Dike Failures: Risks, Causes and Costs

Juni 2010

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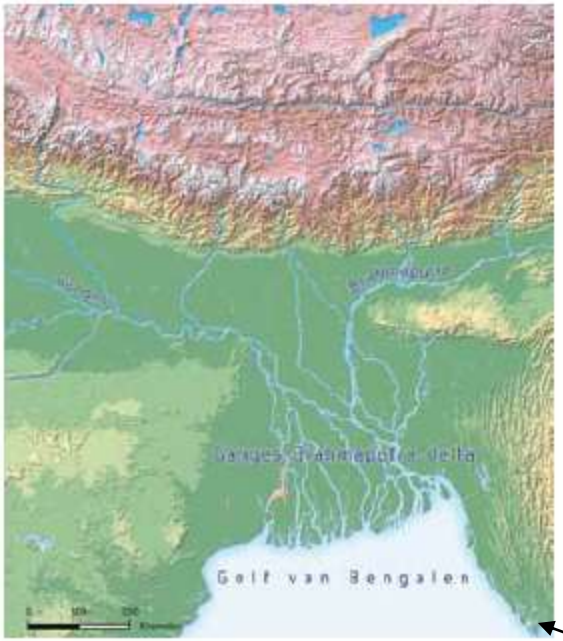
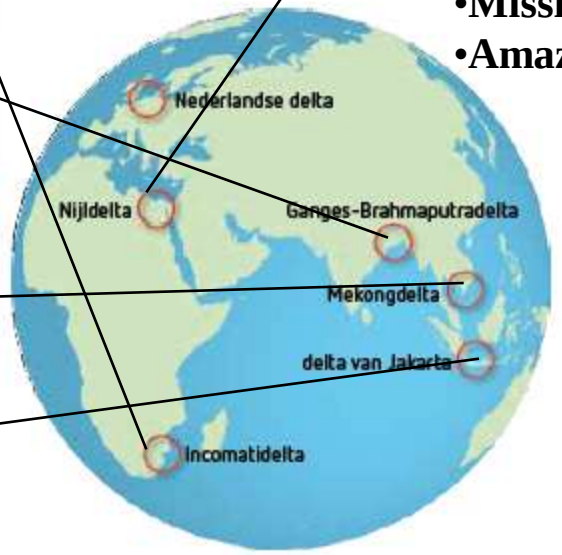
Delft University of Technology
&
University of Luxemburg

Delta's





- **Mississippi**
- **Amazon**

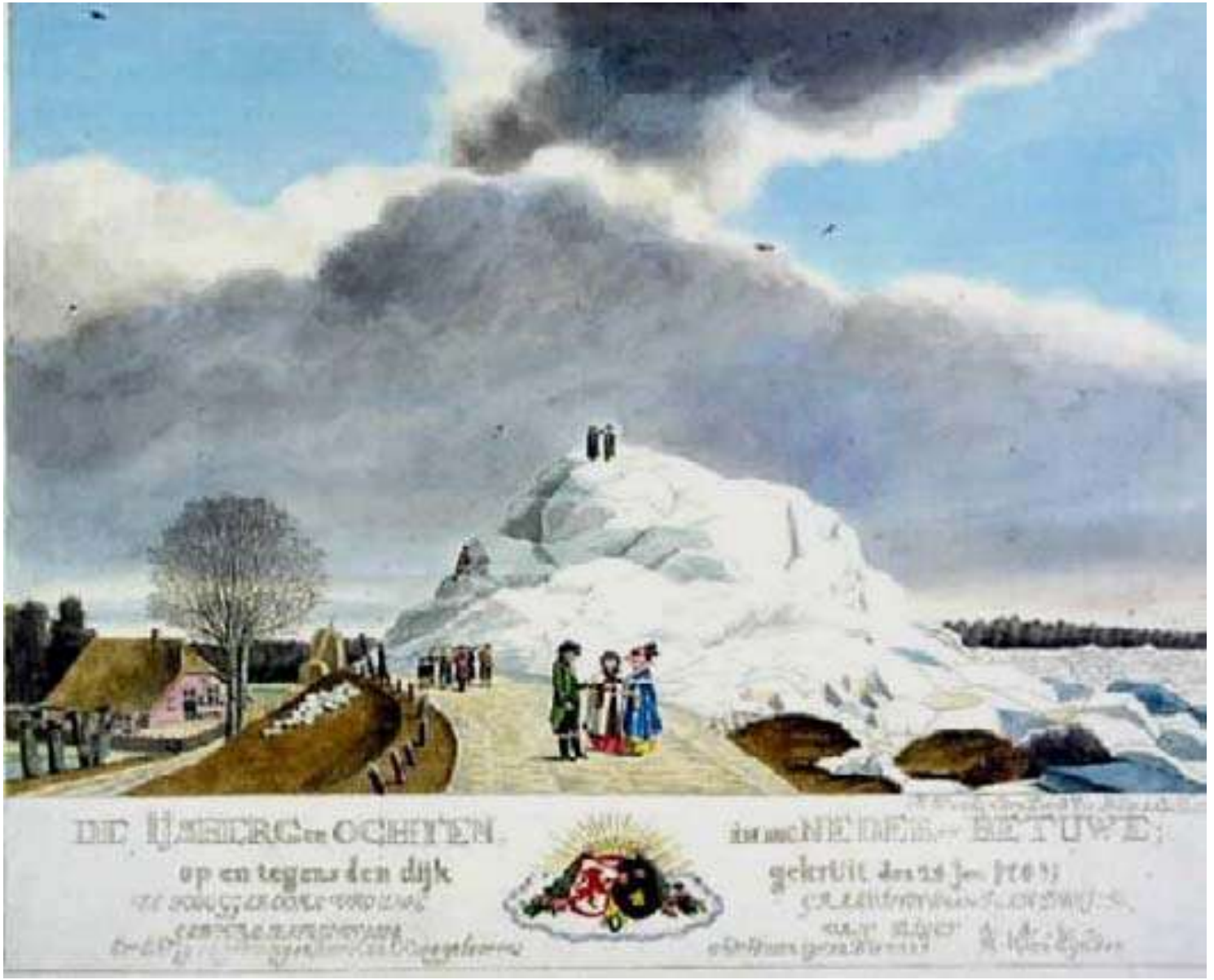

Room for
the Rhine branches

Massive floods in the Netherlands

Flood	Location	Date	Casualties
St. Stephen's flood	Friesland, Groningen	26 December, 838	2437
St. Michael's flood	Zeeland and Flanders	29 September, 1014	thousands
Seaquake flood	Zeeland	October, 1134	unknown
St. Juliana's flood	North coast	17 February, 1164	thousands
St. Lucia's flood	Friesland, Groningen	14 December, 1287	50,000
2nd St. Elizabeth's flood	Zeeland, Holland and Flanders	18 November, 1421	2000
All Saints' flood	Zeeland	1 November, 1570	20,000
River Delta flood	Central + East Rivers	5 – 15 March, 1595	3000
St. Marten's flood	Northeast coast	12 November, 1686	(Dutch) 3000
Christmas flood	Northeast coast	25 December, 1717	(Dutch) 2500
1953 Flood	Zeeland and Flanders	1 February, 1953	(Dutch) 1836

St. Anthonis dike failure during St. Peter's flood, P. Nolpe, 4-5 March, 1651

Zierikzee, Netherlands, 1770

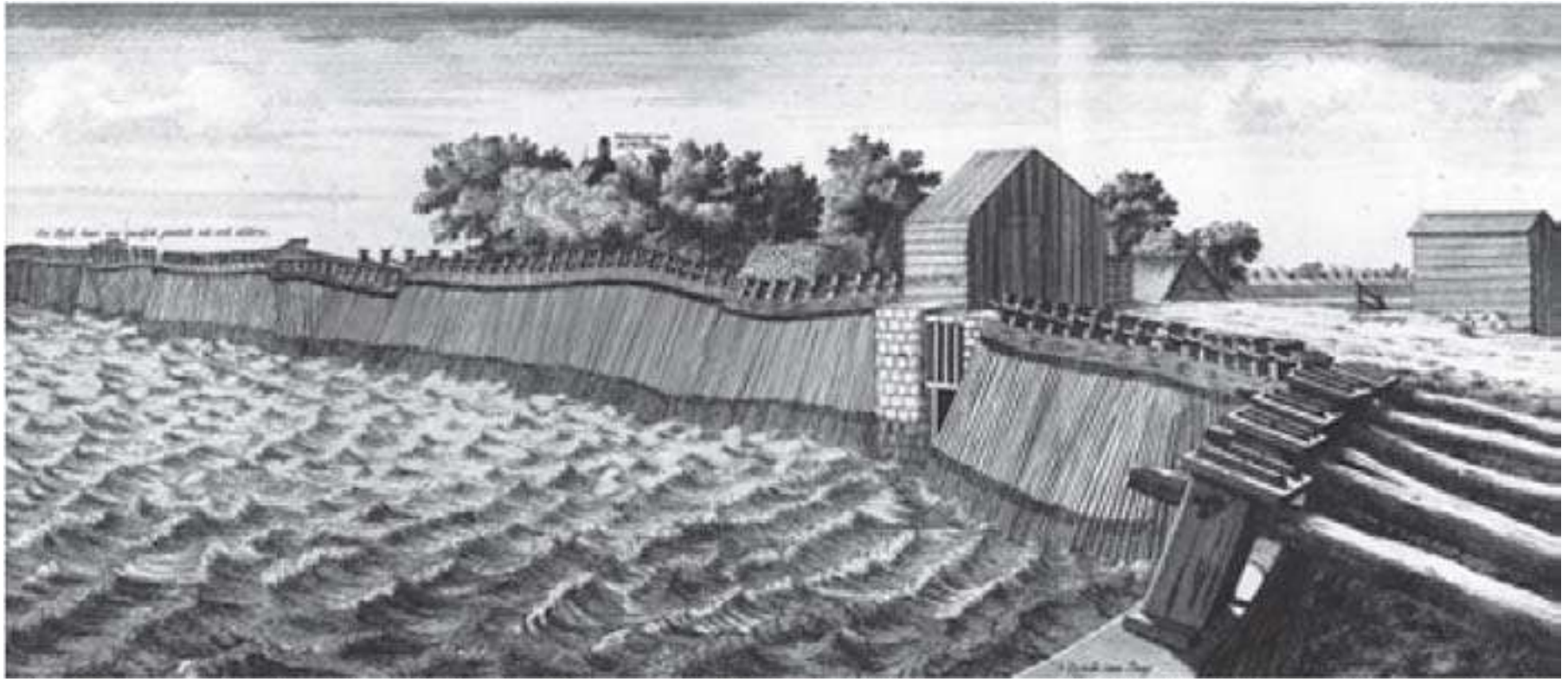


“The iceberg of Ochten (a village along the river Rhine) ... detonated on 24 January, 1789”

Dike failure cause by ice in 1799

“*The government asked the preachers to change the common preaching service on Wednesday evening to a prayer service. Early on the morning of Thursday, February 3rd, 1729 at 3:30 AM, everybody was startled by a loud distant thump: the ice dam had broken loose. In minutes the water level had decreased by nine inches and the joy of the people was incredible*.”

2010!!!



Wooden piles protecting the Diemer sea dike near Amsterdam (N. Listingh, 1702)

"*... a Dutch complaint over God's coming judgments, clearly being recognized in the gnawing of the worms at the piles of the Dutch sea dikes - for the occasion of the thank, fast and prayer day - ...*"

Overflow of dike along the river Maas after heavy rain, Nederasselt, 8 January, 1925

Zeeland, The Netherlands, 1953

Rotterdam, Delft, Den Haag and Leiden nearly inundated.

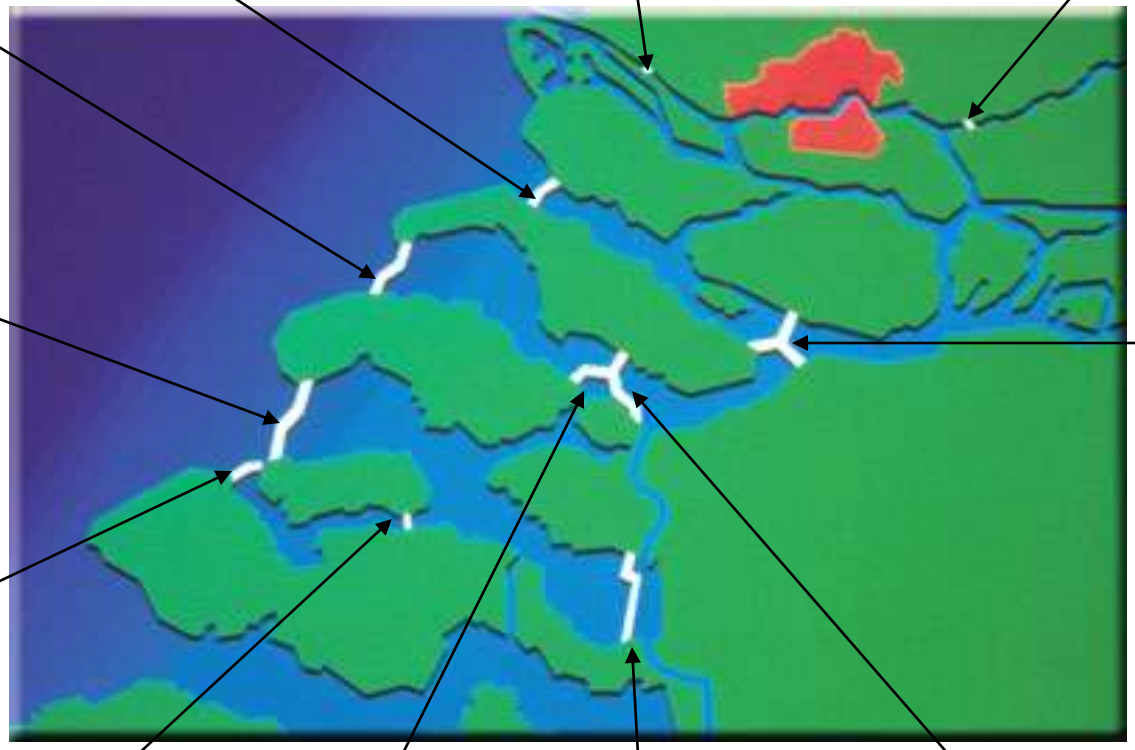
DeltaWorks

Haringvlietdam + Uitwateringsluizen 1971

Maeslantkering 1997

SVK Hollandse IJssel 1958

Brouwersdam 1971



SVK Oosterschelde 1986

Volkerakdam + Sluizen 1969

Veerse Gatdam 1961

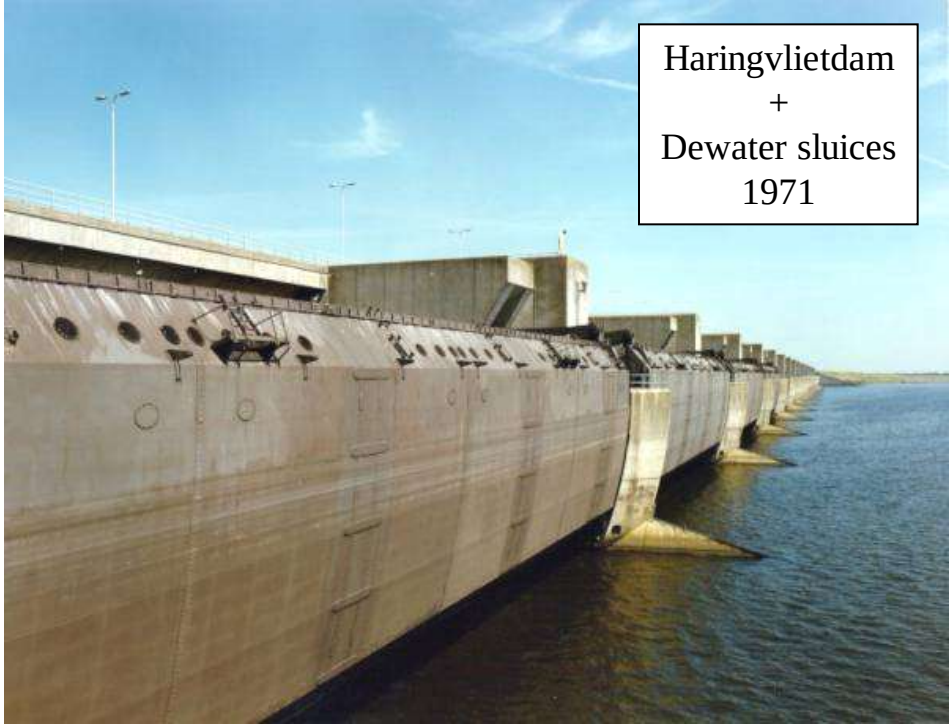
Grevelingendam 1965

Zandkreekdam 1960

Oesterdam 1986

Philipsdam 1987


1958
Dutch IJssel Storm Surge Barrier


Haringvlietdam
+
Dewater sluices
1971


1986
Eastern Scheld Storm Surge Barrier


Maeslant barrier 1997

DeltaWorks

Probability: 1/250 years → 1/10.000 years

Deaths: 1836

€ 1 = fl. 2.20

Costs: DeltaWorks: fl 11 billion
(of which fl. 8 billion for Easternscheldtbarrier and fl. 1 billion for Measlandtbarrier)
Other repairs: ???
Houses citizens: ???
Etc…???

(I pay € 135,- per year for my house for dike-, canal- and polder maintenance)

Failing mechanisms:

1. Run-over (dike too low for water level);
2. Wave overflow (waves too high or too much run up);
3. Instability of outer slope protection or erosion (damage to masonry pitching or rock fill);
4. Erosion of inner slope protection (or dike crest, often by wave overflow infiltration);
5. Micro-instability (washing out of the dike core sediment, such as piping below the dike);
6. Piping (local groundwater flow, sediment transport and erosion below/behind dike);
7. Heave (lifting of and liquefaction of inner sand layer by vertical groundwater up-flow);
8. Bursting (forcing up of polder top clay layer by high pore water pressure in sand layer below);
9. Liquefaction of shore line (loose sand layer in front of dike becomes unstable through wave action);
10. Sliding outer slope (macro instability of steep outer slope);
11. Sliding inner slope (macro instability of steep inner slope);
12. Horizontal sliding (complete dike pushed aside by water pressure);
13. Ice drift (both thrusting water load and direct ice load through current or wind);
14. External factors (Human: piercing, bombing, ship collision. Animal: worms, rats).

run over

piping

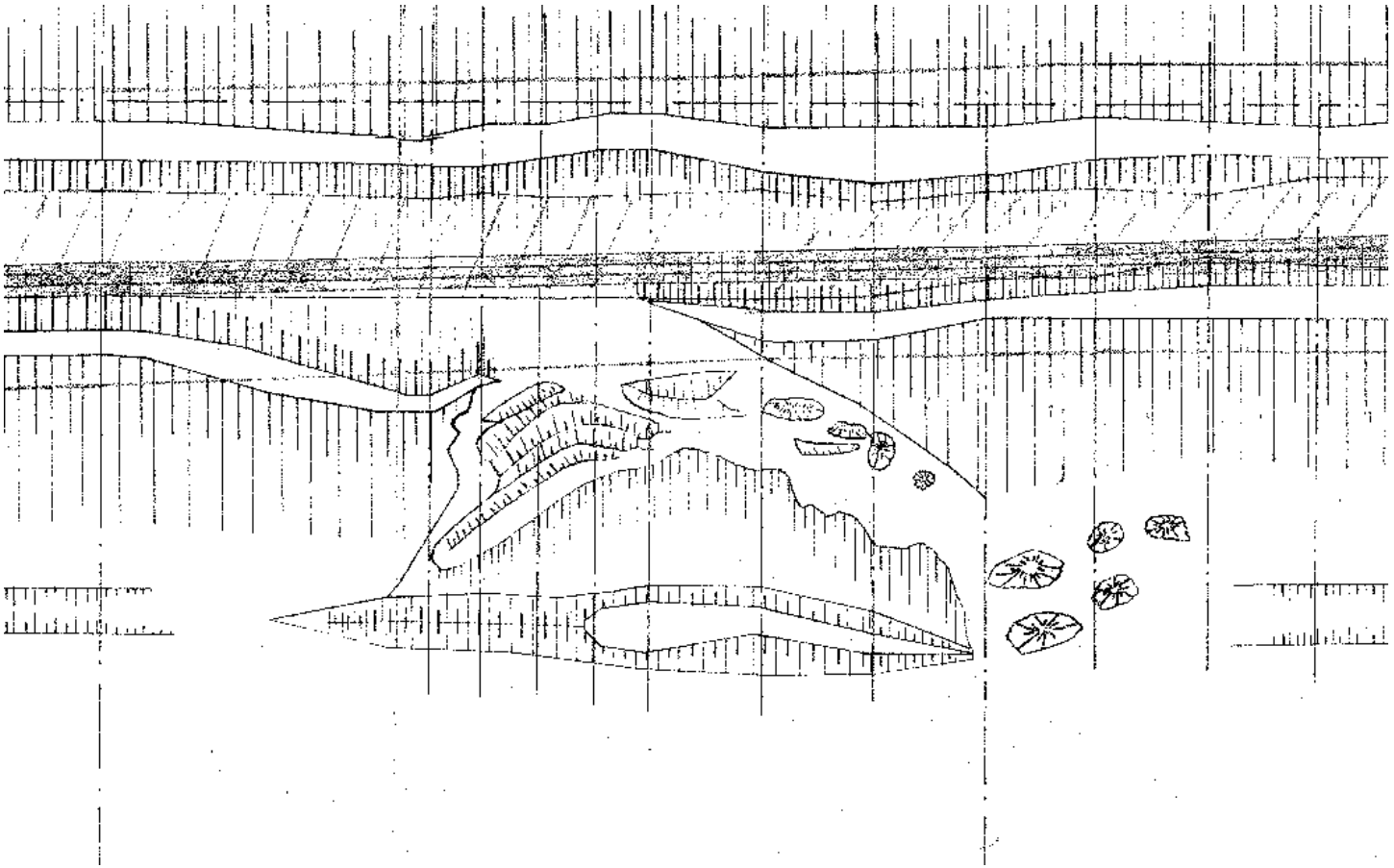
Failure mechanisms in the Netherlands between 1134 and 2006

Mechanism	Distribution
Erosion of inner slope protection + crest	67%
Ice drift	11%
Erosion or instability of outer slope protection	6%
Sliding inner slope	5%
External (human and animal)	4%
Sliding outer slope	3%
Liquefaction of shore line	2%
Piping	1%
Micro instability	0.5%
Horizontal shear	0.5%
Bursting of inner clay layer	0.0%
Heave	0.0%
Total	*1735*

Horizontal sliding / peat dike failure

Dike failure Edenderry Jan. 1989:

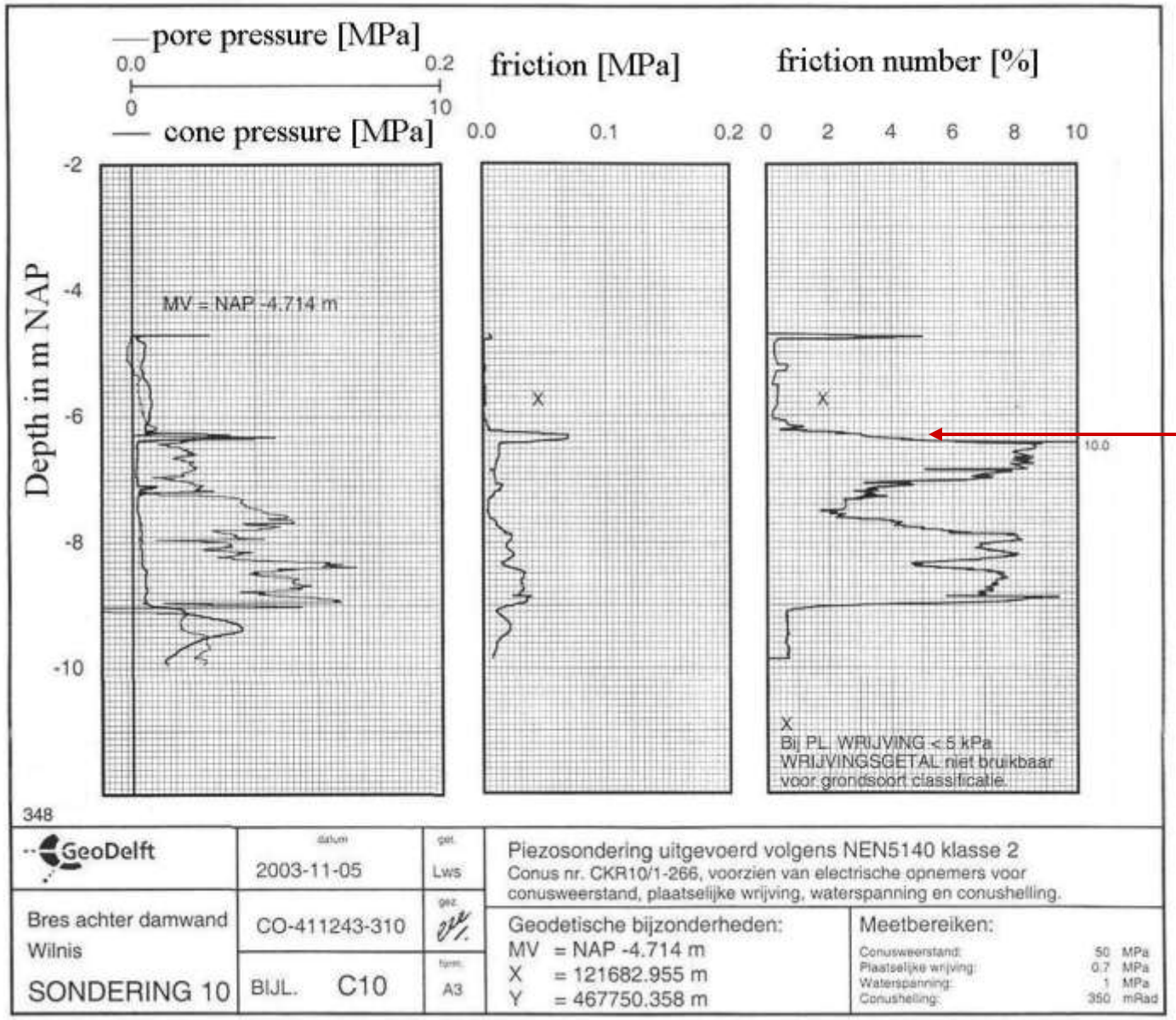
Dike failure Zoetermeer summer 1947:



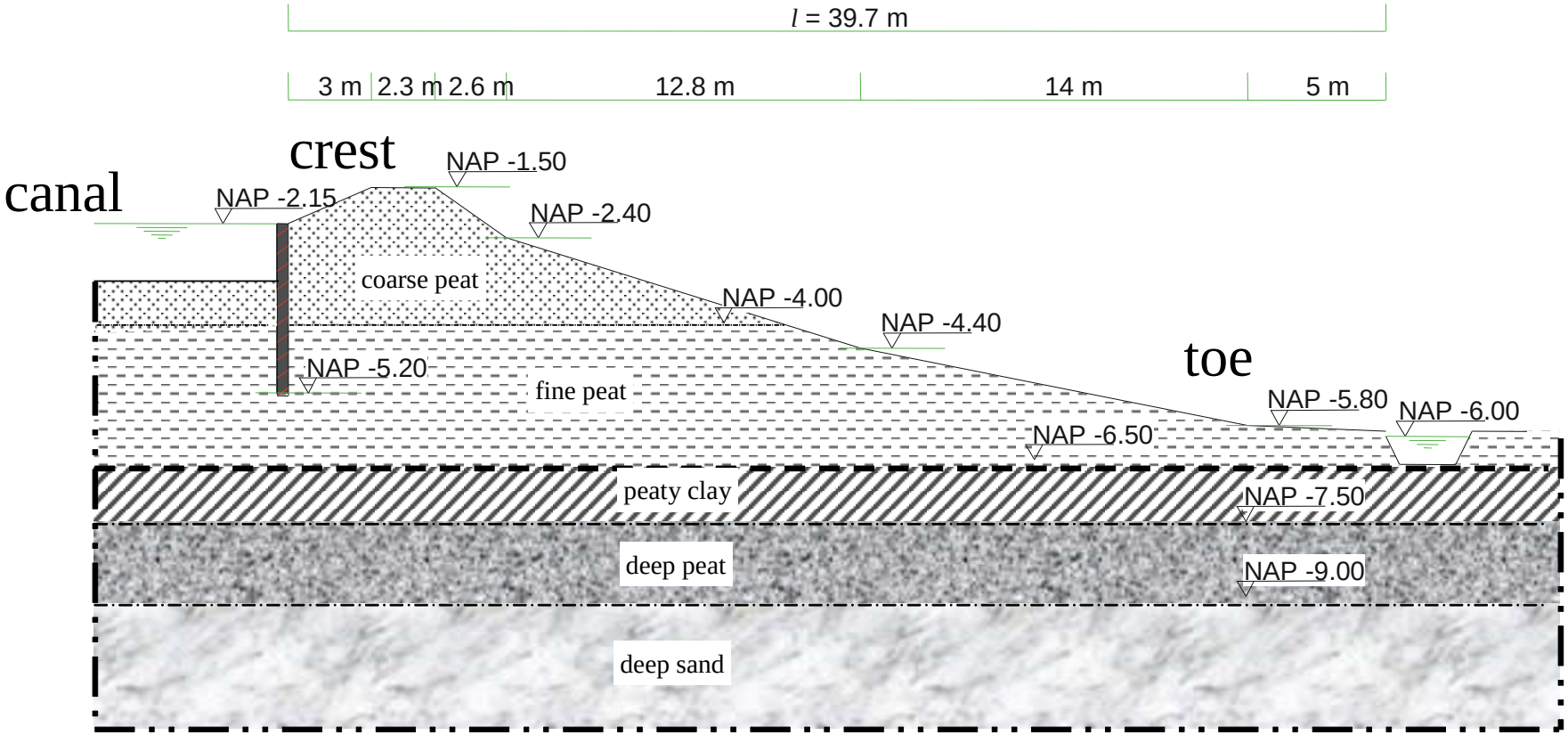
Wilnis, The Netherlands, Summer 2003

Canal of Wilnis in open connection with 10 km^2 Finch Peat Lakes!!

toe shears higher than bottom ditch



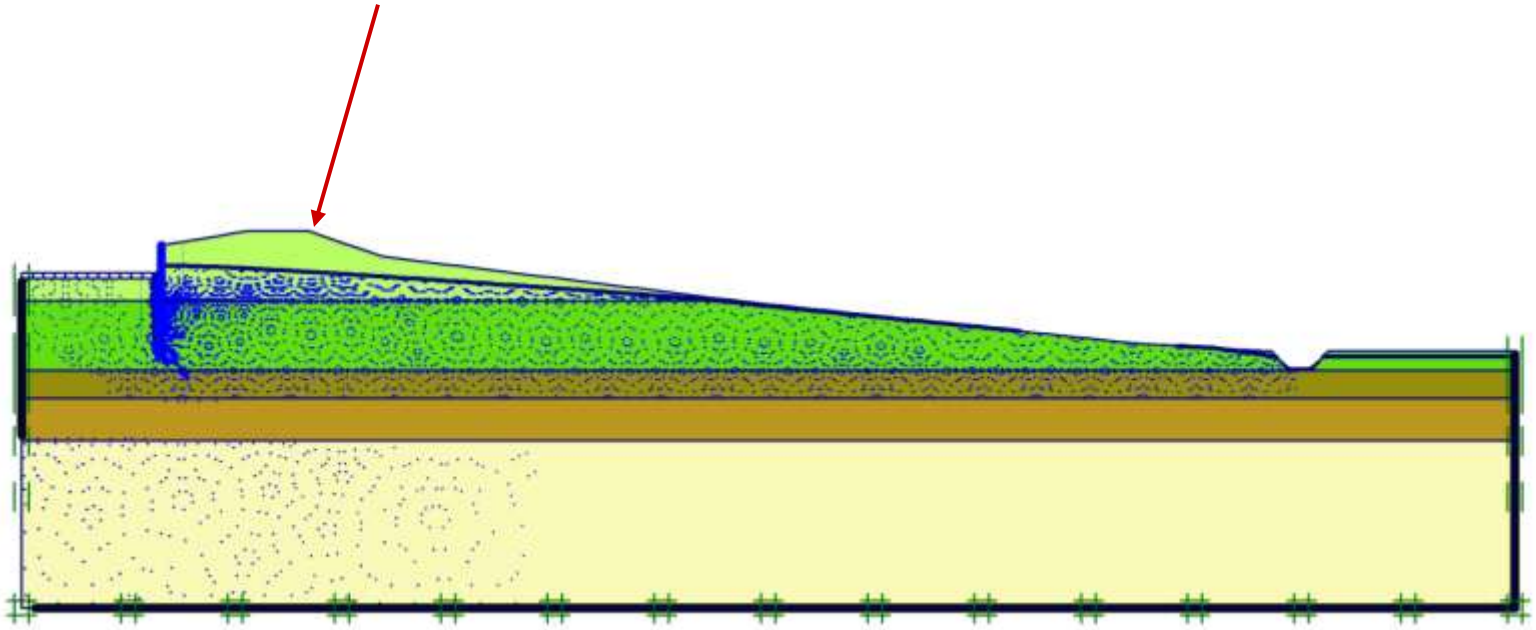
dike shears above NAP –6,5 m = bottom ditch



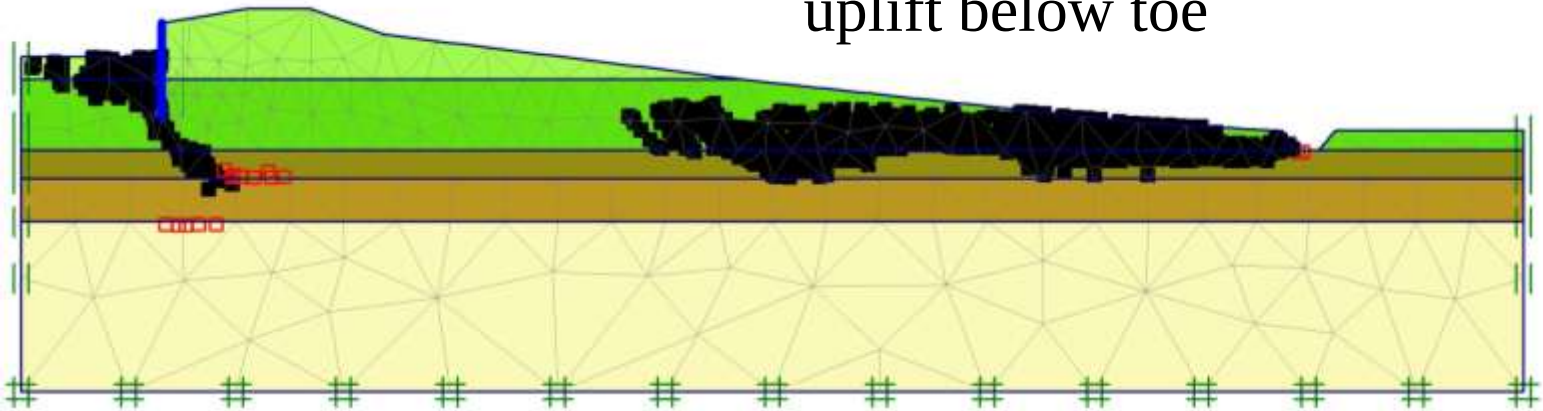
sheet pile not deep enough for stopping sliding at NAP –6.5 m
(but deep enough to let the crest dry out)

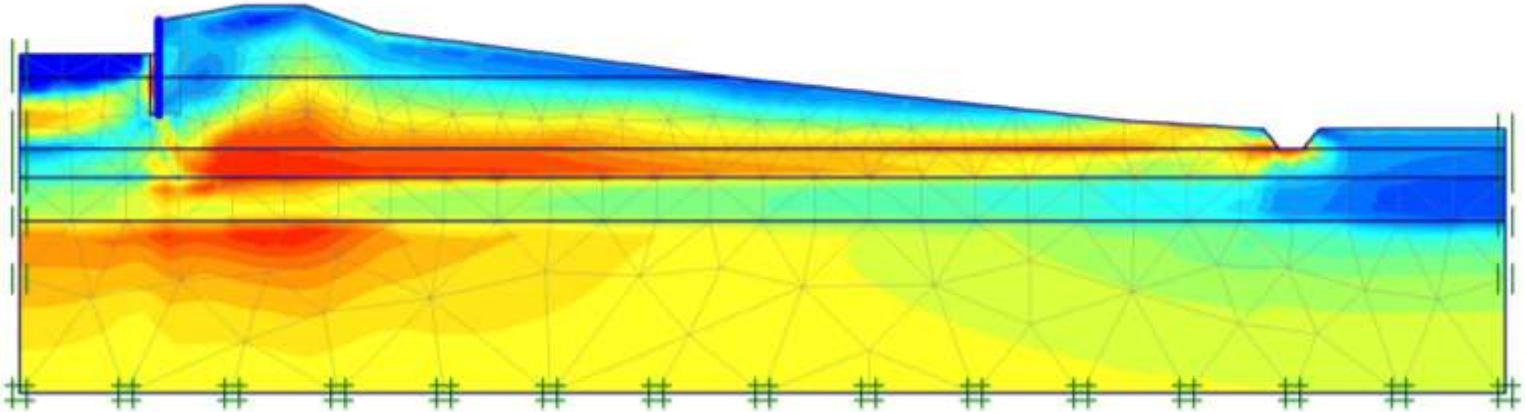
Finite Element Computer Simulation (Plaxis)

drying out until 7,5 kN/m^3 above freatic line = failure!



uplift below toe





shear failure below crest

90 procent schade Wilnis vergoed / 90% damage Wilnis refunded

90 procent schade Wilnis vergoed

DEN HAAG - Inwoners van Wilnis die getroffen zijn door de dijkdoorbraak van augustus, krijgen de schade aan hun woning voor 90 procent vergoed. Ondernemers kunnen voor schade aan hun bedrijfspanden en de inboedel een vergoeding van 65 procent verwachten.

Dat heeft het ministerie van binnenlandse zaken bekendgemaakt. Het kabinet besloot al eerder dat de getroffenen een beroep kunnen doen op de Wet tegemoetkoming schade bij rampen en zware ongevallen.
Beschadigde inboedel tot 9100 euro krijgen particulieren voor 90 procent vergoed. Boven dit bedrag loopt het percentage af. Voor inboedelschade boven de 27200 euro krijgen de bewoners niets terug. Aangetaste tuinhuisjes en ondergelopen tuinen zijn geheel voor eigen rekening. Opruimen en voorkomen van verder onheil betaalt het rijk voor 65 procent.

Cases	Requests	Damage
Company	11	€ 387.237
Foundation	5	€ 54.215
Gouverment	2	€ 2.297.452
Citizens	278	€ 419.509
Totaal	**296**	**€ 3.158.413**

Cases	Requests	Rejected	Accepted	Payed
Company	11	4	7	€ 431.367
Foundation	5	1	4	€ 17.051
Gouverment	2	0	2	€ 1.830.136
Citizens	278	190	88	€ 351.633
Totaal	**296**	**195**	**101**	**€ 2.630.187**

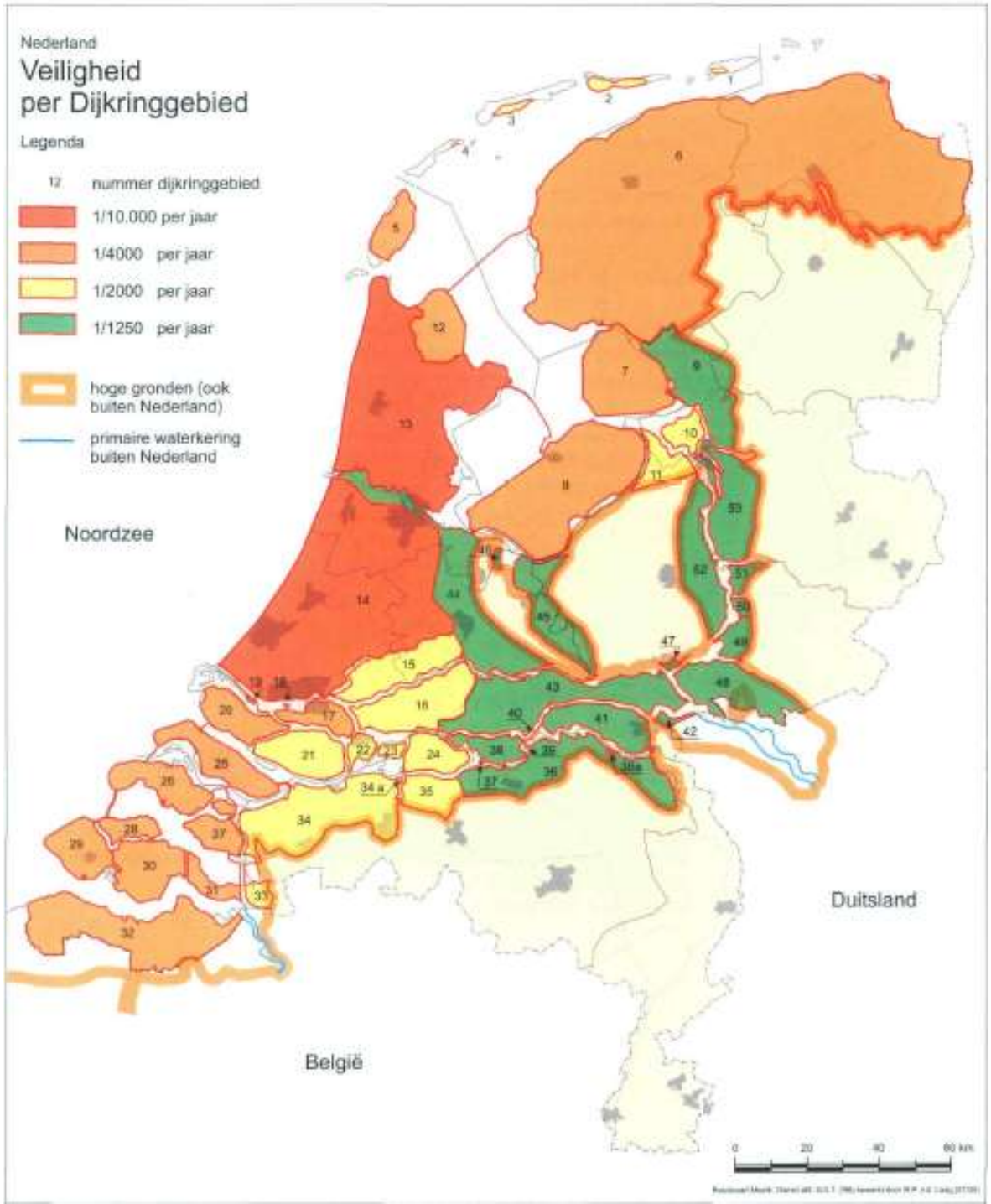
Damage category	Foundation	Companies	Gouverment	Citizens	Total
House	€ 9.499			€ 236.565	**€246.064**
Furniture	€ 5.732			€ 96.569	**€ 102.301**
Rescue			€ 793.053		**€ 793.053**
Cleaning	€ 975		€ 53.204	€ 17.627	**€ 71.806**
Evacuation				€ 872	**€ 872**
Infrastructur			€ 983.878		**€ 983.878**
Other	€ 845	€ 431.367			**€ 432.212**
Total	**€ 17.051**	**€ 431.367**	**€ 1.830.135**	**€ 351.633**	**€ 2.630.186**

Real Costs:

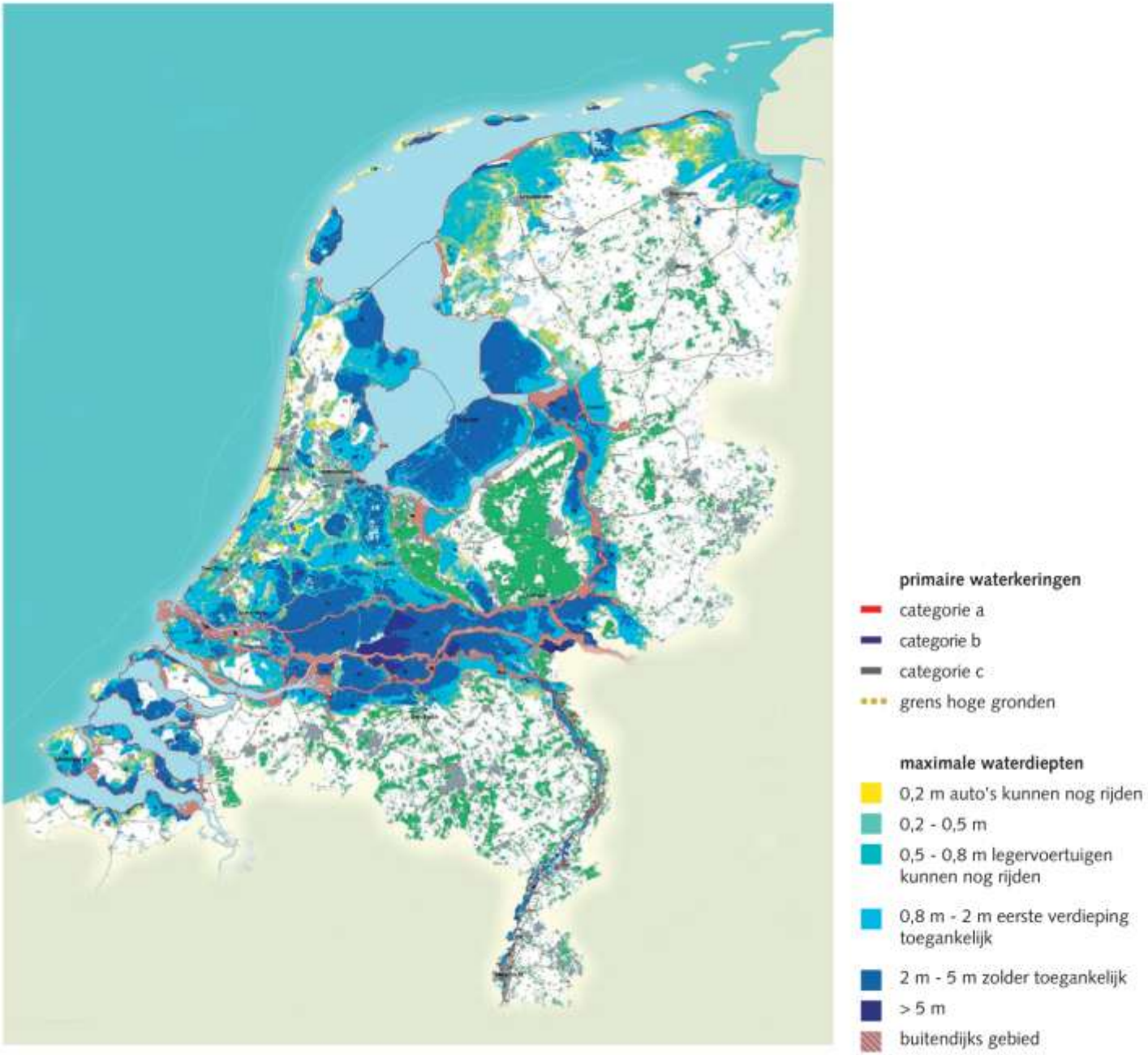
- **Waterboard € 8 million**
- **Municipality € 7 million**
- **Citizens € 2 million**

??????


You know
I'd some other ideas about a once in a fifty year drought...
WILNIS


Nederland
Veiligheid
per Dijkringgebied
Legenda
12 nummer dijkringgebied
1/10.000 per jaar
1/4000 per jaar
1/2000 per jaar
1/1250 per jaar
hoge gronden (ook buiten Nederland)
primaire waterkering buiten Nederland
Noordzee
Duitsland
België
0 20 40 60 km

Figuur 3.1 Landelijke overstromingsrisicokaart



Bron: Ontwerp Nationaal Waterplan, 2008

Hurricane Katrina

New Orleans

August 2005

Coastal Louisiana Land Surface Elevation

DOTD

by James E. Blalock
Information Technology Section

Legend

Cities

2000 Census Population

- 8000 - 10000
- 10001 - 25000
- 25001 - 1000000

Elevation

Mean Sea Level

- Above 30 Feet
- 26 - 30 Feet
- 21 - 25 Feet
- 16 - 20 Feet
- 11 - 15 Feet
- 6 - 10 Feet
- 1 - 5 Feet
- 0 or Lower
- Interstate Highway
- US Highway
- LA Route
- Pontchartrain Causeway
- Parish Boundary

105 0 10 20 30 40 Miles

N

Potential Hurricane Flooding

- Category 5
- Category 4 - Category 5
- Category 3 - Category 4
- Category 2 - Category 3
- Category 1 - Category 2

Hurricane Storm Surge Height

Category	Wind Speed	Storm Surge
5	>155 mph	>18 feet
4	130 - 155 mph	12 - 18 feet
3	110 - 130 mph	9 - 12 feet
2	95 - 110 mph	6 - 9 feet
1	74 - 95 mph	4 - 6 feet

(Based on Saffir-Simpson Hurricane Scale)

Without levees / dykes, a cat. 1 hurricane can flood the city

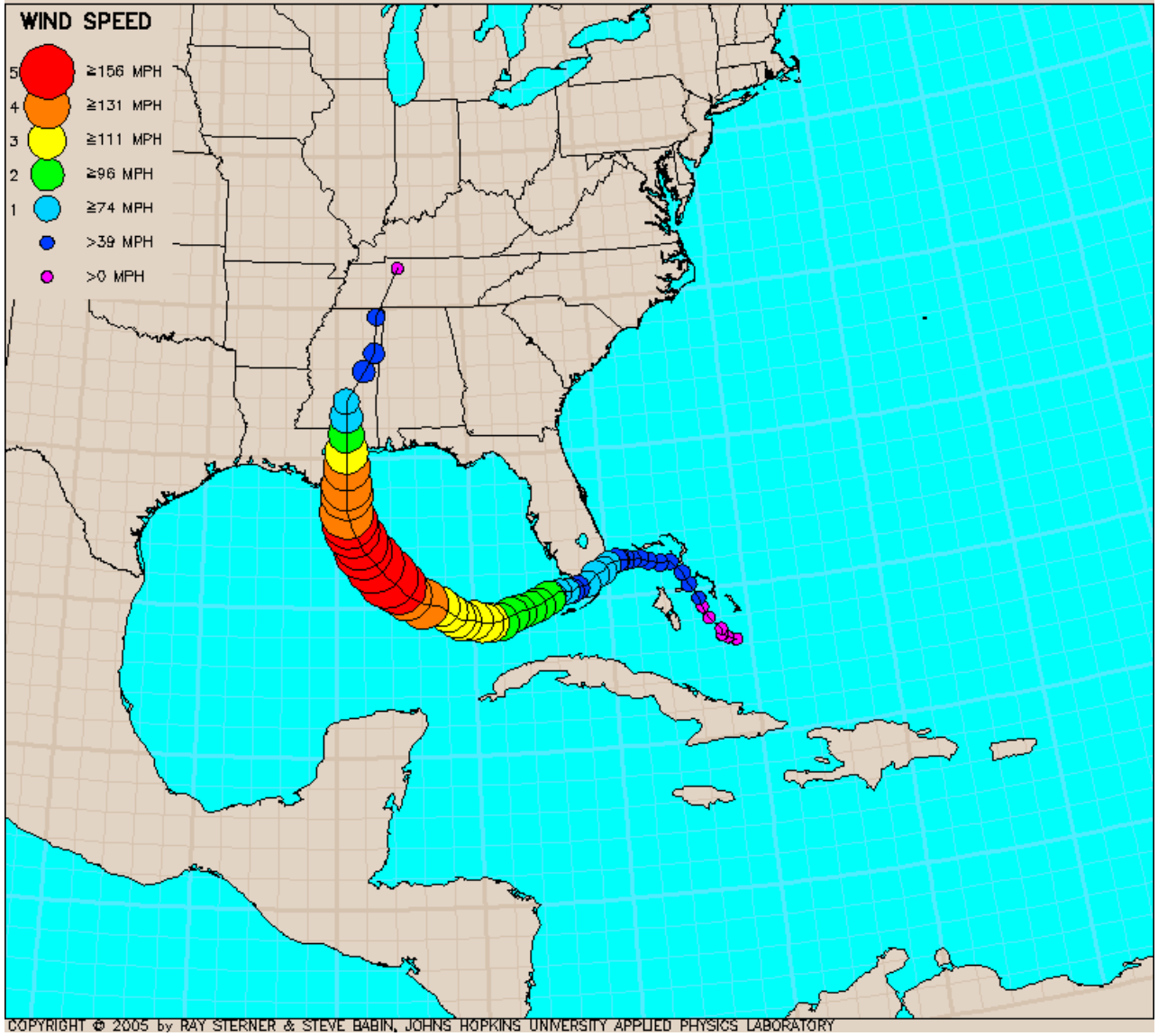
Katrina

August, 29th

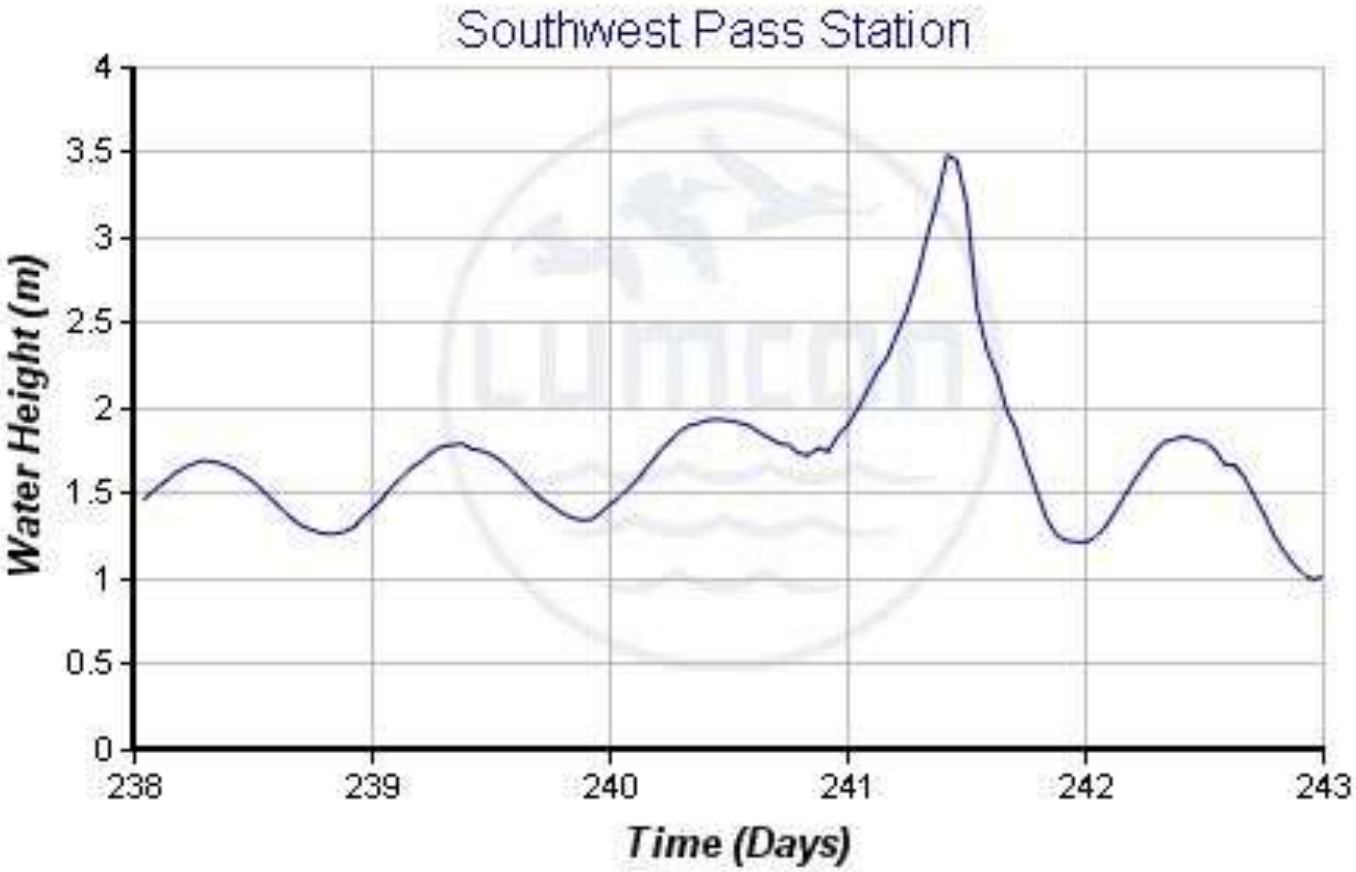
Evacuation

Hurricane Katrina

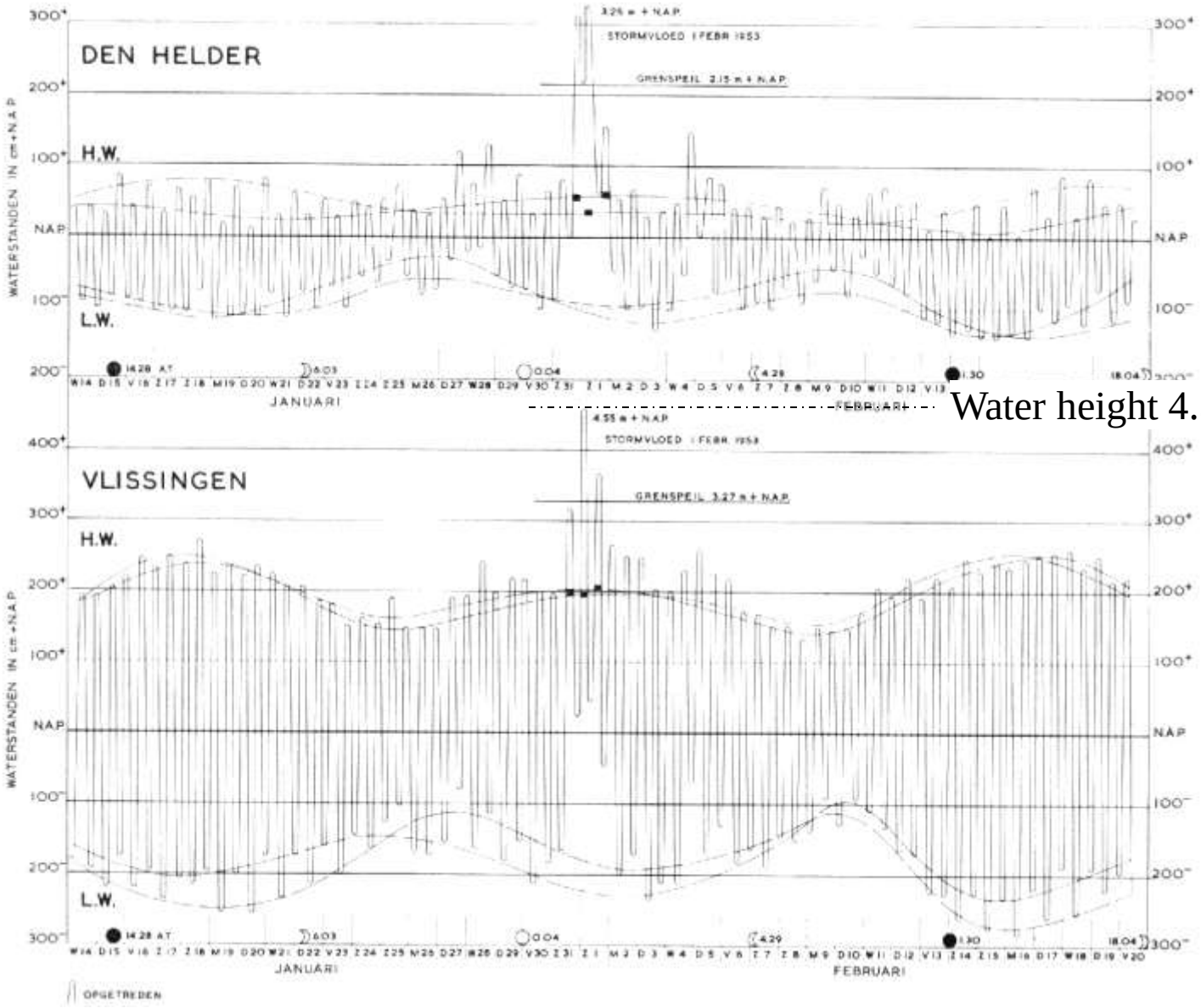
21:00 Tue August 23, 2005 to 15:00 Tue August 30, 2005 UTC



Average Hourly Water Height 5 Days

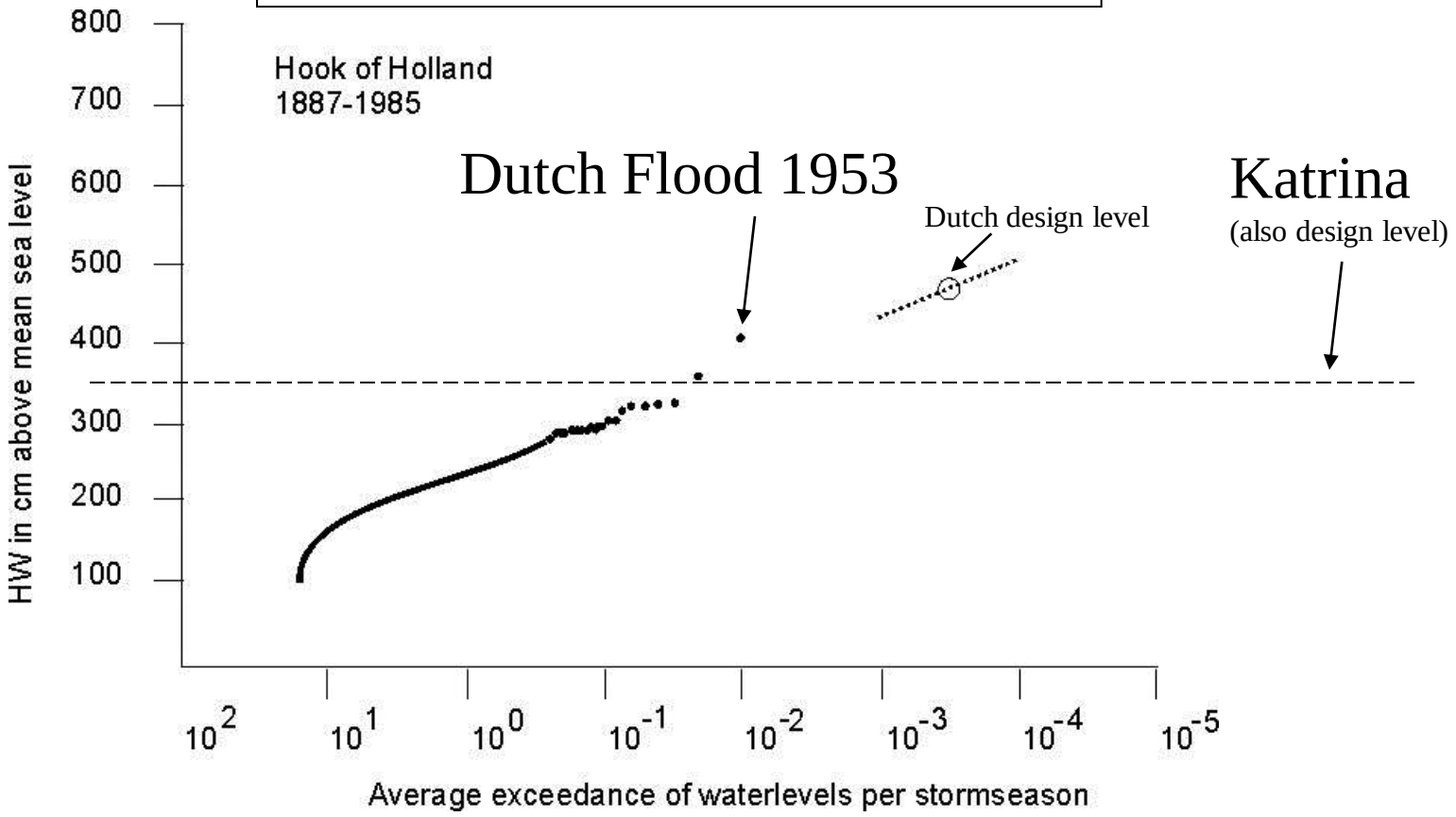


Dutch Flood 1953



Water height 4.55 m

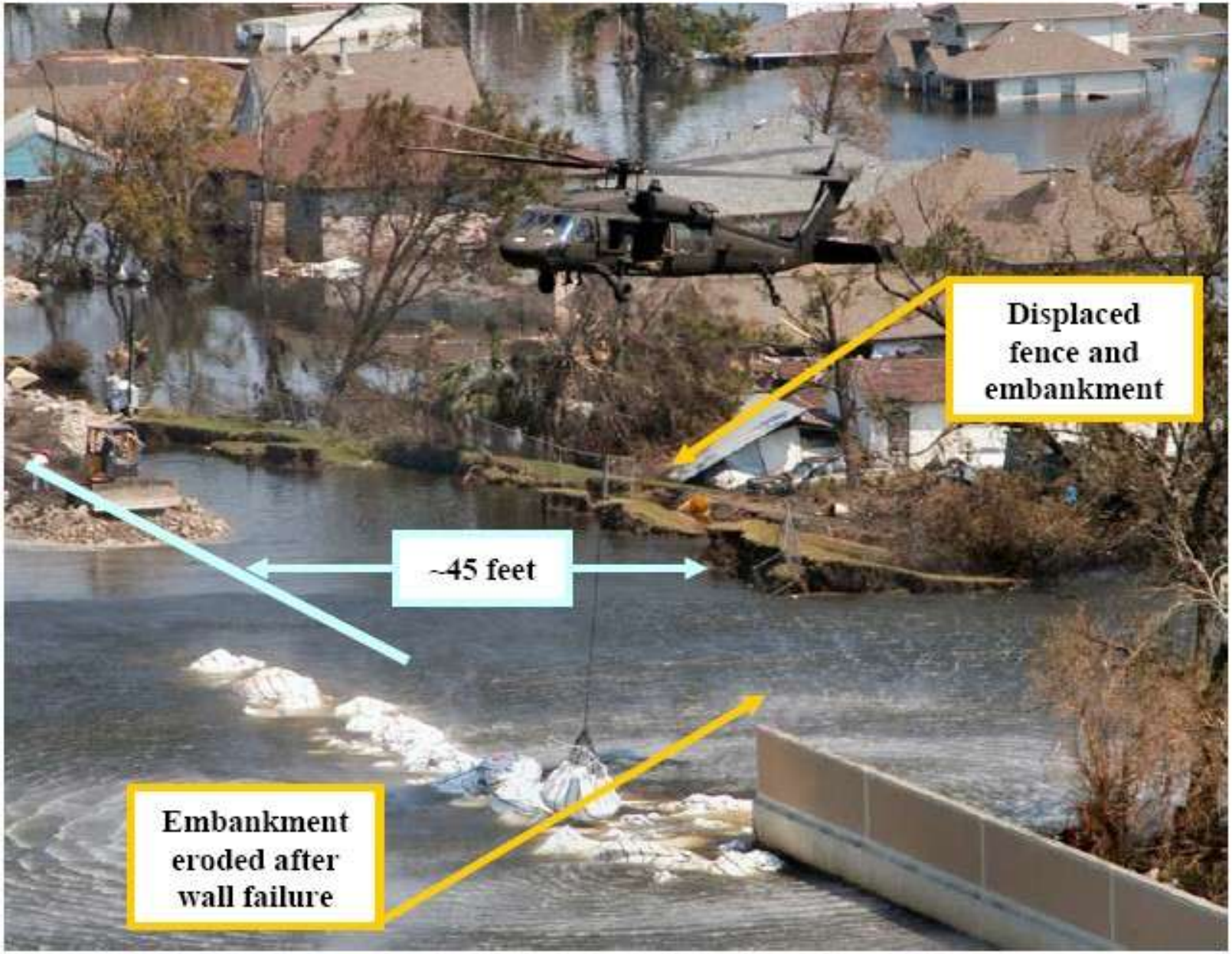
Katrina versus Dutch Flood 1953



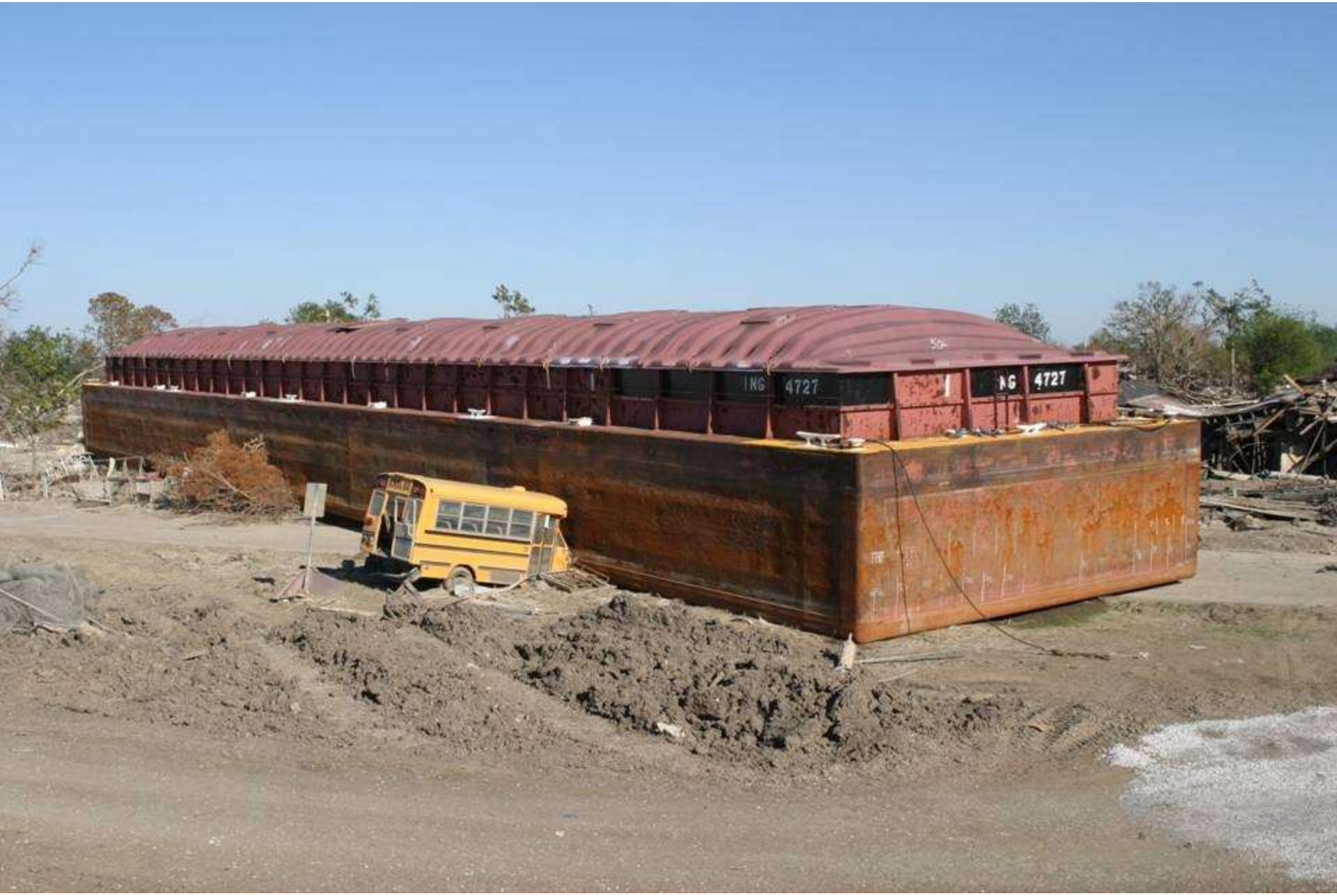
HW/year	Delfzijl	Den Helder	Scheveningen	Vlissingen	Bath
10^{-1}	4.10 m	2.75 m	3.05 m	3.85 m	4.75 m
10^{-2}	4.95 m	3.40 m	3.70 m	4.40 m	5.45 m
10^{-3}	5.60 m	3.95 m	4.40 m	4.95 m	6.10 m
10^{-4}	6.20 m	4.45 m	5.15 m	5.50 m	6.75 m
1 Feb. 1953	-	3.25 m	3.97 m	4.55 m	5.60 m


David J. Phillip / Pool via Reuters


WE NEED HELP
AP

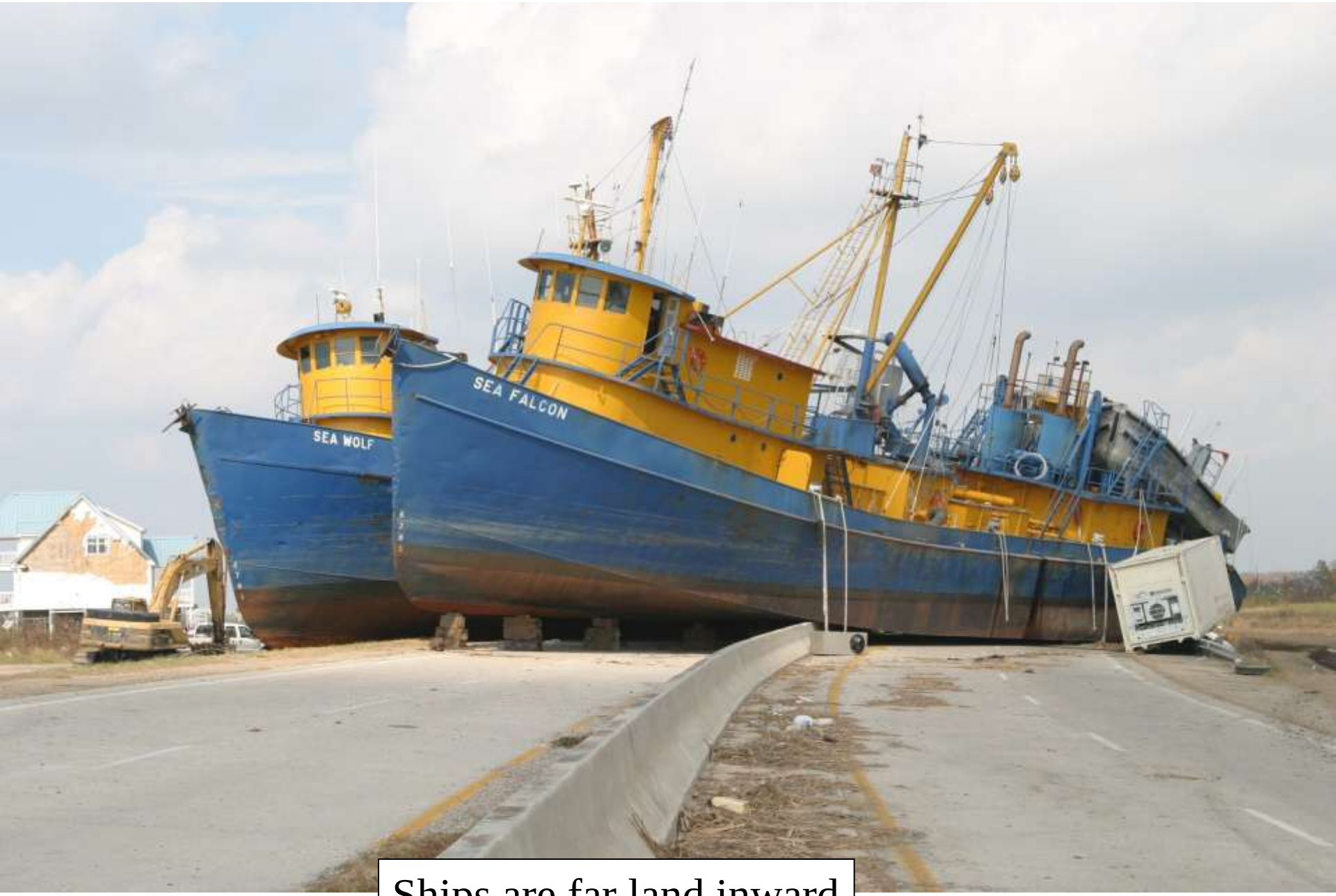


Source: http://www.usace.army.mil/katrina-images/NO-A-09-04-05_0072.jpg


ING 4727
NG 4727


New Orleans East: Lower 9th Ward


AP



Ships are far land inward


9-10

Senator, Colonel, Coordinator, Sen. wife, Senator, Van Gelder, Kok, Kanning, Van Baars, Wagemaker, Klaver, Sen. Wife

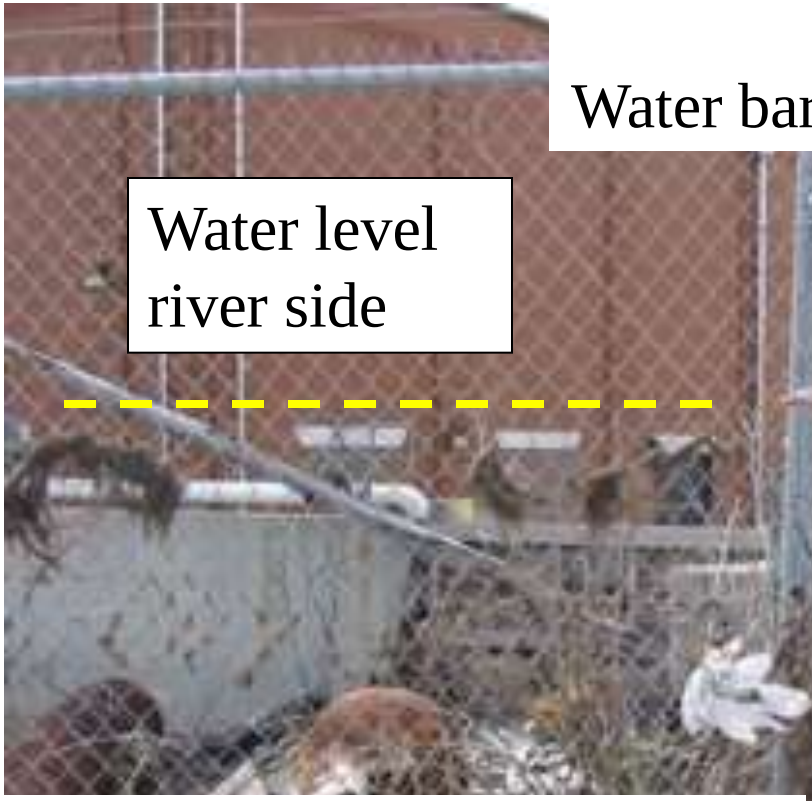
Mistakes New Orleans

1.

Water defence system too long by not using secondary dikes / canals

2.
Dikes / Levees different hights

3.
Water barrier very often too low



4.
Too much I-walls / I-walls are too light

5.
Missing I-wall or dike

6.

Hard-soft mistakes / piping

7.
Sifons must be over /not through dike

8.
Dikes must be more impermeable

Xynthia, February 2010

Formed 26 February 2010
Dissipated 1 March 2010
Countries or regions affected Belgium, Denmark, France, England, Germany, Poland, Portugal, Spain, Sweden and South-East England.
Damage €1.3 - 3 billion[1]
Fatalities 62 and 12 missing

A car damaged by a falling tree is seen near Arianzon, Spain, on early Sunday. The two passengers of the car were killed. (AP Photo/I. Lopez)

URBANISME Après la tempête Xynthia

L'État veut détruire près de 1500 maisons

Dauphiné 6 avril 2010

Les autorités s'apprêtent à annoncer cette semaine un plan de destruction de 1300 à 1500 maisons en zones inondables après le passage de la tempête Xynthia qui a fait 53 morts les 27 et 28 février dans l'ouest de la France, a annoncé hier *le Journal du Dimanche*, citant "les préfets de Charente-Maritime et de Vendée. D'après la préfecture de Vendée, une réunion à huis clos est prévue avec les maires mercredi soir, et les habitants de La-Faute-sur-Mer et de l'Aiguillon-sur-Mer en seront informés jeudi.

Définir des "zones rouges"

Toujours selon le JDD, "les services des préfectures et de l'Equipement planchent encore sur les cartes côtières pour définir et délimiter les derniers contours des *zones rouges*, territoires où plus aucune habitation ne pourra être construite".

Autre révélation du JDD : les indemnisations atteindraient au total 200 millions d'euros, soit environ 150 000 euros par maison en moyenne.

Par ailleurs, le président du conseil général de Charente-Maritime, Dominique Bussereau, va proposer une hausse exceptionnelle de la fiscalité de 6 % pour 2010 pour faire face au coût de la tempête, a-t-on appris hier auprès du premier vice-président, Jean-Louis Frot. Le coût estimé de la tempête pour les finances départementales serait de l'ordre de 27 millions d'euros. Et cette hausse apporterait huit millions d'euros supplémentaires au budget 2010...

Poland/Hungary, June 2010