# UNIVERSITY OF CALIFORNIA, DAVIS


## DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING


## Lecture notes and hand outs

## ECI 146: Water Resources Simulation

**Prepared by:**


***Prof. Fabián A. Bombardelli***

## Preface

This is a basic compilation of hand outs and class notes that I have been gathering and preparing during the years of teaching of ECI 146, since 2004, at the Department of Civil and Environmental Engineering of UC Davis. When I had to prepare the notes for the course for the first time (starting from zero), I soon realized that there was not a single book including all the needed material for a course on "Water Resources Simulation" (at least, not with the perspective that I consider useful and interesting for such a course). This assertion is unfortunately true even today, in my modest opinion.

Thus, these pages assemble some portions of text from very well-known books, in addition to notes I prepared for the course. The course initially review material from basic numerical analysis in order to place the application to water resources in the right context, and in the proper understanding the source of the different schemes. I humbly consider this approach to be not common in usual books dealing with water resources. Immediately after the explanation of each numerical technique, the course emphasizes its application to solve problems in water resources engineering, ranging from flow in pipes to the flow in open channels and transport of pollutants.

This compilation is expected to be improved in quality of presentation, content, and number of notes prepared by myself. It was put together following some requests from the students in order to have a unique repository on paper for all handouts, provided up to now in electronic form in the course website.

I will particularly thank any comment, suggestion or direct collaboration to make this a better compilation for ECI 146.

Yours truly,

Fabián A. Bombardelli, Davis, CA
January

*UNIVERSITY OF CALIFORNIA, DAVIS*
*DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING*

# COURSE: WATER RESOURCES SIMULATION (ECI 146)

**INSTRUCTOR:** *Fabián A. Bombardelli (fabombardelli@ucdavis.edu, bmbrdll@yahoo.com, fabianbombardelli2@gmail.com)*
**OFFICE: 3105, Engineering III building**
*Class: Tuesdays and Thursdays-1:40 PM to 3:00 PM (Hutch 115)*
*Computer lab: Fridays-11:00 AM to 11:50 PM (Chem 166)*
**READER:** *Mr. Carlos Zuritz (Ph.D. Student)*
**TEACHING ASSISTANT:** *Mr. James Kohne (M.S. Student)*

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## COURSE DESCRIPTION

This course focuses on the development and application of numerical simulation techniques for the analysis, design and operation of surface water systems. The course especially addresses problems associated with surface run-off, water quality in streams and ponds, and management of reservoirs. The course possesses a strong emphasis on the theory conducive to the development of simple codes to analyze different cases of practical importance.

## PREREQUISITES

ECI 141, ECI 145, and ECI 142.

## TEXT

There is *no* formal text that covers what we cover in the course. Hand outs and supplemental reading material will therefore be provided, compiled in a book.

## SOME REFERENCES

1. Chapra, S. C., and Canale, R. P. (2006). "*Numerical Methods for Engineers*." Fifth Edition, McGraw Hill Higher Education Series. Only some chapters from this book will be used.
2. Mays, L. (2006). "*Water Resources Engineering*." John Wiley and Sons. Only some chapters from this book will be used.
3. Mays, L., Ed. in Chief (2001). "*Stormwater Collection Systems Design Handbook*." McGraw-Hill.
4. Chow, V. T., Mays, L., and Maidment, D. (1998). "*Applied Hydrology*." McGraw-Hill.
5. Linsley, R. K., and Franzini, J. B. (1979). "*Water-Resources Engineering*." McGraw-Hill.
6. Burden, R. L., and Faires, J. D. (2004). "*Numerical Analysis.*" Brooks-Cole Publishing, Eighth Edition.
7. Isaacson, E., and Keller, H. B. (1966). "*Analysis of Numerical Methods.*" Dover.

8. Abbott, M. B. (1979). *"Computational Hydraulics. Elements of the Theory of Free Surface Flows."* Pitman, UK.
9. Koutitas, C. G. (1983). *"Elements of Computational Hydraulics."* Pentech Press, UK.
10. Press, W. H., Teukolsky, S. A., Vetterling, W. T., and Flannery, B. P. (2007). *"Numerical Recipes in Fortran. The art of scientific computing."* Cambridge.


## OFFICE HOURS

Tuesdays and Thursdays after class

Mondays and Fridays, 12:00 to 2:00 PM. Also, e-mail me to make special appointments (fabombardelli@ucdavis.edu or bmbrdll@yahoo.com .or fabianbombardelli2@gmail.com)

## GRADING

| | |
|---|---|
| Assignments | 10% |
| Computer problems | 20% |
| 1 hourly in class exam | 20% **(individual effort)** |
| 1 special project | 20% **(individual effort)** |
| Final exam (2 hours) | 30% **(individual effort)** |

## NUMERICAL TOOLS

The codes can be developed in Fortran, Basic, C, Pascal, Matlab, or Excel (if applicable).

## ASSIGNMENT, COMPUTER PROBLEM, PROJECT, AND EXAM POLICIES

The purpose of homework is to contribute significantly to the learning process. Students are strongly encouraged to develop assignments and computer problems [redacted] in teams. The total number of team members should not exceed three (3). The composition of the team can be varied from homework to homework, but the students have to turn in just *one* solution to the homework. Team members receive the same grade. Based on this, it is mandatory that the students of the team share similar loads of work. It is not necessary to report the names of the team members to the instructor in advance. Just make a cover page with the names of the members when turning in the homework solution.

Normally, each assignment should be completed in 7 to 15 days. Assignments, computer problems and projects turned in one (1) week after the deadline will be penalized with 30 points out of 100. After two (2) weeks, assignments, computer problems or projects will not be accepted.

Examination *and project* solutions must represent the efforts of *individuals* only. It is strongly recommended that the students have a copy of the graded solution before the examination. Exams will be *closed notes, closed books*, and they may include the development of code flow charts.

## IMPORTANT DATES

**Midterm exam (in class): Tuesday, February 17, 2009**
**Final exam (in class): Saturday, March 21, 2009, 3:30 PM to 5:30 PM**
**Review session for the midterm: Thursday, February 12, 2009 (half hour)**
**Review session for the final: Thursday, March 12, 2009 (entire class)**

**Computer Problem 1:** Iterative solution of the Colebrook-White Equation and of systems of non-linear equations for the design of pipes
Assigned: 01/08/09
Due with no penalization: 01/20/09
Due with 30% penalization: 01/27/09

**Computer Problem 2:** Solution of the water-quality problem in a lake by finite differences
Assigned: 01/29/09
Due with no penalization: 02/10/09
Due with 30% penalization: 02/17/09

**Computer Problem 3:** Solution of backwater curves using the explicit and implicit methods in finite differences **(after Midterm)**
Assigned: 02/26/09
Due with no penalization: 03/05/09
Due with 30% penalization: 03/12/09

**Assignment 1**
Assigned: 01/20/09
Due with no penalization: 01/29/09
Due with 30% penalization: 02/05/09

**Assignment 2 (after Midterm)**
Assigned: 02/19/09
Due with no penalization: 02/26/09
Due with 30% penalization: 03/05/09

**Project**
Assigned: 01/15/09
Due with no penalization: 03/12/09
Due with 30% penalization: 03/19/09

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## SYLLABUS OF ECI 146, WATER RESOURCES SIMULATION

### 1. Introduction.

1.a) Importance of water resources (01/06/09).

1.b) Definition of simulation. Evaluation of simulation of water resources as a tool for management (01/06/09).

1.c) Classification of modeling approximations: 0D, 1D, 2D and 3D. Examples of water bodies in California (01/06-08/09).

1.d) The Moody diagram (01/08/09).

### 2. Basic concepts on numerical techniques. Part I.

2.a) Heuristic classification of equations (01/08/09).

2.b) Iterative solution of non-linear equations by the methods of Newton-Raphson, bisection, Regula-Falsi, and iteration of a point (01/13-15/09).

2.c) Advantages and disadvantages of each method (01/15/09).

2.d) Iterative solutions of *systems* of non-linear equations applied to the solution of flow in pipes (01/15-20/09).

2.e) Computation of normal-flow depth (01/20/09).

### 3. Basic concepts on numerical techniques. Part II.

3.a) Introductory ideas on the solution of ordinary differential equations by finite-difference methods. Forward, backward or centered schemes (01/22/09).

3.b) Approximation of first and higher-order derivatives by finite differences. Explicit and implicit solutions of Ordinary Differential Equations (ODEs) (01/22/09).

3.c) Euler and Runge-Kutta methods (01/22/09).

3.d) Consistency, convergence and stability of numerical solutions (01/27/09).

3.e) Notions on the finite-element method (01/27/09).

3.f) Computations of backwater curves by finite differences (01/27-29/09).

### 4. Zero-order models for water-quality simulations in water bodies.

4.a) Phenomena associated with pollution in water bodies (01/29/09).

4.b) Reactor models for the simulation of the time evolution of phosphorus and nitrogen in lakes. Lake model (02/03/09).

4.c) A simple sedimentation-resuspension model for rivers (02/03/09).

5. **Simulation of water retention in ponds and reservoirs.**

5.a) Methods for flood-wave routing in reservoirs and rivers (02/05/09).

5.b) Hydrologic reservoir modeling (02/05/09).

5.c) Reservoir flood management (02/05/09).

6. **One-dimensional hydrodynamic models.**

6.a) *Hydrologic* river routing. Muskingum method (02/10/09).

6.b) Derivation of the one-dimensional equations of fluid motion in rivers (02/10/09).

6.c) *Hydraulic* river routing (02/12/09).

6.d) Kinematic wave model. Kinematic wave model for overland flow (02/12/09).

6.e) Different numerical schemes used to solve the flow equations (02/17/09).

6.f) Muskingum-Cunge method (02/19/09).

7. **One-dimensional models of water quality in streams.**

7.a) Basic equations of one-dimensional advection-diffusion (dispersion) of pollutants (02/19/09).

7.b) Transport models including reactive terms (02/19/09).

7.c) Transport models for organic matter in streams (02/24/09).

7.d) Transport models for suspended sediment in streams (02/24/09).

7.e) Transport models to assess pollution in water bodies (02/24/09).

7.f) Numerical schemes to deal with transport equations of the advection-diffusion type (02/26/09).

8. **Introduction to two- and three-dimensional, flow and water-quality models.**

8.a) Basic concepts and models most used in practice (03/05/09).

8.b) Description of case studies (03/05/09).

8.c) Shallow-water equations (03/05/09).

Note: Dates for each topic are subject to change.

# HAND OUT 1: Importance of water resources (Chapter 1 of our syllabus)

# ECI 146: Water Resources Simulation

## Classes 1-2

Hand out 1

# Review of concepts

## Water resources

1) Water=life. Key to the development of civilization. Fresh water is very scarce (see table in Hand out 2)

2) "Resources" has two meanings:

   a) Something we can profit from (obtain benefits for irrigation, drinking water, power generation, navigation, recreation, etc.)

   b) Something we need to care about, because it is a finite resource. Sustainability of hydraulic designs

3) Water has an economic value:

   a) Water stored in reservoirs is valuable because it can generate energy and produce money

   b) Water is very expensive in some developing countries because it is scarce

# Review of concepts

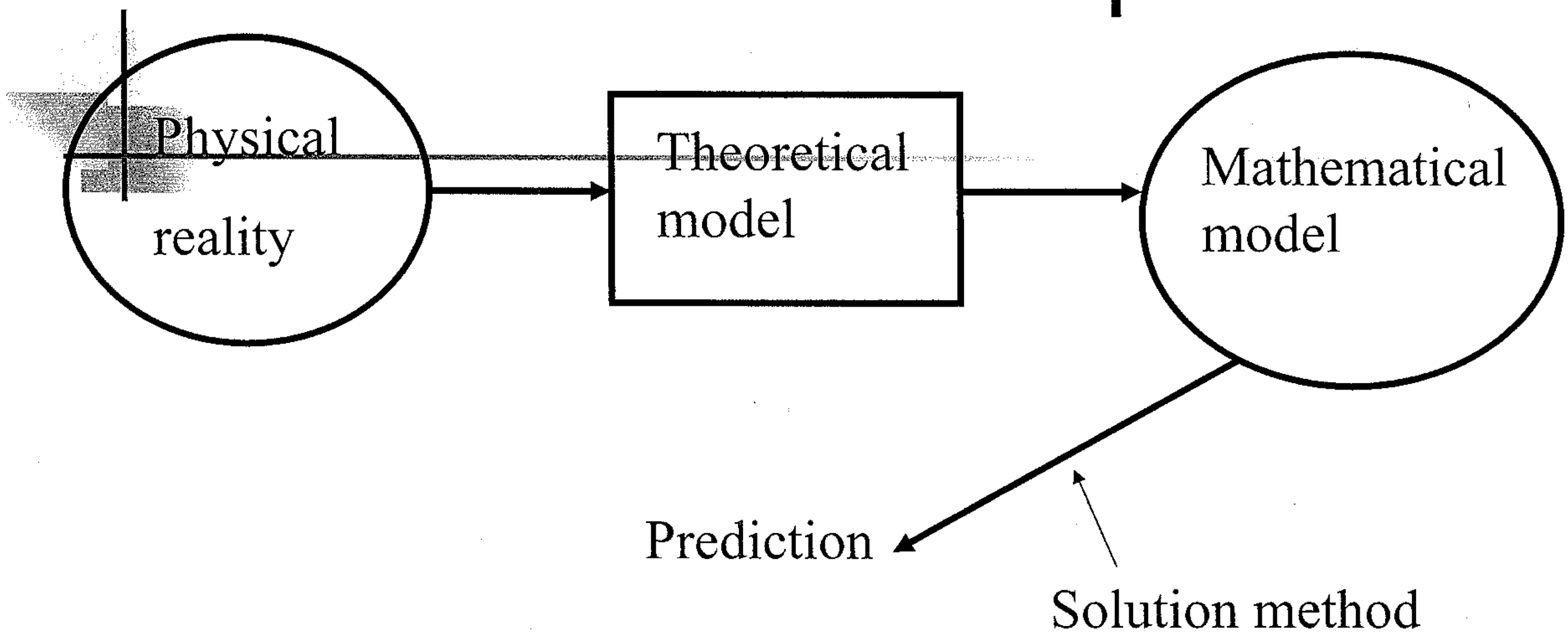
## Simulation

It is the analysis of a phenomenon under controlled conditions. The objective of the simulation is the study of the phenomenon and the prediction of its behavior.

## Types of simulation

1. Experiments
   a) Full scale
   b) Small scale
2. Analog solutions
3. Theoretical-numerical solutions

# Review of concepts




Solution method:

a) Analytical

b) Numerical

# Problems with water resources

1) Rivers:
   a) Floods
   b) Release of heated discharges from power plants
   c) Dispersion of pollutants by currents and velocity gradients (water quality)
   d) Density currents in low-velocity environments
   e) Bed changes
   f) Dam removal
2) Lakes:
   a) Dispersion of pollutants by currents and velocity gradients (water quality)
   b) Stratification: water layers with different density
   c) Eutrophication: incorporation of nutrients to the water body
   d) Sediment resuspension

# Problems with water resources

3) Aquifers:
   a) Dispersion of pollutants by currents and velocity gradients (water quality)
   b) Phreatic-level depletion due to pumping

4) Wetlands:
   a) Dispersion of pollutants by currents and velocity gradients (water quality)
   b) Sedimentation
   c) Sediment resuspension

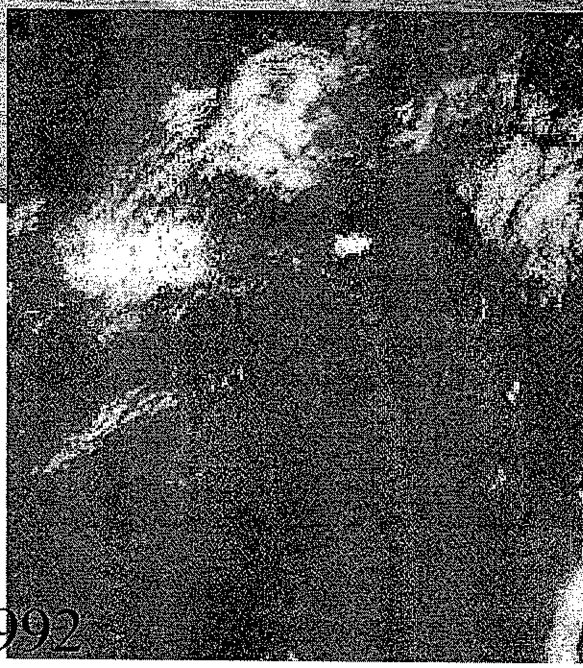
5) Estuaries:
   a) Dispersion of pollutants by currents and velocity gradients (water quality)
   b) Sedimentation
   c) Sediment resuspension

6) Fjords

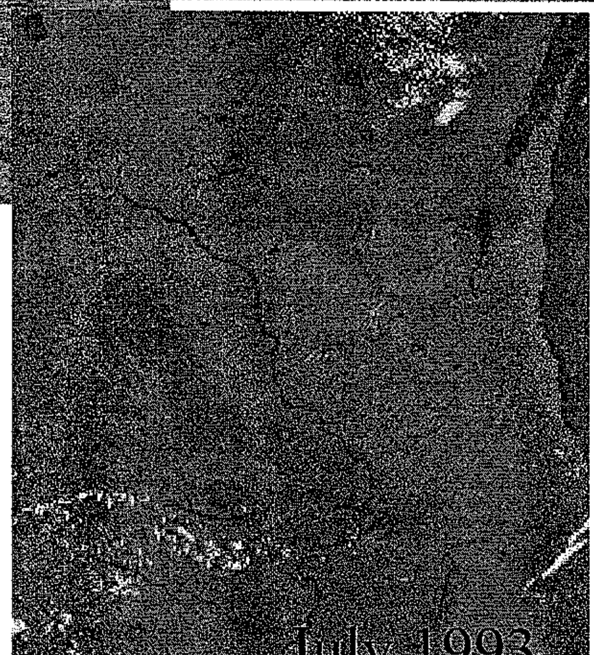
7) Seas and oceans

# Rivers: Floods

Mississippi river

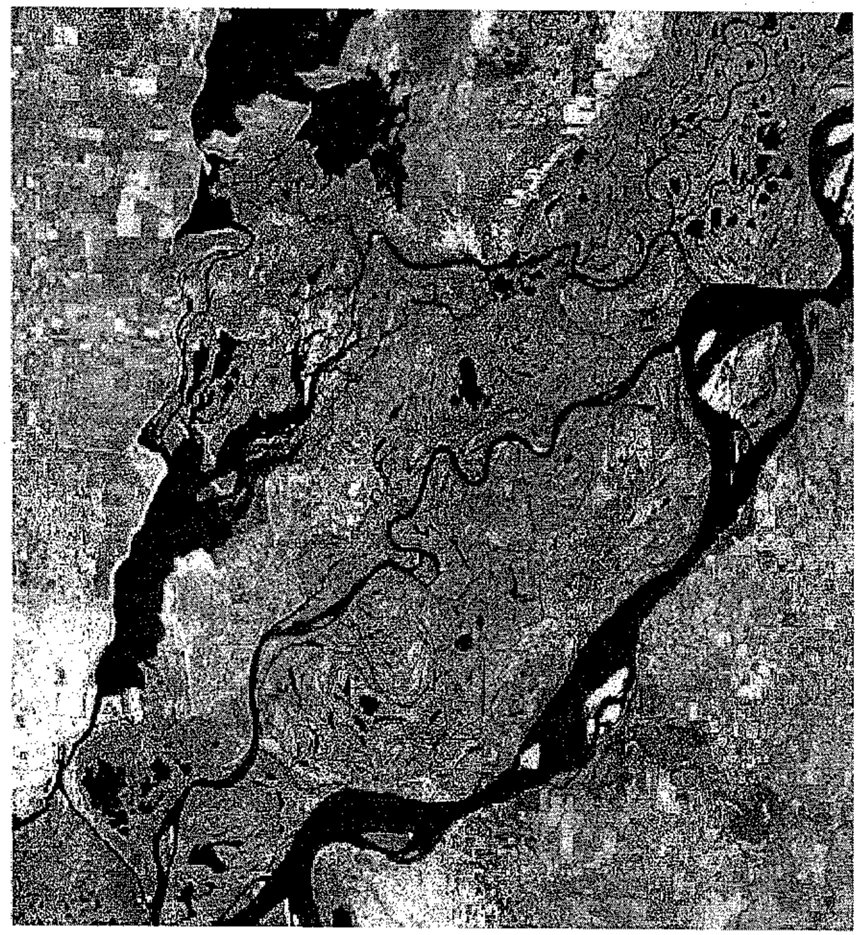


July 1992



July 1993

# Rivers: Floods

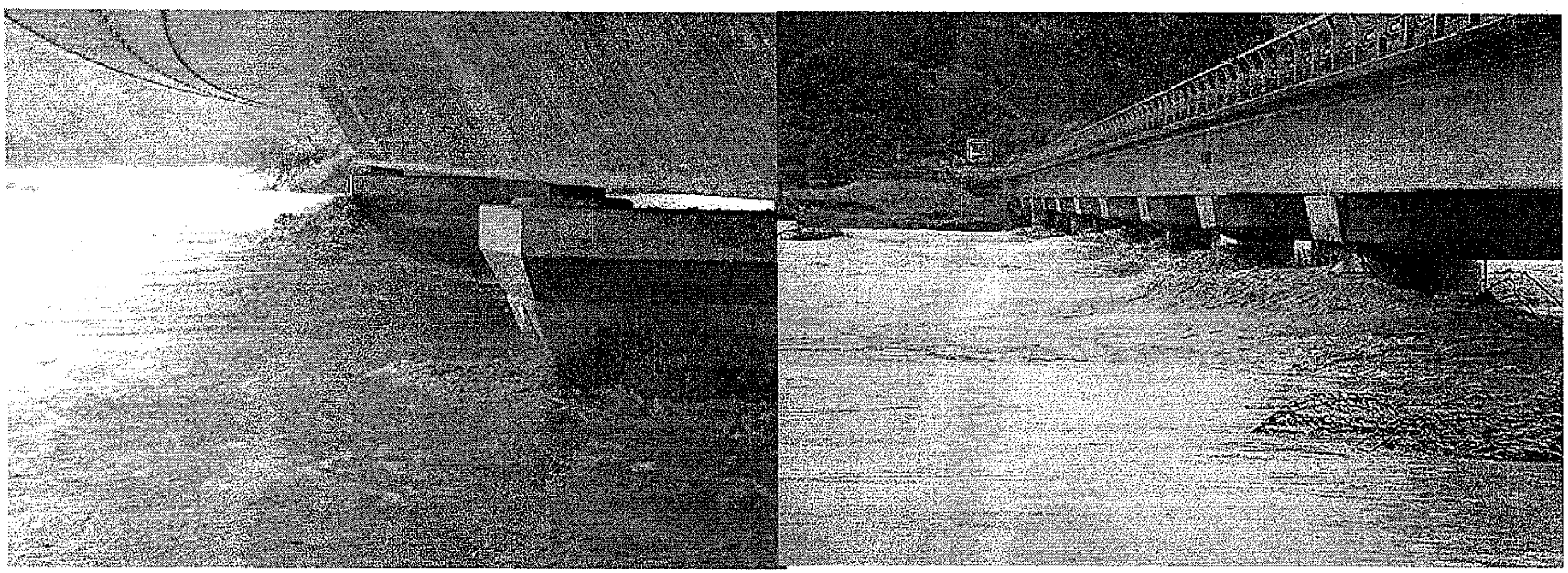


Paraná River, Argentina, South America

# Rivers: Floods

http://www.ourregion.co.nz/home.php - Manawatu, New Zealand

# Bridges that work



http://www.ourregion.co.nz/home.php - Source: Prof. Maidment (UT)

# Bridges that don't work

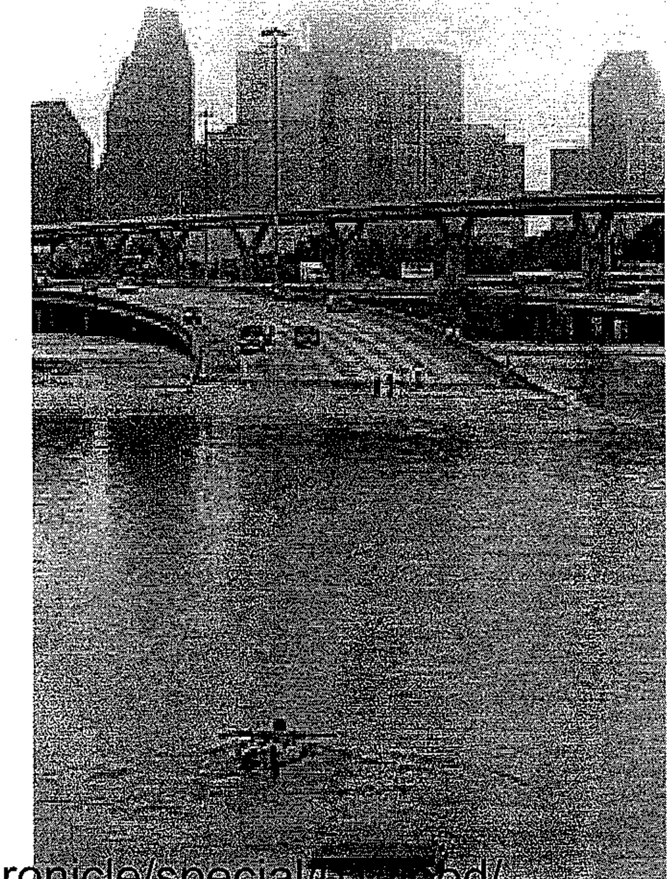
Small bridge on a country road is washed away

http://www.ourregion.co.nz/home.php - Source: Prof. Maidment (UT)

# Major highways in Houston during tropical storm Allison

I-10 West

I-45 South



http://www.chron.com/content/chronicle/special/01/flood/

Source: Prof. Maidment (UT)