4	0.1	0.1	0.8	0.2	0.4	0	0.3	211.4	0	0	0	0	0	0
FEED GRAINS	344.6	0	0	39.0	0	0	0	0	0	3.1	215.7	0	0	1.7	0	0	0
HAY & GRASS	564.2	1.1	0.1	2.4	2.8	1.4	0.3	0.7	0.1	10.0	0	0	0	0	0	0	0.9
FRUITS	2.8	2.5	0.3	0.3	0.2	3.3	0.8	1.7	0.2	1.2	934.4	0	0	0	0	0	0
TREE NUTS	0.6	0.6	0.1	0.1	0.1	0.7	0.2	0.4	0	0.3	34.0	0	0	0	0	0	0
VEGETABLES	2.5	1.7	0.2	0.2	0.2	2.3	0.5	60.9	0.1	0.8	530.2	0	0	0	0	0	0
MISC CROPS	0.4	0.3	0	1.5	1.2	0.4	0.1	0.2	14.3	0.2	173.1	0	0	0	0.3	2.2	14.3
FOREST PRODCTS	189.5	171.0	20.2	20.6	16.8	308.2	60.5	146.2	10.8	192.6	83.3	146.4	0	0.1	19.9	173.3	8.6
FOOD PROCESSING	872.9	0.4	0.3	0.6	0.5	0.8	0.1	0.8	0.1	21.4	3282.6	58.3	9.2	2.3	2.0	3.3	83.0
SERVICES	68.9	23.3	17.6	26.7	21.5	169.3	17.3	52.7	8.0	186.7	3766.6	39139.8	1293.9	48.7	186.1	424.2	915.9
NONAG INDUSTRY	66.3	51.7	62.0	77.4	63.7	205.9	45.7	92.8	17.1	260.7	277.0	2741.0	9931.6	45.5	42.7	155.6	663.9
OILGAS & REFINING	3.9	27.8	16.3	30.5	24.6	51.5	8.1	40.4	8.0	116.8	3.2	17.3	4.8	17.2	0.2	1.1	14.3
AG CHEMICALS	1.5	0	0	1.0	0.9	5.6	1.4	6.5	0	14.9	9.5	417.7	1.8	0.5	795.1	12.2	2.5
TEXTILES	8.7	0.4	0.2	0.4	0.4	8.2	1.5	7.4	0.1	4.2	185.0	2805.8	4.6	5.2	17.1	1120.3	29.1
WOOD & PAPER	17.2	4.8	2.6	6.0	4.8	9.5	1.7	7.8	1.5	42.0	137.6	1859.5	226.3	17.9	43.0	128.5	505.0
NONAG CHEMICALS	15.4	1.6	2.9	3.6	2.9	5.2	0.6	5.0	0.8	7.7	143.2	464.8	34.9	5.1	3.7	53.9	43.9
RAILROADS	307.7	204.1	126.1	142.6	116.8	171.0	41.2	229.6	52.9	586.0	1800.0	19200.2	3078.5	45.5	399.7	321.3	793.7
TRUCKING	64.1	5.0	4.0	8.1	6.6	13.6	1.9	21.2	2.5	27.9	562.4	1735.4	89.8	17.1	30.8	66.1	94.7
AIR TRANSPORT	2.1	1.1	0.1	0.2	0.2	6.3	1.1	12.5	0.1	61.2	116.2	1272.8	81.8	4.7	28.3	27.6	52.2
UTILITIES	25.3	23.2	6.7	16.3	13.7	39.5	0	30.8	15.5	48.3	304.1	1603.8	627.0	17.1	38.2	103.9	113.4
LABOR	279.9	147.6	30.7	30.2	21.8	588.3	132.0	374.5	33.3	1645.9	4308.6	57651.4	1535.8	60.9	1631.7	1465.6	1466.7
CAPITAL	401.9	282.5	176.3	265.8	196.2	812.3	244.0	1384.3	158.2	711.3	2947.4	5214.2	4571.8	78.8	437.0	456.4	901.6
ENTERPRISES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LOW INCOME HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MED INCOME HH	0	0	0	0	0	0	0	0	0	0	0	7.9	0	0	0	0	0
HIGH INCOME HH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GOVERNMENT	117.7	14.7	12.7	22.6	13.6	47.9	11.1	37.2	5.2	110.7	947.3	2338.9	1696.0	8.6	48.5	52.6	120.8
CAPITAL ACCOUNT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM IMPORTS	715.2	127.6	93.1	158.6	120.6	277.5	42.6	259.3	47.5	651.0	5802.7	27470.8	6999.1	139.0	2257.0	1567.6	1205.6
ROW IMPORTS	8.1	6.2	5.0	8.6	6.9	11.9	2.0	11.0	2.1	29.6	787.4	2708.7	3219.3	12.7	166.4	115.7	136.1
TOTAL	4644.2	1121.4	609.0	895.9	651.4	2748.9	616.5	2794.7	379.9	4793.6	30360.9	166854.5	33406.3	528.5	6165.4	6255.3	7168.1

TABLE 3. THE CURRENT ENVIRONMENTALLY ADJUSTED SAM (continued)

RAIL	SERVICES	TRUCK	AIR TRANS	UTILITIES	LABOR	CAPITAL	ENTER-PRISES	HOUSEHOLDS LOW	HOUSEHOLDS MED	HOUSEHOLDS HIGH	GOVT	CAPITAL ACCOUNT	DOMESTIC EXPORTS	FOREIGN EXPORTS	TOTAL
0	145.3	0	0.3	0	0	0	0	94.6	270.2	166.1	0	22.7	505.7	11.1	4644.2
0	0	0	0	0	0	0	0	0	0	0	135.3	9.8	550.9	315.7	1121.4
0	0	0.2	0	0	0	0	0	0	0	0	48.2	12.1	0	308.2	609.0
0	100.7	0	0	0	0	0	0	1.6	0	0	0	0	0	189.5	895.9
0	0	0	0	0	0	0	0	3.4	19.1	20.5	0	0	13.9	10.4	651.4
0	21.3	0	0	0	12.0	0	0	75.8	206.7	147.0	0	0	1056.9	281.3	2748.9
0	0	0	0	0	13.2	0	0	3.4	0.0	9.2	0	0	362.5	191.1	616.5
0	163.7	0	0	0	0	0	0	95.4	284.7	183.7	0	0	1348.7	118.9	2794.7
0	12.6	0	0	0	0	0	0	0	0	0	0	0	154.7	4.0	379.9
0.3	563.8	0.3	0.5	1.0	0	0	0	43.0	174.0	192.5	16.5	0.0	2155.6	78.2	4793.6
0.3	4709.6	0.6	10.8	0.9	0	0	0	2152.3	6865.5	4516.3	134.8	5.5	5952.9	1672.7	30360.9
344.6	13967.8	131.9	320.6	675.1	0	0	0	963.9	4328.4	4033.6	12368.8	29942.6	38186.4	15223.6	166854.5
169.9	3333.9	543.9	2231.6	1998.9	0	0	0	683.4	2835.3	1958.6	216.2	29.9	142.9	4461.1	33406.3
0.9	32.9	0	0	0.4	0	0	0	2.9	11.0	10.0	0	0	0	84.4	528.5
0.4	348.8	4.6	3.8	0.8	0	0	0	436.0	1691.0	1769.5	397.1	101.5	46.2	94.6	6165.4
0.6	586.3	4.4	3.1	17.8	0	0	0	98.8	365.2	295.5	25.1	10.2	222.8	427.0	6255.3
1.2	1107.2	4.1	4.1	21.7	0	0	0	290.8	896.2	673.7	295.9	21.6	469.0	367.0	7168.1
57.7	203.1	26.7	4.8	80.6	0	0	0	52.2	134.1	161.7	133.8	45.3	0	163.0	1858.3
142.5	58320.0	944.4	1791.9	498.1	0	0	0	20549.7	70643.9	63019.5	30819.6	2959.7	54772.3	11269.3	343347.6
11.2	1186.3	999.9	82.8	39.5	0	0	0	199.3	507.5	438.8	771.4	109.9	147.5	224.9	7470.4
4.2	1699.2	15.1	651.7	18.3	0	0	0	547.4	1389.0	1658.4	573.8	42.6	418.2	516.0	9202.4
5.5	3461.4	18.0	28.2	1406.6	0	0	0	590.7	1820.9	1321.0	306.1	0	534.2	19.1	12538.3
820.8	133638.3	3112.7	2237.1	1519.5	0	0	0	0	0	0	0	0	16577.5	0	229310.7
114.0	83272.8	1138.9	339.8	2700.4	0	0	0	0	0	0	0	0	13919.8	0	120725.7
0	0	0	0	0	21.5	70170.2	0.0	3365.2	3838.3	1369.6	10073.1	0	0	0	88838.0
0	0	0	0	0	12086.8	0	8435.8	0	0	0	17749.5	3317.4	0	0	41589.4
0	29.0	0	0	0	108619.3	4691.4	27950.8	0	0	0	17672.8	0	0	0	158971.2
0	30.4	0	0	0	77187.5	7639.1	27213.7	0	0	0	3884.8	0	0	0	115955.4
63.8	20569.7	196.8	331.8	461.9	31320.8	0	22145.4	6285.0	31130.1	10440.3	50714.4	20501.2	0	0	199767.1
0	0	0	0	0	30.3	37800.6	3088.4	72.6	12834.3	7590.9	39550.8	1114.3	0	0	102082.3
110.0	14128.0	307.5	411.1	3022.9	19.3	424.5	4.0	4351.1	16191.0	13821.3	10770.6	21405.1	0	4637.6	137538.5
10.3	1715.6	20.4	748.4	73.9	0	0	0	630.9	2534.6	2157.5	3108.8	22430.8	0	0	40668.8
1858.3	343347.6	7470.4	9202.4	12538.3	229310.7	120725.7	88838.0	41589.4	158971.2	115955.4	199767.1	102082.3	137538.5	40668.8	1879858.6

Figure 1
Private vs. Social Cost

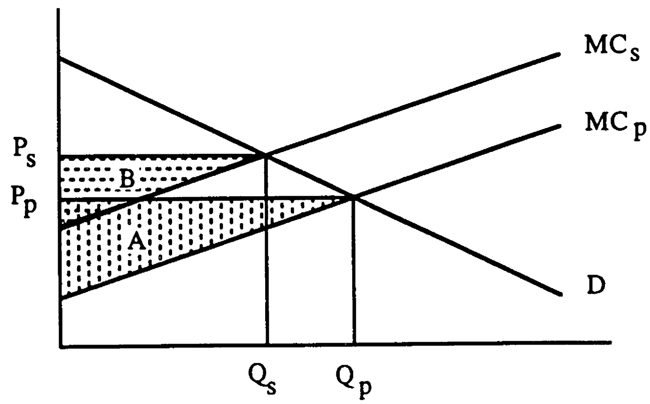

Figure 2
Positive Incremental Producer Surplus

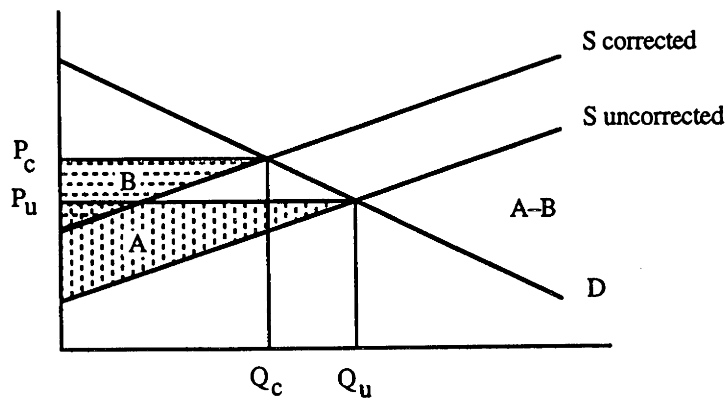

Figure 3
Positive Incremental Purchaser Surplus

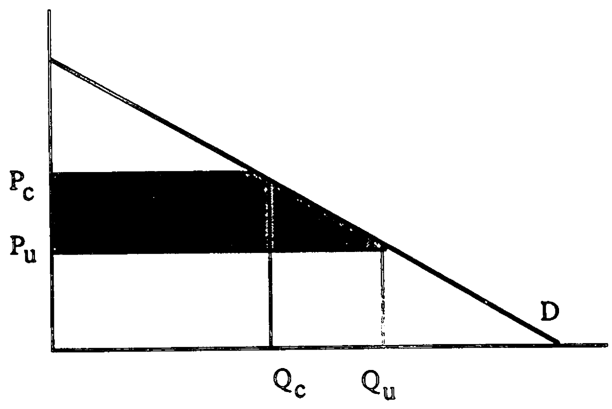

Figure 4
Positive Incremental Derived Producer Surplus

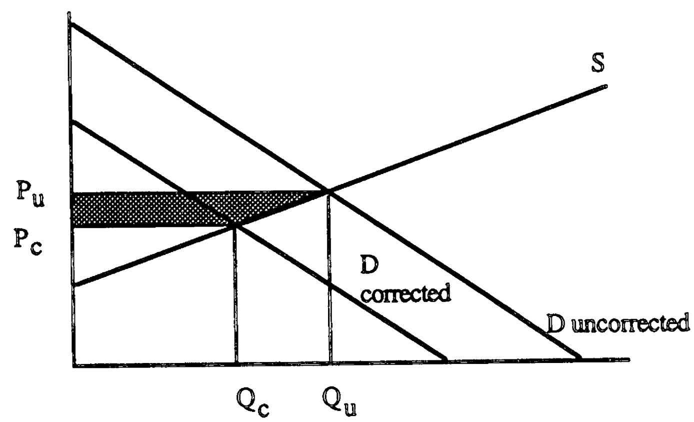

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Figure 5
Negative Incremental Producer Surplus

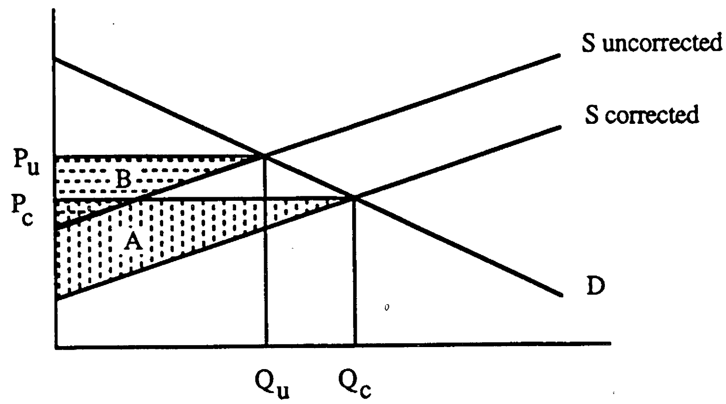

Figure 6
Negative Incremental Purchaser Surplus

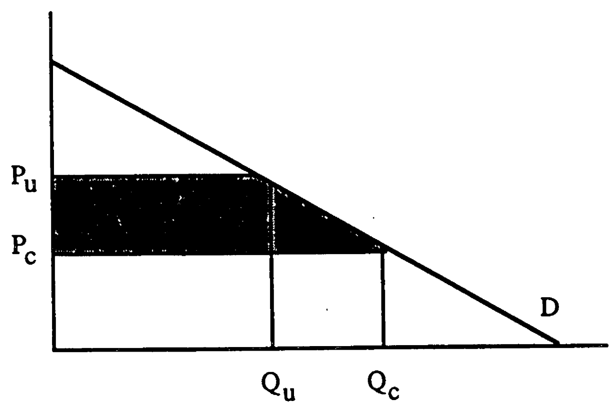

Figure 7
Negative Incramental Derived Producer Surplus

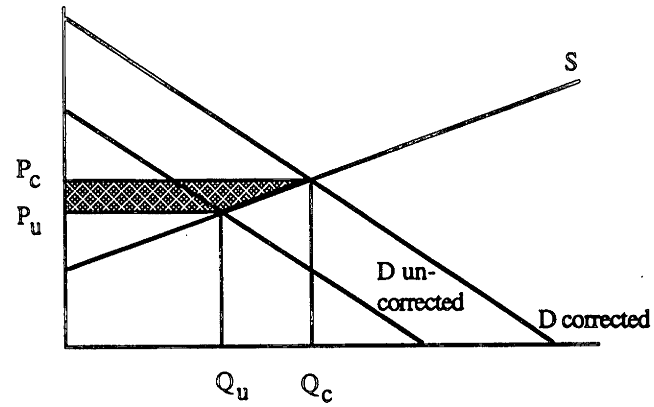

Figure 8
Demand Shift

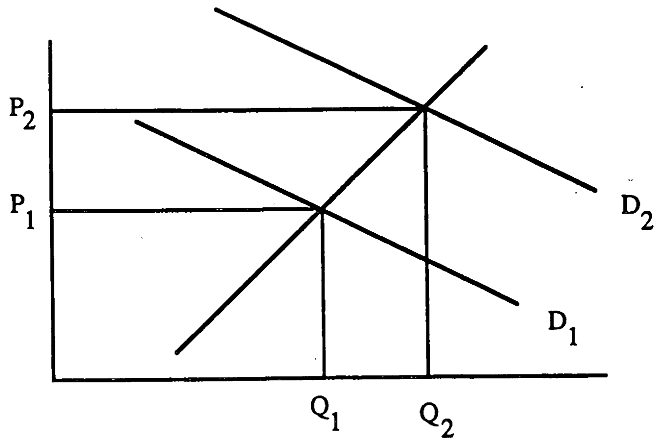

Figure 9
Quality Control

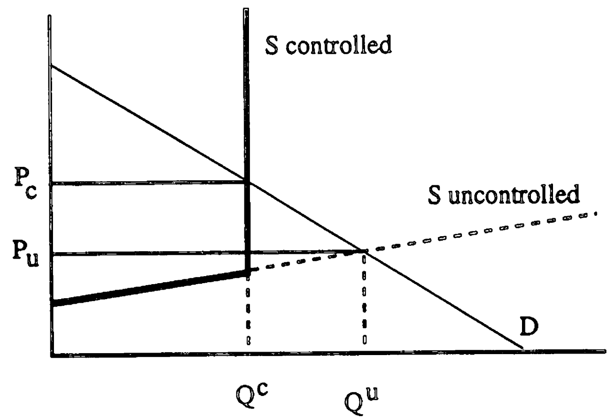

Figure 10
Input Restrictions, Direct Pollution Control, and Defensive Expenditures

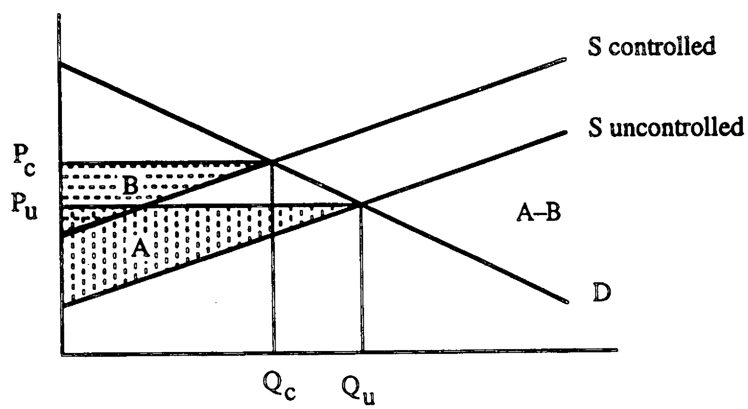

FIGURE 11. THE SCHEMATIC EXTERNALITY SAM

	Activities Ag Other Ind	Value Added Lab Cap Dep	Institutions Enterprises Households	Exog Flows Govt. Inv ROW	T
Activities Agriculture Other Ind	Block A +Polluting industry and its suppliers increase production as a result of the externality. +Suppliers of environmental defense expand supply to match increased demand. - Industies injured by the externality decrease production. +- Intermediate demand enjoys (suffers) lower (higher) priced inputs. - Decrease in productivity due to pollution		Block F +Increase in expenditure on goods and services that experience a decrease in price due to the externality. +Increase in expenditure on environmental defensive goods and services. -Decrease in expenditure on goods and services that experience a rise in price due to the externality.	Block I Change in government expenditure in response to change in relative prices induced by the externality. Increase in govt. defensive expenditures. Change in investment due to externality-induced changes in productivity and capital use. Change in type and quantity of exports in reponse to relative price changes induced by the externality.	
Value Added Labor Capital Depreciation	Block B Change in value added divided between wages and profits. Change in depreciation.				
Institutions Enterprises Households		Block D Changes in returns to capital and returns to labor allocated to households and enterprises.	Block G Changes in corporate earnings as a result of the externality distributed to households		
Exog Flow Government Gross Investment Rest of World	Block C Change in value-added tax revenue and tariff revenuedue to externality-induced redistribution of production. Change in imported input demand	Block E Change in employer's portion of social-security-tax revenue due to net change in household income. Change in unincorporated profit-tax revenue. Change in savings for unincorporated businesses. Change in foreign investment in unincorporated businesses.	Block H Change in income-tax revenue. Change in incorporated business profit-tax revenue. Change in foreign investment in incorporated businesses.		
Total					

FIGURE 12. THE SCHEMATIC NNP SAM

	Activities Ag Other Ind	Value Added Lab Cap Dep	Institutions Enterprises Households	Exog Flows Govt. Inv ROW	T
Activities Agriculture Other Ind	Block A		Block F	Block I	
Value Added Labor Capital Depreciation	Block B Value -Added - Depreciation +				
Institutions Households Enterprises		Block D Employee Compensation + Distributed Earnings on Capital	Block G		
Exog Flow Government Gross Investment Rest of World	Block C Value-Added Tax	Block E	Block H		
Total	NNP	National Income			

TABLE A1

Approaches of environmental accounting systems *

NATURAL ENVIRONMENT ------------------------> ECONOMY

Physical data	Physical description (with spatial orientation) (1)	Physical flows between the natural environment and the economy (2)	Physical flows within the economy (3)
Monetary data	No economic valuation (4)	Additional non-market valuation: direct (preference inquiries); indirect (cost data) (5)	Disaggregation of the national accounts (6)

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(1) : Environment statistics system in a narrow sense

(6) : Economic accounting system (SNA)

(2) + (3) + (5) + (6) + part of (1) : System for Integrated Environmental and Economic Accounting (SEEA)

(1) + (2) : natural resource accounts and environment statistics in a broader sense

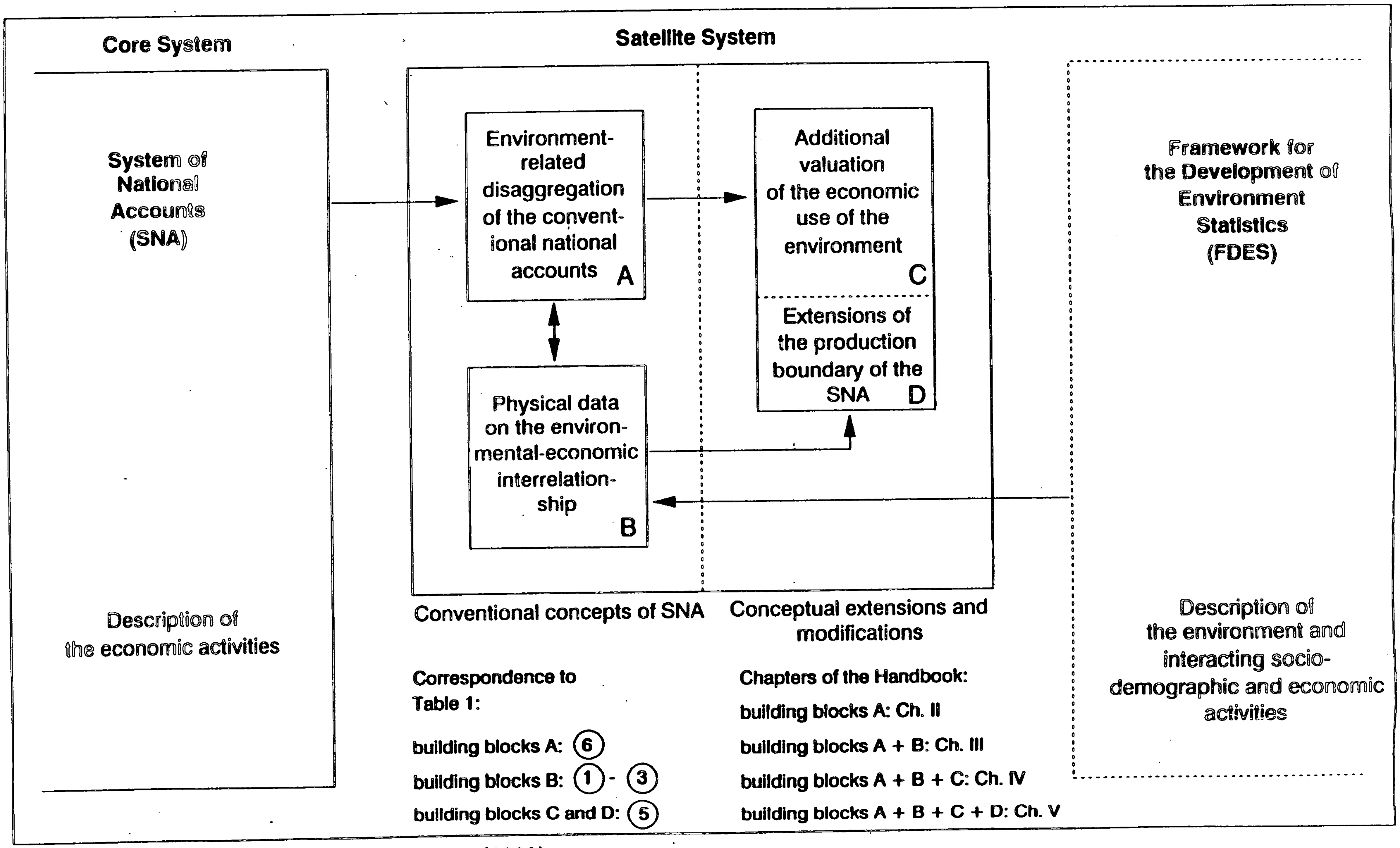
(2) + (3) : material/energy balances

(5) + (6) : extended economic accounting system

Taken from Stahmer (1992)

TABLE A2

SNA Satellite System for Integrated Environmental and Economic Accounting (SEEA) *



*Taken from Stahmer (1992)