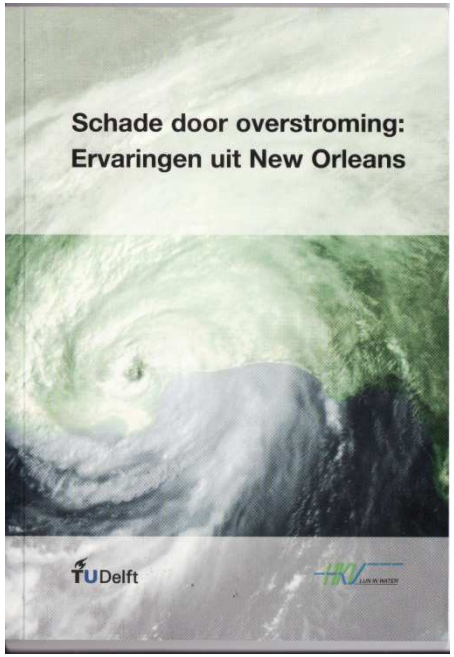
Floods in Germany (June 2013)

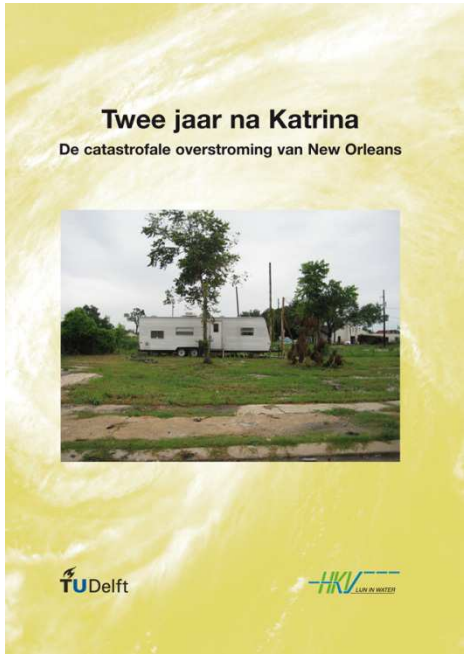
Post-flood field investigation, July 2&3, 2013
Preliminary Findings

Bas Jonkman, Timo Schweckendiek, Guy Dupuits (TU Delft);
Torsten Heyer (TU Dresden); Joop de Bijl (STOWA); Astrid Labrujere (RWS)

in collaboration with:

New Orleans, 2005





Xynthia, Frankrijk, 2010



Japan, 2011



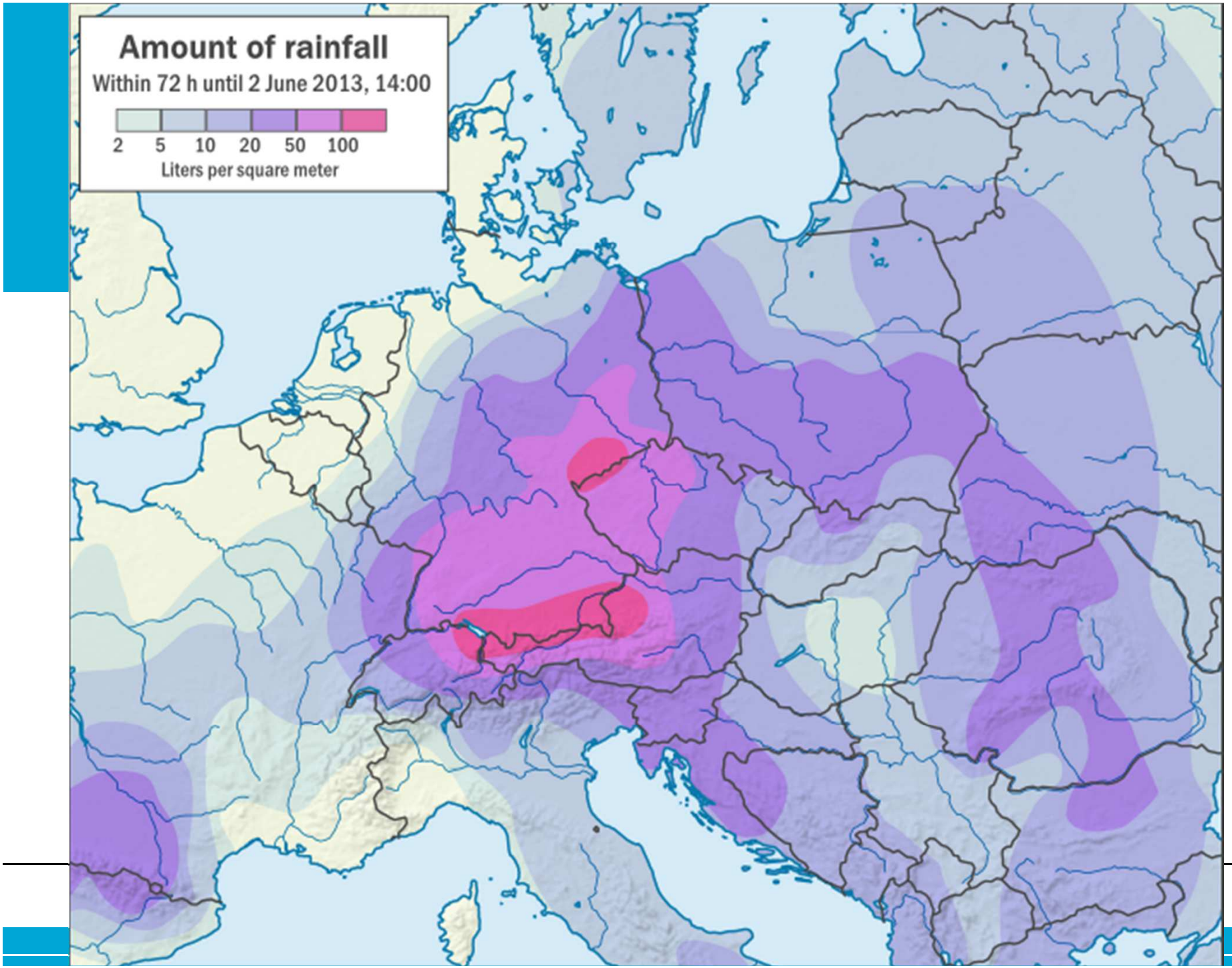
Thailand, 2011



Objectives and scope

- Post-flood field investigation July 2 & 3
- Focus on dike breaches and emergency measures
- Team:
  - Torsten Heyer (TU Dresden)
  - Bas Jonkman (TU Delft, Rijkswaterstaat, ENW)
  - Timo Schweckendiek (TU Delft, Deltares, ENW)
  - Joop de Bijl (STOWA, Waterschap Aa en Maas)
  - Guy Dupuits (TU Delft)
  - Astrid Labrujere (Rijkswaterstaat)
  - July 2, Reinhard Pohl (TU Dresden)
  - July 3, Koos Wieriks (Dutch Embassy in Berlin)

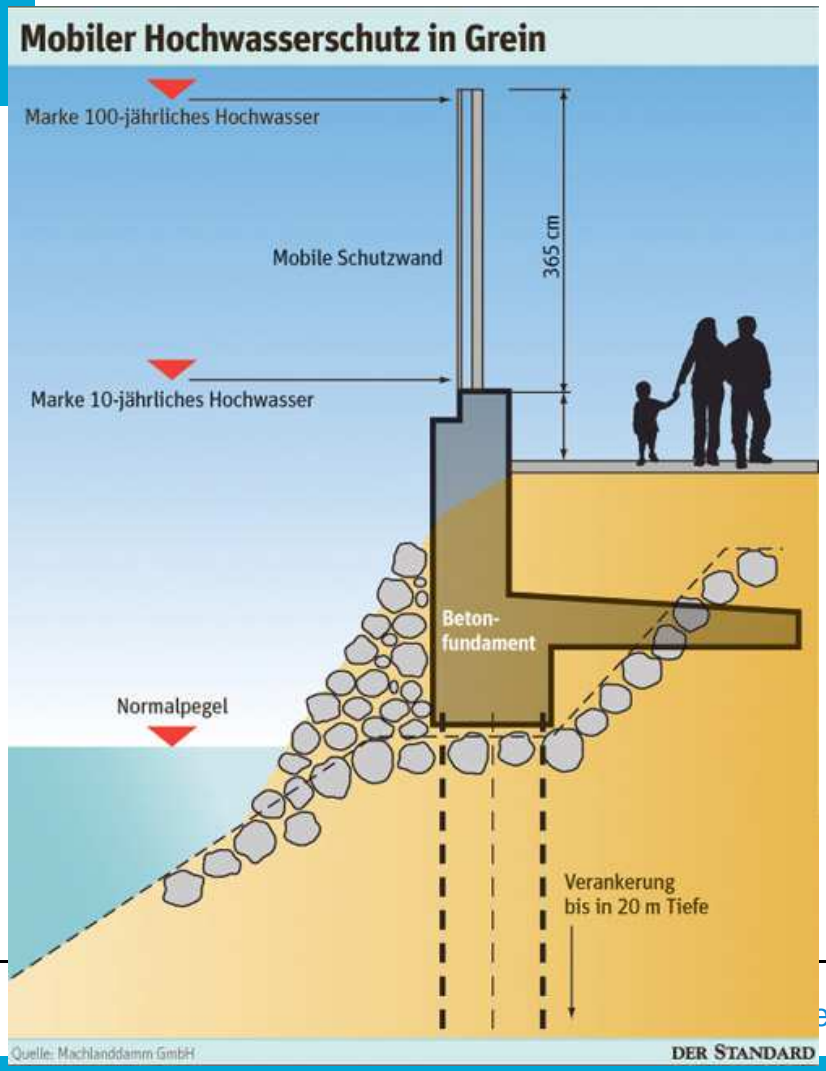

Deichbruch
Achtung allgemeine Gefahrenstelle !
Das Betreten des Deiches durch Unbefugte ist untersagt !
Landestalsperrenverwaltung des
Freistaates Sachsen
Betrieb Elbaue/Mulde/Untere Weiße Elster
Flussmeisterei Bad Düben
Tel. 034243 / 333 00
Flussmeisterei Bad Düben
Tel.034243 / 33300


Amount of rainfall
Within 72 h until 2 June 2013, 14:00
2 5 10 20 50 100
Liters per square meter



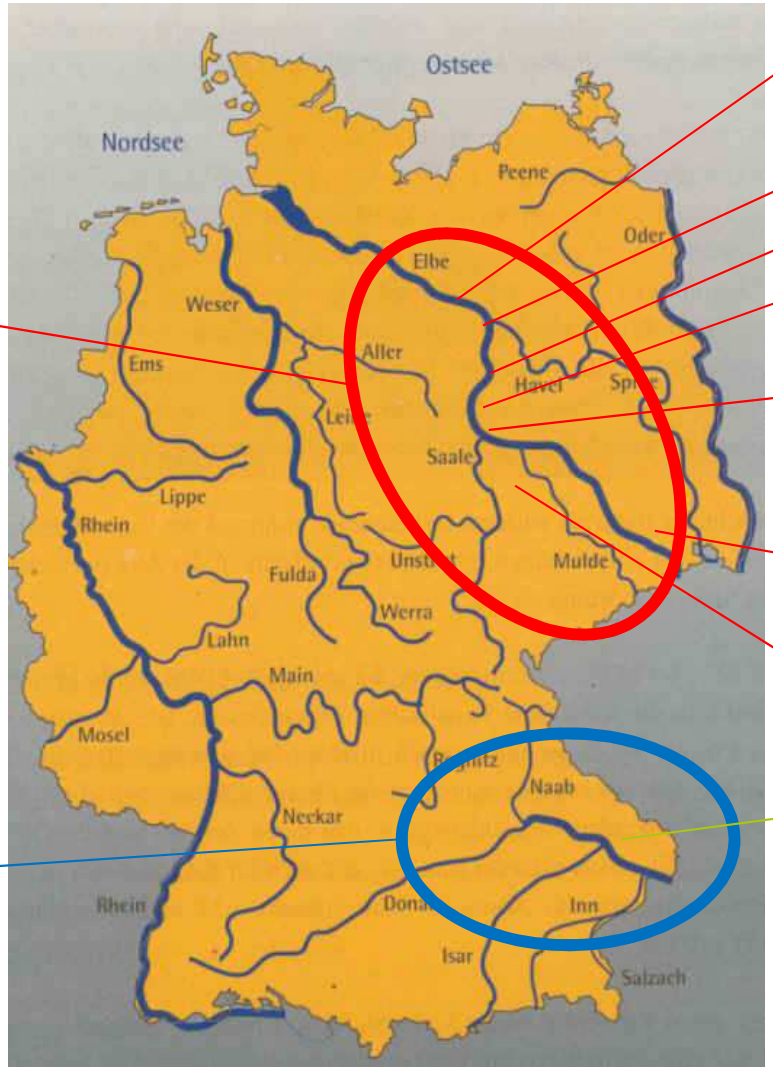
- Large flood event:
  - Return period 50 – 500 year depending on location / river
  - At some places larger than 2002 flood event

Temporary flood defence (Grein, Austria)





Affected areas Germany



Wittenberge

Havel -> Elbe

Fischbeck / Tangermünde (Elbe)

Magdeburg (Elbe)

Saale -> Elbe

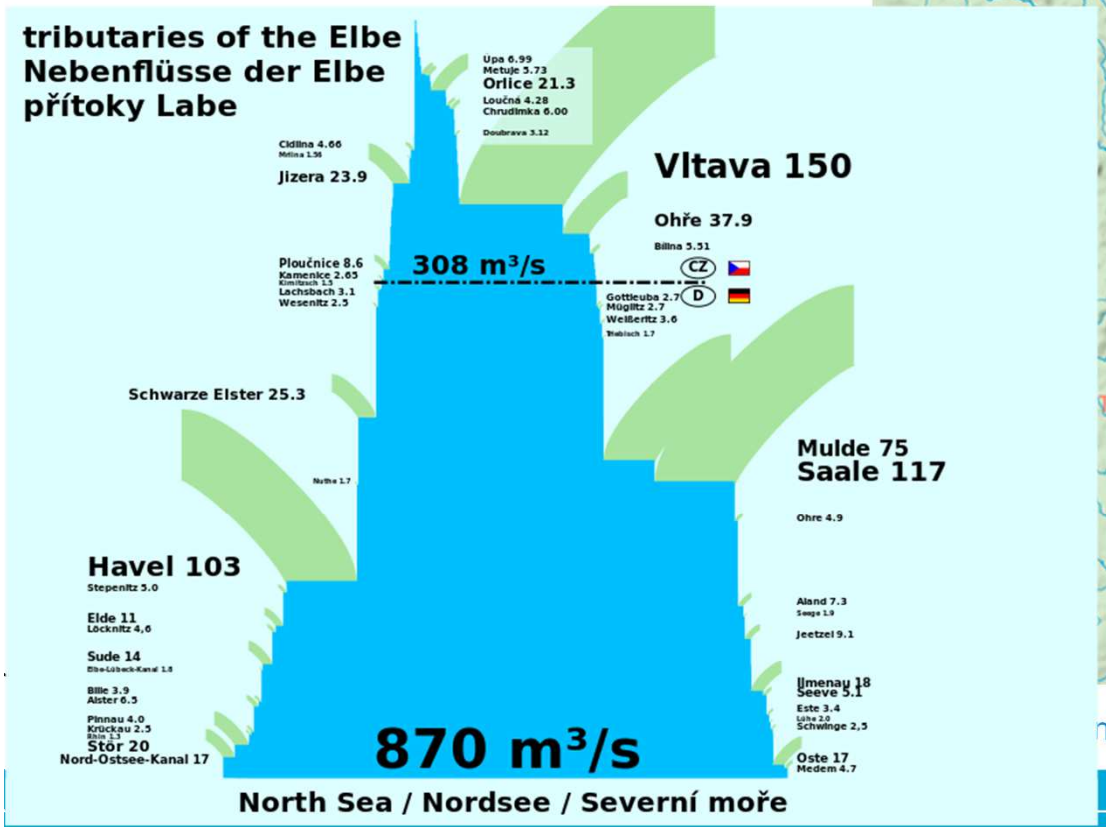
Elbe
Saale
Mulde
Aue
Havel
Elster

Dresden (Elbe)

Bitterfeld (Aue)

Passau (Donau)

Donau
Isar
Inn

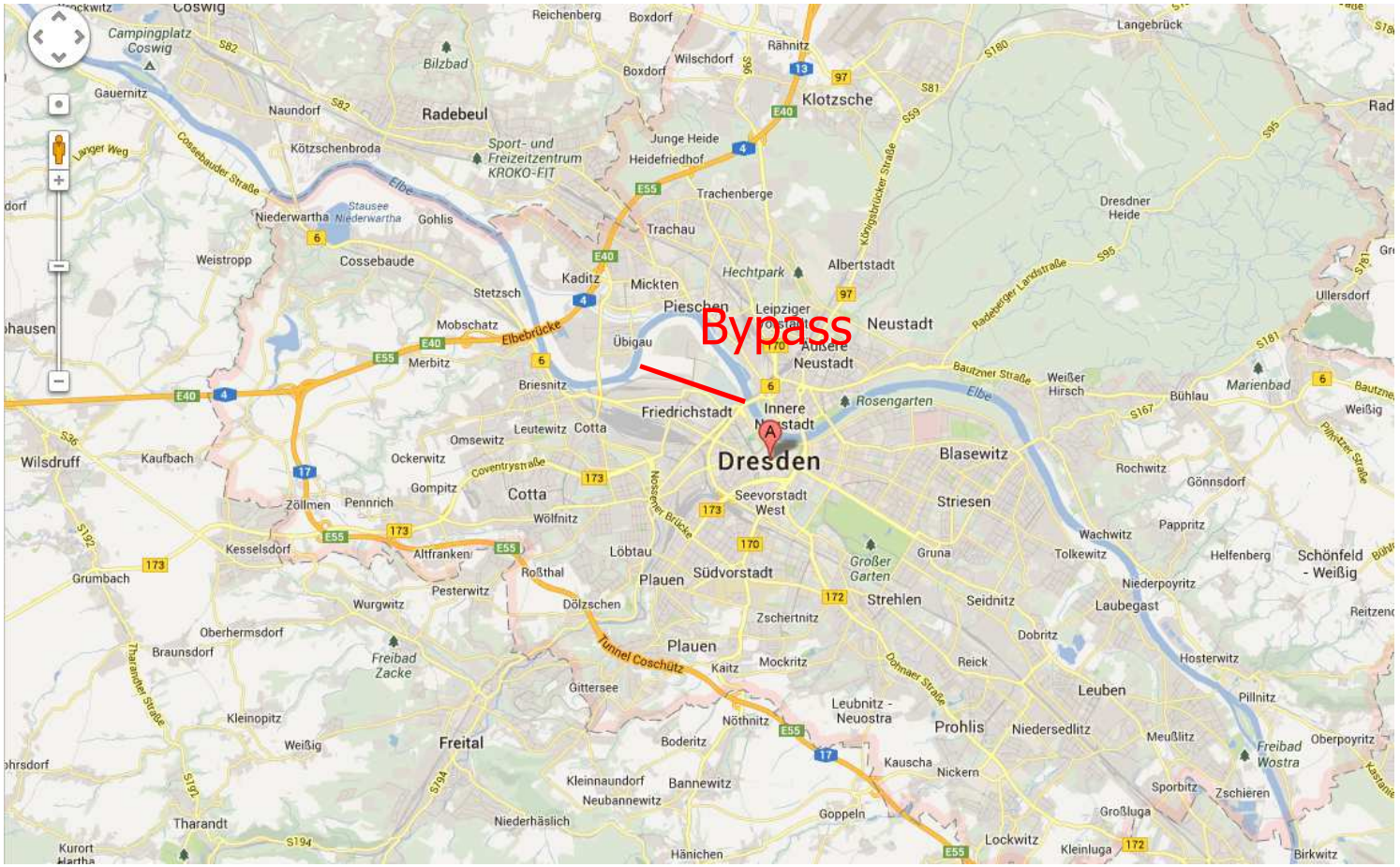

tributaries of the Elbe
Nebenflüsse der Elbe
přítoky Labe
Úpa 6.99
Metuje 3.73
Orlice 21.3
Loučná 4.28
Chrudimka 6.00
Doubrava 3.12
Cidlina 4.66
Mrlina 1.56
Jizera 23.9
Vltava 150
Ohře 37.9
Bílina 3.51
Ploučnice 8.6
Kamenice 2.65
Kimitzsch 1.3
Lachsbach 3.1
Wesenitz 2.3
308 m³/s
CZ
D
Gottleuba 2.7
Müglitz 2.7
Weißeritz 3.6
Trebisch 1.7
Schwarze Elster 25.3
Nuthe 1.7
Mulde 75
Saale 117
Ohre 4.9
Havel 103
Stepenitz 5.0
Elde 11
Löcknitz 4,6
Sude 14
Elbe-Lübeck-Kanal 1.8
Bille 3.9
Alster 6.3
Pinnau 4.0
Krückau 2.5
Rhin 1.3
Stör 20
Nord-Ostsee-Kanal 17
Aland 7.3
Seege 1.9
Jeetzel 9.1
Ilmenau 18
Seeve 5.1
Este 3.4
Lühe 2.0
Schwinge 2,5
Oste 17
Medem 4.7
870 m³/s
North Sea / Nordsee / Severní moře


NORD-
SEE
Brunsbüttel
Cuxhaven
Hamburg
Schwerin
Waren (Müritz)
Oste
Sude
Elde
Lüneburg
Elbe
Wittenberge
Havel
BERLIN
POLEN
Ohre
Havel
Spree
Potsdam
Magdeburg
Wittenberg
Bode
Saale
Dessau-
Roßlau
Schw. Elster
Cottbus
Halle (Saale)
Mulde
Elbe
Leipzig
Unstrut
Dresden
Erfurt
Gera
Ilm
Weiße Elster
Zwickau
Ústí nad Labem
(Aussig)
Saale
Ohře
(Elbe)
Hradec Králové
(Königgrätz)
Hof
(Eger)
Karlovy Vary
(Karlsbad)
PRAHA
(Prag)
Labe
Berounka
Sázava
TSCHLAND
Plzeň
(Pilsen)
Vltava
TSCHECHIEN
České Budějovice
(Budweis)
(Moldau)
ÖSTERREICH
0
150 km

Overview of investigated sites


Fischbeck
Breitenhagen
Bitterfeld
Magdenburg
Dresden
Grimma
Havel
Elbe
Saale
Mulde
Hannover
Bremen
Hamburg
Berlin
Magdeburg
Leipzig
Dresden
Rostock
Szczecin
Braunschweig
Wolfsburg
Lüneburg
Celle
Potsdam
Cottbus
Halle (Saale)
Kassel
Erfurt
Jena
Zwickau
Plauen
Chemnitz
Praha
Praha 12
Karlovy Vary
Most
Ústí nad Labem
Liberec
Jelenia Góra
Görlitz
Bautzen
Hildesheim
Salzgitter
Osnabrück
Münster
Paderborn
Dortmund
Wuppertal
Siegen
Fulda
Koblenz
Frankfurt am Main
Wiesbaden
Aschaffenburg
Coburg
Bayreuth
Hof
Gera
Eisenach
Gotha
Weimar
Dessau-Roßlau
Oranienburg
Eberswalde
Frankfurt
Gorzów Wielkopolski
Zielona Góra
Kostrzyn
Prawobrzeże
Świnoujście
Kołobrzeg
Greifswald
Stralsund
Wismar
Schwerin
Güstrow
Neubrandenburg
Demmin
Anklam
Lübeck
Travemünde
Neumünster
Cuxhaven
Bremerhaven
Oldenburg
Delmenhorst
Varel
Wilhelmshaven
Minden
Detmold
Hamm
Bielefeld
Korbach
Mühlhausen/Thüringen
Eisenbachwiesen
Kulmbach
Bayreuth
Hradec Králové
Pardubice
Mladá Boleslav
Děčín
Chomutov
Kladno
Ribnitz-Damgarten
Ortsamt 8
Neustadt in Holstein
Elmshorn
Norderstedt
Bergedorf
Harburg
Zetel
Wangerland
Waren (Müritz)
Pölnoc
Neuruppin
Brandenburg an der Havel
Stendal
Großräschen
Lübbenau/Spreewald
Kamenz
Radebeul
Meißen
Riesa
Torgau
Bad Düben
Wittenberg
Lutherstadt
Bernburg
Aschersleben
Quedlinburg
Wernigerode
Goslar
Seesen
Northeim
Einbeck
Holzminden
Höxter
Bad Pyrmont
Hameln
Nienburg
Verden
Soltau
Uelzen
Lüchow
Dannenberg
Salzwedel
Stendal
Havelberg
Perleberg
Ludwigslust
Parchim
Waren
Neustrelitz
Templin
Prenzlau
Angermünde
Schwedt
Pasewalk
Ueckermünde
Anklam
Wolgast
Greifswald
Stralsund
Rügen
Hiddensee
Usedom
Świnoujście
Kołobrzeg
Koszalin
Szczecinek
Słupsk
Lębork
Wejherowo
Gdańsk
Gdynia
Sopot
Malbork
Elbląg
Frombork
Braniewo
Olsztyn
Ostróda
Iława
Grudziądz
Toruń
Włocławek
Płock
Mława
Ciechanów
Nowy Dwór Mazowiecki
Modlin
Warszawa
Legionowo
Pruszków
Grodzisk Mazowiecki
Żyrardów
Skierniewice
Łowicz
Sochaczew
Gostynin
Kutno
Łęczyca
Zgierz
Łódź
Pabianice
Tomaszów Mazowiecki
Piotrków Trybunalski
Bełchatów
Radomsko
Kamieńsk
Wieluń
Sieradz
Zduńska Wola
Pabianice
Konstantynów Łódzki
Ozorków
Aleksandrów Łódzki
Głowno
Brzeziny
Rawa Mazowiecka
Inowrocław
Mogilno
Gniezno
Poznań
Luboń
Puszczykowo
Mosina
Kostrzyn
Słubice
Frankfurt
Eisenhüttenstadt
Fürstenwalde
Strausberg
Bad Freienwalde
Schwedt
Angermünde
Prenzlau
Templin
Oranienburg
Eberswalde
Bernau
Hohen Neuendorf
Potsdam
Teltow
Stahnsdorf
Kleinmachnow
Zehlendorf
Wannsee
Spandau
Charlottenburg
Tiergarten
Mitte
Prenzlauer Berg
Pankow
Weißensee
Hohenschönhausen
Lichtenberg
Friedrichshain
Kreuzberg
Neukölln
Tempelhof
Schöneberg
Steglitz
Zehlendorf
Treptow
Köpenick
Adlershof
Johannisthal
Rudow
Britz
Buckow
Marzahn
Hellersdorf
Biesdorf
Karlshorst
Lichtenberg
Friedrichsfelde
Rummelsburg
Oberschöneweide
Niederschöneweide
Grünau
Müggelsee
Müggelheim
Rahnsdorf
Wilhelmshagen
Erkner
Woltersdorf
Schöneiche
Rüdersdorf
Strausberg
Bad Saarow
Fürstenwalde
Eisenhüttenstadt
Frankfurt
Słubice
Kostrzyn
Gorzów Wielkopolski
Międzyrzecz
Sulęcin
Krosno Odrzańskie
Zielona Góra
Nowa Sól
Żagań
Głogów
Lubin
Legnica
Chojnów
Złotoryja
Jawor
Świdnica
Wałbrzych
Kamienna Góra
Jelenia Góra
Szklarska Poręba
Karpacz
Kowary
Piechowice
Lubań
Zgorzelec
Bogatynia
Hradec Králové
Pardubice
Chrudim
Ústí nad Orlicí
Česká Třebová
Svitavy
Litomyšl
Polička
Žamberk
Náchod
Trutnov
Vrchlabí
Harrachov
Jablonec nad Nisou
Liberec
Česká Lípa
Děčín
Ústí nad Labem
Teplice
Most
Chomutov
Litvínov
Louny
Žatec
Kadaň
Klášterec nad Ohří
Karlovy Vary
Sokolov
Cheb
Aš
Mariánské Lázně
Plzeň
Rokycany
Beroun
Kladno
Slaný
Kralupy nad Vltavou
Mělník
Neratovice
Brandýs nad Labem-Stará Boleslav
Nymburk
Poděbrady
Kolín
Kutná Hora
Čáslav
Havlíčkův Brod
Jihlava
Třebíč
Znojmo
Hodonín
Uherské Hradiště
Zlín
Vsetín
Valašské Meziříčí
Rožnov pod Radhoštěm
Frýdek-Místek
Havířov
Karviná
Ostrava
Opava
Krnov
Bruntál
Jeseník
Šumperk
Olomouc
Přerov
Prostějov
Kroměříž
Uherské Hradiště
Hodonín
Břeclav
Mikulov
Znojmo
Moravský Krumlov
Vyškov
Blansko
Boskovice
Tišnov
Brno
Kuřim
Rosice
Ivančice
Slavkov u Brna
Šlapanice
Modřice
Hustopeče
Pohořelice
Mikulov
Znojmo
Jihlava
Třebíč
Pelhřimov
Tábor
Písek
Strakonice
Vodňany
Prachatice
Český Krumlov
České Budějovice
Jindřichův Hradec
Dačice
Telč
Pelhřimov
Humpolec
Havlíčkův Brod
Ledeč nad Sázavou
Světlá nad Sázavou
Čáslav
Kutná Hora
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Svitavy
Česká Třebová
Ústí nad Orlicí
Chrudim
Pardubice
Hradec Králové
Jičín
Turnov
Semily
Železný Brod
Tanvald
Nové Město nad Metují
Hradec Králové
Jaroměř
Dobruška
Rychnov nad Kněžnou
Kostelec nad Orlicí
Solnice
Týniště nad Orlicí
Hořice
Dvůr Králové nad Labem
Jaroměř
Broumov

Dresden – overview



Dresden – facts and figures

- 2002 flood event:
  - +9.40 meter water level in the Elbe (1/200 per year event), 1000 million euro in damage
- Various measures were taken after this event: floodgates, mobile flood protection, improvement of hydraulic roughness, increasing protection to at least 1/100 per year

- 2013: +8.77 m water level Elbe (1/50 per year event)

Dresden – impressions



2013 - Picture taken by Reinhard Pohl

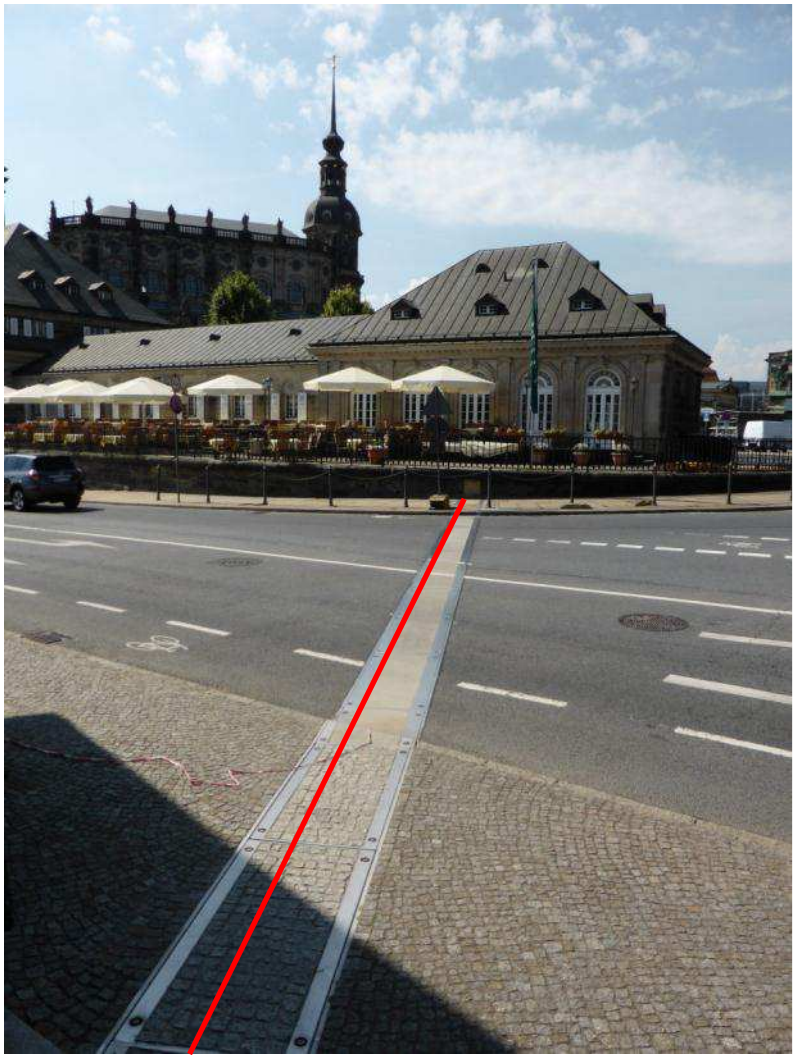
Dresden - impressions



2013 - Picture taken by Reinhard Pohl

Dresden – flood gates





Dresden bypass



Dresden – erosion



unexpected erosion next to the Marienbrücke in the bypass (after removing obstacles downstream)



Overview of investigated sites



Bitterfeld - situation

- Coal mining, leaving pits of 60 meters deep
  - Mining activities have stopped
  - Turned into a recreational area with shipping harbour
- Concentration of chemical industry in the area
- City of Bitterfeld
  - On the border between Sachsen en Sachsen-Anhalt
  - Thousands of people were evacuated because of threat from lakes

Bitterfeld (pre-breach situation)



© Jens Wolf/dpa



(lower water level)

1. Breach in river dike

Mulde

pumps

canal

ΔH_{normal} = 3m

ΔH_{flood} = 9m

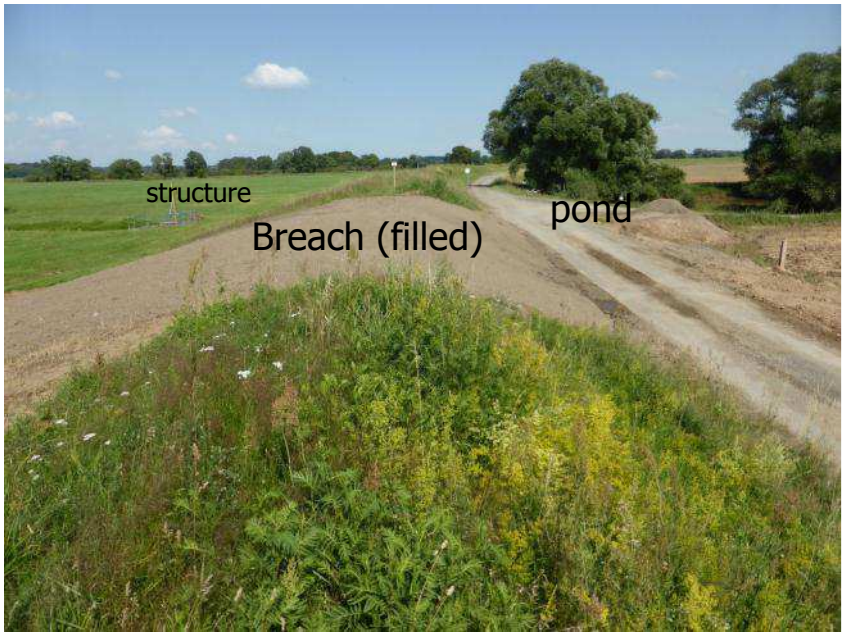
3. Double breach

2. Overland flow, breaching of road

Seehausener See (higher water level)

1. Bitterfeld – Mulde breach

- Breach on the Mulde river, one of multiple breaches
- 25 m wide breach, relatively high on slope
- Wells on the inside of sandy material, possibility of piping mechanism
- Highest water about 1m (?) below crest

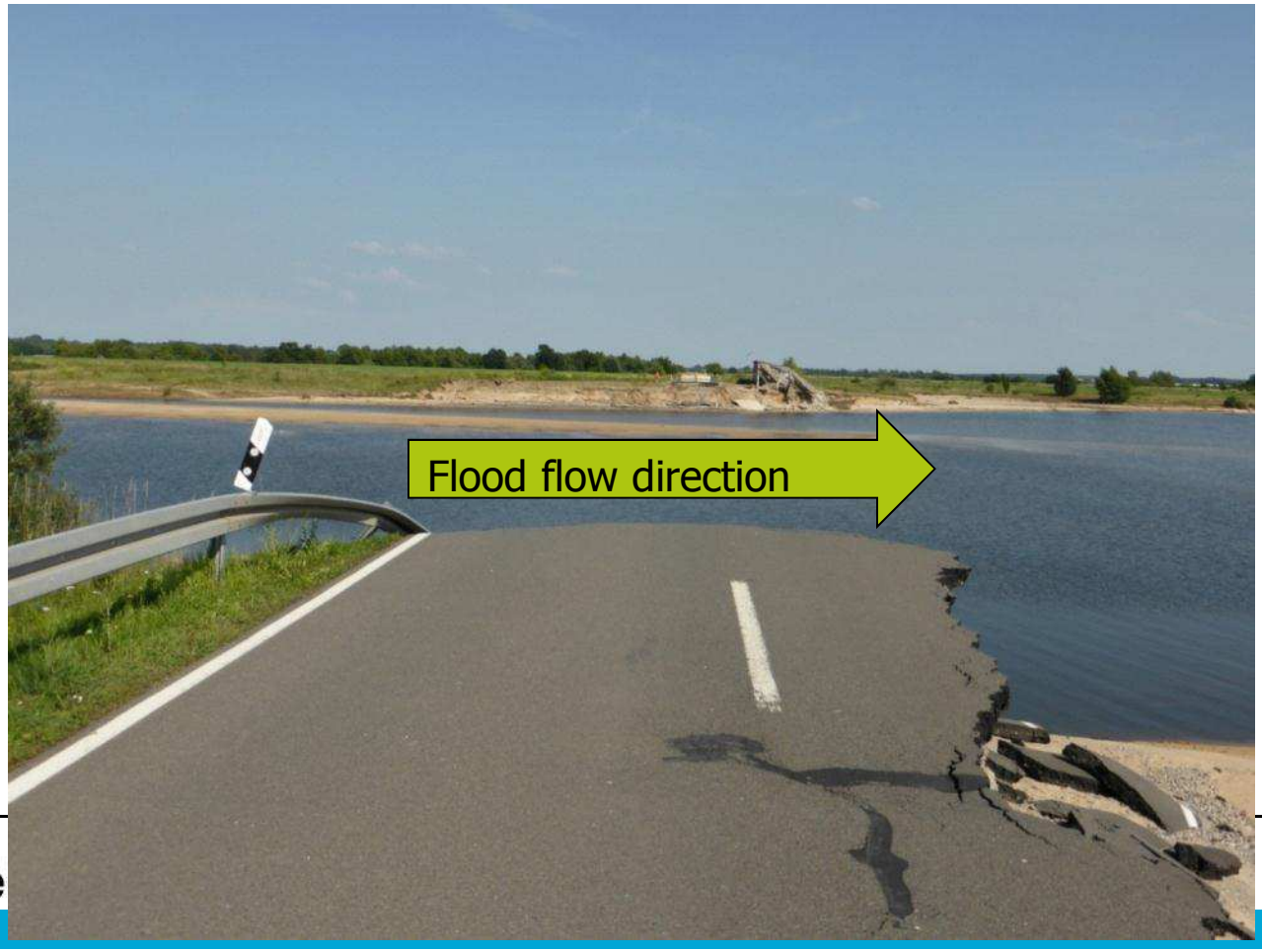


Context:

- Next to small dewatering structure and small pond
- In 2002 a breach occurred in the same area, a few hundred meters upstream from the current breach.

2. Bitterfeld - Breaches in Road Nr. S12

- Large breach in road (200m or more)
- Overtopping and erosion of road and bike path



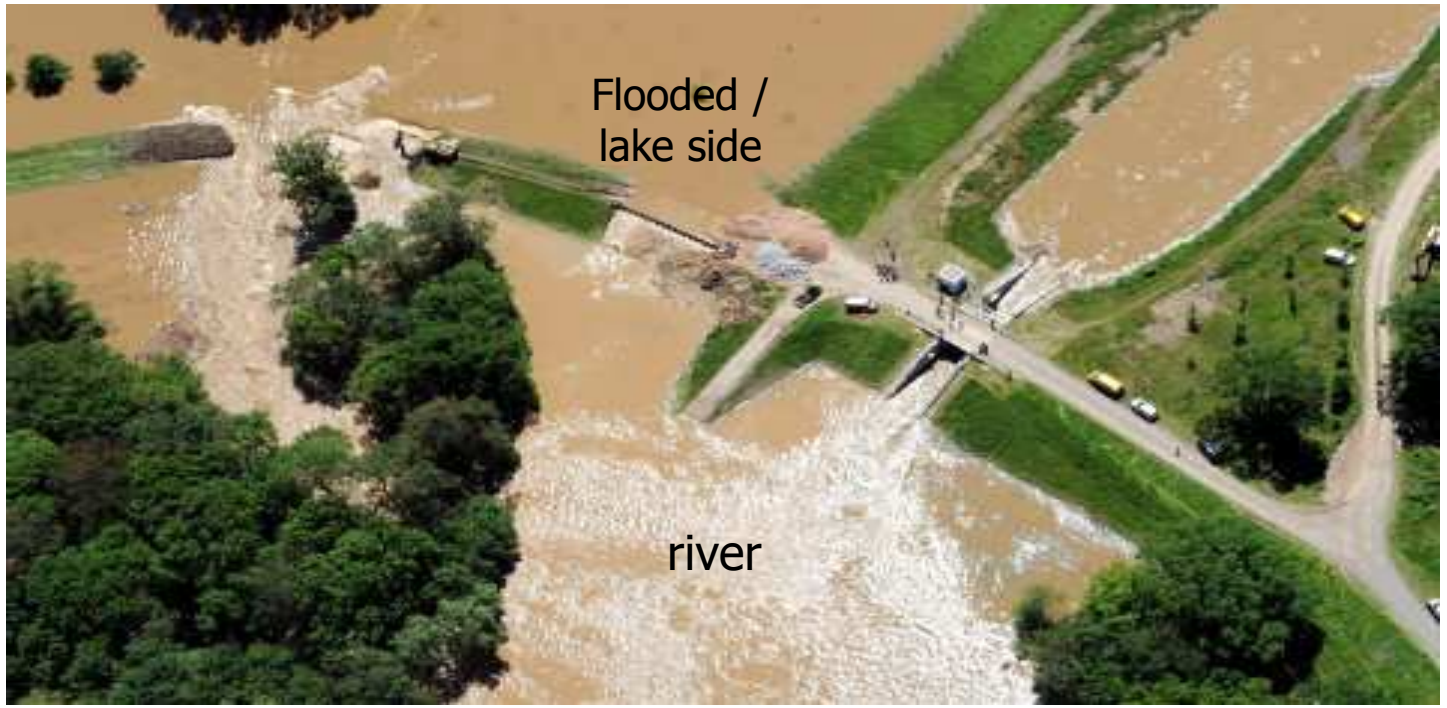
3. Bitterfeld, Breaches in Channel embankments between lakes

- Seelhausener Lake fills due to breach (several meters)
- Overflow and breaching of adjacent canal dikes
- Unsuccessful attempt to close breaches with bigbags by helicopters
- Cascading effects to Grosse Goitscherzee, threatening city of Bitterfeld



Bitterfeld – dewatering

- Breaches created with dynamite for dewatering



Source???

Overview of investigated sites



Breitenhagen - levee breach



DPA / Salzlandkreis

Breitenhagen - inner slope failure



Reuters

Breitenhagen

- Located on Elbe river, water levels about 1~1.5m below crest
- Trees located in front of dike
- Dikes consisted of clay, slope about 1:2.5 to 1:3

- Slip circle occurred on inside, on landside of the road
  - Part of the dike remained for 10 hrs, then breached
  - 150m breach
- Dike reinforcement plan was available, but not yet implemented
- Emergency measures:
  - First round of bigbags delivered by helicopters
  - After that no army assistance available anymore
  - For dewatering:
    - Explosions were not effective to blow up dike
    - Breach opened by equipment for dewatering
    - Pumps installed to dewater the urban area

Overview of investigated sites


Fischbeck
Breitenhagen
Bitterfeld
Dresden
Magdenburg
Grimma
Havel
Elbe
Saale
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Hannover
Bremen
Hamburg
Berlin
Magdeburg
Leipzig
Dresden
Szczecin
Rostock
Lübeck
Schwerin
Braunschweig
Wolfsburg
Halle (Saale)
Potsdam
Cottbus
Frankfurt
Kassel
Erfurt
Jena
Zwickau
Plauen
Praha
Bautzen
Görlitz
Liberec
Most
Chomutov
Ústí nad Labem
Karlovy Vary
Aschaffenburg
Wiesbaden
Koblenz
Siegen
Fulda
Coburg
Bayreuth
Hof
Oranienburg
Eberswalde
Neubrandenburg
Prawobrzeże
Gorzów Wielkopolski
Zielona Góra
Jelenia Góra
Hradec Králové
Pardubice
Kostrzyn
Świnoujście
Kołobrzeg
Greifswald
Stralsund
Ribnitz-Damgarten
Neustadt in Holstein
Travemünde
Wismar
Güstrow
Demmin
Anklam
Neumünster
Cuxhaven
Elmshorn
Norderstedt
Bergedorf
Harburg
Lüneburg
Celle
Wangerland
Bremerhaven
Zetel
Varel
Oldenburg
Delmenhorst
Osnabrück
Minden
Hildesheim
Salzgitter
Bielefeld
Detmold
Paderborn
Münster
Hamm
Dortmund
Wuppertal
Korbach
Mühlhausen/ Thüringen
Eisenbachwiesen
Frankfurt am Main
Wiesbaden
Kulmbach
Bayreuth
Rauher- und Haarbachtal
Kladno
Praha 12
Mladá Boleslav
Děčín
Hennigsdorf
Großräschen
Großräschen und Fichtengrund
Dessau-Roßlau
Staßfurt
Oranienburg
Potsdam
Berlin
Frankfurt
Cottbus
Bautzen
Görlitz
Dresden
Zwickau
Plauen
Hof
Coburg
Bayreuth
Aschaffenburg
Koblenz
Siegen
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Pardubice
Praha
Kladno
Świnoujście
Kołobrzeg
Szczecin
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Wolfsburg
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Osnabrück
Minden
Hildesheim
Salzgitter
Bielefeld
Detmold
Paderborn
Münster
Hamm
Dortmund
Wuppertal
Korbach
Kassel
Mühlhausen/ Thüringen
Erfurt
Jena
Siegen
Fulda
Eisenbachwiesen
Koblenz
Frankfurt am Main
Wiesbaden
Aschaffenburg
Coburg
Kulmbach
Bayreuth
Hof
Plauen
Zwickau
Chomutov
Most
Karlovy Vary
Kladno
Praha
Praha 12
Pardubice
Hradec Králové
Mladá Boleslav
Liberec
Jelenia Góra
Görlitz
Bautzen
Kamenz
Großräschen
Großräschen und Fichtengrund
Dessau-Roßlau
Staßfurt
Halle (Saale)
Cottbus
Frankfurt
Potsdam
Berlin
Oranienburg
Eberswalde

Fischbeck (levee breach)



Foto: REUTERS/Thomas Peter

Fischbeck dike breach - general

- breach location located at “corner”
- Western side of the Elbe,
- water level below crest (0.2m ~ 0.4m)
- dike: about 5m high, moderate/steep slope (about 1:3?), no berm
- dike body: clayey sand (sandy clay in lower part)

Fischbeck dike breach

Failure process (according to eye witnesses)

- cracks in crown, stage-wise settlement of the inner slope
- heavy flood fighting to prevent breach (sand bags, big packs)
- breach occurred around midnight (Sunday 9 June around 00:01 AM)
- inner slope sliding/breach occurred fast (10 ~ 20s)
- initial width 50m, growth to 100m within hours, 2-3m deep scour hole
- estimated inflow up to 700-1000 m^3/s (different figures in BfG report)
- Water was within town of Fischbeck (~ 2km) within 5 minutes
- Fischbeck had been evacuated previously
- flooding extended in a wide area (up to the Havel river, tens of km)

Fischbeck - post-breach



modified after dpa photo

Fischbeck breach emergency





dpa / dpa

- Three barges sunk in front of the breach using explosives
- inflow reduced significantly
- breach finally closed when water was levelled out
- Temporary flood defence:
  - Sheet pile in the breach (8 ~ 11m)
  - Earthen dike / roadway in front
  - Ships are being removed, new dike will follow different alignment

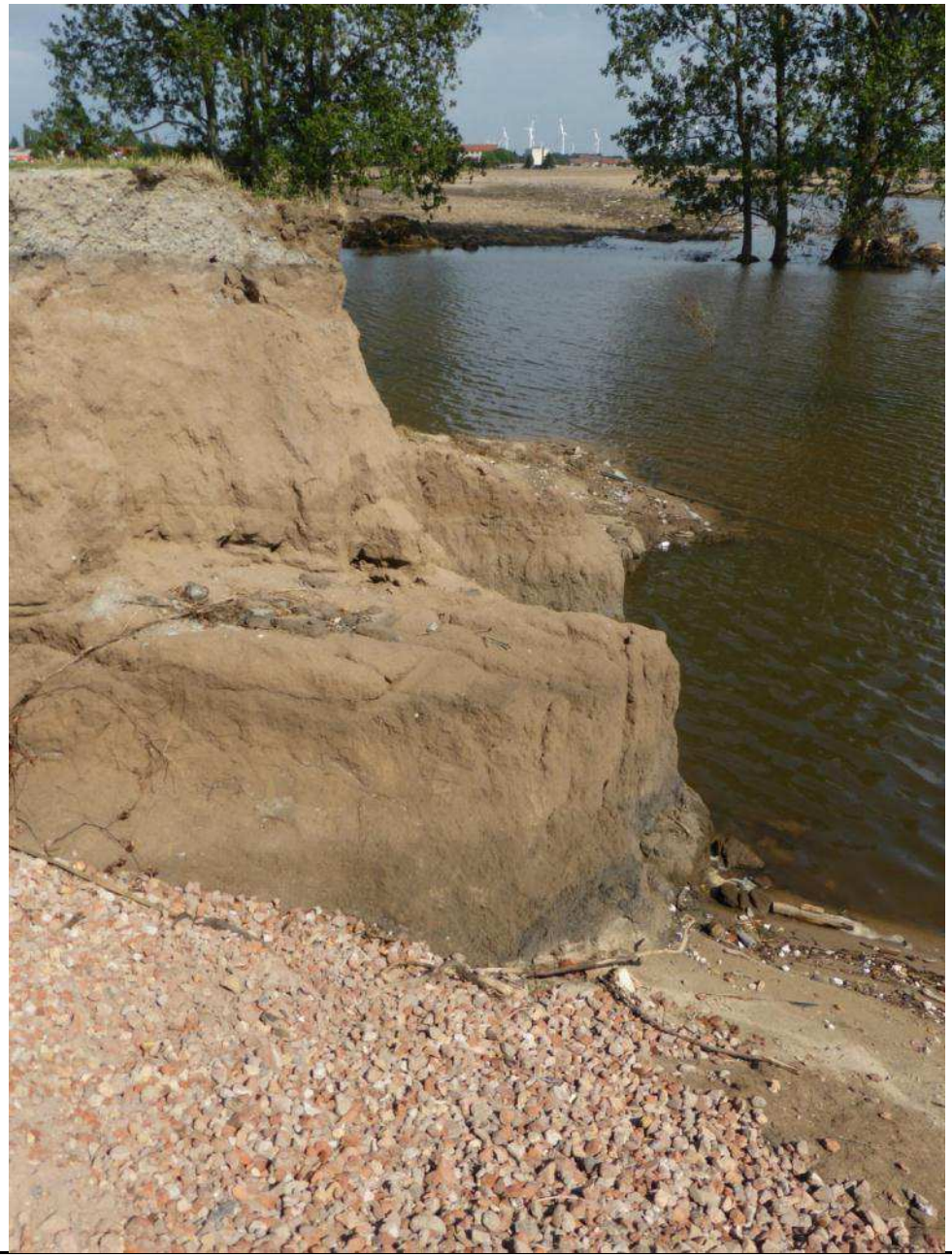

Press Esc to exit full screen mode.
n-tv

Fischbeck breach emergency repairs



Photo: Doreen Jonas / MDR


barges
river
breach
Temporary
dike &
sheetpile



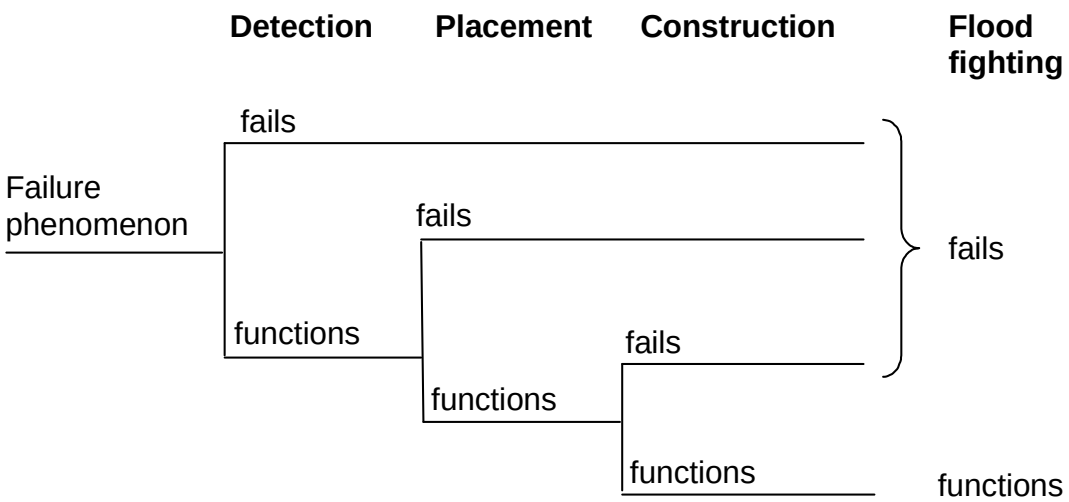
Fischbeck - local instability

- Few hundred meter from breach site
- Seems initiation of slip circle over about 25 ~ 30m
- Sheet pile in dike and bigbags on slope implemented as emergency measures



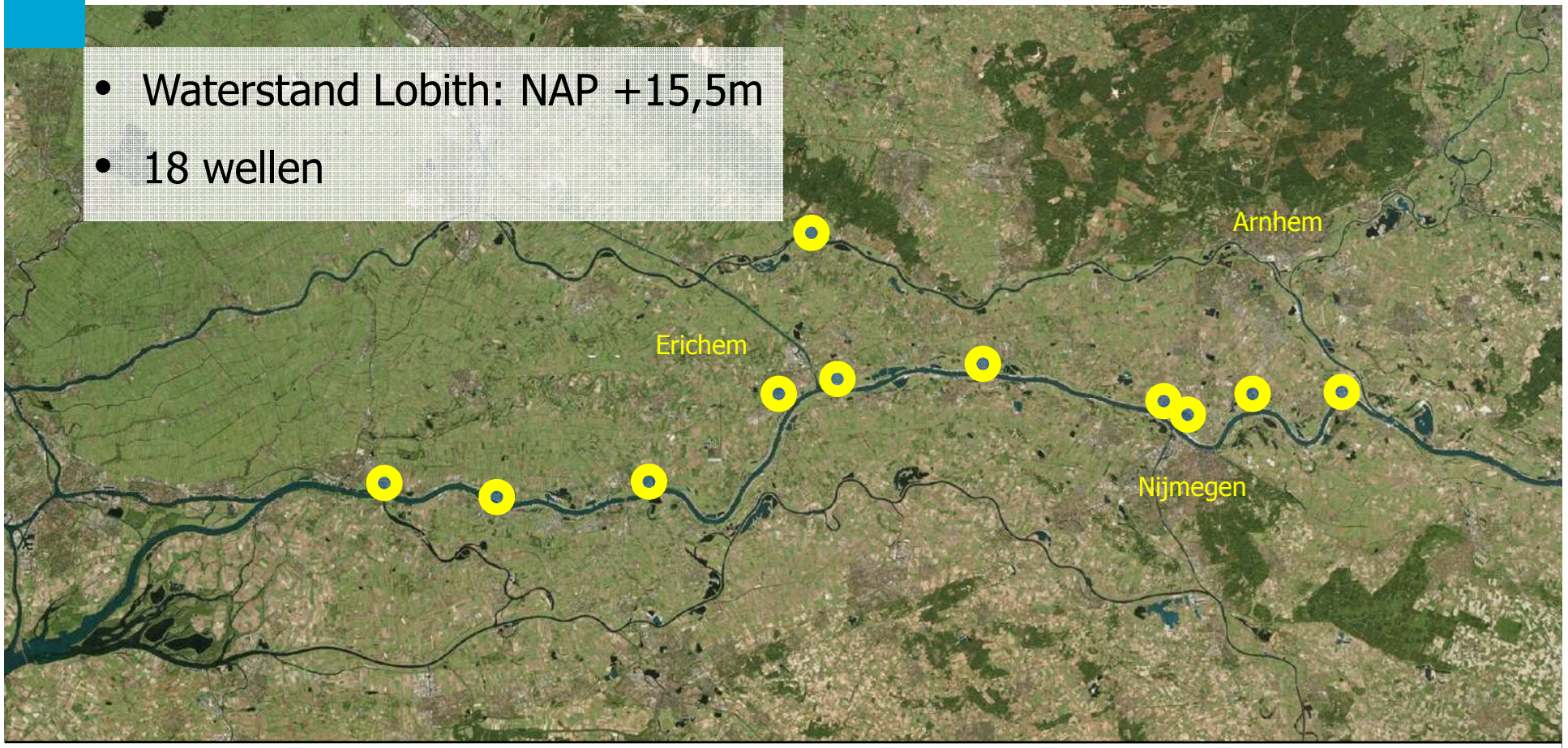
Nood- en beheermaatregelen







Pipinglocaties hoogwater 2011



TU Delft

Bronnen: Rivierenland; Arcadis, 2012

Concluding remarks

- Large flood event:
  - Return period 50 – 500 year depending on location / river
  - At some places larger than 2002 flood event
- Water levels mostly close to the crest of dikes (no overflow)
- Several dike failures
- Visited failures were due to geotechnical mechanisms at several sites
  - Instability at Fischbeck and Breitenhagen
  - Possibly piping at Bitterfeld river dike breach, and overflow for canal and road breaches
- Complex system / cascading effects at Bitterfeld
  - Dike failure -> road breaching -> lake fills -> canal dikes fail -> Second lake fills up, threatens town of Bitterfeld
- Breaches could not be closed by emergency measures (barges, bigbags etc.)

Recommendations / follow-up

- Analyze and hindcast dike failures (data collection, stability and piping analysis)
- Evaluate performance of emergency measures
- Evacuations and emergency response
- Further analysis of other topics:
  - Hydrological system performance (incl. cascades and retention)
  - Damage
  - Risk management / multi-layered safety
- Second mission in Autumn (?)

- For the Netherlands:
  - Geotechnical failures! (multiple)
  - Use and effectiveness of emergency measures
  - Plans for dewatering and breach closure?

Acknowledgements

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TECHNISCHE UNIVERSITÄT DRESDEN

stowa

enw expertisenetwerk waterveiligheid

Bedenkt u het nieuwe grote waterbouwkundige project voor Nederland?

Doe mee en meld u aan!

SBR CUR net

KIVI NIRIA

ie-net INSPIRED BY ENGINEERS

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

VERENIGING VAN WATERBOUWERS