CHAPTER 4

Management of Flood Catastrophes

An Emerging Paradigm Shift?

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THE NETHERLANDS has witnessed quite a number of water-related disasters in its history. In fact, catastrophes have been recorded from the 15th century on. The last major flood dates to 1953, when large parts of the southwestern part of the country were flooded, and about 1,835 people lost their lives. More recently, in 1995, 250,000 people were evacuated because a polder along the Rhine River was in danger of being inundated.

In the European spectrum of countries, the Netherlands occupies a special place, with a number of distinguishing factors. Probably the most important one is its geography along the North Sea coast, with a quarter of its territory below sea level and two-thirds vulnerable to flooding. The country is a delta where four of Europe's rivers reach the sea: the Rhine, Meuse, Ems, and Scheldt. In combination with the uncertain dynamics of possible climate change, with its implications of a rising sea level, increasing peak flows in the rivers, and a growing frequency and intensity of extreme rainfall events (MNP 2005), as well as a greater amount of precipitation and a gradually subsiding ground level, the Netherlands faces a continuous, probably increasing risk.

For a long time, the Netherlands has addressed the problems posed by the sea and rivers in an essentially technocratic way. This basically meant raising the dikes according to the latest calculations regarding the frequency of critical peak flows. The 1953 flood was a decisive event in the formulation of flood protection policy as it currently exists. The country responded to this event by a combined strategy of building higher dikes and developing an integrated structural approach for the entire delta area, known as the Delta Plan.[1] The major outlets to the sea were cut off by dikes or a storm surge barriers (with the exception of the Scheldt, motivated by the interests of Antwerp Harbor). The Delta Plan was completed in 1997 with the building of the Maeslant Barrier (Maeslantkering), a storm surge barrier in the

New Waterway (Nieuwe Waterweg), near Rotterdam (see Deltawerken 2006). The idea was not new. In 1932, a closure dam called the Afsluitdijk was finalized, cutting off the Zuider Zee, which then became an interior lake, the IJsselmeer. This was combined with other large infrastructural works such as creating new polders to provide room for new towns, farming, nature, and recreation.

Since the 1960s, the policy of raising the dikes aimed at reducing the probability of a flood to close to zero. This was supported through model calculations based on standards such as one flood in 10,000 years at the utmost for the most vulnerable areas in the western part of the country. The high standards applied have created a general feeling of security and an expectation that public authorities can always guarantee safety. This permitted phenomenal economic growth in the protected areas behind the dikes, which rapidly transformed into a highly urbanized economy that claimed a significant role in the "global village," reflecting a near absolute faith in the physical, geographical, and climatological foundations of the underlying (model) calculations. Policy mainly focused on managing the probability of flooding, meaning that less attention was given to policies for controlling and reducing the consequences of such an event. This has resulted in the current situation in which the *risk of a flood*, defined as the product of the probability of a flood and the expected loss in case of a flood, is addressed one-sidedly by looking only at the first term of the product.

It is increasingly recognized, however, that the state cannot completely control natural variability or changes therein—which means that extreme situations will remain possible. Because flooding frequency standards during the past 50 years have not changed and economic expansion behind the dikes was exponential, expected risks actually have increased (RIVM 2004). In other words, although the probability of flooding is relatively low at present, potential damage is enormous. Against this background, insight is developing that the current strategy cannot be sustained ad infinitum and that new solutions have to be found (see, e.g., Commissie WB21 2000).

A corresponding development in this context is the growing importance of system risks (see, e.g., OECD 2003; Hoekstra 2005), which threaten the stability of the entire social system. For the Netherlands, this means that the relevant question has become which combination of technical, economic, legal, and administrative measures can contribute to improved risk control and, in particular, to decreasing the economic and social vulnerability of flooding. This includes attention to the governance structure that can assist in creating the political conditions and reaching the necessary consensus for effective choices.

Here we shall not discuss related developments such as the establishment of modern systems for data storage and retrieval in water monitoring. We should mention, however, the Netherlands' High Water Information System (HIS) (V&W 2005b), recently developed by the Dutch Ministry of Transport, Public Works and Water Management. This system has been designed to monitor flood defenses and present inundation and loss calculations. Several stakeholder organizations are involved, with a central role for the ministry. We will only briefly touch on international dimensions in flood cooperation, where several highly interesting developments have occurred.

This chapter focuses on developments in water policy and management in the Netherlands, including a discussion of currently circulating methodologies on economic flood consequence estimation, which differ significantly in background philosophy, objective, and scope. We will briefly go into such issues as the choice of time horizon and the demarcation between individual and state responsibility. Some main trends are evident, but for the most part, the debate is just beginning.

THE SHIFT FROM PROBABILITY TO RISK MANAGEMENT

The practice of guaranteeing public safety in the Netherlands by raising and strengthening the dikes in combination with land claim policies has a long history. It reached its culmination in the Delta Plan after the catastrophic 1953 flood. The decisions made in that context fixed Dutch policy for the next 50 years. Certain elements of safety standard differentiation according to the relative economic importance of the area were included in the design of the plan.

Central focus was to ensure safety under the motto "never such a flood again." The Delta Commission asked van Dantzig, a well-known statistician, to address the problem of calculating the optimal investment strategy in flood protection. He developed a general formula for the optimal height of the dikes in a dynamic context in which investments at regular intervals are required (van Dantzig 1956). His formula gives a fixed exceedance probability after each investment in the relevant safety structure.[2] The method is still in use today in cost–benefit analysis of flood-protection measures.

The high protection levels permitted accelerating socioeconomic development behind the dike system. The increasing growth of human and economic interests behind the dikes slowly created a problem in itself, however. In fact, the protective system and that which it is protecting are bound together in a seemingly endless action–reaction system with ever-increasing stakes and potential damage. This means that lowering the probability of a particular flood, such as protection against a 10,000-year flood, is not sufficient to guarantee sustainable development for the country in the long run, as flood risk is continuously increasingly because of population growth and economic expansion.

The conclusion has emerged that not only decreasing the probability of flooding should be considered, but also the possible consequences of a flood (RIVM 2004). The new question has become how to balance lowering both the probability of a flood *and* potential damage. This means an entirely different conceptual basis, reflecting the paradigm shift in Dutch thinking and policymaking about protection strategies. The concept of risk is being rediscovered and is the key to understanding the future direction water policy in the Netherlands should take.

We can observe the revival of the concept of risk in flood management, which is the product of the probability of flooding and its consequences (i.e., the costs inflicted). If we denote the flooding probability by the symbol P and potential loss (potential economic consequences) by E, the risk R can be defined as $R = P \times E$. Acknowledging the fact that full flood risk is the sum of different flood scenarios, it is more precise to write $R = \Sigma_i (P_i \times E_i)$, with $i = 1$ to n, where n denotes a number of flood scenarios. For many years, public policy aimed at lowering P as much as possible. Simultaneously, however, the country experienced a period of rapid growth, which meant that E, the potential flood effects, in the risk formula became larger and larger. The Netherlands is thus now confronted with a low probability of a flood and potentially extremely high consequences. In the coming decades, this must be translated into a policy aimed at decreasing *overall risk* (RIVM 2004), evidently a formidable task, because it requires insight into not only the risk equation and its dynamics, but also the relation between the two terms constituting risk. This clearly is the place where the water management specialist and the social scientist meet.

The part of the country vulnerable to flooding from sea or rivers is subdivided into a number of regions called dike-ring areas. Each is surrounded by a ring of natural or man-made water defenses, such as dikes, dunes, concrete structures, or high grounds, and may consist of one or more polders or low-lying areas. Ninety-nine such dike-ring areas exist in the country (V&W 2005a, *13*). One of the largest comprises the densely populated western part of the Netherlands, covering important parts of the provinces of Noord-Holland, Zuid-Holland, and Utrecht and including several major cities: Amsterdam, Rotterdam, and the Hague. In the western coastal area, the standard for exceedance probability is most stringent, once per 10,000 years, followed by the southern and northern coastal areas at once per 4,000 years. Several dike-ring areas with lower population and economic significance, such as in Limburg, have exceedance probabilities in the neighborhood of once per 150 or 200 years. The standards differ among regions because of variations in population and capital densities. All these standards are laid down in the Flood Defence Act (1996).

One element of the new risk thinking is that risk analysis is about the probability not only that the rivers or sea will reach a certain critical water level, but also that a particular link in the entire defense line will succumb (TAW 2000; Vrijling 2001). That is, one should be looking for possible dike failure mechanisms, stability of dike closing mechanisms (such as sluices), and more generally, the weakest links in the entire system.[3] The real probability of a flood is thus equal to the probability of the water reaching a particular level in conjunction with other processes.

The first comprehensive study presenting an evaluation of flood safety policy was *Dutch Dikes and Risk Hikes* (RIVM 2004), which concludes that although the water barriers have never been as strong as now, the country's vulnerability has increased significantly and potential loss can be very large, not only in material terms, but also in terms of the population at large. The report signals a discrepancy between the legal standards regarding dike height and socioeconomic growth over the past decades. A second study, *Flood Risks and Safety in the Netherlands* (V&W 2005a), by the Ministry of Transport, Public Works and Water Management, focuses on safety within the Dutch system of interconnected polders. It presents a series of calculations based on an adapted framework that accounts for not only dike overtopping, but also several other causes of dike breaching.

The signaled awareness is causing a gradual shift in thinking about water policy, with increasing attention paid to the possible effects of flooding and measures to prepare the country for the new situation. New ideas such as "room for water" or "room for the river" fit very well in this context (Silva et al. 2001), combined with fresh views on concepts such as vulnerability, resilience, and minimizing system risks. All this presumes integration among spatial planning, economic development, and water management, as the "room for water" strategy means the creation of retention areas available for controlled inundation in case it becomes necessary. Such an approach will require a revision of spatial patterns for land use, and adjustments that may cause changes in economic structure and infrastructure in the long run.

The above clearly signals a paradigm shift in water and flood management in the Netherlands—that is, a shift from focusing on the probability of flooding to thinking in terms of the risk of flooding. The essence of the old thinking in this sense was to keep the probability of flooding constant in conformity with the accepted standards. The new thinking takes into account the risk connected to the event of a flood, which implies balanced attention to both flooding probabilities *and* effects. A further step in this direction would focus the attention of politicians and decisionmakers particularly on managing the potential effects of a flood. The accumulation of assets and accelerated urbanization in the flood-prone areas of the Netherlands dictate these new rules. The probabilities of a flood set by the National Flood Defence Act (1996) actually are minuscule, especially in comparison with the standards imposed around the globe, averaging once per 100 years.

The signaled shift in perspective furthermore implies that it is increasingly important to properly account for the economic consequences of any particular decision, as the country now has to weigh these against the costs of a possible flood. Thinking in terms of risk also implies that the ultimate decision about the acceptable level should be made by society at large. That is, flood protection is not solely a matter of engineering anymore, but must be decided in public debate and compromise. The question is whether everyone, wherever he or she lives, has a right to the same protection level, or whether protection levels should be a function of population and capital densities. In the former case, the safety level in each dike-ring area should be of the same order of magnitude. In the latter case, different safety levels should be accepted, with the final choice of staying in a higher risk area left up to its residents. Reaching a compromise requires that many parties become involved in the decisionmaking process, which in turn may result in a significant rise of political transaction costs. Increasingly, analysis of the social, environmental, and economic costs and benefits should be performed to determine the most cost-effective measures (such as allowing more "room for the rivers," compartmentalizing existing dike rings, creating emergency inundation areas, adjusting building methods, or rearranging spatial patterns of living and economic activity) that would correspond to the accepted level of risk.

A next question concerns the responsibility issue. Up to now, the Dutch government had full responsibility for flood safety, at least as perceived by the public, but can that continue in the future? One aspect is that no government can guarantee perfect safety from natural hazard; residual risks will always remain. Here the question appears to be how to cover this residual risk. Public or private initiatives are needed, as well as mixed solutions. So far, government has always provided aid to the victims of natural disasters based on the solidarity principle, which needed reinterpretation for each particular case (see the Decision and the Law on Compensation of Damage in Case of Disasters and Serious Accidents, both from 1998). Recent years, however, have seen an intensification of the debate over private insurance against flooding. Addressing this issue touches immediately on the future scope of governance, which brings entirely new elements into the debate. In any case, the role of the Dutch water boards, the age-old public bodies governing water safety, will have to be reconsidered. On the economic side, cost–benefit analysis will be a central element, combined with willingness-to-pay explorations (see Chapter 5).

CONCEPTUAL ISSUES

This section addresses a number of problems in assessing flood damage. It does not put forward any new views about best practices, as the wide variety of problems requires a corresponding wide set of methodologies. Rather, this section is meant to draw attention to the existence of some of the fundamental choices involved, highlighting the issues that are essential in constructing consistent frameworks for disaster modeling. The discussion is limited to economic damage.

Defining Economic Damage

Important questions concerning economic damage caused by a disaster are what precisely should be measured, and to what purpose. A whole range of issues are involved here. Above all is the issue of human health or life. Many studies recognize the fact that nonmaterial issues are involved but skip the emotional or psychological ones, which require separate attention. We will also leave those aspects out of our current discussion. The reason for doing so is twofold. Valuation in economic terms of emotional or psychological effects, as well as human life itself, is an extremely intricate task that involves indirect valuation methods, as one cannot estimate such losses directly by assigning monetary values to them. Additionally, by engaging in such valuations, one enters a gray area of ethical issues, involving questions of whether human lives and emotional aspects of disasters can or should be valued at all. We leave it to the discretion of the individual researcher to decide whether to include such valuations. What can be done, however, is to view the loss in terms of human capital, which can be analyzed economically. Because many of the issues discussed here have appeared in international disaster studies, we refer to both Dutch and international expertise.

A first observation is that no uniformity exists in the use of damage concepts (Mitchell 2000; NRC 1999). This is reflected in the treatment of *loss* (in concepts such as direct, indirect, primary, secondary, or induced damage), the role of substitution effects, and the statistical databases. With respect to damage classification, however, one may notice a certain tendency toward the direct-indirect loss distinction. Here two main approaches can be discerned. According to the *spatial criterion,* all losses attributable to the affected area are direct, and losses incurred elsewhere are indirect (Bočkarjova et al. 2007; Chang 1998; Cochrane 1997a; Cole et al. 1993;

Rose and Lim 2002). According to the *stock-flow differential criterion*, on the other hand, losses that refer to physical damage are considered stock losses and are direct. All losses associated with production curtailment, whether within or outside the affected area, are indirect and measured as a flow (Booysen et al. 1999; BTRE 2001; Messner and Meyer 2006; Parker et al. 1987).[4] In this context, depending on the chosen framework, direct losses may refer to the costs to replace the lost assets based on their market value or on their restoration or rebuilding value.

For the purposes of our discussion, we do not need to make a choice in favor of one of these definitions. We therefore will refer broadly to indirect damage as loss of connectivity and interruption of flows in the production network and the losses due to it. In applied studies, however, it is important to state which definition is chosen, for transparency as well as comparability purposes.

Second, a study on disaster effects requires a clear delineation of its spatial and temporal dimensions. Whether the analysis is performed for a part of the country or the country as a whole makes quite a difference in terms of analysis. A recent example is provided by Hurricane Katrina in New Orleans in 2005. In relative terms, effects evidently are much more serious at the level of the state of Louisiana than at the federal level. In terms of the time dimension, damage assessment requires a clear insight into what precisely is meant by the term "recovery period" (ECLAC 2003); that is, at which point in time should damage be measured? In one respect, the answer is quite simple: direct damage—that to the constructed environment, physical assets, and property—is best recorded immediately after the calamity. One should also account for indirect damage, however, which involves interruptions to the flows of goods and services. Dealing with these effects requires a broader time horizon, extending several years after the catastrophe.

Here a fundamental issue arises: in establishing the effects of a flood, one should take into account not only losses as a result of the disturbance, but also emerging sequential effects, such as possibilities for product substitution and adjustments in the production and consumption markets. Such accommodations to the new situation, often referred to as "resilience," make the economy reach a new equilibrium faster, thereby moderating the initial negative effect. For the country as a whole, other effects may occur, such as businesses outside the affected area increasing their production if spare capacities are present or consumers adjusting their consumption patterns during the emergency situation. In many respects, the disaster aftermath can be viewed as a new situation with new underlying conditions; what is lost cannot be recovered anymore, and in this sense lost assets essentially are sunken costs. Thus decisions such as whether to resume production should be made based on the new realities without undue reference to the predisaster situation.

Third, damage is a multidimensional concept, because it serves various purposes. Multiple groups of stakeholders have their own views about the aims disaster analysis and damage assessment should serve (NRC 1999). Some of these can be easily identified, such as governments or industry representatives; insurers or reinsurers, including their associations and government insurance regulators; business corporations; individuals; and research analysts and experts in disaster analysis. A range of analyses is needed to cover the multiple aspects of disasters, because each of the parties that have a stake in damage estimation generally is interested in a specific aspect.

Fourth, a clear distinction should be made between financial and economic appraisals. The former type deals with the financial and accounting aspects, and the latter deals with alternative or opportunity costs. Many insurance companies' or governmental expenditure reports on damage are based on financial considerations. Using the economic concept of opportunity cost in valuations requires a quite different approach. When both economic and financial concepts are used at the same time, methodologically inconsistent results may be obtained, which makes assessments difficult to compare or interpret (Benson 1997).

Costs and Double Counting

In economic appraisal studies for damage assessment, one is immediately confronted with the notion of opportunity or alternative costs. Standard alternative costs represent anything that has to be sacrificed to obtain some specific commodity or service. Conventionally, this means, for example, that government may have to decide between two options, such as dike strengthening and a public campaign on raising flood-risk awareness. The alternative cost of investing in dike strengthening in this case would be forgone investment in public campaigning.

Unfortunately, the concept of alternative costs is a complex one, and its application in disaster damage assessment offers many conceptual problems. Because assets are lost as a result of the hazard, we have to deal with the loss of resources. Losses due to flooding are not a choice; in other words, no trade-off can be made between various ends on which money could be spent (opportunity costs). This is a problem in itself: it is not straightforward how to define disaster losses in terms of alternative costs. Because of this difficulty, the methodological underpinnings of the damage concept, and consequently damage estimation, remain disputable.

In addition, another issue to consider is that when accounting for the various categories of damage, the risk of double counting exists as a result of the failure to make a correct distinction between stock and flow concepts (Riddell and Green 1999; van der Veen et al. 2001). In economic terms, the value of capital goods, a stock measure, must be equal to the discounted value of the flow of outputs that a capital good can produce during its lifetime. The problem of double counting arises when one has to assess the value of lost capital goods involved in the production of goods and services, such as machinery, various types of equipment, or the industrial installations involved in the production process. In this situation, adding direct losses, which refer to the stock value of lost assets, and indirect losses, which refers to the loss of the flow of goods and services that are not produced anymore by these assets, implies double counting.

A second source of double counting is accounting for both loss of income and expenditure. Cochrane (in NRC 1992, *101*) observes that the level of economic activity can be measured by counting expenditures or incomes. On the consumption side, income is spent on the goods and services supplied throughout the economy. On the production side, expenditures are made in providing these goods and services. Price of a good or service in this case reflects the value of overall production and covers all costs incurred in the production process, including raw materials, wages, taxes, and profits. This means that when a good or service is consumed, an accounting balance is fulfilled: income is equal to expenditure. Thus, theoretically, accounting for either of them should result in the same outcome.

RESPONSIBILITY FOR FLOOD PROTECTION

For a long time, responsibility for flood protection in the Netherlands has lain solely with the government. Recently, however, opinion has shifted toward more interactive decisionmaking involving more parties. Lately, government has also expressed its views on a more deregulated mode of dealing with flood risks.

Public versus Private Responsibility

The National Policy Agreement on Water (2003) puts forward that issues should be addressed at the level where they appear. This principle, in practice, should mean that individuals, municipalities, and provinces should show more initiative in taking care of their own safety without relying solely on the protection provided by the national government. This is a remarkable development, marking a shift in the approach to flood risk. Up to now, flood prevention has been a 100% public good. The observed shift signals a change in the nonexcludability characteristic of a public good. That is, the producer of the good, here the national government, may gradually introduce a policy of excluding particular parties from consuming it. One can thus observe here a tendency toward growing institutional diversity, thereby attributing more direct influence and responsibility to the parties involved. This may be interpreted in terms of a Williamson-type alignment in which governance structure and product (or transaction) are aligned such that total transaction costs are minimized (Williamson 2000).[5]

A related point concerns flood insurance. At present, private insurance against flooding is not available in the Netherlands. This has historical grounds. After the flood of 1953, insurers basically refrained from selling policies covering flood damage, arguing that flooding is an uninsurable catastrophic risk (see Kok 2005). Recently, however, the issue of private insurance has been surfacing more and more. Herein lies a fundamental problem: insurance is based on diversification and generally covers events with a reasonably known frequency distribution. As a rule, insurance companies collect insurance premiums that should cover the payments of claims over a fixed period. Premiums are calculated on the basis of the average expected replacement value of the insured asset and the probability of the event against which the asset is insured. This means that incurred costs in case of a calamity are spread among the policyholders on a periodical basis, with premiums reflecting average expected loss plus a markup.

A disaster, however, especially flooding in the Netherlands, is typically characterized by uncertain low frequency and very high cost. Large numbers of people inhabiting a polder as well as property may be affected, leading to substantial claims.

Covering claims associated with such a disaster would require access to a large amount of capital. This leaves basically two options: either premiums would have to be so high to cover the costs of low-frequency, high-consequence events that insurance would be virtually inaccessible for consumers, or insurance companies would need access to supplementary emergency capital sources in case a major calamity occurs. To this end, Jaffee and Russel (2006) point to the possibility of the government providing insurance companies with loans to guarantee smoothness of accounting and prevent bankruptcy, but they say that even this may not be enough.[6] Because residual risk is high and hard to measure, reinsurers covering insurance company losses may be reluctant to provide this type of financial service, and the available ones may be expensive.

Nevertheless, this may be the way future developments evolve. A central issue will be that all agents on the insurance market should have appropriate incentives. In the Netherlands, the government, though it is not obliged to provide assistance in case of a disaster, often does so based on the solidarity principle. This serves as a disincentive for citizens to buy insurance, as they rely on government support in case a flood does take place. Eventual transition to the principle of shared responsibility and the emergence of a market for private insurance will demand clear roles of each participant.

Government Involvement in the Economy

The role of government in economic policymaking in the aftermath of a disaster is of predominant interest. If a region where important production facilities are located is hit, that specific part of the established economic network is lost, temporarily or forever, and the system suddenly is not able to keep on functioning as before. The problem is that often various production sectors may suffer damage to a different extent, which implies asymmetry of effects. This creates imbalances among sectors in the economy, leading to supply and demand shortages in diverse markets. We cannot rely on such imbalances being automatically restored. This in turn means that economic policy is required to provide appropriate incentives for all agents and parties concerned. To be prepared in emergency situations, the government thus needs to have full knowledge of its options, and above all to have insight into how the economy may respond to a variety of stimuli.

A time horizon issue clearly exists for proactive policy formation for the risk-averse policymaker. Short-and medium-term approaches should be conceptually distinguished from, yet compatible with, those with a long-term perspective. When talking about long-term policy, often Hicksian sustainability concepts enter, in the sense that the choices of future generations should not be compromised. The case of flooding presents an intertemporal choice dilemma: whereas the present generation needs to invest in flood protection, most of its benefits will be reaped by the next generations in the form of greater safety and lower expected losses. This implies that we have to think of ways to enhance the robustness and resilience of the systems in question in the long run. It also implies a different set of concepts and variables in making today's decisions than in cases where policymakers are aiming only at a short-term horizon.

PREPARATION EFFORTS

In the debate about long-term effects of flooding and society's capability to recover, a number of concepts are gaining increasing attention in disaster analysis, among others, *resilience* and *adaptation*. A problem is that neither multidisciplinary literature covering disaster modeling nor economic literature has developed generally accepted definitions. They certainly deserve more elaboration (Alexander 1997). Nevertheless, some tendencies can be observed.

Taking into account a wider temporal span in disaster analysis, resilience becomes an essential matter, as it has direct implications for total damage sustained. Resilience reflects a system's capacity to adjust in the face of tribulation and respond to it in a way that cushions the immediate negative impact, maintaining its main characteristics (Allenby and Fink 2005; Gunderson and Holling 2001). Some authors, especially from the socioecological field, attribute learning and adaptive capacity to resilience as well (see Kendra and Wachtendorf 2003; RA 2005). In connection with this, it is assumed that a higher resilience level can make an economy recover faster and with fewer costs (Rose 2004a). Recently, in disaster consequence studies, resilience has played a more prominent role, becoming a goal in itself (de Bruijn 2004). Besides, a prudent policymaker would wish to link this goal to the sustainability principle, providing resilience with normative contents (Tobin 1999).

To enhance the resilience of a system, one has to think in terms of disaster preparedness. In this sense, it is connected to the concept of adaptability. Adaptation is directed at the preparation of the system to the expected adversity and may cover local, national, and even global aspects. Adaptation is intended to reduce the inherent vulnerability of a system to a calamity, as well as improve its response capacity, or resilience. It differs from the widely used *mitigation* strategies in that, contrary to adaptation, which is aimed at the system under attack, mitigation is seen as the entirety of strategies that address the source of adversity.

We may distinguish here a number of efforts to make adaptability more tangible. Essentially, these are aimed at the definition of critical system characteristics that should guarantee the continuity of operation in the face of calamity. Pingali et al. (2005) offer the following strategies to augment the food system's resilience and apply these to a more general case: strengthening diversity, rebuilding local institutions and traditional support networks, reinforcing local knowledge, and building on economic agents' ability to adapt and reorganize. Such a strategy signifies the importance of an integrated approach to flood management, where the multiple dimensions of contemporary society overlap.

Besides, a more proactive approach can be positioned for the risk-averse policymaker. According to the precautionary principle (COMEST 2005), an activity should not be undertaken if one might expect that it will bring substantial or irreversible negative effects. In the case of flood protection, one can also interpret this in a slightly different manner, in terms of activities or policies that have to be implemented, because idleness may lead to an incident whose consequences cannot be precisely estimated in advance but can be expected to have serious negative or even irreversible effects on the entire economy or society, such as in the form of system and group risks. This represents a fundamental break with the past, when progress typically was a matter of trial and error within a particular vision on growth and development.

INTERNATIONAL COOPERATION

International cooperation has been gaining prominence in the last decade. Two intergovernmental initiatives in this context are the International Commission for the Protection of the Rhine against Pollution (ICPR) and the Convention of the International Meuse Commission (IMC).[7] Founded in 1950, ICPR currently unites the efforts of five countries from the Rhine basin, ensuring sustainability of one of the largest river basins in Europe. It includes cooperation in protection against floods and provisions for ecological amelioration of the Rhine and its floodplains. IMC was established in 1994 with the goal of achieving sustainable and integrated water management of the international river basin of the Meuse. In recent years, both ICPR and IMC have been showing signs that they intend to build more cooperation in the area of flood protection and monitoring (see, e.g., ICPR 2002).

At the EU level, the European Commission's Communication on Flood Risk Management (2004) aims to foster cooperation among the member countries in the field of flood protection in the wider context of sustainable development. Among recent important developments is a Directive on the Assessment and Management of Flood Risks (2007), an initiative that fills the gap since the Water Framework Directive (2000) was adopted, with the goal of developing integrated management plans for river basins in order to achieve a good ecological and chemical status.

FLOOD DAMAGE MODELING

In looking at recent modeling efforts in flood damage assessment in the Netherlands, it appears that no unique methodology exists; rather, researchers employ different types of models depending on the kind of questions they wish to address. Some models focus on the micro or sectoral level, others on the macro level. Additionally, new research lines have been developed in the macroeconomic sphere.

In some of the studies, we may recognize the difference between *measurement* and *inference*. We can observe, and measure to a certain extent, direct damage caused by the hazard, such as loss of human life or production capacity. Much more difficult to observe or measure are the *consequences* of this loss—the indirect effects. These have to do with business and production activity interruptions within an interconnected network. A temporary or persistent disappearance of suppliers or consumers from an established system has significant effects on the welfare of society at large. It is here that modeling claims its place.

One model is the standard method, developed by HKV Consultants in a study for the Dutch Ministry of Transport, Public Works, and Water Management (Vrisou van Eck and Kok 2001). This method is based on specific standardizations and is also used in the Netherlands' High Water Information System (HIS), which provides information about high-water developments in the primary dikes system to professionals and policymakers. The standard method addresses various types of direct physical damage, as well as loss of life. It uses extensive GIS data by zip code and detailed unit loss functions for direct damage estimation per dike ring, depending on the inundation level. Each loss function includes the maximum damage value, based on replacement value, as well as damage factors, which are determined in scenario simulations using hydrodynamic calculations and GIS maps, thereby taking into account intermediate defenses, differences in elevation and water levels, and building types. This method determines damage functions per activity sector: agriculture and recreation, pumping stations, means of transport, infrastructure, companies, and housing. It pays relatively little attention, however, to indirect losses throughout the economy. The classification of losses underwent some changes, and in a recent version of the standard method (see V&W 2005a), direct material damage is defined as damage caused to objects, capital goods, and movable goods as a result of direct contact with water; direct damage due to business interruption refers to losses resulting from interrupted production of businesses in the flooded area; and indirect damage is viewed as damage to business suppliers and customers outside the flooded area and travel time losses because of the inaccessibility of roads and railways in the flooded area.

The Netherlands Economic Institute (NEI) (Briene et al. 2003) presents a method to assess the maximum damage caused by a flood in a dike ring, including the calculations of indirect effects of production loss throughout the country (following the classification of damage as put forward in the standard method), using a study by the Tebodin consultancy group (van den Berg et al. 2000) as a background document. In that study, the intraindustry economic effects of shutting down part of a productive sector in the country are estimated in a way that attempts to avoid the rigidity of the standard input–output multiplier in favor of "corrected" coefficients for each industry, thereby accounting for substitution effects in the reconstruction period. This correction ratio is multiplied by the sectoral input–output multiplier to obtain losses due to business interruption. Furthermore, both Briene et al. and van den Berg et al. do not account for the market value of the lost assets, but take the replacement value (after accounting for depreciation) as a threshold for direct damage, which is basically a financial concept. Methodologically, this may suggest disparity in the chosen concepts for the estimation of direct and indirect effects.

The Netherlands Bureau for Economic Policy Analysis (CPB) has published several studies on water management and policy assessment. In a recent study, it presented a cost–benefit analysis rooted in economic welfare theory; an example is the analysis for infrastructural alterations of rivercourses, *Giving Room for Water* (CPB 2000), with only limited attention to typical indirect effects. In two other studies (Ebregt et al. 2005; Eijgenraam 2005), the CPB presents a further developed methodology based on cost–benefit analysis, focusing at the macroeconomic level rather than using standard damage calculations for a particular dike ring. It aims at providing a more complete picture of the overall effects among the constituent parts of the entire economic system under study. Eijgenraam (2005) discusses optimal safety standards for dike-ring areas, correcting the 50-year-old contribution of van Dantzig (1956), and gives the formulas for the optimal investment in the heightening of dikes, where key questions are "when" and "how much." The basic principle is the aforementioned balancing of P and E in the risk equation for each dike-ring area. Using the year 2015 as a reference point, the study provides the calculated time paths of the first investment in the protection structures and the resulting factual flood probabilities.

These are the concepts currently in use in the Netherlands, along with their interpretation and justification. The methodologies on economic cost assessment are still being developed and are rarely described in detail. This is one factor that may explain the difficulty in comparing the relative merits of the various methodologies, as well as the fact that the underlying concepts often vary in dimensions. At best, we may conclude that at the moment, many studies in the form of partial analyses are available. These, however, do not easily add up to provide a single picture. In future work, convergence to clarify and possibly create uniform definitions of the concepts, as well as make explicit choice of the modeling framework, will be a priority.

Although a number of studies have focused, broadly speaking, at the micro and meso levels, so far macroeconomic studies are relatively underrepresented. New research lines are being pursued in several directions, however. An overview of damage evaluation methods as a result of flooding is provided in the study of the Erasmus University of Rotterdam Centre for Sustainable Development and Management team (van Ast et al. 2004). The report outlines ample possibilities for establishing the value of assets, also including indirect monetary assessment strategies for nonmarket goods (including revealed and stated preference, cost avoidance, and other methods).[8] Ultimately, the authors develop a risk assessment approach, based on a discounted cost–benefit analysis framework, acknowledging the nonmonetary damage aspects (e.g., damage to the nature and environment, emotional damage, as well as uncertainty) and the risk perception of policymakers.

Some recent Dutch work in the macroeconomic sphere (Bočkarjova et al. 2004; van der Veen and Logtmeijer 2005) concentrates on the effects of large-scale calamities in highly industrialized economic systems. Bočkarjova et al. (2004) offer a three-stage procedure using an adjusted input–output framework with a geography component. The first stage is accounting for the immediate postdisaster disequilibrium situation when an essential part of a socioeconomic network is suddenly not available anymore. The second stage concerns the design of recovery scenarios and an investigation of possible new equilibria. The aftermath of a calamity is often accompanied by complex adjustments in the system, which may require government involvement in steering economic recovery. Clearly a number of options exist here, and these should be studied as well. For example, the country may wish to reestablish the status quo as soon as possible. On the other hand, it may wish to use the occasion to renew selected parts of its physical infrastructure. Finally, the model offers a cost–benefit analysis of various policy options when the outcomes of multiple preventive measures and recovery paths can be compared.

Other existing analytical frameworks circulating internationally contain computable general equilibrium (CGE) and input–output (I–O) models, including their linear programming variants and social accounting matrices (SAMs). All have their strong and weak points. I–O models offer a transparent structure of an economy by sector, allow concentrate specifically on the physical side of the problem at hand, and are temptingly simple, but they seem to be somewhat underutilized or underdeveloped as a methodology for dealing with disruptions of the type we are discussing. In fact, standard I–O methodology, stressing interaction and equilibrium, does not offer a very flexible set of tools to deal with postdisaster situations that are characterized by disruption and disequilibrium. The problem here is partially shared by CGE methodology. Standard I–O, however, being limited by fixed production functions, is an antipode of CGE models, which are deemed to be intricate, involve multiple actors and markets, and be overflexible, allowing markets to adjust elastically through the price mechanism to the new circumstances. One thus is confronted with trade-offs between complexity and flexibility when choosing a model for situations where an economy is facing an entirely new set of circumstances and decisions have to be made in a nonstandard way in the light of suddenly restricted or unavailable resources (Steenge and Bočkarjova 2007).

Up to now, the economic analysis of flood disasters is a field that to a large extent is still developing. One issue to be explored concerns policies in countries differing in political and economic structure. In a pure market economy, calamity consequences and policy priorities can be expected to differ from those in a more regulated country such as the Netherlands. In the United States, for example, a number of market-based approaches have been put forward recently focusing on short- and medium-run disequilibria (see, e.g., Cochrane 1997b, 2003; Cole 1998; Cole et al. 1993; Okuyama 2004; Okuyama et al. 2004; Rose 2004b; Rose and Lim 2002). To apply the experience in disaster modeling from other countries to the Dutch situation, one has to bear in mind that the Netherlands requires a quite different approach. Here we have to look for novel solutions that would address the entire range of preconditions. First of all, we should decide on the level of analysis: at the moment, a macro-oriented framework is needed that would provide insight into the working of the entire socioeconomic system. Next, efforts should aim at modeling a wide range of effects inflicted by a disaster, in particular covering the extent of direct and indirect economic losses throughout the system. Finally, it is essential that models be capable of covering available policy options. Whether proactive or recovery-oriented, policy measures should be tested with an appropriate (statistical) reliability level for the response that these might cause throughout the economy. Such models, being able to assess relative costs and benefits of various policy options, will be indispensable means for policy analysis.

CONCLUSIONS

This chapter has looked at recent developments in Dutch water management and policy, signaling a paradigm change in thinking about flood risks. For many years, both sea and rivers have continuously been a source of danger. The Delta Plan, which came into being after the disastrous 1953 flood, has for decades set the stage for flood protection. It was based on the concept of a very strong sea defense, organized to withstand extreme situations. For the highly developed and populated central part of the Netherlands, this amounted to the chance of a flood on average once per 10,000 years.

This permitted a spectacular economic growth in the provinces below sea level, which ultimately made the country a world player on many markets. The discrepancy between the infinitesimal probability of dike overtopping and the high and ever-growing risk of flooding requires, however, a different type of calculation. The country has to prepare for future challenges, finding a balance between expected risks and growth and development desires.

Several issues stand out. Many of these are a consequence of the way Dutch spatial structure has developed. The country is a patchwork of interconnected polders, each of which has different characteristics, such as population, economic value, and safety standards. This means that probability calculations should be based on the much more complex concept of systemic risk, where a number of dike-rings should be seen as an interdependent system.

This also implies other questions, such as whether everyone has the same right to protection from water, which is not the case right now. In fact, there also is a discrepancy between safety standards as fixed by Dutch law and the actual situation as it has developed. Here *the country faces the task of redistributing safety in a reasonable and acceptable way.* This relates to other issues. At the moment, the Dutch government has full responsibility for protection against threats posed by the water, coming from either outside (the sea) or inside (the rivers). In the next decade, however, this may evolve into a more decentralized policy. For example, if people want to settle in low-lying areas, they also may have to bear a part of the involved responsibilities. This can take various forms, all of which have to be sorted out.

The wealth of issues concerns the present spatial distribution of activities. It is a big question whether the western part of the country can remain as prominent in Dutch society as it is now. Systemic factors do not look favorable, with a sea level rise, subsiding ground level, increased precipitation, and peak river discharges. The Netherlands has to decide how it will develop in the next decades. Should it keep its core economic activities located in the areas directly behind the dikes, or should it adopt a policy of spreading these activities to the higher areas in the eastern and southern parts of the country? It is here that further research is needed.

In this chapter, we have drawn attention in particular to the effect constituent of the risk equation. A number of fundamental issues with respect to potential damage assessments were outlined as a part of disaster consequence analysis. The models and methods for economic damage evaluation currently circulating in the Netherlands represent a spectrum of possibilities and have the potential to mature as damage estimation techniques are further explored. Opportunities to use international experience and expertise in this field should be well considered.

Finally, we are not proposing that any single model should be capable of covering all the outlined aspects that are relevant in the economic analysis of flood disasters. Rather, we would welcome the emergence of a multiplicity of models aiming at the achievement of the ultimate goal of providing better knowledge about the impacts of large-scale catastrophes on a 21st century economy and how best to prepare for them. We recognize that the diversity of models may create a selection problem. Simultaneously, however, this should act as a challenge and stimulate modelers to propose integrated multi- or interdisciplinary approaches, which are often lacking at the moment.

NOTES

1. The first comprehensive study of the Delta Plan was presented by Maris (1954), Tinbergen (1954), and Zeegers (1954) and discussed its engineering, economic, and social aspects.

2. The term "exceedance probability" refers to the chance that the water level will exceed the crest of the dike, resulting in overflow and breaking of the dike and thus flooding of the land behind it.

3. Nine dike failure mechanisms are distinguished by RIVM (2004, *110*): overtopping, instability through infiltration and erosion after overtopping, piping, heave, macroinstability at land side, macroinstability at river side, microinstability, instability of dike cover, and sliding off at riverside.

4. In addition, some authors advise conducting analysis at the macroeconomic level (ECLAC 2003; Murlidharan and Shah 2003; Freeman et al. 2004; Mechler 2004; Linnerooth-Bayer et al. 2005). ECLAC notes, however, that macroeconomic analysis acts as complementary statistics that reflects the impacts of a catastrophe in terms of macrovariables.

5. Transaction costs are interpreted here in a broad sense, including information, bargaining, and monitoring costs.

6. In cases where governments are not able to absorb the losses and provide help to the population, international organizations such as the World Bank and International Bank for Reconstruction and Development (IBRD) may provide loans to prevent bankruptcy of a state; see, for example, Parker (2000) and Arnold (2006).

7. For more information, see the ICPR and IMC websites, www.iksr.org and www.meuse-maas.be.

8. Other models estimating nonmarket goods include loss of human or animal life (e.g., Jonkman et al. 2002) or loss of landscape, natural, or historical values (Nieuwenhuizen et al. 2003).

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