CHAPTER 7 MIKE 11 HD+ST MODEL (TASK 5)

7.1 Bridges

The bridges are important because they produce backwater and hence increases flooding. A very good example was filmed during the 2005 flood at the 14 Metry Bridge where the whole Madarsoo was backed up behind the road and bridge (described in detail under the 14 Metry Bridge section).

The bridges will be included as a culvert type structure to represent the bridge opening and a weir to represent the road. In technical terms each of the structures is given a Q-H relation calculated from the energy equation.

The flow through a culvert will be a function of especially the culvert geometry and invert, and the resulting Q-H relation essentially states how much water will flow through the bridge opening as function of the upstream water level. The Q-H relation can be thought of as an internal condition on the discharge through the bridge opening. For a given upstream water level there will be a certain amount of water going through the bridge opening, depending on especially the size of the opening. For a narrow opening the water level will be forces up higher than for a wide opening, and this is essentially how it works.

For the road overtopping a simple weir formula applies, which states how much water discharge will be flowing over the weir as function of the upstream water level. The invert and the width (function of water level) dictate the flow over the weir.

The Q-H relations for the culverts and weirs are applied in parallel such that each Q-H relation (structure) accounts for a fraction of the total discharge, and yield the total discharge in combination.

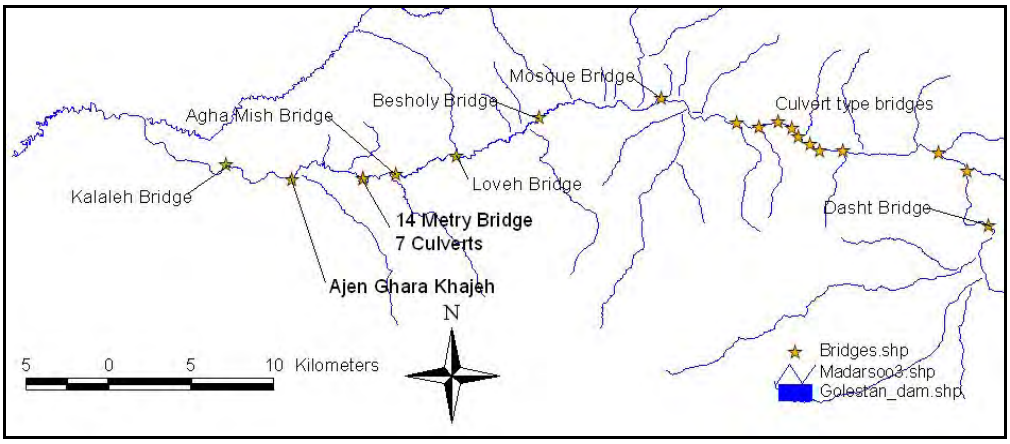

Figure 7.1 The 19 Bridges in the MIKE 11 model. The Ajen Ghare Khajeh Bridge is new compared to the list data from February.

Table 7.1 The 19 bridges to be included in the hydraulic model; road elevations and culvert inverts estimated from cross-section survey data.

ID	Name	Easting (m)	Northing (m)	Chainage (m)	Culvert (m)	Road (m)
1	Dasht Bridge	413,133	4,131,946	694	953.00	954.50
2	Existing Bridge	411,847	4,135,223	5,895	861.80	863.30
3	Existing Bridge	410,105	4,136,355	8,240	813.50	815.00
4	Existing Bridge	404,351	4,136,462	14,499	674.80	676.30
5	Existing Bridge	402,910	4,136,485	15,950	640.50	642.00
6	Existing Bridge	402,369	4,136,880	16,652	623.50	625.00
7	Existing Bridge	401,651	4,137,308	17,559	606.50	608.00
8	Existing Bridge	401,239	4,137,809	18,234	593.50	595.00
9	Existing Bridge	400,389	4,138,182	19,200	577.00	578.50
10	Existing Bridge	399,276	4,137,850	20,466	558.50	560.00
11	Existing Bridge	397,880	4,138,158	22,004	533.00	534.50
12	Mosque Bridge	393,326	4,139,646	28,032	457.00	462.00
13	Besholy Bridge	385,966	4,138,451	37,474	348.00	353.00
14	Loveh Bridge	380,955	4,136,124	44,854	281.00	284.00
15	Agha Mish Bridge	377,263	4,135,087	49,749	246.00	248.00
16	14 Metry Bridge	375,322	4,134,787	52,682	228.80	237.00
17	7 Culverts	375,304	4,134,803	52,707	231.00	233.00
18	Ajen Ghare Khajeh	370,976	4,134,762	59,891	176.00	180.00
19	Kalaleh Bridge	366,976	4,135,633	64,980	133.00	140.00

Table 7.2 Geometries for each of the culverts and weirs, estimated from the MoE cross-section survey data. The three first columns are for the culvert, while the two last columns are for the weir. For "Geometry" one number indicates a diameter, while two numbers are width and height, and for 14 Metry Bridge the culvert is special to represent the arch opening, which is described in detail in a sub-section.

Name	Length (m)	Amount (-)	Geometry (m)	Base width (m)	Max width (m)
Dasht Bridge	14	10	1	45	251
Existing Bridge	14	10	1	62	219
Existing Bridge	14	10	1	37	180
Existing Bridge	14	10	1	60	181
Existing Bridge	14	10	1	108	278
Existing Bridge	14	10	1	42	162
Existing Bridge	14	10	1	99	203
Existing Bridge	14	10	1	88	189
Existing Bridge	14	10	1	26	219
Existing Bridge	14	10	1	70	262
Existing Bridge	14	10	1	36	243
Mosque Bridge	6	1	20/5	90	237
Besholy Bridge	5	2	5/5	63	198
Loveh Bridge	6	1	30/5	44	446
Agha Mish Bridge	6	1	15/5	70	403
14 Metry Bridge	12	1	Level-Width	150	590
7 Culverts	10	7	1.2/2	93	592
Ajen Ghare Khajeh	6	4	10/4	400	400
Kalaleh Bridge	12	4	14/8	200	200

For simplicity we will implement all the bridges as culverts (bridge openings) and weirs (overtopping). The difference between this and using e.g. the FHWA module is small compared to the inconsistencies in the elevation data.

The geometry parameters for each of the bridges are tabulated in Table 7.1.

A structure location in MIKE 11 is characterized by a chainage value, which is a location in the network, and not directly a geographical location. The locations of the bridges were determined by matching up the location according to the AutoCAD files with the network chainage. The chainage values match exactly the river survey data that we have available in the project, such that the bridge location is geographically identical to the location in AutoCAD. If any changes are made to the network because of inconsistencies in the survey data, the bridge chainage locations will have to be altered.

7.1.1 Transformation to a different network and cross-sections

The bridges are defined with a UTM location from which we calculate a chainage by simply finding the closest point in the river network. A small utility program was written for figuring out the chainage locations depending on the UTM coordinates and the river network, and this can be invoked when the final network is decided.

The geometry of the culverts and roads do not need to be altered; only the inverts. The inverts of the culvert and roads have thus far been determined from the MoE cross-sections. The elevations in these sections do not match with the Iran Systems DEM, so we will have to alter the inverts once the final model is being put together, so the inverts match with the local cross-sections.

7.1.2 Bridges of Golestan Forest

The first 11 bridges are in Golestan Forest, and all are taken as 10 culverts with a length of 14 m, a diameter of 1 m and inverts equal to the road elevation minus 1.5 m.

The road elevations were estimated from the cross-sections and level-width curves were calculated for each of the bridges to represent the V-shaped overall cross-section of Golestan Forest.

Golestan Forest was closed after the 10 August 2005 flood. According to the information available, all bridges in the forest were destroyed. This does not have any influence on our modeling; we will still assume that the bridges survive a flood, as this is in fact worst case in terms of flooding.

7.1.3 14 Metry Bridge

Videos taken at the 14 Metry Bridge during the 10 August 2005 flood show overtopping of the bridge, as well as partial destruction of the 7 culvert bridge downstream of the 14 Metry Bridge.

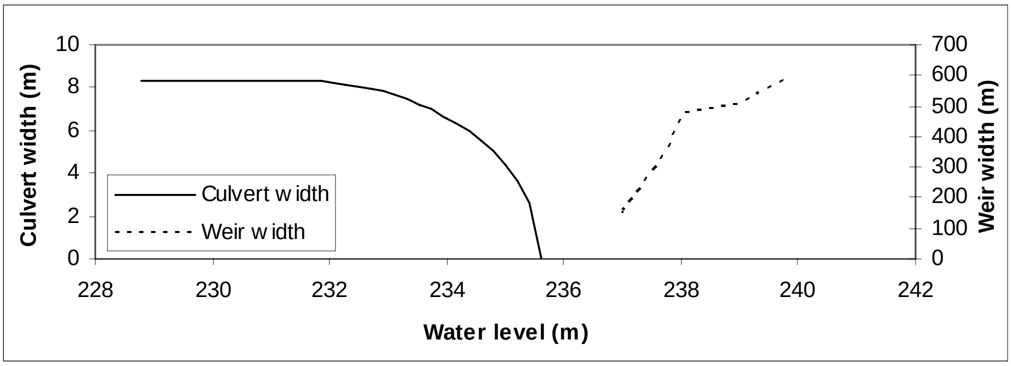

Figure 7.2 Level-width curves for 14 Metry Bridge (culvert and weir).

The videos also show substantial backing up of the water behind 14 Metry Bridge, which again underlines the importance of including this bridge in the MIKE 11 model as a hydraulic structure. The inclusion of the bridge with a weir to represent overtopping is therefore vital.

14 Metry Bridge falls out of the normal category by having a level-width curve prescribed for the culvert rather than dimensions (diameter or width and height). This is necessary to describe the arch opening. The arch opening is described by simply calculating the width of the opening as function of the water level and insert into the MIKE 11 structure module. The resulting level-width curve is shown in Figure 7.2 along with the curve for the weir. The way to read the level-width curve is that it starts at 8.3 m width for 228.8 m water level (invert) and then decreases, as the arch shape sets in, resulting in zero width around 235.62 m water level, which is the estimated elevation for the top of the arch (the road is estimated at 237 m).

Note: The geometry for 14 Metry Bridge was based on a photo taken on 11 February 2005 with the DHI expert as scale in the picture. The geometry is only approximate, but no drawings were available for the bridge. The good thing about it is that the geometry does not have to be very accurate to produce reasonable backwater. Considering that elevation data is with 2 m contour intervals, the accuracy of the backwater is sufficient.

7.1.4 Backwater calculation for 1600 m^3/s

Backwater curves were calculated by running the model with and without the bridges included for 1600 m^3/s discharge all the way down through the river (though this is not correct, it still provides insight into the amount of backwater).

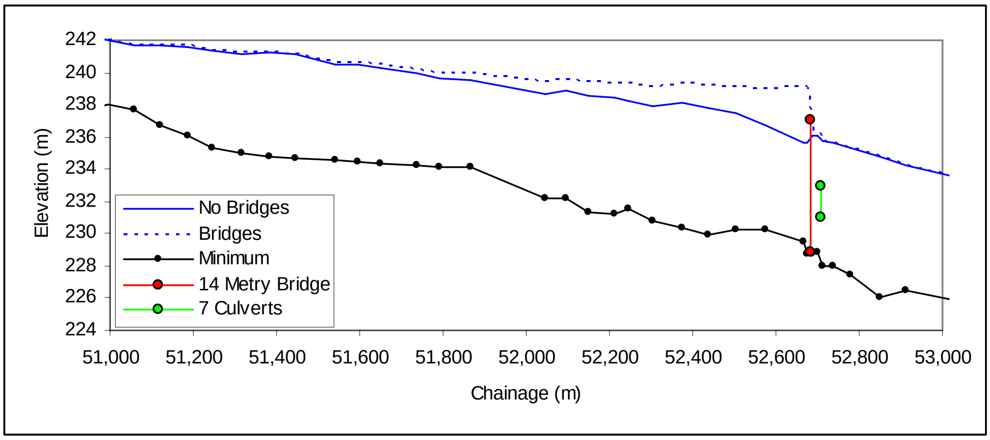

Figure 7.3 Backwater calculation at 14 Metry (and 7 Culverts) Bridge. The inverts (culvert and road) are shown for each bridge. It is seen that 14 Metry backs the water up more than 1 km.

The purpose is to demonstrate the backwater calculations in MIKE 11, to demonstrate the importance for flood mapping, and to demonstrate that the estimates that we have made for the bridge geometries and elevations are good enough for modeling the bridge backwater.

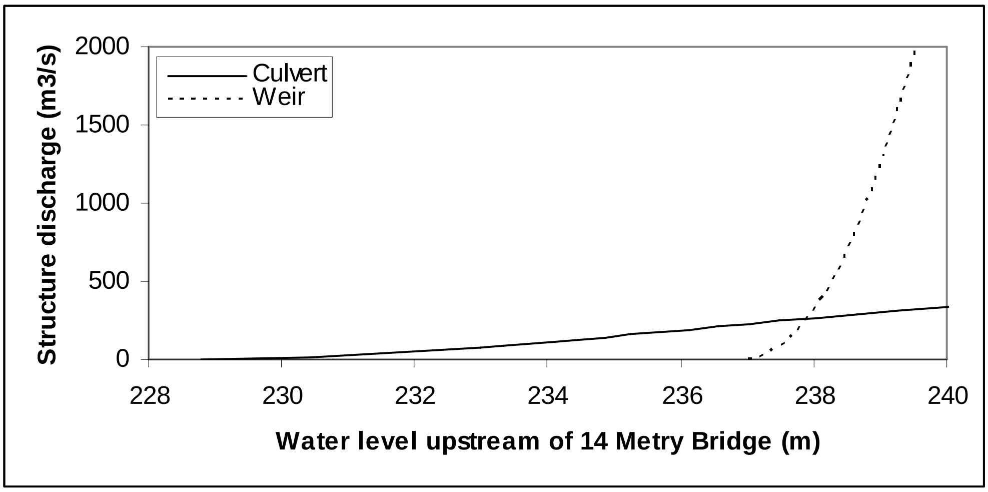

Figure 7.4 Q-H relations for the two structures (culvert and weir) comprising 14 Metry Bridge.

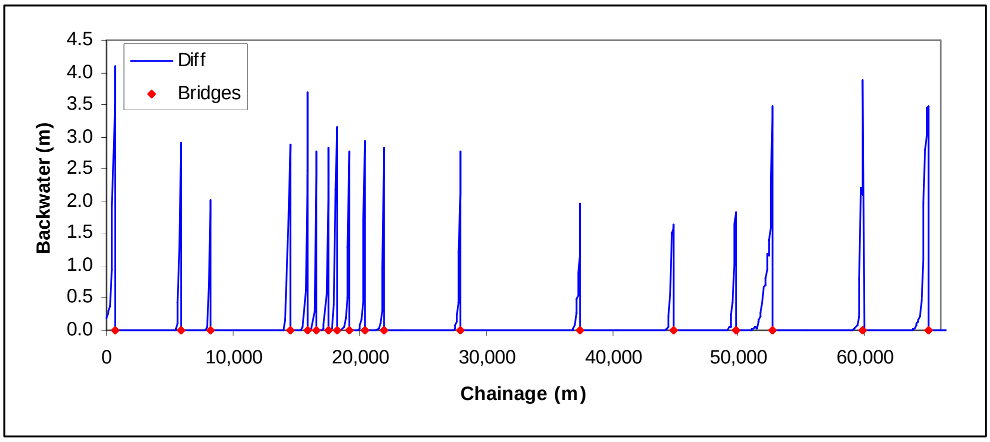

Figure 7.5 Backwater curves for all 19 bridges calculated for a constant discharge of 1600 m^3/s.

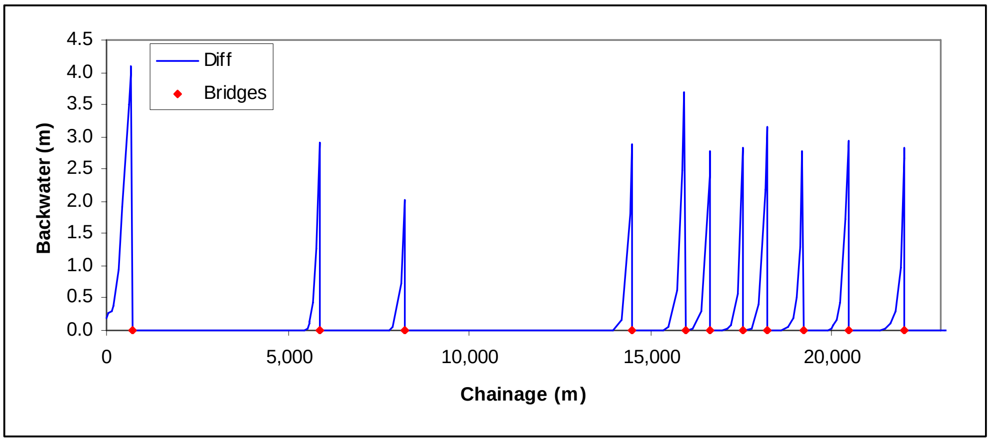

Figure 7.6 Backwater curves for the bridges in Golestan Forest

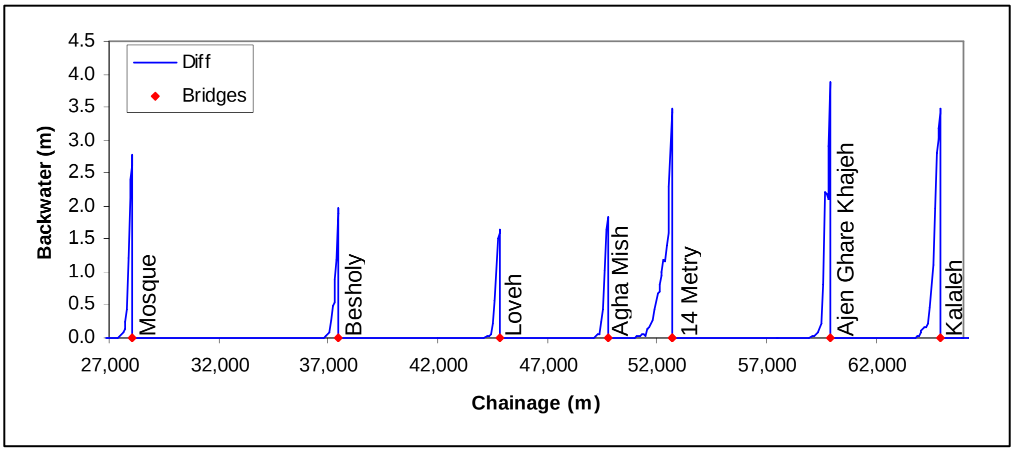

Figure 7.7 Backwater curves for the bridges downstream of Golestan Forest.

First we take the most complicated part, namely the area at 14 Metry Bridge, see Figure 7.3. The water level is shown with and without bridge, and it is seen that the water is backed up behind the bridge and overtops the road, as also observed for the 2005 flood. According to the simulation the water depth over the road is about 2 meters for the 2001 flood. The videos from the 2005 flood suggest that the water depth was less than 1 m above the road, but 2001 is of a larger magnitude.

We can in fact calculate how the water level upstream of the 14 Metry Bridge should be, as we have the Q-H relations that were calculated in the MIKE 11 model preparation, see Figure 7.4. The water level upstream of 14 Metry Bridge in the simulation was about 239 m, which gives about 300 m^3/s discharge through the arch opening, and 1300 m^3/s over the road. The flow area through the arch is estimated to 44 m^2 when it is flowing full, so the flow velocity through the arch is about 7 m/s. For the weir the flow area for 239 m water level is about 400 m, which gives a velocity of about 3.5 m/s over the weir. These are reasonable velocities, and clearly the 14 Metry Bridge was constructed with design velocities higher than these (the road was damaged during the 2005 flood with lots of undercutting).

The difference in water level between the two simulations is the backwater, shown in Figure 7.5.

7.2 MIKE 11 model based on "mosaic" DEM

A mosaic DEM was created on August 25 and we now use this DEM for creation of what could be the project MIKE 11 model.

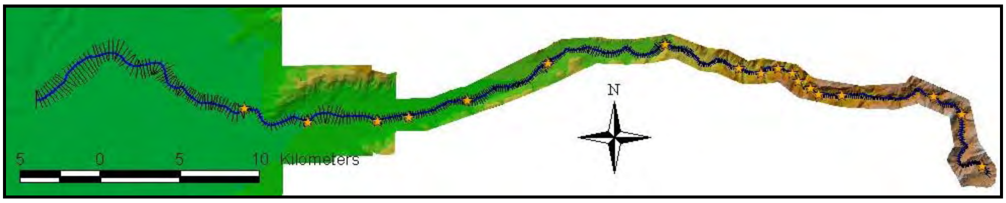

Figure 7.8 Mosaic DEM with MIKE 11 network and MIKE 11 cross-sections. The bridge locations are only for reference; they are not included in this model. The bridges will be included if we deem that this is the MIKE 11 model we will use, but it requires changes to the chainages and inverts of the bridges.

First of all the Madarsoo network has to be redefined, as the MoE survey data does not match up with the DEM. We also opt for what we will likely do no matter what in the final MIKE 11 model: We make the branch less meandering so the flow path is that of that floodplain flow. It is far more realistic for a model to be used for flood mapping, though it also means that the model should not be used for low flow, but this is already prohibited by the absence of the Madarsoo river channel in the DEM.

The branch was digitized by looking at the contours of the DEM, such that the local river location was the lowest point in the valley. The digitized branch is shown in Figure 7.8, and it is noted that it only has a length of 72,609 m, which is almost 20 km shorter than the branch obtained with the MoE survey data (91,592 m). However, the shorter length is very reasonable, as the length of the meandering Madarsoo is not what the flood water experiences on its way down through the valley; the path is much less meandering.

The branch is purely for distance measuring (in the flow equations), while the flood coverage is controlled by the cross-sections.

The cross-sections were digitized based on a flood extend calculated with MIKE 21; the 553 cross-sections are shown in Figure 7.8. It is important to make sure that the cross-sections house the full extend of flooding, which can result in changes being made to the cross-section in future model versions if we find that the flood extend is not properly housed.

The 533 cross-sections were extracted from the mosaic DEM and imported to a MIKE 11 cross-section database.

With the cross-sections and network ready, a MIKE 11 model can be put together fast and used for hydraulic simulations to be further used for flood mapping.

It is noted that the bridges are not included in this test MIKE 11 model. Inclusion of the bridges takes some work in order to get reasonable invert elevations that have to match the mosaic DEM rather than the MoE cross-sections, as well as alterations to the chainage locations (easily done by finding the chainage corresponding to the bridge location). It takes a couple of hours of work to alter and implement the bridges now that we have them in tabular form.

7.3 Bridges in the “mosaic” network

The bridge chainage locations are calculated in a network by translating the UTM coordinates into chainage using the branch and the UTM locations.

The chainages in the Mosaic network as well as the UTM coordinates corresponding to those chainages are shown in Table 7.3. The UTM coordinates are different because the Mosaic network often does not match with the MoE network. The bridge locations are altered as much a 100 m.

The inverts that were estimated from the MoE survey data cannot be used in conjunction with the Iran Systems DEM because the two elevation data sources do not correspond. We repair this by estimating the inverts of the culverts from the Mosaic cross-sections and then assume that the road elevation is the same relative to the culvert, and of course the geometry is kept the same.

Table 7.4 shows the inverts estimated from the Iran Systems cross-sections along with the road elevation (same relative to the invert) and the difference between the invert and the invert from the MoE sections. It is hardly surprising that the invert elevations are very different with the two data sets.

Table 7.3 Bridge locations in network based on MoE data and Iran Systems DEM.

	Network based on MoE survey			Network based on Iran Systems		
Bridge	**Easting (m)**	**Northing (m)**	**Chainage (m)**	**Easting (m)**	**Northing (m)**	**Chainage (m)**
Dasht Bridge	413,133	4,131,946	694	413,151	4,131,958	670
Existing Bridge	411,847	4,135,223	5,895	411,851	4,135,224	5,734
Existing Bridge	410,105	4,136,355	8,240	410,110	4,136,366	7,998
Existing Bridge	404,351	4,136,462	14,499	404,351	4,136,462	14,258
Existing Bridge	402,910	4,136,485	15,950	402,920	4,136,521	15,713
Existing Bridge	402,369	4,136,880	16,652	402,379	4,136,895	16,379
Existing Bridge	401,651	4,137,308	17,559	401,667	4,137,329	17,321
Existing Bridge	401,239	4,137,809	18,234	401,261	4,137,839	18,000
Existing Bridge	400,389	4,138,182	19,200	400,387	4,138,203	18,971
Existing Bridge	399,276	4,137,850	20,466	399,274	4,137,854	20,223
Existing Bridge	397,880	4,138,158	22,004	397,872	4,138,109	21,700
Mosque Bridge	393,326	4,139,646	28,032	393,322	4,139,722	26,999
Besholy Bridge	385,966	4,138,451	37,474	385,928	4,138,501	35,336
Loveh Bridge	380,955	4,136,124	44,854	380,950	4,136,048	41,214
Agha Mish Bridge	377,263	4,135,087	49,749	377,245	4,135,204	45,150
14 Metry Bridge	375,322	4,134,787	52,682	375,326	4,134,825	47,121
7 Culverts	375,304	4,134,803	52,707	375,307	4,134,827	47,141
Ajen Ghare Khajeh	370,976	4,134,762	59,891	370,967	4,134,886	51,708
Kalaleh Bridge	366,976	4,135,633	64,980	366,977	4,135,630	56,401

Table 7.4 Culvert and road elevations for the bridges estimated from the Mosaic cross-sections. The "Difference" is to the MoE section estimated elevations.

ID	Bridge	Chainage (m)	Culvert (m)	Road (m)	Difference (m)
1	Dasht Bridge	670	959.0	960.5	6.0
2	Existing Bridge	5,734	870.5	872.0	8.7
3	Existing Bridge	7,998	801.5	803.0	-12.0
4	Existing Bridge	14,258	663.7	665.2	-11.1
5	Existing Bridge	15,713	630.5	632.0	-10.0
6	Existing Bridge	16,379	625.5	627.0	2.0
7	Existing Bridge	17,321	594.5	596.0	-12.0
8	Existing Bridge	18,000	591.0	592.5	-2.5
9	Existing Bridge	18,971	590.5	592.0	13.5
10	Existing Bridge	20,223	564.5	566.0	6.0
11	Existing Bridge	21,700	542.5	544.0	9.5
12	Mosque Bridge	26,999	463.3	468.3	6.3
13	Besholy Bridge	35,336	355.0	360.0	7.0
14	Loveh Bridge	41,214	292.5	295.5	11.5
15	Agha Mish Bridge	45,150	247.0	249.0	1.0
16	14 Metry Bridge	47,121	226.5	234.7	-2.3
17	7 Culverts	47,141	228.7	230.7	-2.3
18	Ajen Ghare Khajeh	51,708	187.5	191.5	11.5
19	Kalaleh Bridge	56,401	152.0	159.0	19.0

7.4 Backwater calculations in the mosaic MIKE 11 model

The bridges were tested in the "mosaic" MIKE 11 model to make sure there were no nasty surprises when we constructed the final MIKE 11 model.

Backwater was calculated for a discharge of 1600 m^3/s and with two different Manning n values, n=0.04 $s/m^{1/3}$ and n=0.2 $s/m^{1/3}$, see Figures 7.9-10. The magnitude of backwater is not too different from the backwater we calculated with the MoE survey cross-sections for the low resistance (n=0.04 $s/m^{1/3}$), while the backwater magnitude is much lower with the high resistance (n=0.2 $s/m^{1/3}$).

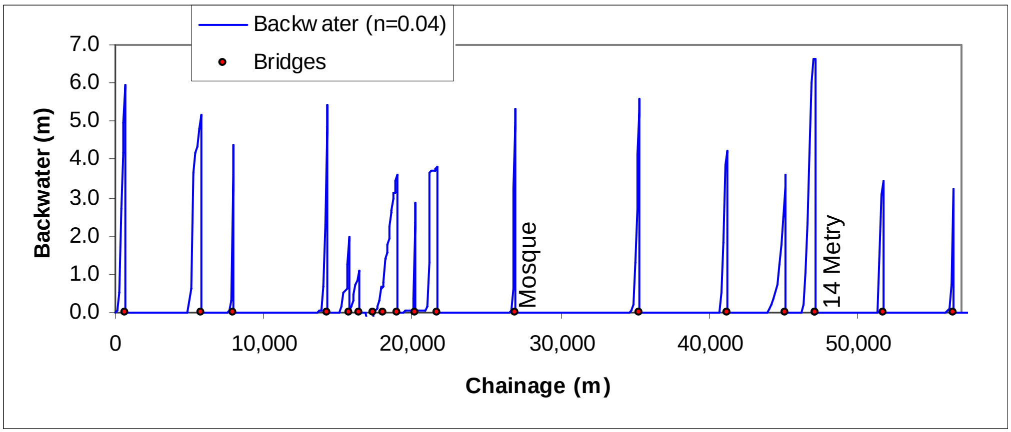

Figure 7.9 Bridge backwater (water level with bridges minus water level without bridges) calculated with "Mosaic" MIKE 11 model with a Manning n=0.04 $s/m^{1/3}$.

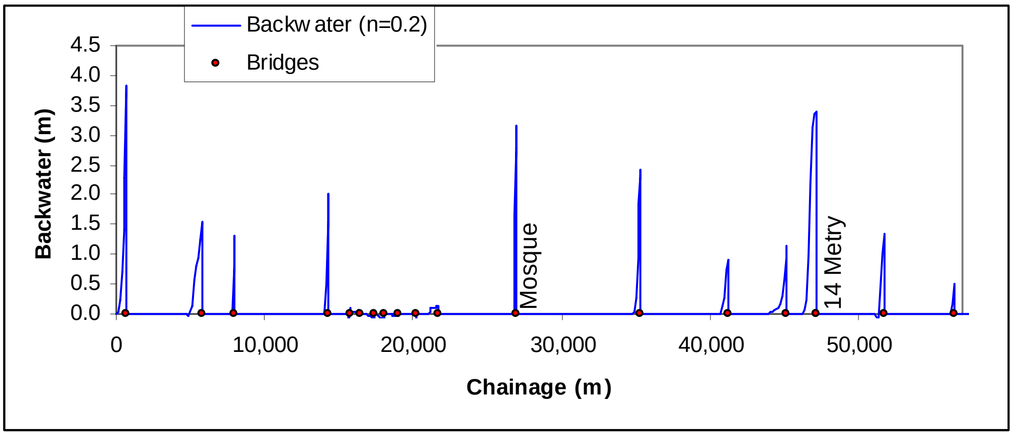

Figure 7.10 Bridge backwater (water level with bridges minus water level without bridges) calculated with "Mosaic" MIKE 11 model with a Manning n=0.04 $s/m^{1/3}$.

To understand why it is so, we need to look at how the backwater is calculated. The dominating part of the water overtops the road over the Golestan Forest bridges (about 100 m^3/s goes through the culverts), and the discharge dictates the water level upstream of the structure through the weir Q-H relation. This energy equation dictates water level is independent on the flow resistance, while the water level without the bridge present will be higher for high resistance. Hence the presence of the bridge has a larger effect with a low resistance because the water level is forced higher than it would be without bridge. This is exactly what we see when comparing Figures 7.9-10.

The bridges in Golestan Forest are literally "drowned" so their backwater effect disappears with the high (more realistic) resistance. We did not expect to find this, but it is fully reasonable, and possibly even an effect sought with the design of the bridges.

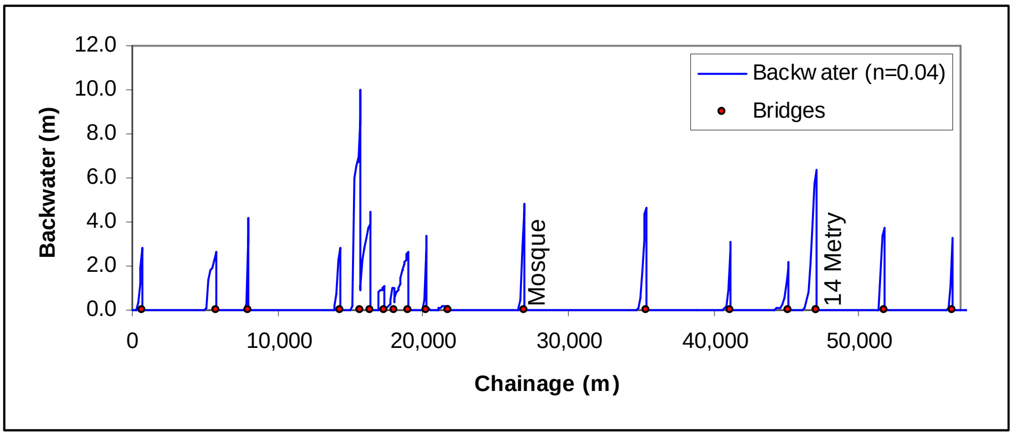

Figure 7.11 Bridge backwater (water level with bridges minus water level without bridges) calculated with "Mosaic" MIKE 11 model with a Manning n=0.04 s/m$^{1/3}$, and modified level-width curves that match the cross-sections.

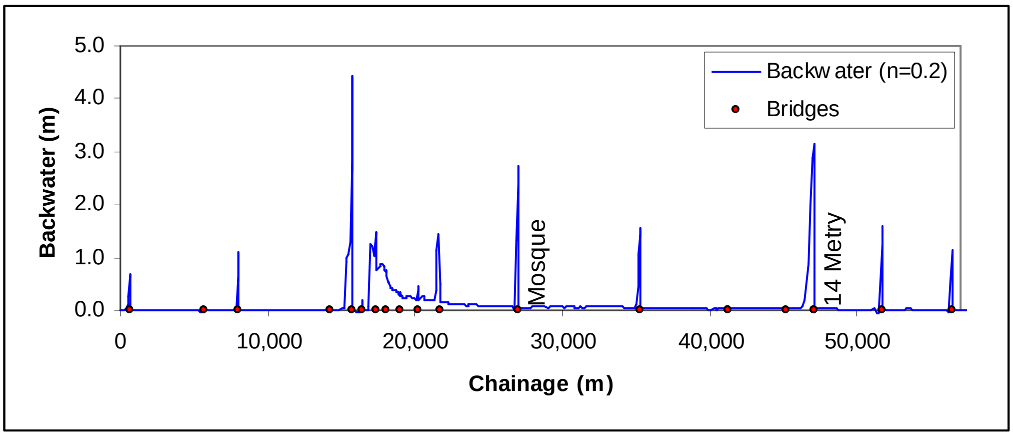

Figure 7.12 Bridge backwater (water level with bridges minus water level without bridges) calculated with "Mosaic" MIKE 11 model with a Manning n=0.20 s/m$^{1/3}$, and modified level-width curves that match the cross-sections.

It is more reasonable to recalculate the level-width curves of the weirs based on the new cross-sections, which we did not do in the first attempt. By not doing so we might get a wider road opening than the upstream/downstream sections, which requires some manipulation of the energy equation to function.

Instead we recalculated the weir level-width curves from the mosaic cross-sections and reran the bridge backwater calculations, and the results are shown in Figures 7.11-12.

The effect of the flow resistance is the same, which it should be, while backwater is different. Most bridges in Golestan Forest are no longer drowned, which is due to the narrower valley being represented in the level-width curve (narrower brings up the backwater). The first five bridges in Golestan Forest (from Tangrah) actually bring the water level up in a cascade, which results in an overall raised water level along the reach with many bridges.

It is most realistic to use level-width curves that conform to the cross-sections.

7.5 Inclusion of debris flow in mosaic model

Herein we describe the inclusion of the debris flow in the mosaic model.

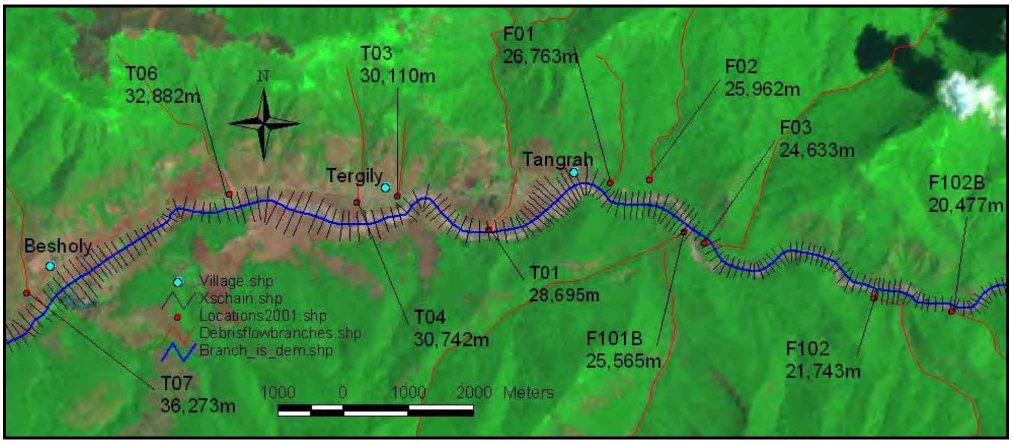

Figure 7.13 The eleven debris flow tributaries and the chainages in the Madarsoo network to which the debris flow time-series are added.

The debris flow is added at the 11 chainages shown in Figure 7.13 as point source dropping sediment into the MIKE 11 model. The distribution is taken from the expression given in section 4 with 80% chosen as the limit (a=0.8).

7.6 MIKE 11 morphological model parameters

The choice of Manning n=0.2 s/m$^{1/3}$ is mostly based on experience and our impression of the river system. Most of this resistance is actually form resistance from trees, rocks etc, and form resistance should not be counted in the sediment transport shear stress.

Under normal circumstances we would also resolve both the river channel and the floodplain, and then calculate the sediment transport in the river channel. For the present application this is not reasonable, as the debris will clearly be deposited and transported all over the inundated cross-section for flood conditions.

The demonstration model made in February 2005 (DHI, February 2005) employed the Meyer-Peter formula.

The Meyer-Peter formula is normally a fairly good choice for coarse sediment transported as bed-load. However, in MIKE 11 there is a modification of the Shields parameter used in the Meyer-Peter formula, which does not give good results when using the Manning n=0.2 s/m$^{1/3}$ that we are using.

Instead of the Meyer-Peter formula we employ the Engelund-Hansen formula where the sediment transport is reduced to 50% to account for the fact that not all the resistance is shear stress. This reduction factor was estimated by matching the sediment transport for low and high resistance.

7.7 Model based on Final Iran Systems DEM

Iran Systems came back with an improved DEM on September 12 2005 during the last week of the DHI expert's stay in Iran for Phase 2. Time was very short, but it was nonetheless decided to let this DEM replace the mosaic DEM that was created earlier by the DHI expert in the model application. The final Iran Systems DEM is better than the mosaic DEM and the DEM could be matched with the Quick Bird satellite image.

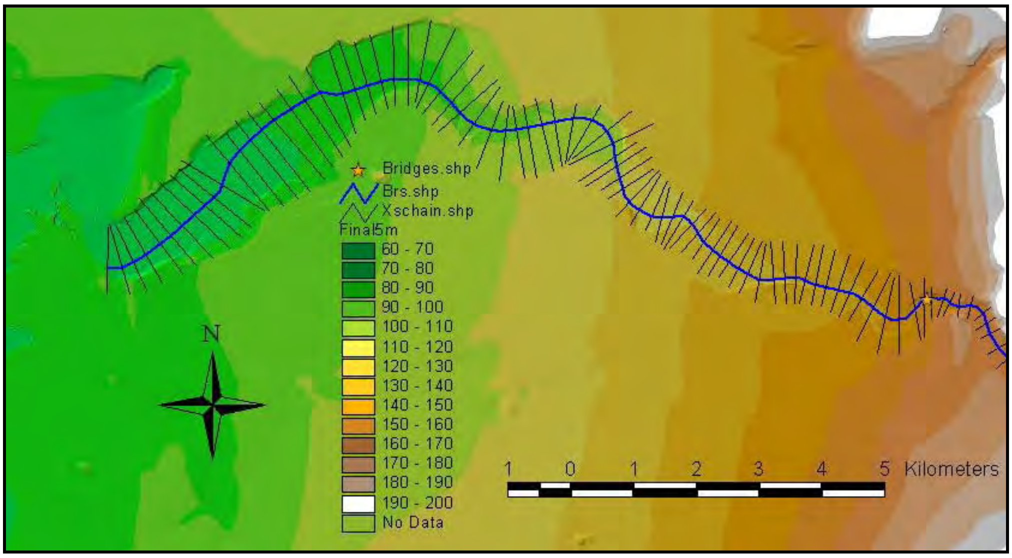

Figure 7.14 Downstream end of the Iran Systems DEM received on 12 September 2005. The DEM is vastly improved over the DEM received in August in which the terrace was not represented.

Figure 7.14 shows the final Iran Systems DEM in the downstream end. The DEM is only slightly altered further upstream, and hence matches the mosaic DEM that we created earlier. The DEM now resolves the terrace, which is decisive for flood mapping. On a side note the Madarsoo downstream floodplain elevation is 67 m in the DEM, while the Golestan reservoir spillway is at 62 m elevation.

The following modifications were made to the model to conform to this new DEM:

- The DEM had two depressions in the upstream end with a local elevation drop of about 50 m; these depressions were removed manually. Such depressions were also present in older versions of the Iran Systems DEM. The depressions may not seem like much, but they can cause big troubles in a hydraulic model that wants to fill up the depressions with water.
- The branch (MIKE 11 network) that was created for the mosaic model was reused; no changes made. Changes to the network require recalculation of boundary conditions and bridge locations, which are fairly significant tasks.
- The cross-section lines (553 lines) were reused as well without modifications. The flood maps are generated without a mask, so flooding is allowed outside the cross-section coverage.
- The 553 cross-sections were extracted from the final DEM in GIS and exported to ASCII format that can be imported in a MIKE 11 cross-section database.
- Cross-sections just upstream and downstream of bridges were copied from the mosaic model in order to ensure compatibility with the bridge inverts. For Kalaleh Bridge the situation required redefinition of the Kalaleh Bridge invert, where we found 147 m as appropriate for the culvert invert (still does not match at all with the MoE elevations).
- The modifications were then inserted into the mosaic model framework where the boundary conditions are all reused except the downstream water level that had to be set to 68 m to match the final DEM.
- The modified model was used for simulation of the 25, 50 and 100 year events and flood maps were generated from these simulations as well as flood animations from the flood maps.

CHAPTER 8 MODEL APPLICATIONS

At this point we have a "functional" MIKE 11 model that we will use in preliminary simulations. This constitutes the deliverables as per the scope of work for this Phase 2 of the project. The model is constructed with the following:

- DEM: Final Iran Systems DEM with improvements in downstream end compared to earlier "final" DEM.
- Cross-sections: Extracted from Final Iran Systems DEM, ignore MoE sections.
- Madarsoo network: Digitized from Final Iran Systems DEM; not fully compatible with MoE survey data or satellite imagery.
- Two different models are applied. An overall HD model with bridges included, but no debris flow, while a local model in the debris prone reach is used for determining the impact of debris flow.
- Scenarios: 25 year, 50 year, 100 year floods defined through boundary conditions and source points.
- The local model takes the discharge from the overall model in the point corresponding to the inflow boundary of the local model and uses the same lateral and tributary inflows that are in the local model reach.
- Bridges: Implemented with elevations estimated from the Final Iran Systems DEM cross-sections
- Debris flow: Time-series prepared by using a=0.8 for all five scenarios, defined as sediment sources at 11 different locations. All the debris is taken as the coarse fraction (54 mm) at this point.
- Sediment: 0.5 mm and 54 mm fractions, Engelund-Hansen sediment transport formula.
- "Calibration": Manning n=0.2 s/m$^{1/3}$
- The following simulations are carried out:
- 25, 50, 100 year floods (overall HD)
- 100 year flood (local HD+ST) with and without debris included in order to isolate the impact of the debris

8.1 Results for overall MIKE 11 HD model

The results for the overall MIKE 11 HD model are presented herein:

- Animation of the 100 year flood
- Flood maps 25, 50 and 100 year floods
- Road overtopping between 14 Metry Bridge and Tangrah
- Water depth over the 14 Metry Bridge deck

8.1.1 Animation of the 100 year flood

Two animations were made from the 100 year flood:

- 742 satellite image as background
- Quick Bird image as background

The Quick Bird animation is pending until the Quick Bird image has been processed. Figure 8.1 shows every second hour (10 August 22:00 to 11 August 22:00) of the animation with the 742 image background.

These animations are available at the JICA study team office. It is noted that the model is not designed for low flow, as it does not represent the river channel itself (this requires that the survey sections and the DEM are compatible). Therefore the animations should only be viewed for the peak flows and how the flood peak migrates through the Madarsoo valley and floodplain.

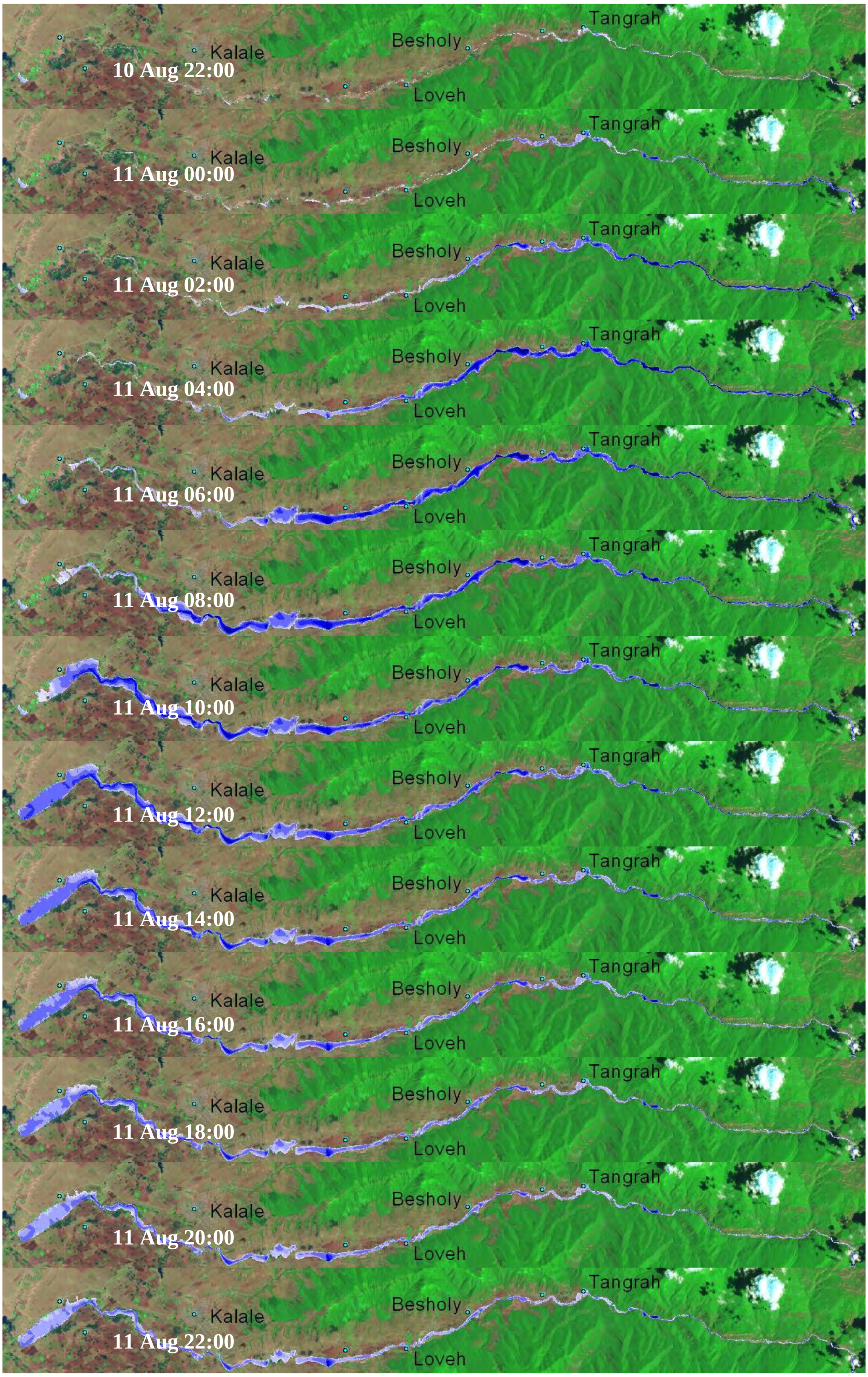

Figure 8.1 Flood maps (100 year event) from the animation with the 742 satellite image.

8.1.2 Flood maps

Flood maps have been delivered to the JICA team GIS expert for use in hazard map preparation. For the sake of completeness the raw (non-processed) maps that were produced with MIKE 11 GIS are shown in the following, see Figure 8.2.

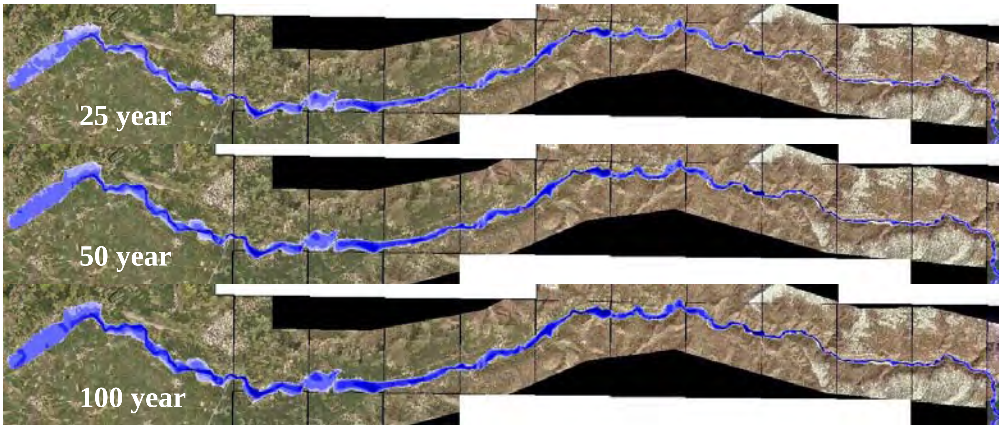

Figure 8.2 Flood maps based on simulated maximum flood levels, from top 25 years, 50 years and 100 years return period.

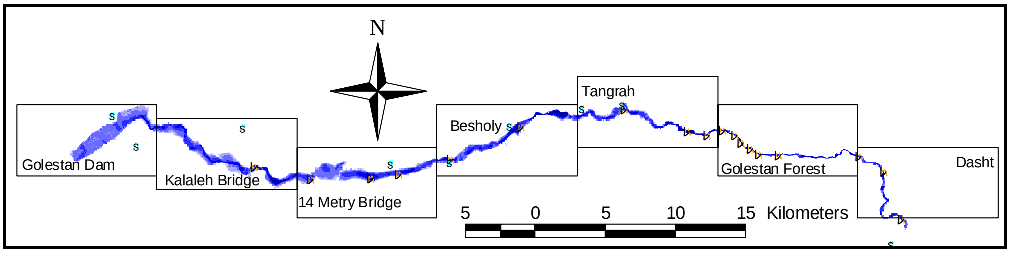

Figure 8.3 The seven (10 km long starting from 360 km Easting UTM-40) areas where the flood maps are shown in Appendix A.

Appendix A contains detailed flood maps for the 100 year flood in the seven areas shown in Figure 8.3.

8.1.3 Comparison with flood markers for the 2001 flood

Flood markers for the 2001/2002 floods were obtained by the JICA team in January/February 2005. The flood markers are the only means of calibrating the model, as no water level gauge data is available for flood conditions.

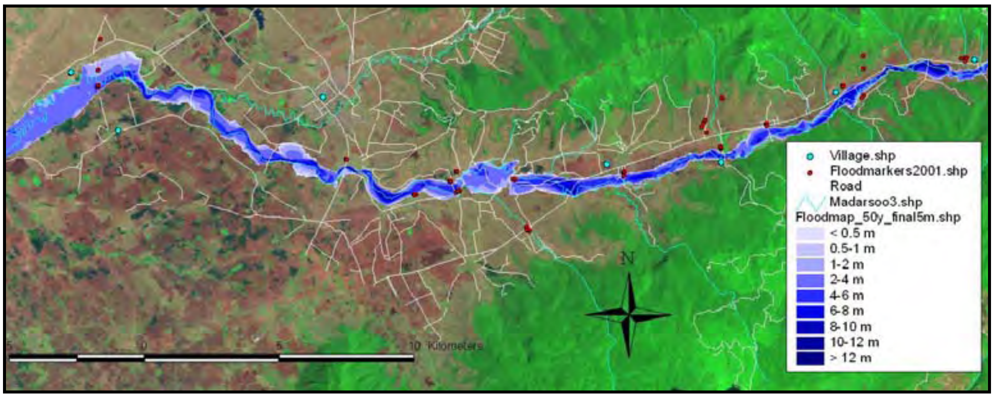

Figure 8.4 Comparison between the 50 years flood extend and flood markers for the 2001 flood.

In order to be useful for calibration of the model, flood markers should be taken along the edge of the flood extend and the DEM has to be accurate. Having these two conditions fulfilled means that the flood markers can be used for estimating the maximum water level, which can then be used for adjusting the model resistance number. Unfortunately these conditions are not met with the flood markers, as seen in Figure 8.4.

8.1.4 Road overtopping between 14 Metry Bridge and Tangrah

Herein we determine where Tangrah Road is overtopped as well as the flood depth over the road between 14 Metry Bridge and Tangrah for the 100 year flood event.

Again it is stressed that the Iran Systems DEM is unreliable, but nonetheless the results at least seem qualitatively correct.

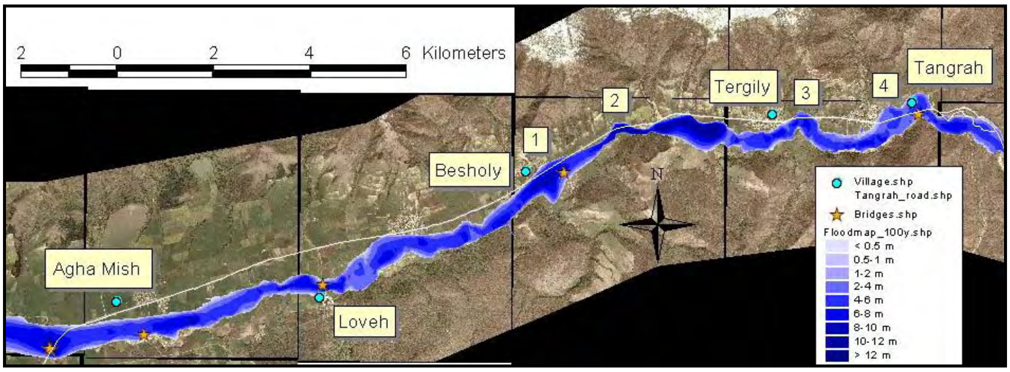

Figure 8.5 Overtopping of Tangrah Road between 14 Metry Bridge and Tangrah determined from the 100 year flood map and the location of Tangrah road (from 1:25,000 map confirmed with GPS points). Four locations (1-4) are identified from this map.

Figure 8.5 shows the 100 year flood map on the Quick Bird image and the Tangrah Road. Four locations (1-4) are identified from this map. These four locations are shown in detail in Appendix B, and are analyzed in the following.

Area 1 just upstream of Besholy is seen to have a depression between the river location and the road (deeper water between the river and the road than in the river), which makes the DEM in this area dubious. Tangrah road actually runs through a local depression as well here, which causes the inundation of the road. The water depth on the road exceeds 6 m according to the model simulation for the 100 year flood.

Area 2 between Besholy and Tergily has a very narrow floodplain, which partly causes the inundation of the road. According to the model calculation the water depth on the road is as high as 10 m, which seems unrealistically high. However, according to the Iran Systems DEM the road actually runs into a depression and is only 2 m above the riverbed elevation.

Area 3 just upstream of Tergily has a water depth up to 5 m above the road level. Again the picture is the same when looking at the contours.

Area 4 just upstream of Tangrah is close to the Mosque, and it is known as a narrow reach where the Madarsoo inundated Tangrah Road during the 2005 flood (roughly 25 year return period). According to the model the flood depth should be as high as 7 m over the road here.

The water depths determined here are most likely exaggerated, but there is nothing we can do about this; it is all controlled by the Iran Systems DEM.

8.1.5 14 Metry Bridge

The water depth above the road over 14 Metry Bridge was determined from the simulation results. The water depth over the weir was not directly available in the result file, but was determined by combining the result files with information about the weir Q-H relation.

Table 8.1 Calculation of water depth above 14 Metry Bridge for 25, 50 and 100 year peak discharge

Return period (years)	Peak flow (m^3/s)	Peak water level upstream (m)	Peak weir water level (m)	Water depth over weir (m)	Width of river, flood maps (m)
25	1363	235.82	235.36	0.66	650
50	1913	236.17	235.56	0.86	680
100	2527	236.53	235.78	1.08	700

The Q-H relation for the weir is used as an internal condition on the discharge over the weir as function of the upstream water level. The Q-H relation in the MIKE 11 network contains this Q-H curve and also a similar curve for the Q-H relation over the weir (road). The methodology is to determine the upstream water level from the MIKE 11 results and then determine the discharge over the road (about 300 m^3/s goes through the arch), and then use the Q-H relation for the weir itself to determine the water level.

The results are shown in Table 8.1; 66 cm, 86 cm and 108 cm water depth over the 14 Metry Bridge deck for 25, 50 and 100 year peak flows.

8.1.6 Appropriate simulation period for MIKE 11 HD+ST model

To save time, the debris flow simulations were only carried out with a local model and only for the 100 year event.

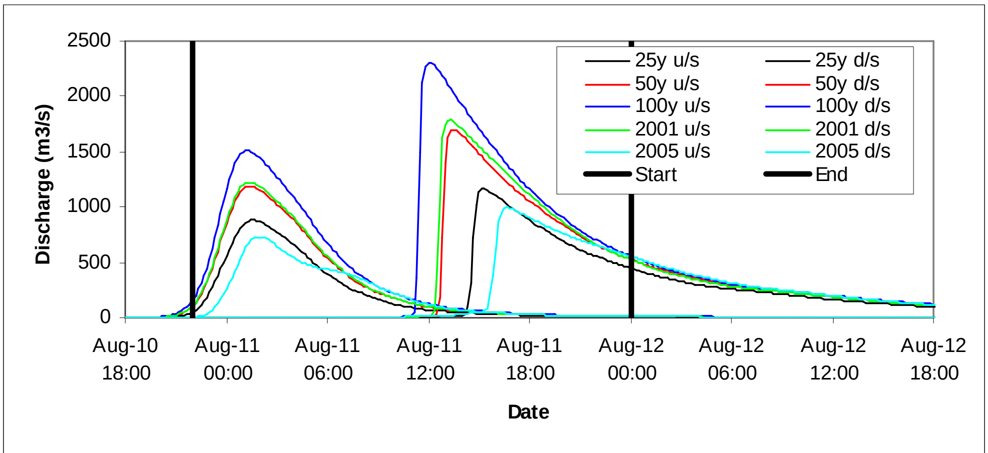

Figure 8.6 Upstream discharge (boundary condition) and downstream discharge (simulated) from the MIKE 11 HD model for each of the scenarios. Note that each scenario starts on 10 August, except the 2005 flood that starts 9 August. For better representation we moved the 2005 flood to start on 10 August in this figure. The simulation period to be used for the HD+ST models is selected as 10 August 22:00 to 12 August 00:00 (9-11 August for 2005 flood).

The HD+ST simulations are CPU demanding, so it is important to cut the simulation period to only what is necessary. By looking at the results of the HD simulations, see Figure 8.6, we identified the period as 10 August 22:00 – 12 August 00:00. For the 2005 flood the period is moved two days back, i.e. 9-11 August.

8.2 Results for local MIKE 11 HD+ST model

The debris model simulations are carried out both with and without debris flow included, which allows a quantification of the debris flow impact. The following results are presented herein:

- Temporal variation of the debris dams
- Bed and water level profiles
- Surging effect
- Flood maps and flood extends

8.2.1 Temporal development of the debris dams

The temporal development of the simulated debris dams is investigated for all the debris inflow points. As we have seen already, the tributaries peak a couple of hours before Madarsoo, and hence debris flow will enter the river before the floodwaters from further upstream. This means that the debris dams will be formed before the floodwaters arrive. In the following we investigate when the debris dams are eroded.

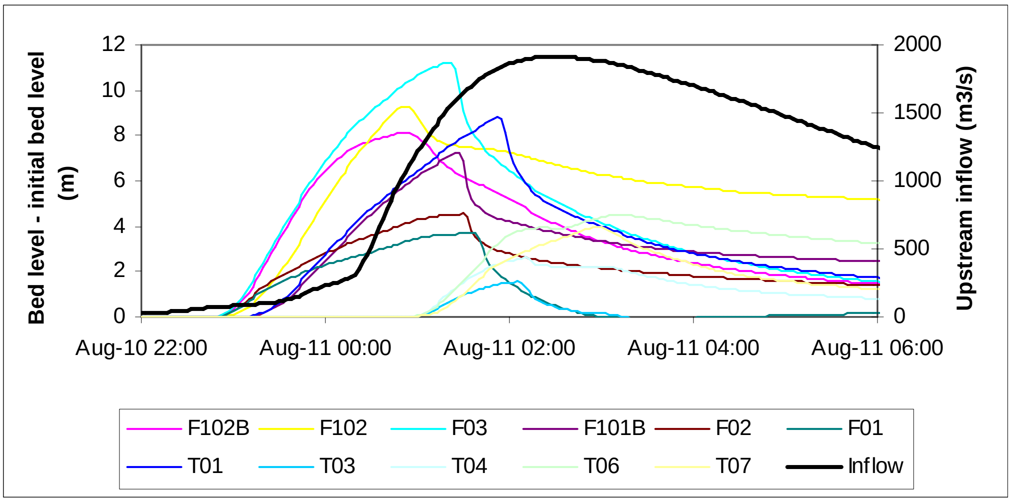

Figure 8.7 Temporal development of the bed level minus the initial bed level for all the debris dams shown along with the water inflow.

Figure 8.7 shows the temporal variation of the bed level in each debris inflow point where the initial bed level has been subtracted for better graphical presentation. It is seen that the debris dams are actually eroded before the 100 year flood peak arrives. Note how quickly the debris dams collapse when the discharge passes a threshold.

The timing of the erosion of the debris dams is sensitive to the calibration parameters, especially the sediment transport capacity. If lowered, the debris dams will last longer and cause more flooding.

The results suggest that the relative impact of debris flow will bigger for smaller flood events that cannot erode the debris dams on the rising limb. This can be investigated in the project Phase 3 (scheduled for January-February 2006).

8.2.2 Bed level and water level profiles

Here we look at the longitudinal profiles of the maximum water level and bed level in the two simulations with and without debris flow included, as well as the difference between the two simulations. Figure 8.8-9 shows the longitudinal profiles of the water level and bed level. The localized effect of the debris flow is seen clearly. Figure 8.10 shows the difference between the two simulations (with and without debris flow). It is worth noting that the bed level difference is higher than the water level difference because the debris dams start eroding before the flood peak arrives. The backwater effects from debris deposits can be felt up to 1 km upstream of the debris deposit.

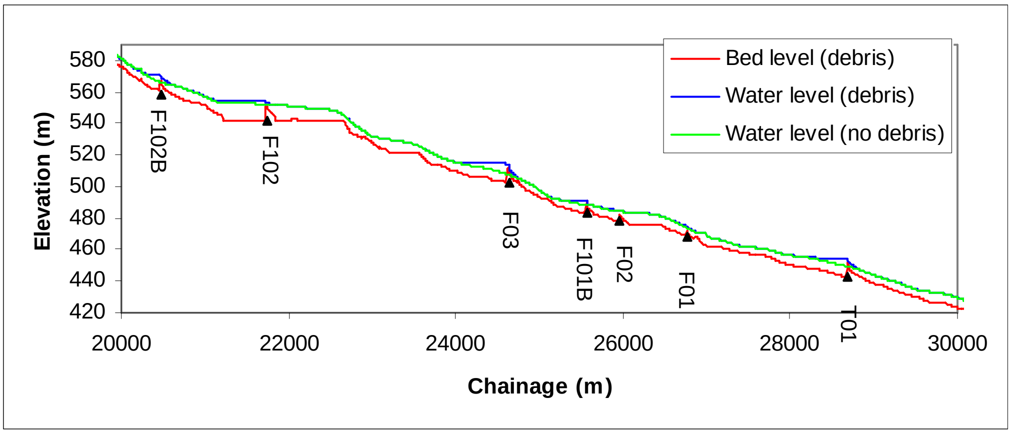

Figure 8.8 Profiles of the maximum water level (with and without debris) and maximum bed level (with debris) for the debris flow simulation with the 100 year event, upstream part of the local debris model.

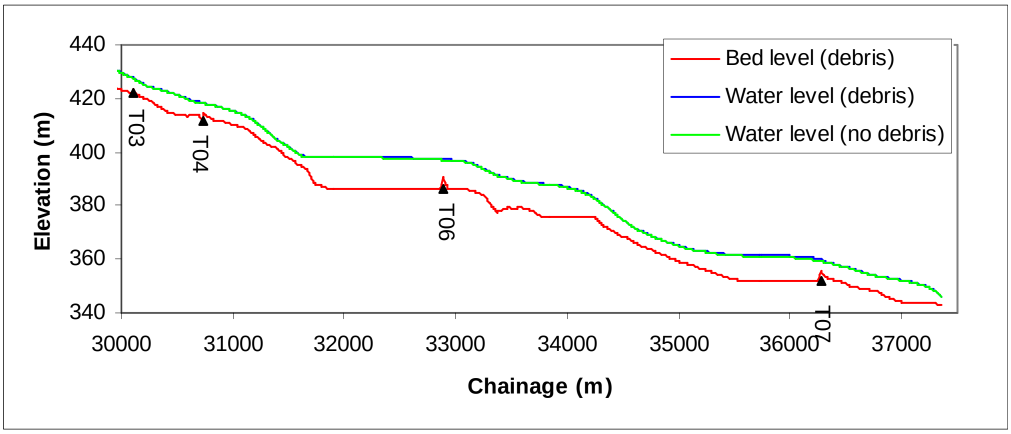

Figure 8.9 Profiles of the maximum water level (with and without debris) and maximum bed level (with debris) for the debris flow simulation with the 100 year event, downstream part of the local debris model.

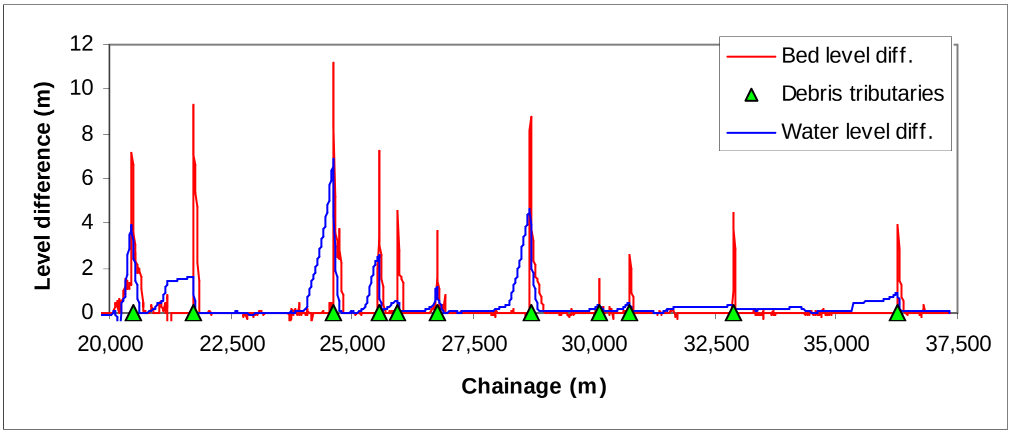

Figure 8.10 Difference in maximum bed and water level caused by the presence of debris flow (100 year event).

8.2.3 The surging effect

During the initial phase of the flood where the debris dams are formed, the debris dams will store some water, which is released when the debris dams are eroded. The surging effect of the debris flow is quantified by looking at the temporal and longitudinal variation of the simulated discharge.

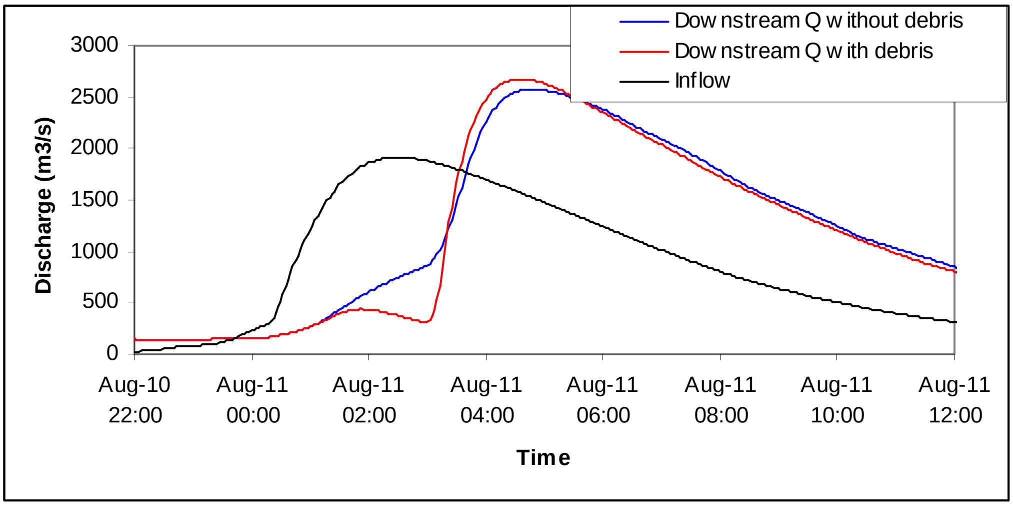

Figure 8.11 Temporal variation of the downstream discharge in the local debris model with and without debris flow included.

First the temporal variation of the discharge at the downstream end is investigated, see Figure 8.11. The figure shows that the debris reduces the downstream discharge in the beginning of the flood; water is held back behind the debris dams. This stored water is then released as the debris dam is eroded by the flood water, and the peak discharge increases about 100 m^3/s, which is not insignificant.

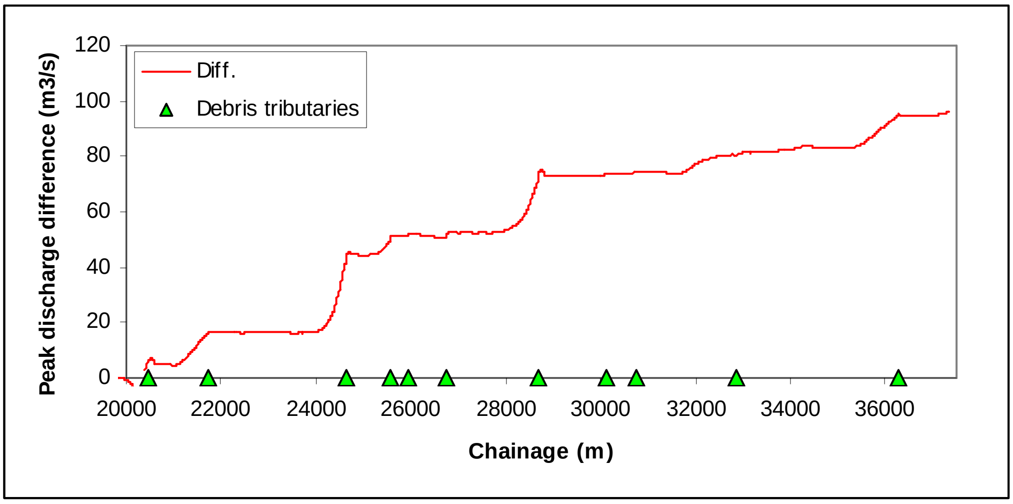

Figure 8.12 The longitudinal variation in the difference in peak discharge (with debris minus without debris) down through the local model.

The longitudinal variation of the peak discharge is shown in Figure 8.12. It is seen that each debris dam gives rise to an increase in the peak discharge, and obviously the most important contributions are made by the large debris contributors, like F03 (24,633 m) and T01 (28,695 m).

The presence of debris flow is estimated with the model to increase the 100 year peak discharge by about 100 m^3/s downstream of the debris flow prone reach. The model shows that the debris increases the 100 year peak discharge in the downstream end of the debris prone area from 2580 m^3/s to 2676 m^3/s, which is an increase of 3.7% in the peak flow.

8.2.4 Flood maps and flood extend

The results of the HD+ST model are used for mapping the floods in MIKE 11 GIS.

The flood map calculated with debris flow included is shown in Figure 8.13. The flood map does not deviate much from what was already determined for this area with the HD model; debris flow is a secondary effect.

The effect of the debris flow was found by making a comparison map in MIKE 11 GIS. Such a map contains the difference in water depth between the two simulations, including areas where there is flooding with debris and not without. The comparison map is shown in Figure 8.14, and it shows what we have already seen from the water level difference (the flood maps are based on 2D maps of the 1D water level and the DEM), namely that the water depth will be increased locally behind a debris dam. The biggest impacts are found for the T01 and F03 tributaries with the water depth increasing more than 5 meters. The F03 tributary is just downstream of a camping area in Golestan Forest.

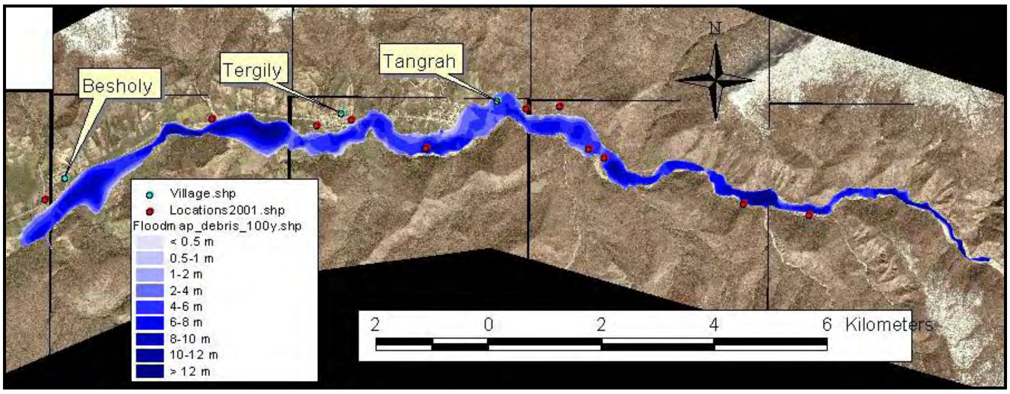

Figure 8.13 Flood map for the local model (100 year flood, maximum flood level) with debris flow included.

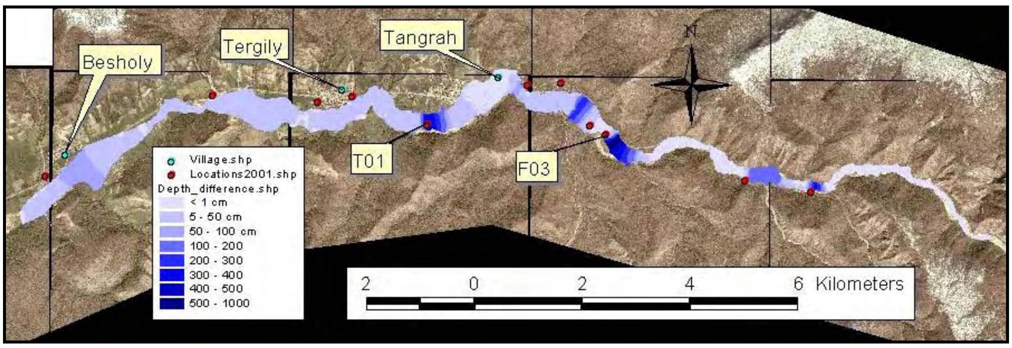

Figure 8.14 Comparison map (maximum depth with debris minus maximum depth without debris) for the 100 year flood.

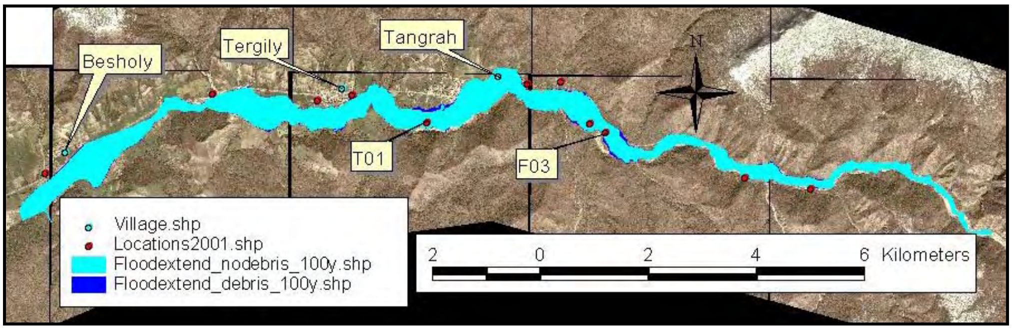

Figure 8.15 Flood extend with and without debris flow for the 100 year flood.

Finally we look at the flood extend with and without debris, see Figure 8.15. The impact of the debris flow in terms of flood extend is seen to be generally small; the impact on the local water depth is much higher. This was anticipated from the very beginning of the project due to the steep valley side slopes.

The flooded areas (100 year event) in the two cases are found from the flood extend polygons:

6,373,500 m^2 with debris flow

6,200,600 m^2 without debris flow

The length of the local model is 20,834 m, which gives an average width with debris of 306 m and without debris 298 m, and an impact of the debris of 8 m increase in width, or 2.8% (also for the flooded area).

The area difference is 172,900 m^2.

CHAPTER 9 SUMMARY OF ACTIVITIES CARRIED OUT 6 AUGUST – 17 SEPTEMBER 2005

The following activities were conducted under Task 1 – Obtain and Review Data:

- **Field inspections (Finalized Task 1-1)**: A field trip was conducted on 14 August 2005. There were two main purposes with the trip, namely to verify the location of Ajen Ghare Khajeh Bridge (not accounted for earlier) and to inspect the downstream end of the river. For the downstream end we found that it is not part of the reservoir, as earlier claimed by MoE, and based on this and the discrepancies between the MoE cross-section data and the Iran Systems DEM, the MoE data can effectively be discarded as very dubious. We took 82 GPS points on the trip, which were useful for verification purposes.

- **Cross-section data (Nearly Finalized Task 1-2)**: As stated above, the MoE cross-section survey data has been discarded, as it is incompatible with the Iran Systems DEM and furthermore dubious. In addition the MoE sections are not wide enough to house the flooding. Instead the cross-sections for the hydraulic model were extracted directly from the DEM. 553 sections were drawn in ArcView and extracted with MIKE 11 GIS to a MIKE 11 cross-section database. The DEM does not resolve the river channel itself, so the model cannot be applied for low flow. In addition the MIKE 11 network was no longer defined from the MoE survey data, but instead drawn from the Iran Systems DEM and the network follows the path of the floodwaters rather than the river channel. Changes to the DEM need to be accompanied by updating the cross-sections.

- **Aerial photos/imagery (Nearly Finalized Task 1-3):** Quick Bird satellite images were received, but were badly geo-referenced in the downstream end (Kalaleh Bridge to Golestan Dam), so they had to be modified and still are being edited by the JICA team GIS expert. The older 742 satellite image was also obtained from the MOJA GIS section, and it was useful for checking the river path before the Quick Bird image became available. The Quick Bird image will be used as background for flood maps. Though the imagery has been received, there is still work to be carried out in cleaning up the images for presentation use, which will be done by the JICA team GIS expert.

- **Bridges (Nearly Finalized Task 1-4):** As noted, an additional bridge (Ajen Ghare Khajeh) was identified on the field trip 14 August 2005. All 19 bridges have been processed into tables with geometry and inverts for a culvert (bridge opening) and a weir (bridge deck). The bridges were hence made ready for implementation in the model. The backwater effect was tested with the MoE cross-sections and sections from the Iran Systems DEM, and it was found that the backwater is less pronounced with the more realistic resistance used in the final model than we found earlier. The only outstanding task here is to alter the inverts if the DEM is altered.

- **Other structures (Finalized Task 1-5):** No other structures were implemented.

- **Hydrometric data (Finalized Task 1-6):** The model was designed for flood conditions where no gauges thus far have survived. In addition gauge datum does not seem to be reliable. Discharge and rainfall data have been collected and applied by the hydrologists on the project, and in the hydraulic model we see this through the boundary conditions (Task 3).

- **Meteorological data (Finalized Task 1-7):** Rainfall data etc was collected and applied in the hydrological modeling. Meteorological data is not directly relevant for the hydraulic model.

- **Coarse DEM (Finalized Task 1-8):** The MOJA 85 m DEM was obtained already when the project was initiated. The DEM actually looked like it would be applied in the flood maps, but Iran Systems came along on 12 September with a new DEM that seems correct in the downstream end.

- **Fine resolution DEM (Ongoing Task 1-9):** Iran Systems came with a DEM on 24 August; a DEM which we must stress does not live up to the standards for flood mapping. In particular the downstream end was beyond dubious as it did not resolve the terrace and incised floodplain. Later (September 12) Iran Systems came with a much improved DEM in which the downstream end looks much more convincing. However, there are still major discrepancies between the DEM and the satellite images, i.e. the flood mapped river not being where the image says it is. The Iran Systems DEM is a shortcoming in the model; the poor quality seriously hampers the quality of the JICA study team output.

- **Sediment data (Finalized Task 1-10):** This was dealt with in February 2005 and reported by DHI (February 2005). Nothing more has been done on this task.

Task 2 – Preliminary 1D Hydraulic Modeling was finalized in February 2005.

Task 3 – Rainfall Runoff Modeling was carried out by the DHI hydrologist in collaboration with the JICA team hydrologist. The following activities are covered by Task 3:

- **NAM model construction (Finalized Task 3-1):** The original plan was to use the NAM rainfall runoff model. However, it was altered to the much more advanced MIKE SHE calculating overland flow from the spatial rainfall coupled to MIKE 11 representing the flow in the rivers and tributaries.

- **NAM model calibration (Finalized Task 3-2):** This was replaced by calibration of the MIKE SHE model coupled to MIKE 11.

- **Altered vegetation model (Finalized Task 3-3):** The effect of vegetation was studied with the hydrological model and reported by DHI (June 2005).

- **Runoff Time-series (Nearly Finalized Task 3-4):** In this task the results of the rainfall runoff model are processed into boundary conditions for the hydraulic model. Five scenarios (25 year, 50 year, 100 year, 2001 and 2005) were carried out by Dr. Lamsal and result files delivered to the DHI hydraulic modeling expert. The result files were processed into time-series for the tributary and lateral flows as well as MIKE 11 boundary conditions input files with point sources for all these inflows. The processing of the boundary conditions has been done in a manner that allows transformation to another branch, which will have to be done, if we obtain a realistic path of the river from an elevation data source that matches with the satellite images. The boundary conditions are presently transformed to the network digitized from the Iran Systems 2 m contours. The only outstanding task is the processing into the final Madarsoo network, which can be done in a few hours, once we have decided upon the final network.

<u>Task 4 – Debris Flow</u> was originally planned to be carried out with a soil erosion model, but the original plan had to be altered because the debris consists of very coarse material. It was therefore necessary to improvise:

- **Catchment delineation (Finalized Task 4-1):** The catchments were delineated and the drainage area determined for each catchment. The drainage areas were used in the debris yield calculation.

- **Soil erosion (Finalized Task 4-2):** This task was dropped and replaced by calculations of the debris yield from the Los Angeles District Debris Method.

- **Identify debris prone tributaries (Finalized).** Eleven tributaries from about 6 km upstream of Tangrah in Golestan Forest down to Besholy were classified as "debris prone" based on historical events; simple classification, a tributary that historically had debris flow was classified debris prone. These tributaries are all characterized by high rainfall and high slope; the key parameters.

- **Debris flow calculations (Finalized)**. Studied monograph "Debris Flow" by Takahashi (1991) with the aim of finding a way to calculate the debris yield. The monograph provides a lot of theoretical background, but unfortunately not application oriented. Takahashi gives some expressions for the debris discharge (m^3/s), but his formulas yield debris volumes an order of magnitude above what was found from the Los Angeles District Debris Method (see below), and the order of magnitude from Takahashi would yield immense blocking of the whole Madarsoo valley, which does not match with observations. Something more application oriented was needed, so a literature search was conducted using Google, resulting in a good application oriented publication from the US Army Corps of Engineers Los Angeles District (2000). The Los Angeles District gives a simple formula that gives the unit debris yield (volume per drainage area, in US units) as function of the peak unit discharge, relief ratio (akin to the slope), drainage area and a "Fire Factor". The Fire Factor was set to its lowest value representing unburned conditions, which is the most reasonable to do for this basin where fire is presumably not a major issue. The necessary parameters were extracted for the Los Angeles debris method from the MIKE 11 model and calculated the debris yields for each tributary and scenario. The volumes were in the order of magnitude that were expected considering the geometry of the river and valley, and what were found necessary for the debris flow to matter in terms of flooding. The volumes range from 4-103 thousand m^3.

- **Sediment load time-series (Finalized Task 4-3):** The calculated debris yields (m^3) were translated into time-series for the debris flow (m^3/s) by using the runoff time-series transformed into distribution functions in which the debris flow was assumed to take place only in the period where the discharge is above 80% of the peak in each tributary.

- **Longitudinal distribution of the debris flow (Finalized).** The debris prone tributaries have their flood peak hours before Madarsoo, and it is very reasonable to assume, as done under Task 4-3, that the debris flow takes place when the tributary is on the peak of its hydrograph. Therefore there is very low sediment transport capacity in Madarsoo when the debris arrives, and therefore the debris will pile up to a height equal to the debris volume divided by the MIKE 11 grid spacing; the model results become grid dependent with higher and higher debris dams for lower grid spacing. Such a pile of sediment is not realistic, so a longitudinal distribution was added in which a longitudinal shape was assumed, resulting in a longitudinal distribution of the debris flow over a distance up to 50 m. Note that this is only necessary because the debris arrives before the floodwaters from the headwaters, and that it is a numerical problem repaired by using sound physics.

- **MIKE 11 ST (Nearly Finalized Task 5-1):** Two separate MIKE 11 models were constructed. The overall model does not contain debris flow, while a local model in the debris prone reach describes the debris flow. The ST module of MIKE 11 was activated with the sediment fractions determined under Task 1-10 and Engelund-Hansen sediment transport formula with a calibration factor of 0.5.

- **Tributary sediment (Nearly Finalized Task 5-2):** The time-series for the debris flow (m^3/s) were prepared under Task 4-3 and were added as source points to the MIKE 11 ST model. The locations for the sediment sources were estimated before the Quick Bird satellite image became available, and it was clear after receiving the satellite image that some locations were wrong. It is also possible that the distribution in time and space will be altered. However, the major part of this task is done.

- **Detailed calibration (Ongoing Task 5-3):** It has not been possible to calibrate the model in detail, only a roughly estimated Manning n was selected. Gauges do not survive the relevant floods in Madarsoo, so only flood markers can be used, but the flood markers are not particularly useful and the DEM is also not accurate enough to determine water levels within a few meters, which is required when doing water level calibration. This task can in principle be considered finalized with the present level of estimated calibration parameters, or continued if new data comes along.

- **Flood maps 2001, 2002 etc (Finalized Task 5-4):** It was the original idea to generate flood maps for the 2001 and 2002 flood in order to use them for calibration of the model by comparing with flood markers. This turned out not to be a relevant path.

- **Prepare scenarios (Finalized Task 5-5):** The scenarios to be simulated were agreed with the JICA team leader, and were 25 year, 50 year and 100 year. The 25 year and 100 year events are called for in the Master Plan. The scenarios were characterized by their boundary conditions extracted from the hydrological model, as described under Task 3.

- **Run scenarios (Nearly Finalized Task 5-6):** The 25 year, 50 year and 100 year floods were simulated with the overall model, while the 100 year event was simulated with and without debris flow included with the local model. Only the 25 year and 100 year events are used by the JICA team. These simulations can be carried out again if there are changes to the data and/or calibration.

- **Flood maps for scenarios (Nearly Finalized Task 5-7):** Flood maps were produced for the 25 year, 50 year and 100 year events with the overall MIKE 11 HD model, while a local flood map and comparison map (hydraulic impact of debris) were produced with the local MIKE 11 ST model. This task is essentially done, though there can be alterations in the whole modeling system, which requires update of the flood maps.

- **Task 5 Presentation (Pending Task 5-8**): The results for Task 5 have not yet been presented by the DHI expert; the results have been delivered to the JICA team GIS expert.

- **Study Report to JICA (Pending Task 5-9):** The Final Report will be written by the DHI expert and submitted after Phase 3.

CHAPTER 10 CONCLUSIONS

The present report describes the progress made in Phase 2 the period 6 August to 17 September in the development of flood maps with inclusion of debris flow for Madarsoo River. The work is a continuation of the work initiated by the DHI Project Leader in the period 18 January to 17 February 2005, and continued by the DHI Hydrologist in June 2005 with handling of Task 3.

Most of the activities that were outlined in the Scope of Work (Appendix C) are done or nearly finalized after this Phase 2. The model has been constructed, simulations carried out and flood maps produced, which is the primary task of the DHI input.

On 24 August the DEM from Iran Systems was received and quality checked. We found major problems with this DEM, especially in the downstream end where the terrace and incised floodplain were literally absent. Iran Systems promised to obtain more data in the downstream end and came back with a much improved DEM on 12 September, just a few days before the DHI expert had to leave. Despite the short time we managed to use this improved DEM in the modeling and flood maps.

It is, however, not only the downstream end of the DEM that has poor quality. There are several cases where the river path according to the Iran Systems DEM does not follow the river in the satellite image, and between Kalaleh Bridge and 14 Metry Bridge there is a whole village supposedly lying directly in the floodplain according to Iran Systems, while the river is further to the north according to the satellite image. We could continue to list the discrepancies, but let us just note that other tasks in the JICA study will be affected by this poor DEM quality.

A Quick Bird image was received, though the geo-referencing was poor and had to be improved by the JICA team GIS expert. This Quick Bird image still needs some editing before it can be used for presentation purposes, and so we use the older 742 satellite image at least for some deliverables. The plan is to use the Quick Bird image for the final deliverables.

A field trip was carried out on August 14 in which the location of Ajen Ghare Khajeh Bridge was verified; this bridge was not covered in the original bridge survey conducted on 11 February 2005. On this field trip we also verified that the downstream end of Madarsoo is not part of the Golestan reservoir, as claimed earlier by MoE.

The MoE sections are too narrow to house the flood extend, and they cannot be combined with the DEM. Most likely the MoE cross-section survey data is erroneous, as also suggested by the GPS data from the field trip 14 August. Therefore the MoE survey data has been discarded, though it should be stressed that it is discarded due to elevation incompatibilities, while the river location (horizontal) actually matches well with the Quick Bird satellite image.

Cross-sections and path of the floodwater (MIKE 11 network) have been defined from the Iran Systems DEM. Hence the whole model is based on the DEM, which is usually the smartest move in a situation with major data inconsistencies. 553 cross-sections were digitized and distance-level tables extracted with MIKE 11 GIS. Having taken this step, we also opted for defining the path of the floodwater instead of the meandering river, which is more realistic in a model designed for flood mapping. The model is hence a flood model, and should not be used for low flow, as it simply does not resolve the low flow channel.

The final list of 19 bridges was compiled and geometry for each bridge estimated from pictures and cross-sections. Inverts were estimated from cross-sections extracted from the DEM to ensure elevation compatibility.

The hydrology was treated by the DHI hydrologist and the JICA team hydrologist in June 2005, and results were handed over to the DHI hydraulic modeling expert in August 2005.

The hydrological results were translated into source points with inflow time-series (upstream inflow, tributary inflows and lateral inflows from runoff) for the single branch Madarsoo model used for flood mapping. Five scenarios were delivered and processed into the single branch model, namely the 2001 and 2002 floods and floods with 25, 50 and 100 year return period.

An overall MIKE 11 HD model could now be put together from the network, cross-sections, bridges and boundary conditions. This model was used for simulation of the 25, 50 and 100 year floods, which were then mapped on the DEM using MIKE 11 GIS. It is stressed that this model cannot be accurately calibrated; there is no water level gauge data for the floods and the flood markers and DEM are not detailed enough to determine the edge of water for the 2001/2002 floods. Flood maps for the 25, 50 and 100 year events were delivered to the JICA team GIS expert, and animations of the 100 year flood were produced as well.

Debris flow was treated by using an empirical relation for the debris yield, known as the Los Angeles District Debris Method. Debris volumes were estimated based on peak discharge, slope and drainage area for 11 tributaries selected from the criterion that a tributary with a history of debris flow is debris prone. These 11 tributaries are all in the Tangrah area with high rainfall intensity and slope. The Los Angeles District Debris Method yielded debris volumes ranging from 4,000-103,000 m^3 during a flood, which matched with the anticipated volumes requires for having a significant hydraulic impact. The temporal variation of the debris inflow was determined from the hydrograph for each tributary to construct a distribution function in which the debris inflow is concentrated when the discharge is above 80% of the peak discharge, and proportional to the discharge minus 80% of the peak discharge. This concentrates the debris flow within a few hours. The timing of the debris flow and the Madarsoo hydrograph is very important, and it turned out that the debris flow will take place before the Madarsoo floodwaters arrive from upstream. This required assumptions about the longitudinal distribution of the debris to avoid unrealistic stacking of debris during a debris event when the sediment transport capacity is low in Madarsoo. The debris MIKE 11 model has 11 sediment source points at the locations where the debris prone tributaries join Madarsoo. It is stressed that the MIKE 11 model addresses the hydraulic effect of debris flow.

A local MIKE 11 HD+ST model was constructed from the overall model in the debris prone reach. The model took its upstream inflow directly from the overall model and the same lateral inflows in the local area. The 11 debris prone tributaries were added and the model was used for simulation of the 100 year flood with and without debris included to assess the hydraulic impact of the debris. The debris model simulations showed that the debris would increase the maximum bed level as much as 10 m, while the maximum water level would be increased up to 7 m. The water level impact is smaller because the debris deposits are formed and partially eroded before the flood peak. The surging effect could also be quantified with the model, and it was found that the peak discharge downstream of the debris prone area would increase roughly 100 m^3/s for the 100 year flood due to the storage and release of water behind the debris deposits. The impact on the flood depth is substantial behind the large debris deposits, with increase in water depth up to 5 m and backwater penetrating 1 km upstream, while the effect on the flood extend is very limited (increase of 172,900 m^2 flood area found, or 2.8% found in the local area due to debris for the 100 year flood) due to the steep side slopes of the Madarsoo valley.

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APPENDIX A FLOOD MAPS 100 YEAR EVENT

Area 1: Golestan Dam

Area 2: Kalaleh Bridge

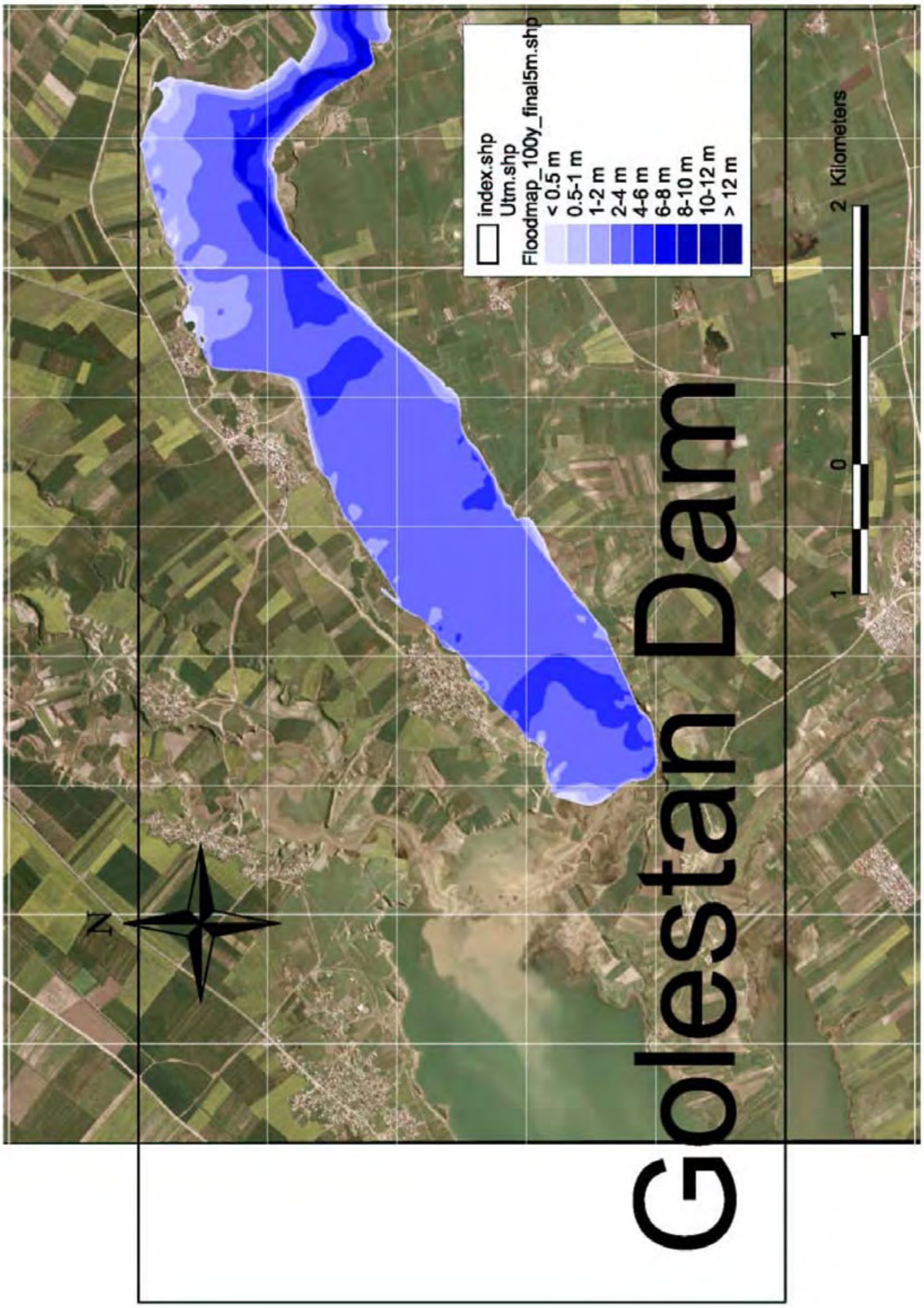
Area 3: 14 Metry Bridge

Area 4: Besholy

Area 5: Tangrah

Area 6: Golestan Forest

Area 7: Dasht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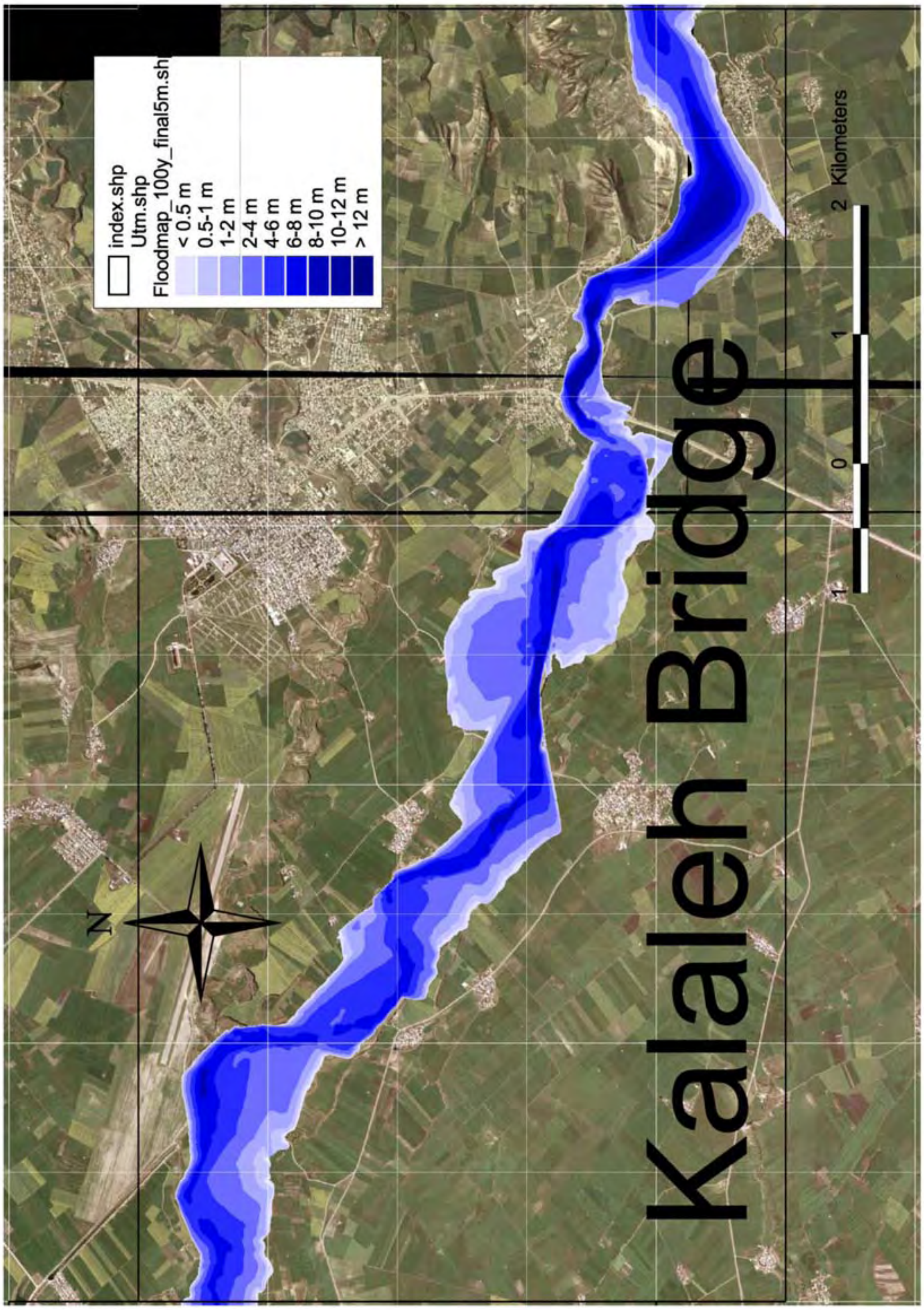
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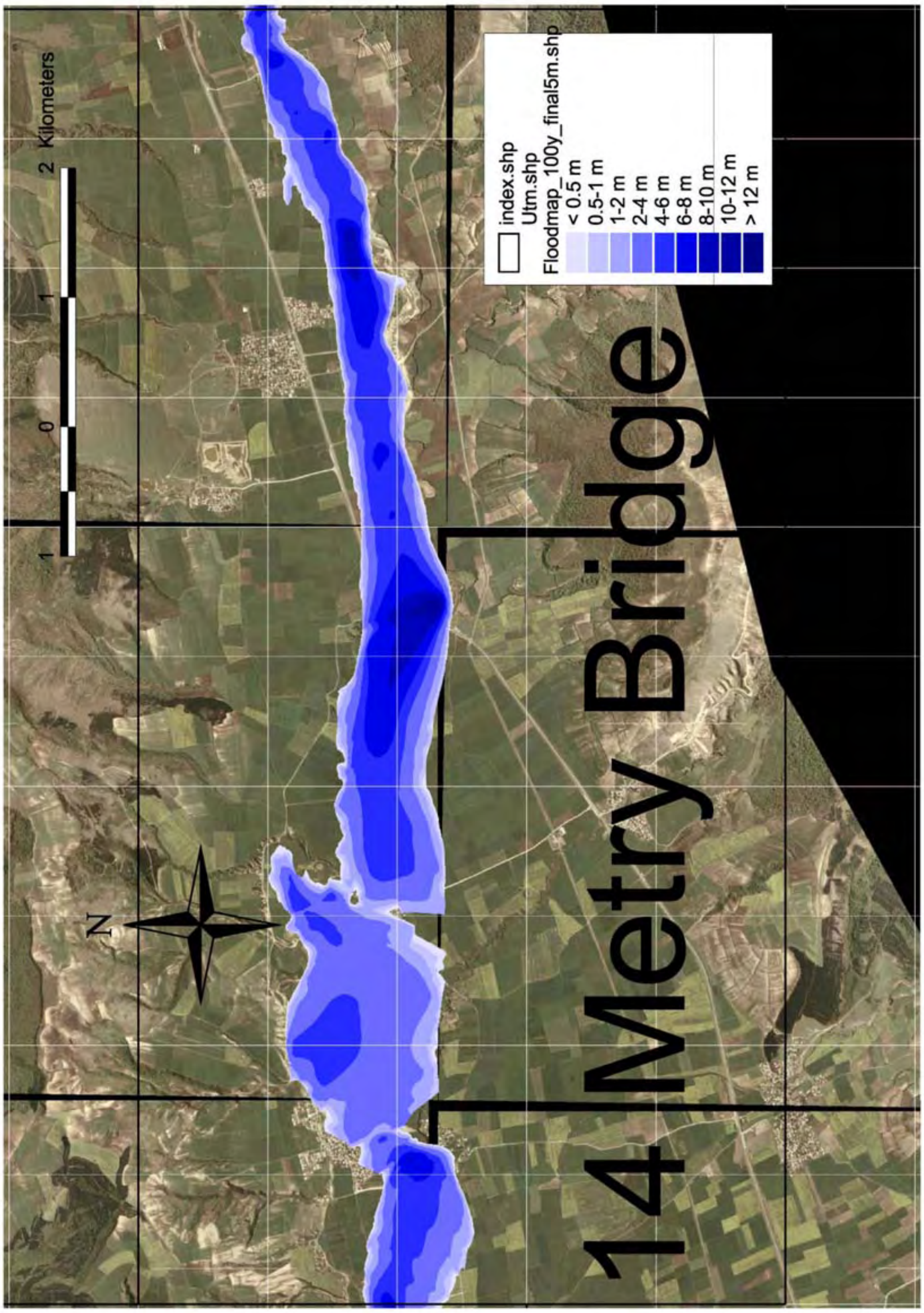
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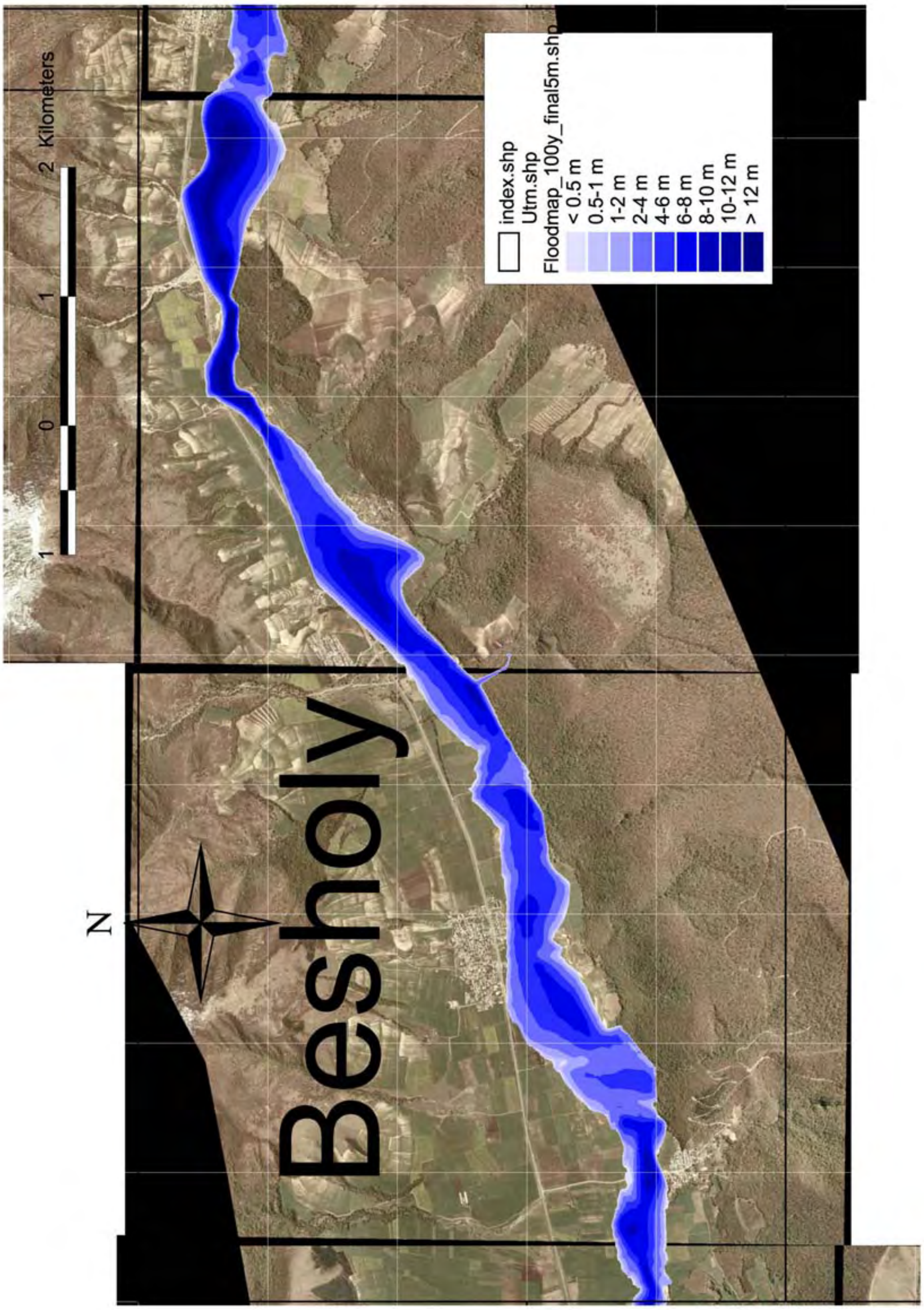
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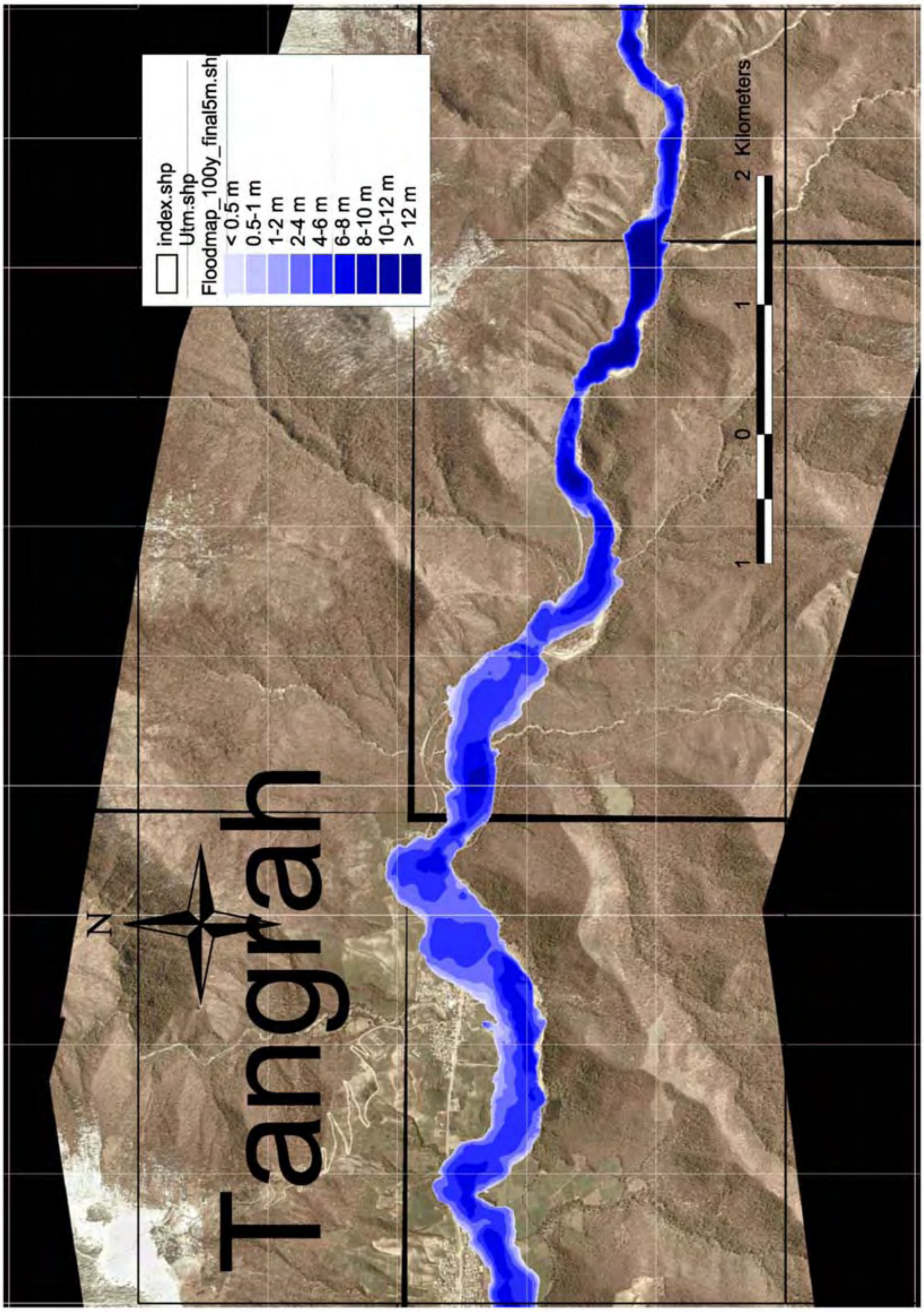
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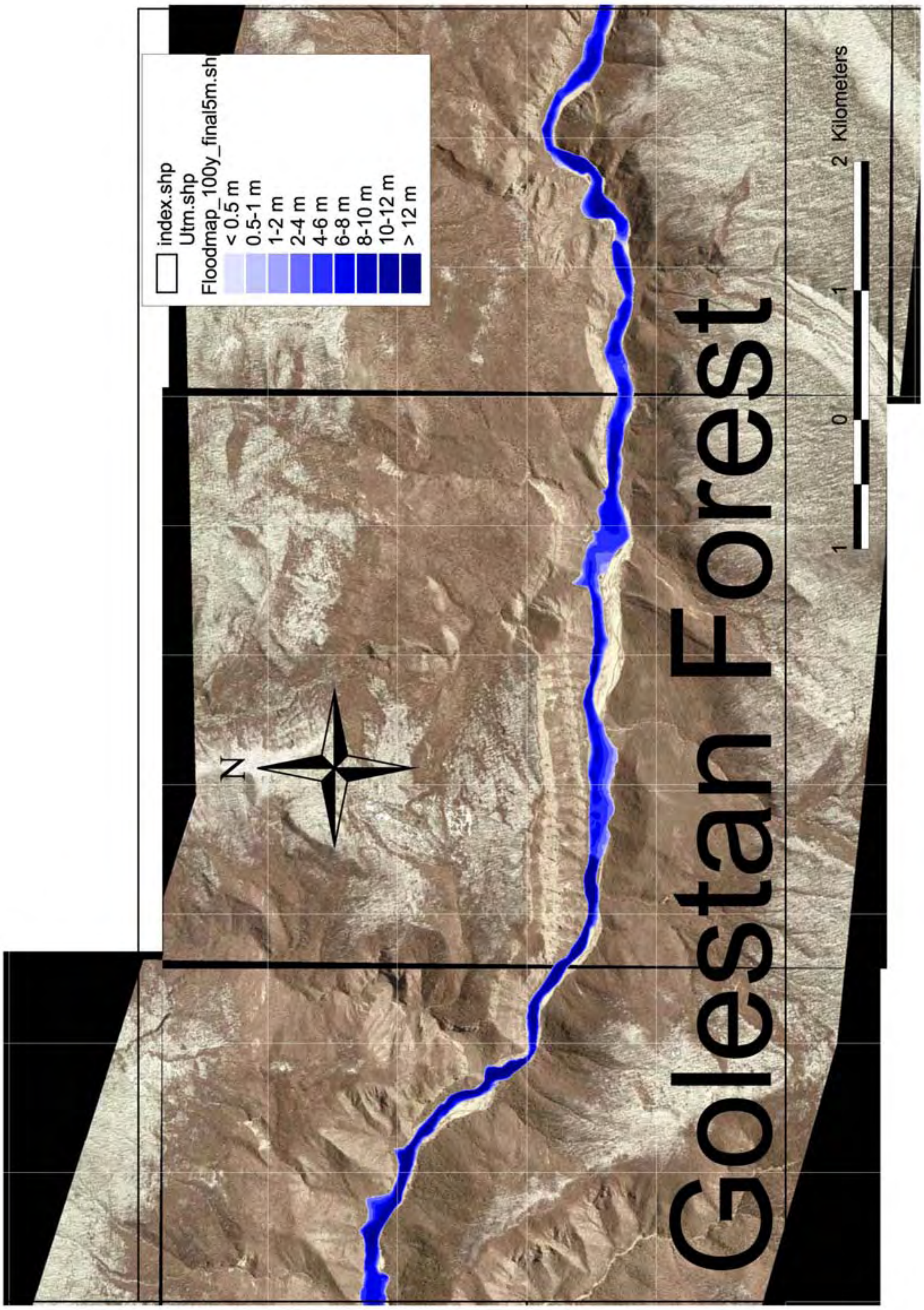
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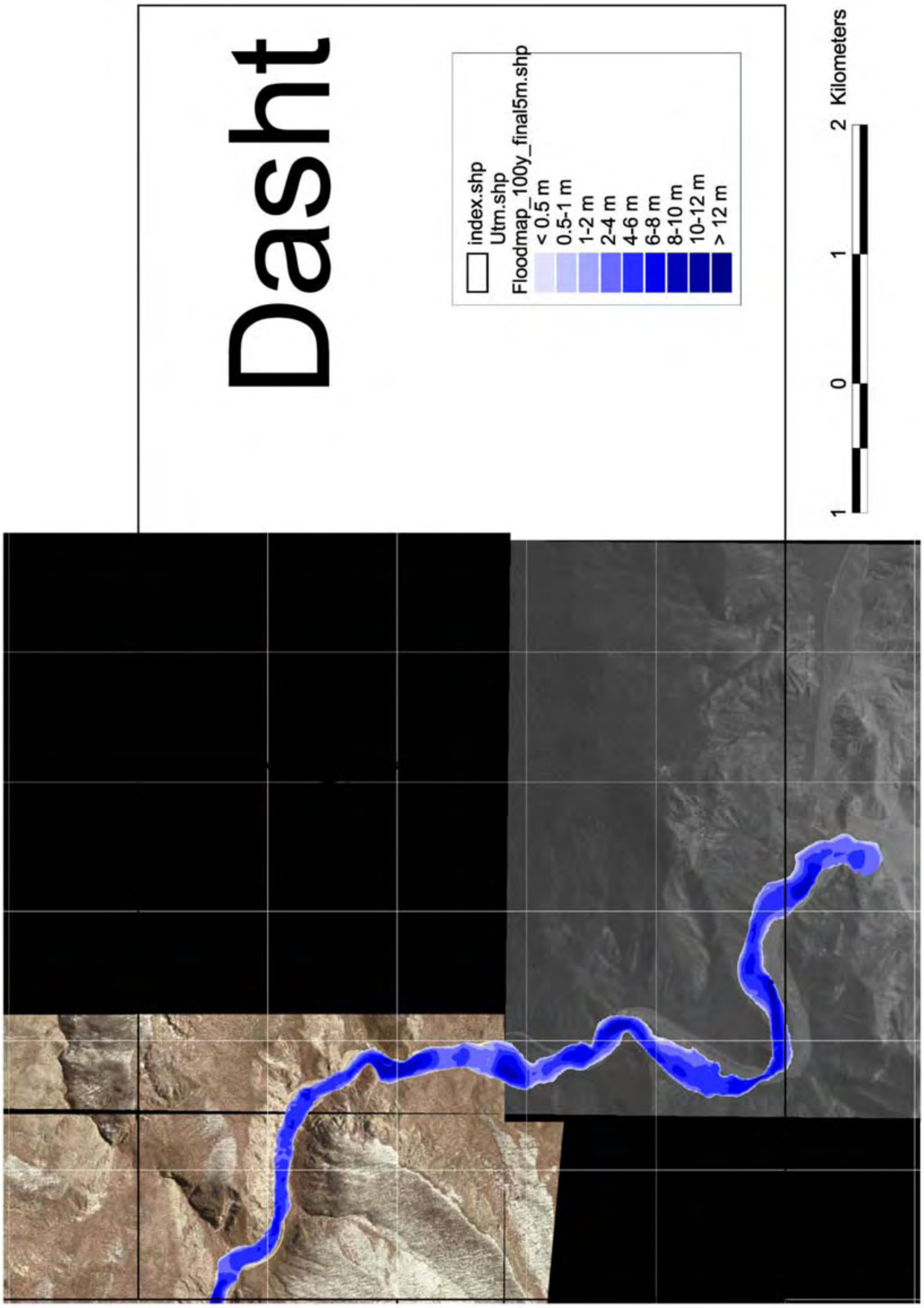
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