

**Indicators for Social and Economic Coping Capacity -
Moving Toward a Working Definition of Adaptive Capacity**

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- **This paper offers a practically motivated method for evaluating systems' abilities to handle external stress.**
- **The method is designed to assess the potential contributions of various adaptation options to improving systems' coping capacities by focusing attention directly on the underlying determinants of adaptive capacity.**
- **The method should be sufficiently flexible to accommodate diverse applications whose contexts are location specific and path dependent without imposing the straightjacket constraints of a "one size fits all" cookbook approach.**
- **Nonetheless, the method should produce unitless indicators that can be employed to judge the relative vulnerabilities of diverse systems to multiple stresses and to their potential interactions.**
- **An artificial application is employed to describe the development of the method and to illustrate how it might be applied.**
- **Some empirical evidence is offered to underscore the significance of the determinants of adaptive capacity in determining vulnerability; these are the determinants upon which the method is constructed.**
- **The method is, finally, applied directly to expert judgments of six different adaptations that could reduce vulnerability in the Netherlands to increased flooding along the Rhine River.**

This paper is also the first in what we hope will be a series of distance seminars loosely organized around the theme of impacts and indicators (indices).

We expect to schedule one talk for the noon to 1PM time slot every third Wednesday.

If you would like to prepare and present a talk, contact Gary Yohe at his e-mail address.

Now...on with today.....

A FUNDAMENTAL PERSPECTIVE OF VULNERABILITY

- **The vulnerability of any system to an external stress (or collection of stresses) is a function of exposure, sensitivity, and adaptive capacity.**
- **Human and natural systems tend to adapt autonomously to gradual change and to change in variability.**
- **Human systems can also plan and implement adaptation strategies in an effort to reduce potential vulnerability or exploit emerging opportunities even further.**
- **The economic cost of vulnerability to an external stress is the sum of the incremental cost of adaptation plus any residual damages that cannot be avoided.**

The *determinants* of adaptive capacity include a variety of system, sector, and location specific characteristics:

- **The range of available technological options for adaptation,**
- **The availability of resources and their distribution across the population,**
- **The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed,**
- **The stock of human capital including education and personal security,**
- **The stock of social capital including the definition of property rights,**
- **The system's access to risk spreading processes,**
- **The ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers, themselves, and**
- **The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.**

Algebraically:

$$\mathbf{V} = \mathbf{F}\{ \mathbf{E}(\mathbf{A}); \mathbf{S}(\mathbf{A}) \} \text{ where} \quad (1)$$

$$\mathbf{A} = \mathbf{AC}\{ \mathbf{D}_1; \dots ; \mathbf{D}_8 \}. \quad (2)$$

So, for any adaptation option identified in \mathbf{D}_1 , we can define a feasibility factor:

$$\mathbf{FF}_j \equiv \min\{\mathbf{ff}_j(2), \dots \mathbf{ff}_j(8)\}. \quad (3)$$

where the $\mathbf{ff}_j(-)$ indicate judgements about the strengths of underlying determinants.

The potential coping capacity of any option must then marry feasibility and possible efficacy; to that end, let

$$\text{PCC}_j \equiv \{\text{EF}_j\} \{\text{FF}_j\}. \quad (4)$$

An overall coping capacity index across all possible options can then be defined:

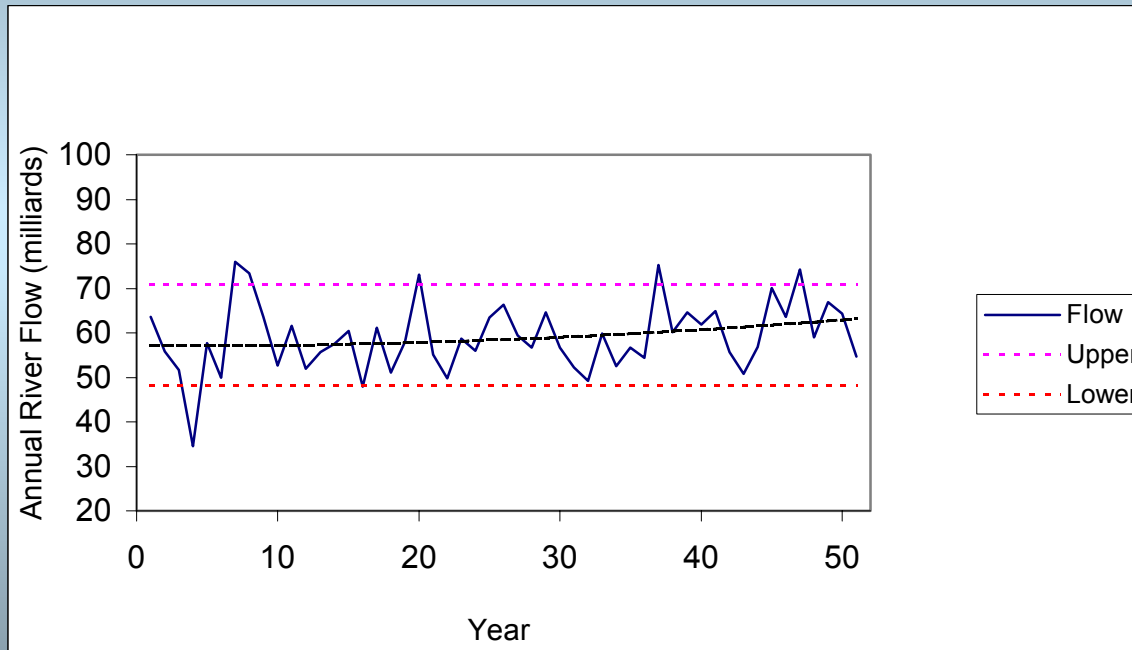
$$\text{CCI} \equiv \max \{\text{PCC}_1, \dots, \text{PCC}_m\} \quad (5)$$

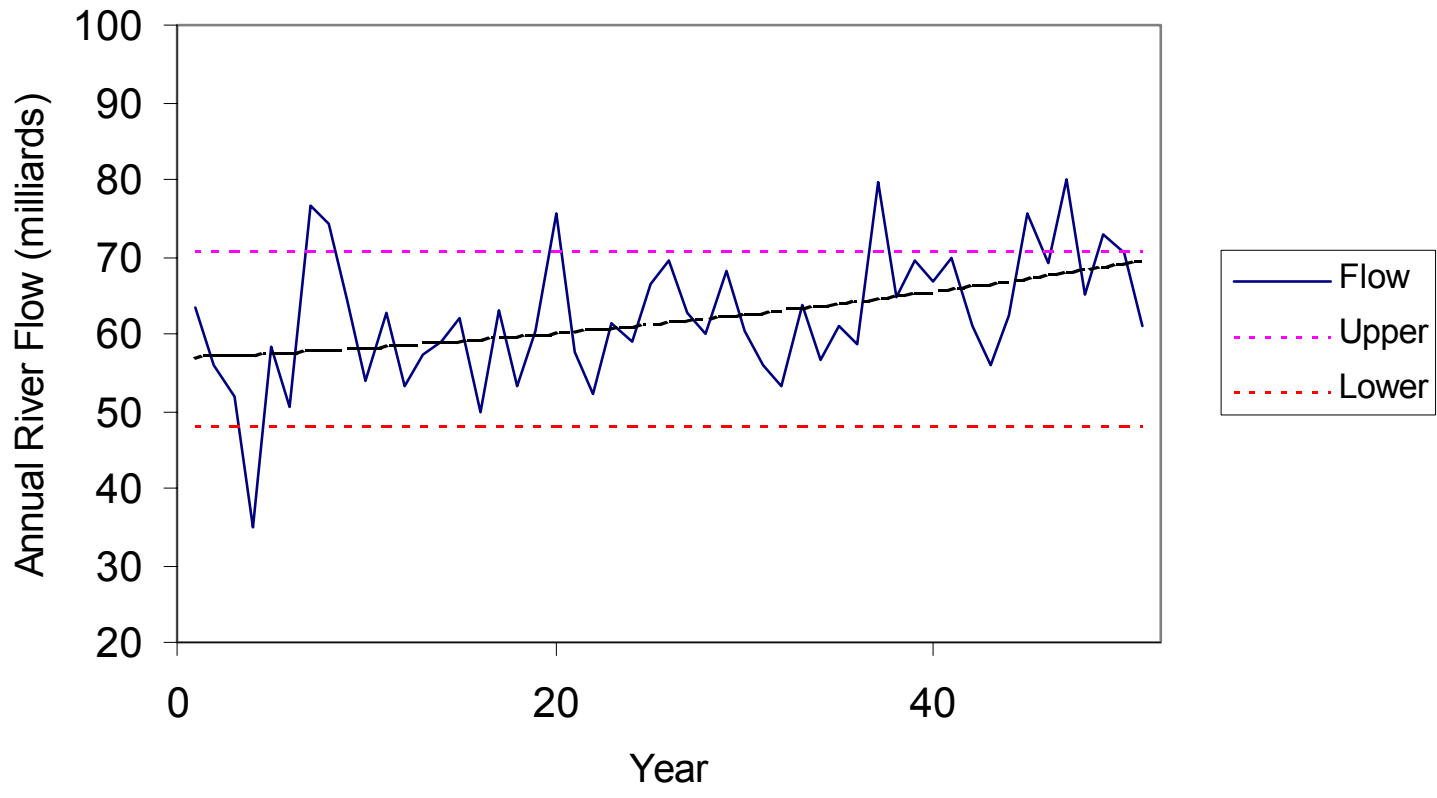
And the robustness of that capacity can be reflected by a composite index of depreciation in PCC:

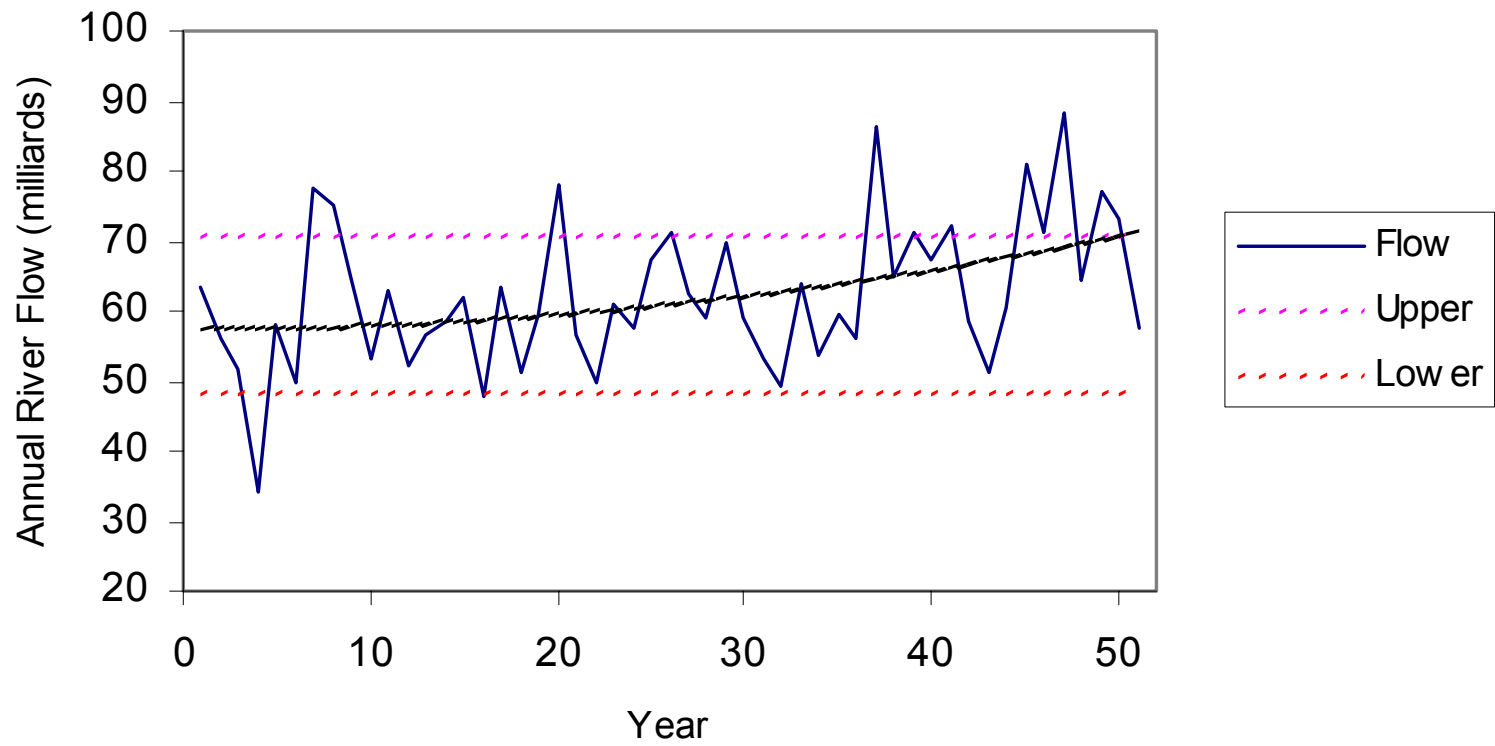
$$\text{R} = \{[\text{PCC}_2 + \text{PCC}_3] / 2 \text{PCC}_1\}. \quad (6)$$

Figure 3

Annual flows of the Nile River into Lake Nassar contrasted against hypothetical impacts thresholds. Panel a depicts the historical time series from 1910 through 1960. Panel b adds a climate induced trend to that series; and panel c reflects a climate induced increase in inter-annual variability.

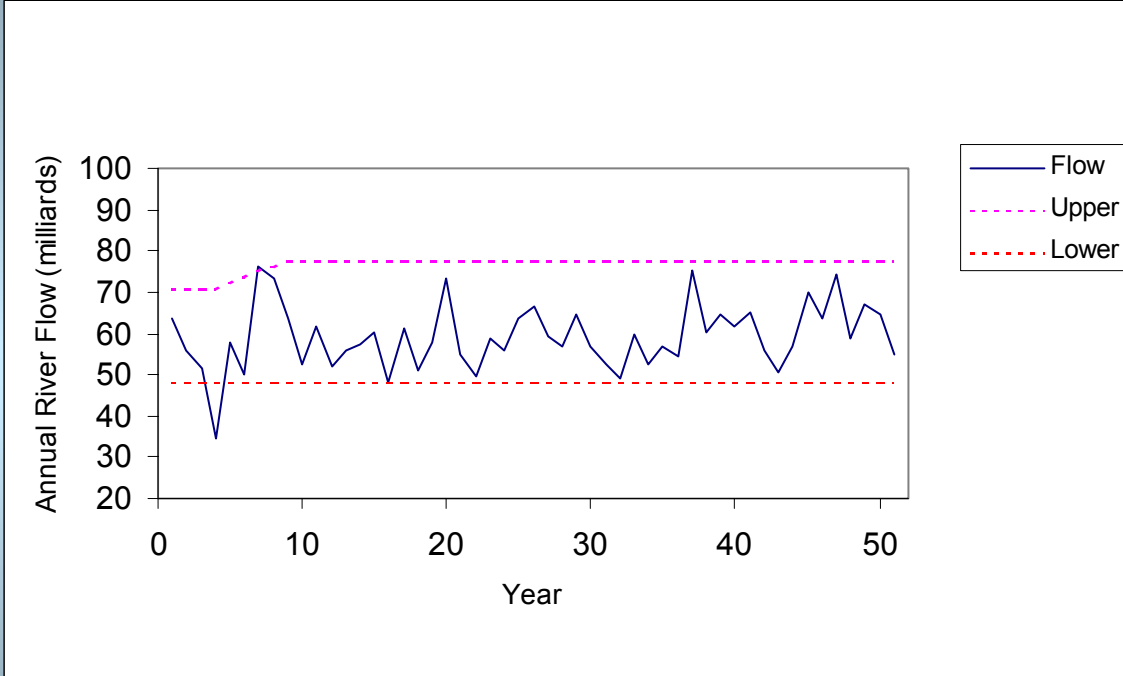






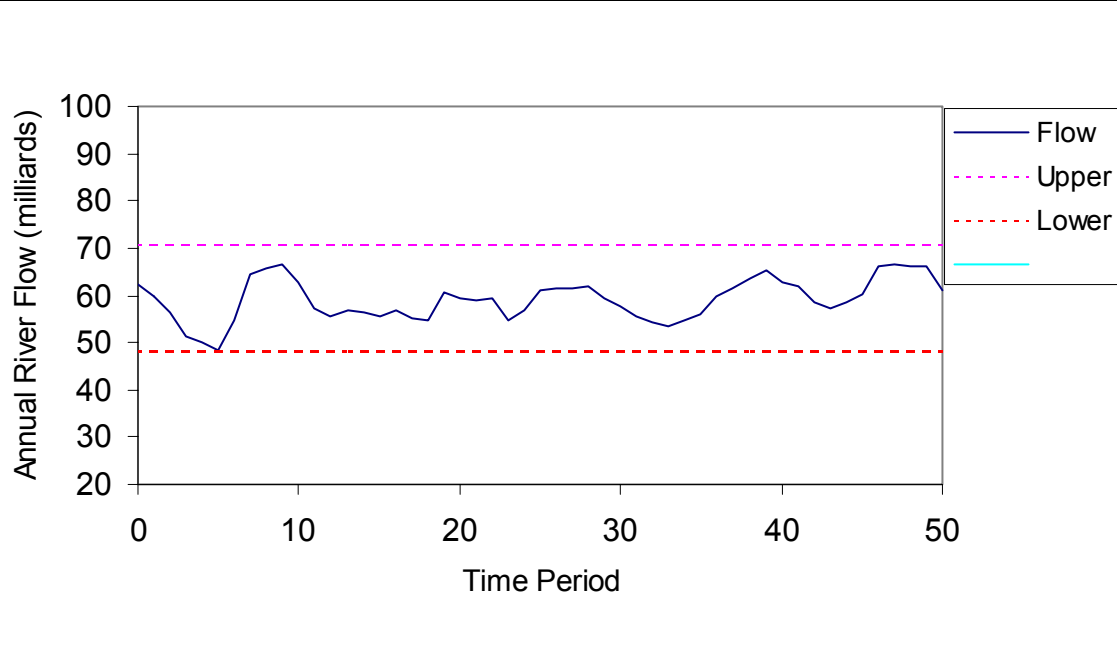
Option A: Construction of a series of protection levies.

Figure 4 portrays the possible effect of building protective levies by expanding the upper threshold of the coping range. The frequency of flooding would be reduced in all cases, but there would be no change in exposure to flows that fall below the lower threshold. Flooding could be eliminated, at least for the historical period, if the levies were large enough; but levies constructed to accommodate historical experience could still be overwhelmed if mean flow or variability rose unexpectedly over time. Construction and maintenance costs would be incurred, to be sure, but local environmental effects, local amenity costs, and increased flooding downstream of the levies could also be experienced.



Option B: Building a dam upstream.

Figure 5 portrays the effect of building a dam like the Aswan upstream by reducing the variability in observed river flow at our location. This option would, in particular, allow managers to release water from the dam during low flow periods and retain water during high flow periods so that the actual flow below the dam would be a moving average over the past few years. Figure 5, in fact, depicts observed flow as a 4 period moving average; it reflects the calculation that Lake Nassar can hold more than one year's flow at any one time. Exposure to flooding could, with a dam of sufficient capacity, limit variability in actual flow to the size of the original coping range of Figure 3. This option therefore holds the potential of eliminating vulnerability to crossing either the high or the low threshold; but it, too, could fail to accommodate an unexpected change in the underlying mean or variance. Construction and maintenance cost would again be incurred, as well as significant environmental impact upstream; but energy, recreational, and tourism benefits could be created.



Option C: Periodically dredging the river.

Figure 6 portrays the hypothetical effects of periodic dredging as a saw-toothed pattern for the upper threshold. Dredging would allow the Nile to accommodate more water and thereby increase the upper threshold, but this benefit would depreciate over time as silt re-deposits on the riverbed. To maintain long-term benefit, therefore, dredging would have to be repeated on a regular basis. This option also holds the potential of eliminating exposure to flooding, but only for short periods of time. On the other hand, opting for dredging regime could allow managers to accommodate unexpected changes in the underlying mean or variance by increasing or decreasing the frequency of dredging operations. The recurring cost of dredging plus some environmental damage could be expected as well as increased flooding risk downstream.

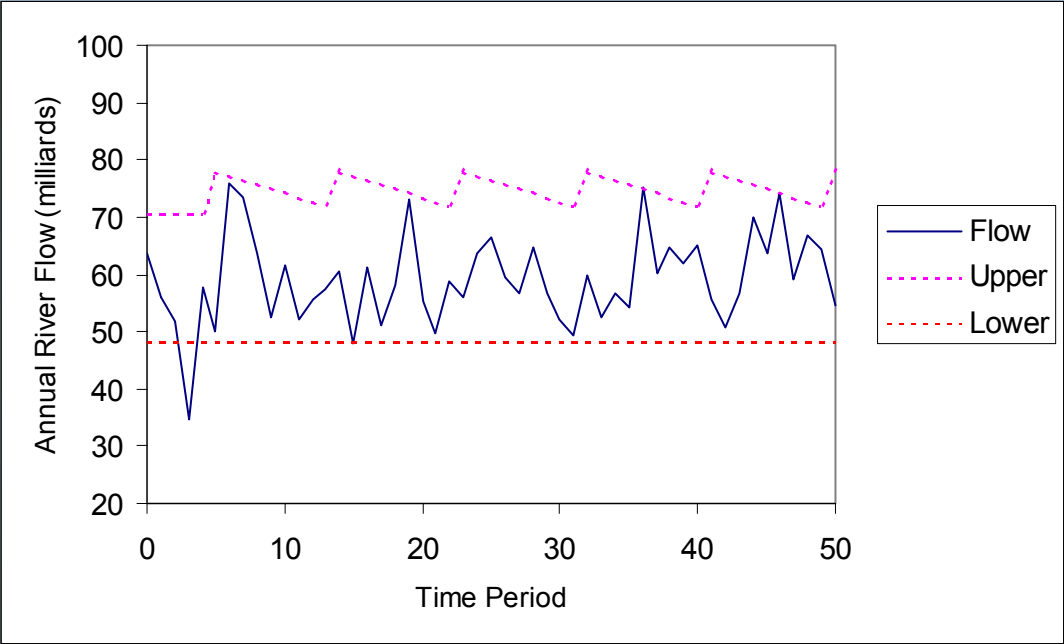


Table 2

Hypothetical Characteristics for the Illustrative Nile Application

Option A: Levies

Cost: Large initial investment; modest on-going expense; modest environmental impact; modest amenity cost; downstream flooding possible.

Benefit: Reduction in the frequency of flooding in the study location.

Institutional Requirements: Mechanisms to sustain modest land taking required

Risk: Possibly vulnerable to change in flow regime over the medium term.

Option B: An Upstream Dam

**Cost: Largest initial investment; large on-going expense;
large environmental impact.**

Benefit: Reduction in the frequency of flooding in the study location and downstream; modest amenity gain; additional power capacity; recreational benefit; increased tourism.

Institutional Requirements: Mechanisms to sustain significant land taking required.

Risk: Possibly vulnerable to significant change in precipitation and run-off patterns over the long term.

Option C: Dredging

Cost: Largest on-going expense distributed unevenly over time; modest environmental impact possible; downstream flooding possible.

Benefit: Reduction in the frequency of flooding in the study location.

Institutional Requirements: Management authority with the authority and responsibility to dredge as necessary.

Risk: Amenable to “mid-course” adjustments in the frequency of dredging as conditions warrant.

Tol *et al.* (2001) report on an extensive assessment of adaptation against increased risk of flooding in the Rhine Delta. Six options for the Netherlands were identified:

- 1. Store excess water in Germany.**
- 2. Accept more frequent floods.**
- 3. Build higher dikes.**
- 4. Deepen and widen the river bed.**
- 5. Dig a fourth river mouth.**
- 6. Dig a bypass and create a northerly diversion.**

- 1. The range of available technological options for adaptation is fairly large; the six options listed above each have a number of variants, and can of course be combined. These options were identified by a major civil engineering consultancy as technically feasible.**

2. The availability of resources is substantial. The Netherlands is the 11th largest economy in the world (by PPP). The distribution of resources across the population is relatively equal but irrelevant for this paper, as flood protection is in the hands of the national government.

3. The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed may be more problematic. The main problem with institutions is the separation between water management and land use planning over various agencies and ministries. The flood plain is increasingly used for housing, industry and infrastructure, increasing the flood risk and limiting the options for water management. Managing a river in a crowded flood plain requires solving conflicts of interests between many stakeholders. Dutch decision making is consensus-oriented, while public works decisions are increasingly advised by public consultations. This typically leads to long delays and hinders radical decisions. However, if needed, the government can be very autocratic, and the population tends to trust the government in that (van der Grijp *et al.*, 2001). The crucial decision criterion in Dutch flood management is a high level of safety, with little geographical variation (Olsthoorn, 2001). Adaptation is thus almost automatic (but see above), but not necessarily efficient.

4. The stock of human capital including education and personal security is very high in the Netherlands. Dutch water engineers are the best in the world.

5. The stock of social capital is also high. The Netherlands is a consensus-oriented society in which the collective need is an effective counterweight to individual interests (van der Werff, 2001). Property rights are clearly defined, and the judiciary is independent.

6. The system's access to risk spreading processes is limited. Flood insurance cannot be purchased. On the other hand, the government guarantees compensation for flood damage, and charity is strong in times of need. For instance, after the floods of the Meuse river in late 1995, the money raised in a national collection exceeded the damage done. Also, few of the evacuees in the same period (1 in 60 of the total population) used government shelters, as the supply of privately offered housing was so great (van der Grijp *et al.*, 2001).

7. The ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers themselves are all high. Dutch bureaucrats are typically well-educated and supported by able consultancies. Water management is controlled by an “old-boys” network of professors, civil servants and consultants; however, this network is fairly large and open-minded (to ideas, not to other people’s competence). Dutch water engineers are held in high regard, and civil servants are largely trusted by the population.

8. The public as well as the water managers are well aware of climate change and its implications for flood risk, as well as of the confounding influences.

Table 5

Determinant	Store Water	Accept Floods	Raise Dikes	Adjust River Bed	Fourth Mouth	Bypass
Resources	1	3	4	4	1	1
Institutions	1	1	3	4	1	2
Human Capital	1	2	5	4	4	3
Social Capital	1	3	4	5	2	2
Risk Spreading	2	1	5	4	4	3
Information	1	2	4	4	2	2
Awareness	3	3	5	5	3	3
<i>Feasibility Factor</i>	1	1	3	4	1	1
<i>Efficacy</i>	0.8	1.0	1.0	0.6	0.8	0.6
<i>COPING INDEX</i>	0.8	1.0	3.0	2.4	0.8	0.6

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