BREACH: Numerical Modelling Test Programme

Introduction

An important part of the IMPACT project is the undertaking of field, laboratory and numerical modelling of breach formation through embankments. Objectives for undertaking this modelling work are:

- To establish a better understanding of the embankment breaching process
- To provide data for numerical model validation, calibration and testing, and hence improved modelling tools
- To provide information / data to assess the scaling effect between field and lab. experiments
- To identify best approach /approaches to simulate breach formation through embankments
- To assess and quantify the level of uncertainty of the current breach modelling techniques

The degree to which these objectives may be achieved can be enhanced by maximising the potential interaction between the three modelling approaches (i.e. field, lab and numerical).

This document provides a brief summary of the entire breach modelling programme, showing the relationship between the field, lab. and numerical modelling work. All modelling participants are invited to review the test programme below and to send any feedback to either Mark Morris (m.morris@hrwallingford.co.uk) or Mohamed Hassan (mam@hrwallingford.co.uk).

Field Modelling Tests

A total of five tests have been undertaken in Norway by Statkraft Groner. These comprise:

- Field Test#1: The first field test (See Figure 1) was the ‘maximum cohesive’ embankment test that was undertaken in September 2002 (coinciding with the 2nd IMPACT workshop). The embankment was built mainly from clay and silt (D_{50} = 0.01 mm) with less than 15% sand and 25% of clay. The purpose of this test was to better understand breach formation and to identify the different failure mechanisms in homogeneous cohesive embankments failed by overtopping.

[Note: An initial data set for this field test was released to numerical modellers in August 2002 with modelling results presented at the 2nd IMPACT workshop in Mo i Rana. However, since the final test conditions proved to vary significantly from the initial theoretical conditions that were provided as a data set to modellers, a further data set with the actual field test conditions was released in February 2003. (See numerical modelling programme below for detailed info.). This permitted modellers to undertake modelling runs that can be compared directly against the field data.]

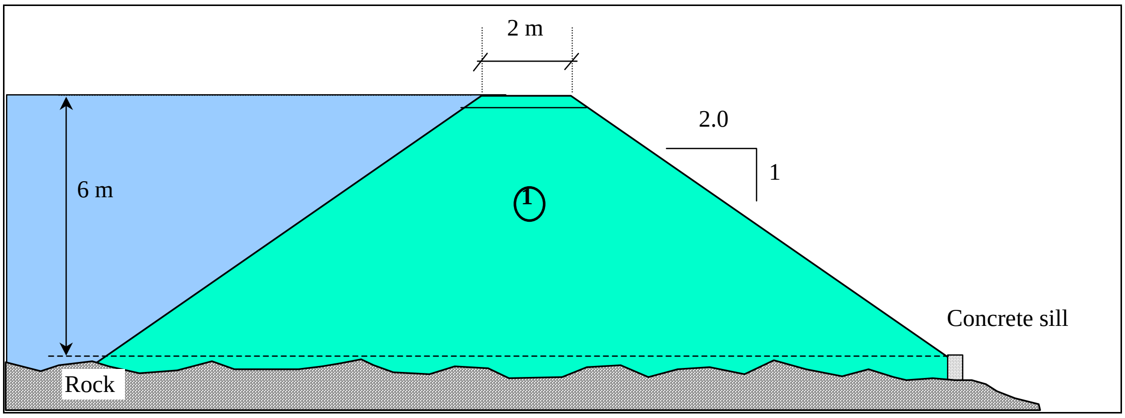

Figure 1: Geometry of Field Test #1

- Field Test#2: The second field test (See Figure 2) was the ‘minimum cohesive’ embankment test (Field Test #2) that was undertaken in October 2002. The embankment was built mainly from non-cohesive materials ($D_{50} \approx 5$ mm) with less than 5 % fines. The purpose of this test was to better understand breach formation and to identify the different failure mechanisms in homogeneous non-cohesive embankments failed by overtopping and also to assess / inspect the effect of seepage on the breach formation processes.

[Note: An initial data set for this test was also released in August 2002 to numerical modellers and the modelling results were presented in the 2nd IMPACT workshop in Mo i Rana. As with the first test case, actual test conditions also varied significantly from the target conditions hence a further data set with the actual field test conditions was released for simulation (See numerical modelling programme below for more info)].

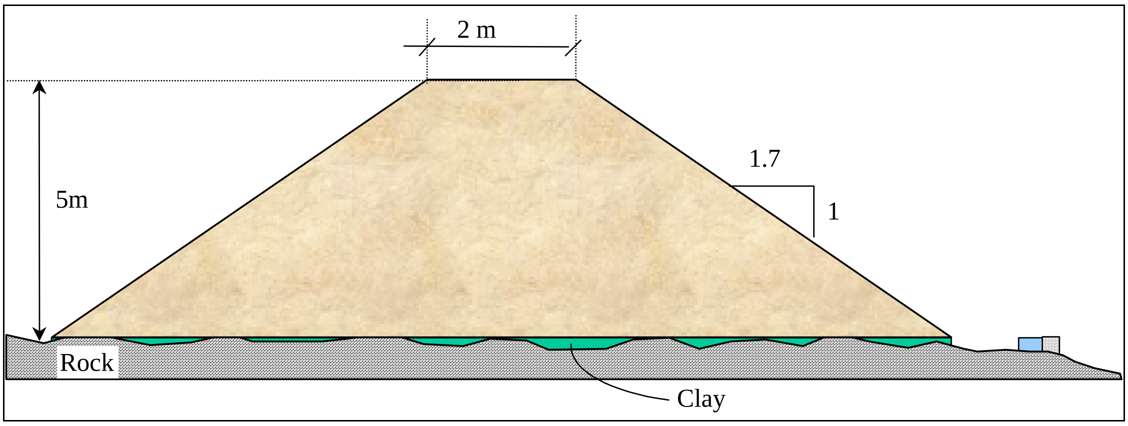

Figure 2: Geometry of Field Test #2

- Field Test#3: The third field test was built as shown in Figure 3 in August 2003. The upstream and downstream shoulders were built from rock fill with a central moraine core. The purpose of this test was to better understand breach formation and to identify the different failure mechanisms in composite embankments failed by overtopping. Numerical modellers will be asked to run at least one 'blind' and one 'aware' run with the data set of this test.

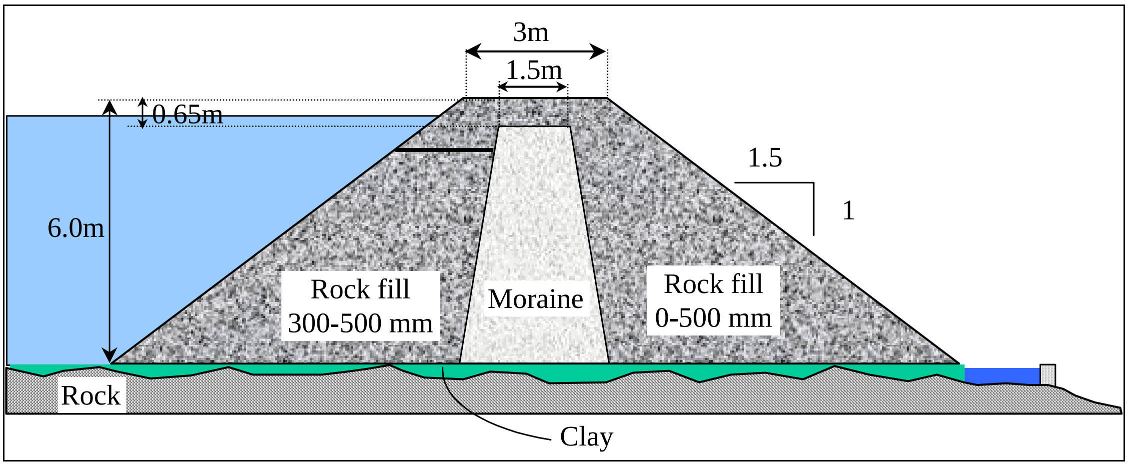

Figure 3: Geometry of Field Test #3

[Note: This field test was originally scheduled for 2002 but due to poor weather conditions in Norway in autumn 2002 it was delayed until summer 2003]

- Field Test#4: The fourth field test was built as shown in Figure 4 in September 2003. The upstream and downstream shoulders were built from rock fill with a central moraine core. The purpose of this test was to better understand breach formation and to identify the different failure mechanisms in composite embankments failed by piping. Two triggering mechanisms were used in this test case. Trigger mechanism #1 was a pipe perforated at the top and had the bottom half removed with the last part of it solid. The pipe was filled and surrounded by sand. The second mechanism was similar to the first one but with the sand fill extending from the bottom of the dam to the top. Trigger mechanism #1 did not appeared to work so failure occurred using Trigger mechanism #2.

As with each of the field tests, numerical modellers will be invited to run at least one 'blind' and one 'aware' run with the field data sets.

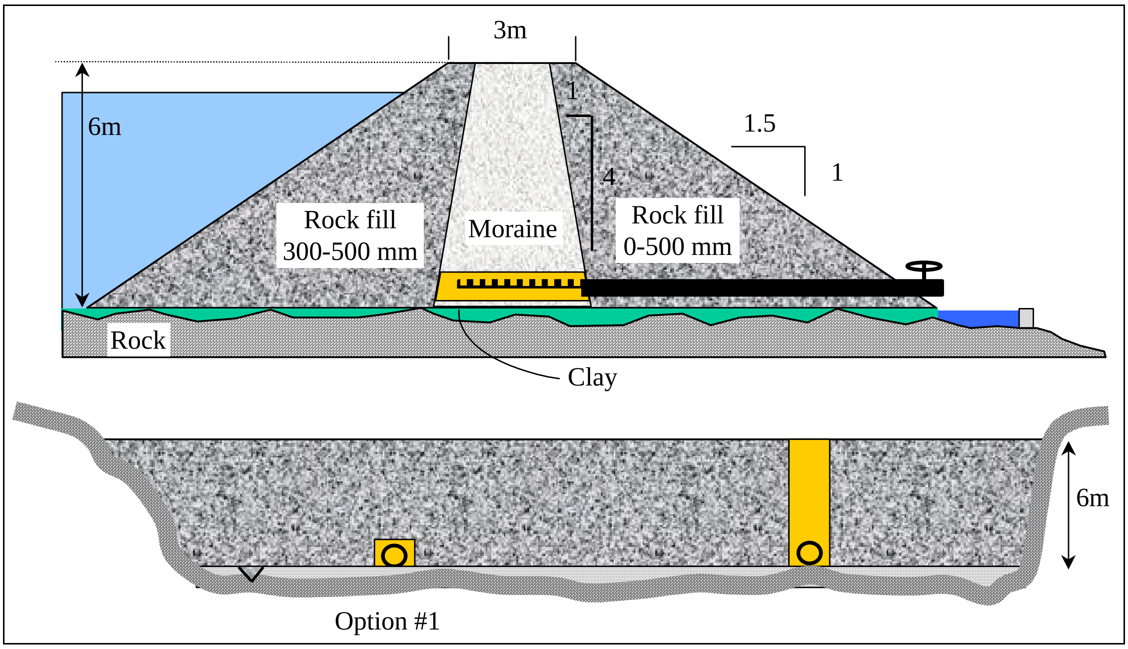

Figure 4: Geometry of Field Test # 4

– Field Test #5: The fifth field test was built as shown in Figure 5 in October 2003. The purpose of this test was to better understand breach formation and to identify the different failure mechanisms in homogeneous embankments failed by piping. Only one trigger mechanism was used in this test which was similar to the first mechanisms used in test #4. As with each of the field tests, numerical modellers will be invited to run at least one 'blind' and one 'aware' run with the field data sets.

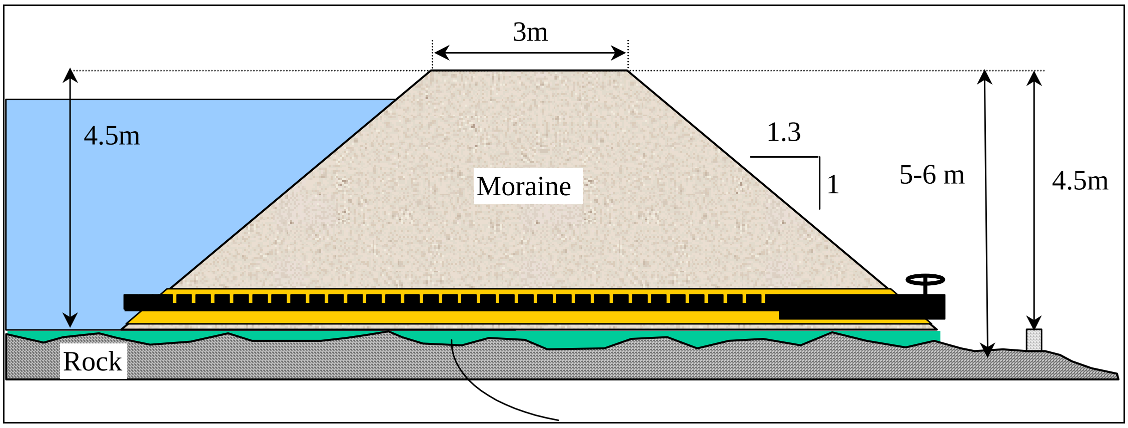

Figure 5: Geometry of Field Test #5

Field Data Collection

Data collected from the each test includes :

- Details of breach growth (rate, geometry, failure mechanisms)
- Water levels upstream of the test dam.
- Water levels at different locations downstream from the test dam.
- Inflow to the test-reservoir
- Measurement of the pore-pressure in the embankment (not available for the Field Test #1).
- Movement of sediment / bed material into, from and along the channel downstream (Not sure if they did this).
- Soil Properties of the materials
- Pictures / Videos

The extent of data collected has varied according to site conditions and decisions taken by the partner during test construction. A report with data describing the test-dam and results from the various tests is currently being produced.

Laboratory Modelling Tests

Nine laboratory tests out of the project programme total of 22 tests were undertaken in the U.K. at HR Wallingford during August-September 2002. This series of tests was based around Field Test #2 – the minimum cohesive, homogeneous embankment. Each embankment was built in the modelling flume (See Figure) from non-cohesive material, however, more than one grading of sediment was used along with different embankment geometry, breach location and time before failure (seepage effect). . This approach allows investigation of the extent to which varying these parameters affect the breach growth. The different sediment gradings used were:

1. Uniform grading with D_{50} = 0.70-0.90 mm
2. Uniform grading with D_{50} = 0.25 mm
3. Wide grading (4 types of sand were used) with D_{50} = 0.25 mm

[Note: Uniform grading = as steep a grading curve as possible, dependent upon sediment suppliers. Wide grading = combination of different materials to match the grading distribution observed in the field. All of these gradings were based upon a 1:10 direct scaling of field test sediments).

Table 1 and Figure 6 below provide details of each test:

Table 1: Details of Laboratory Tests 1-9

Lab. Test Description		Lab. Test Objective	Grading
Lab Test #1	Trial / test experiment	Facility set-up / trial	1
Lab Test #2	Uniform grading with the same D_{50} as Field Test #2	Effect of sediment uniformity	2
Lab Test #3	Same as Lab Test #2	Assess repeatability of test	2
Lab Test #4	Same as Lab Test #2, breach initiation notch against abutment	Assess effect of breach location	2
Lab Test #5	Replicate Field Test #2	Direct replication to field event	3
Lab Test #6	Vary geometry, different face slope (1:2 instead of 1:1.7)	Assess effect of face slope	3
Lab Test #7	Vary geometry, different crest width (0.30 m instead of 0.2 m)	Assess effect of crest width	3
Lab Test #8	Same geometry as Lab Test #2, Uniform grading with higher D_{50}	Assess effect of sediment size	1
Lab Test #9	Same geometry as Lab Test #2, allowing seepage before failure	Assess effect of seepage	3

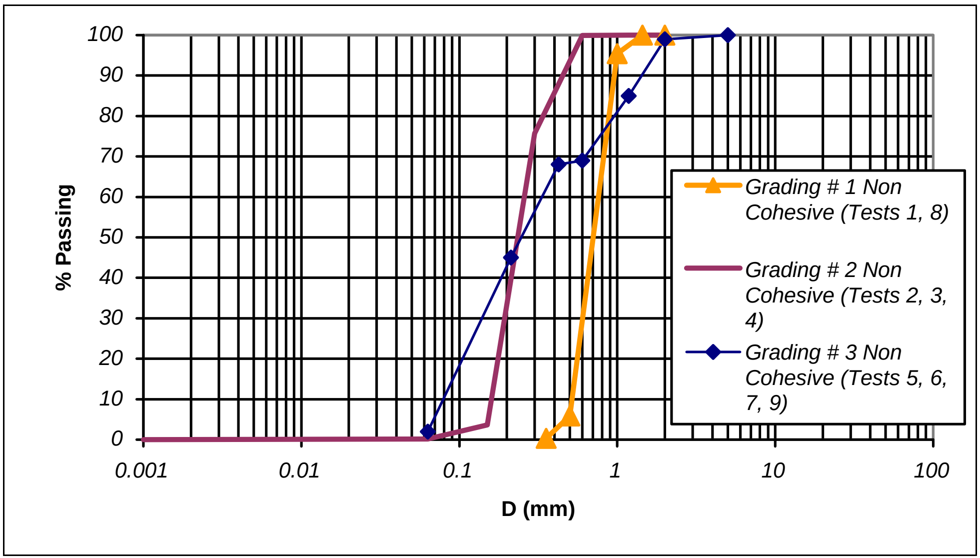

Figure 6: Grading curves for Laboratory Tests 1-9

A further 13 tests were undertaken in 2003:
Tests 10 – 17 were based around Field Test #1 at a scale of 1:10 to the field test. Test 10-16 were built from clay; Test 17 was built from moraine (see graph above for grading curves). Table 2 and Figure 7 provide details of each test:

Table 2: Details of Laboratory Tests 10-17

Lab. Test Description		Lab. Test Objective
Lab Test #10	Replicate Field Test #1	Direct replication to field event
Lab Test #11	Same as Lab Test #10	Assess repeatability of test
Lab Test #12	Same as Lab Test #10 but compacted with half of the compaction effort used for that test	Assess effect of compaction
Lab Test #13	Same as Lab Test #10 but at optimum moisture content (***Partially failed***)	Assess effect of moisture content
Lab Test #14	Remains of Lab Test #13 ***but left overnight***	Assess effect of seepage
Lab Test #15	Vary geometry, different downstream face slope (1:1 instead of 1:2)	Assess effect of downstream face slope
Lab Test #16	Vary geometry, different downstream face slope (1:3 instead of 1:2)	Assess effect of downstream face slope
Lab Test #17	Same as Lab Test #10 but built from moraine instead of clay.	Assess effect of construction material

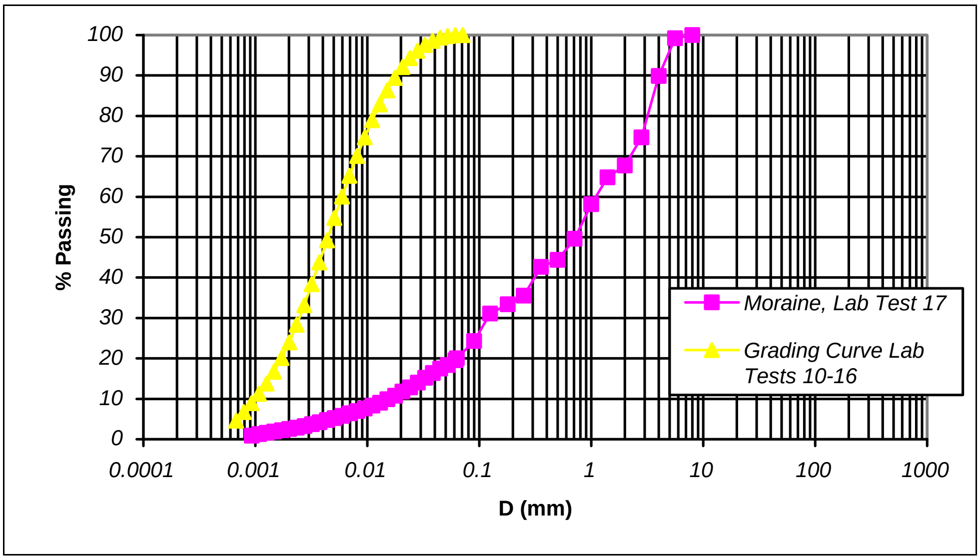

Figure 7: Grading Curves for Laboratory Tests 10-17

Tests #18 and 19 were undertaken in support of Field test # 5, whilst Tests 20-22 monitored the initiation and development of piping failures in samples of real embankment material. Table 3 provides details of each test: Figure 8 shows the grading curve used for tests 18-22.

Table 3: Details of Laboratory Tests 18-22

Lab. Test Description		Lab. Test Objective
Lab Test #18	Replicate initiation of piping for Field Test #5	Provide information about the pipe formation to assist in development of the field test failure mechanism
Lab Test #19	Same as Lab Test #18	Assess repeatability of the test
Lab Test #20 Lab Test #21 Lab Test #22	Material brought from an UK flood embankment. Samples were 1m (W) x 1m (L) x 0.8m (D)	Monitor piping initiation and development

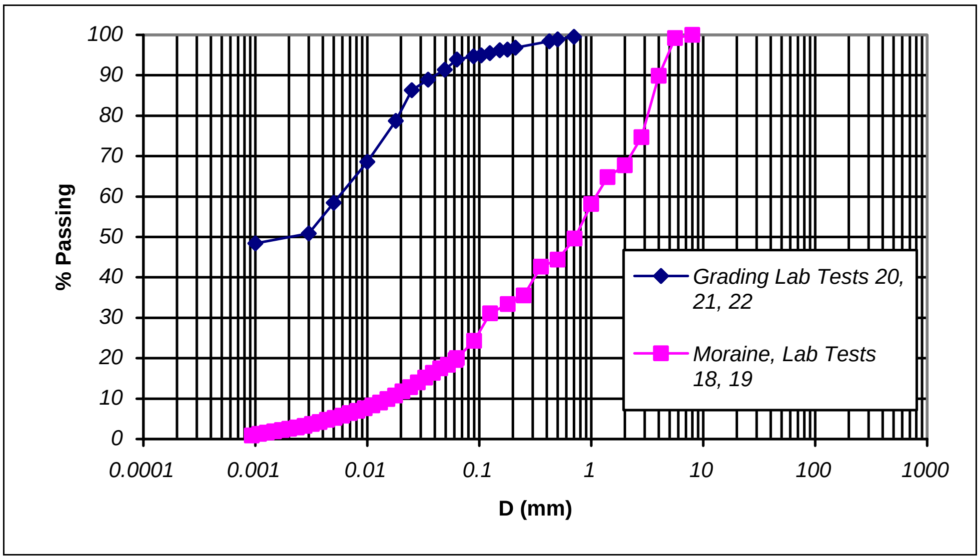

Figure 8: Grading Curves for Laboratory Tests 18-22

Laboratory Data Collection

For Lab Tests 1-17, the following data has been collected:

1. Inflow into the flume (P6).
2. Water levels upstream and downstream of the built embankment (L1, L2, and L3).
3. Approach velocity (Upstream of the built embankment).
4. Pore water pressure in the built embankment (P1-P4).
5. Photos and videos for monitoring breach development.

Limited data was collected for tests 18 and 19, as these tests were primarily undertaken to provide our partners in Norway with information about piping behaviour in moraine embankments. Data from tests 20 to 22 is currently being analysed by UK University and will not be included in the numerical modelling programme. However, data from these tests will be available for further analysis in the future by interested modellers.

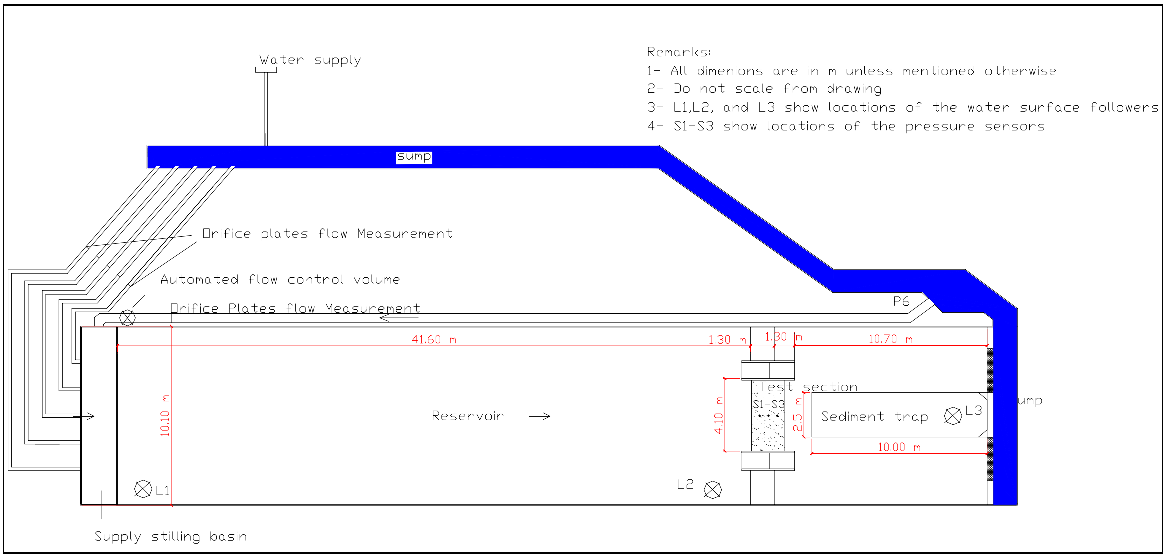

Figure 8: Flood channel facility

Numerical Modelling Programme

In conjunction with the field and laboratory modelling programme is the numerical modelling programme. The objective of the numerical modelling programme is:

- To identify the best numerical approach / approaches for simulating breach formation through embankments
- To assess and quantify the level of uncertainty of current breach modelling techniques
- To incorporate knowledge gained from undertaking the field and laboratory tests into existing modelling tools.

Figure 9 shows the interaction between the numerical modelling work and the field and laboratory modelling tests.

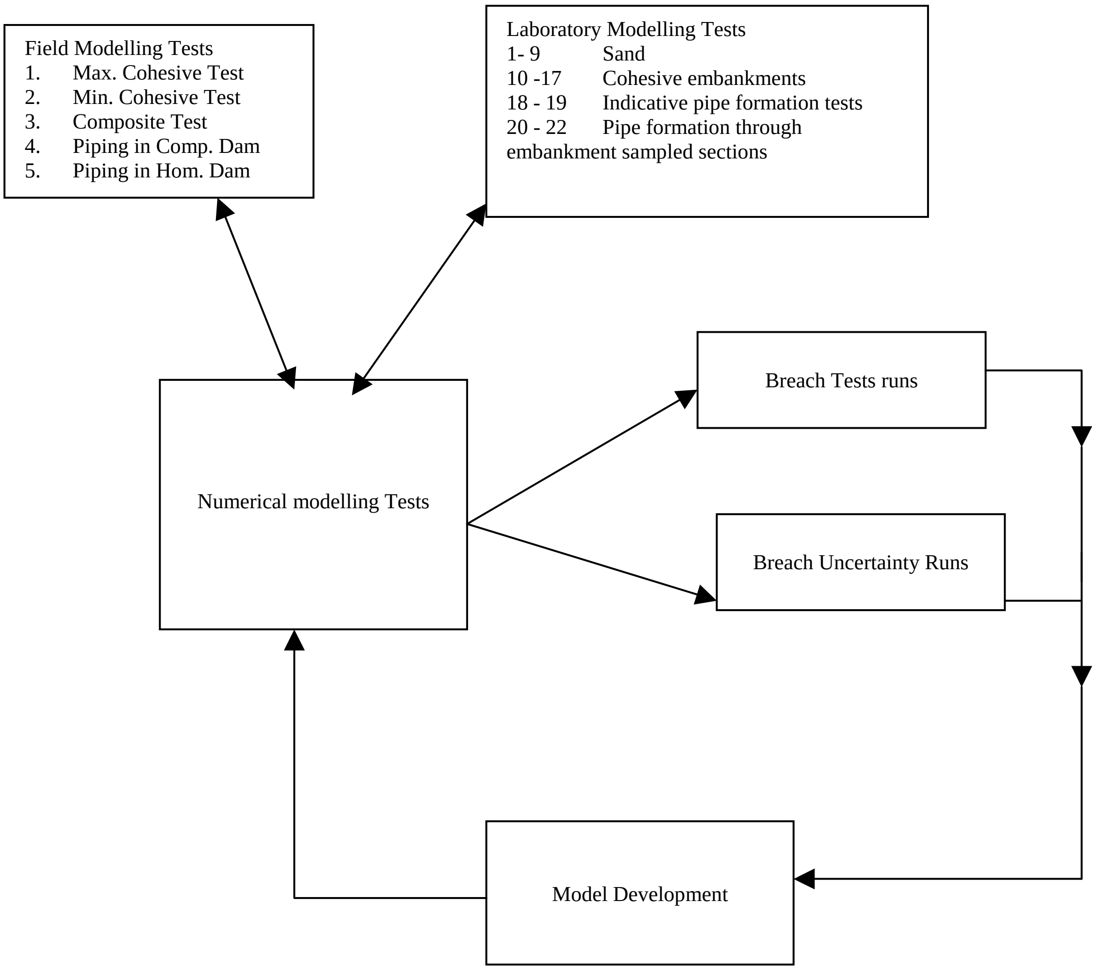

Figure 9: Interaction between field, lab. and numerical work

There are three aspects to this numerical modelling programme:

'Blind' and 'Aware' Testing

A significant number of the numerical model testing will be undertaken as 'blind' tests to ensure complete objectivity. Blind means that numerical modellers will be asked to undertake their work and submit their results the results from the field and laboratory tests are released. Modellers will then also be invited to submit further (revised) modelling results after receiving the field or lab test results ('Aware' testing). Details and justification of any variations to the modelling approach (as compared to the blind tests) should accompany any results submitted.

The following table shows a list of potential numerical modelling runs:

Table 4: Numerical modelling Schedule

Run Code t = theoretical a = aware b = blind	Data set	Test type Blind	Test type Aware	Release date	Submission Date	Test objective /Comments
NF1t	Field Test #1	x		30/07/02	16/08/02	Initial Data set
NF1b	Field Test #1	x		10/02/03	07/03/03	Re release due to new survey and calibration of gates
NF1a	Field Test #1		x	10/03/03	28/03/03	Release of the field data
NF2t	Field Test #2	x		19/08/02	02/09/02	Initial data set
NF2b	Field Test #2	x		10/03/03	28/03/03	Re release due to new survey and calibration of gates
NF2a	Field Test #2		x	31/03/03	18/04/03	Release of the field data
NF3b	Field Test #3	x		26/01/04	1/03/04	Modelling overtopping failure in composite embankments
NF3a	Field Test #3		x	1/03/04	22/03/04	
NF4b	Field Test #4	x		26/01/04	1/03/04	Modelling piping failure in composite embankments
NF4a	Field Test #4		x	1/03/04	22/03/04	
NF5b	Field Test #5	x		26/01/04	1/03/04	Modelling piping failure in homogeneous embankments
NF5a	Field Test #5		x	1/03/04	22/03/04	
NL2b	Lab Test # 2	x		06/11/02	25/11/02	Assess Effect of sediment uniformity
NL2a	Lab Test # 2		x	25/11/02	16/12/02	
NL4b	Lab Test # 4	x		06/11/02	25/11/02	Assess effect of breach location
NL4a	Lab Test # 4		x	25/11/02	16/12/02	
NL5b	Lab Test # 5	x		21/04/03	16/05/03	Direct replication to field event
NL5a	Lab Test # 5		x	19/05/03	27/06/03	
NL6b	Lab Test # 6	x		21/04/03	16/05/03	Assess effect of face slope
NL6a	Lab Test # 6		x	19/05/03	27/06/03	
NL7b	Lab Test # 7	x		21/04/03	16/05/03	Assess effect of crest width
NL7a	Lab Test # 7		x	19/05/03	27/06/03	
NL9b	Lab Test # 9	x		21/04/03	16/05/03	Assess effect of seepage
NL9a	Lab Test # 9		x	19/05/03	27/06/03	
NL10b	Lab Test #10	x		26/01/04	1/03/04	Direct replication to field event
NL10a	Lab Test #10		x	1/03/04	22/03/04	
NL11b	Lab Test #12	x		26/01/04	1/03/04	Assess repeatability of test
NL11a	Lab Test #12		x	1/03/04	22/03/04	
NL12b	Lab Test #12	x		26/01/04	1/03/04	Assess effect of compaction
NL12a	Lab Test #12		x	1/03/04	22/03/04	
NL13b	Lab Test #13	x		26/01/04	1/03/04	Assess effect of moisture content
NL13a	Lab Test #13		x	1/03/04	22/03/04	
NL14b	Lab Test #14	x		26/01/04	1/03/04	Assess effect of seepage
NL14a	Lab Test #14		x	1/03/04	22/03/04	
NL15b	Lab Test #15	x		26/01/04	1/03/04	

Run Code t = theoretical a = aware b = blind	Data set	Test type		Release date	Submission Date	Test objective /Comments
		Blind	Aware			
NL15a	Lab Test #15		x	1/03/04	22/03/04	Assess effect of downstream face slope
NL16b	Lab Test #16	x		26/01/04	1/03/04	Assess effect of downstream face slope
NL16a	Lab Test #16		x	1/03/04	22/03/04	
NL17b	Lab Test #17	x		26/01/04	1/03/04	Assess effect of construction material
NL17a	Lab Test #17		x	1/03/04	22/03/04	

Participation in Numerical Modelling

Participation in as many of the tests listed above is encouraged from as wider a group of participants as possible. However, it is recognised that the number of tests listed above is large and probably beyond the time availability of many participants. Modellers are therefore invited to undertake a number of core modelling tests and as many of the remaining tests as they are able.

Core Runs:
Core modelling tests include both blind and aware runs for:

- 5 field tests (NF1, NF2, NF3, NF4, NF5)
- 9 lab replication tests (NL2 , NL45 , NL5, NL9 , NL10, NL12, NL13, NL15, NL17)

Remaining Runs:

There is considerable value to be gained in also undertaking modelling for the remaining lab tests. Many of these variations will require minimal change to numerical models for simulation and modellers are encouraged to participate wherever possible.

[Note: Analysis of these runs will be undertaken by at least 1 member of the IMPACT project team however multiple analysis is preferred].

Modelling Analysis

Modellers are encouraged to undertake more detailed analysis of model run and performance wherever possible. For example:

1. Tests to check the effect of the different assumptions on the model results.
2. Tests to check the effect of the variation (accuracy) of the field and lab data on the model results.
3. Tests to identify parameters that have a major effect on the model results.

The above is a list of suggestions. Each modeller is encouraged to undertake the tests that he/she sees appropriate for his/her model.

The submitted results have to be in ASCII format. Results should as a minimum include the following:

1- Outflow hydrograph at the breach location.
2- Breach development with time (width and depth)
3- Reservoir water levels hydrograph. (far enough from the breach to avoid the draw down effects)

Modelling Uncertainty

An important aspect of the IMPACT project work is assessing and quantifying uncertainty associated with modelling predictions. In addition to the basic breach simulations, each modeller is invited to submit an assessment of the uncertainty associated with some of the test results. The following two approaches for assessing uncertainty are suggested:

1. Sensitivity Approach
2. Monte Carlo Approach

[See Mohamed and Morris (2003) for an overview on each approach – paper presented at the 3rd IMPACT workshop. A copy can be sent by email upon request (Contact Mohamed Hassan on mam@hrwallingford.co.uk)]

More information of uncertainty analysis can be found under WP5 of the IMPACT project.

Modellers and Model Development

The purpose of field, lab and model testing is ultimately to improve modelling tools for predicting breach formation. Modellers are encouraged to use the data provided to validate, calibrate and develop their models. Details of such development would be welcomed within analysis and presentation of the modelling work.

Modellers Involved

Table 5 provides the current list of researchers who are participating or who have expressed an interest in the numerical modelling programme. If you are aware of a researcher or organisation that has developed a breach model and is interested in participating, please advise Mark Morris on m.morris@hrwallingford.co.uk or Mohamed Hassan on mam@hrwallingford.co.uk.. We welcome as wide a range of participants as possible.

Table 5: Researchers who are participating in the numerical modelling programme

No	Organisation	Country	Modeller	Model(s)
Participating:				
1.	HR Wallingford	UK	Mohamed Hassan	HR Breach NWS BREACH
2.	Cemagref	France	Andre Paquier	Simple model
3.	UniBW	Germany	Karl Broich	Deich_P
4.	ARS-USDA	USA	Greg Hanson	Sites model
5.	Foster Wheeler Environment Corp.	USA	Dave Froehlich	Empirical Formula New model
6.	USBR	USA	Tony Wahl	Peak discharge equations
7.	Delft Hydraulics	Holland	Henk Verheij	SOBEK Rural Overland Flow
8.	Ecole Polytechnique de Montreal	Canada	Mai Phat Tai	Firebird model
9.	Univ. of Ottawa	Canada	Irene Pestov	Head cut model