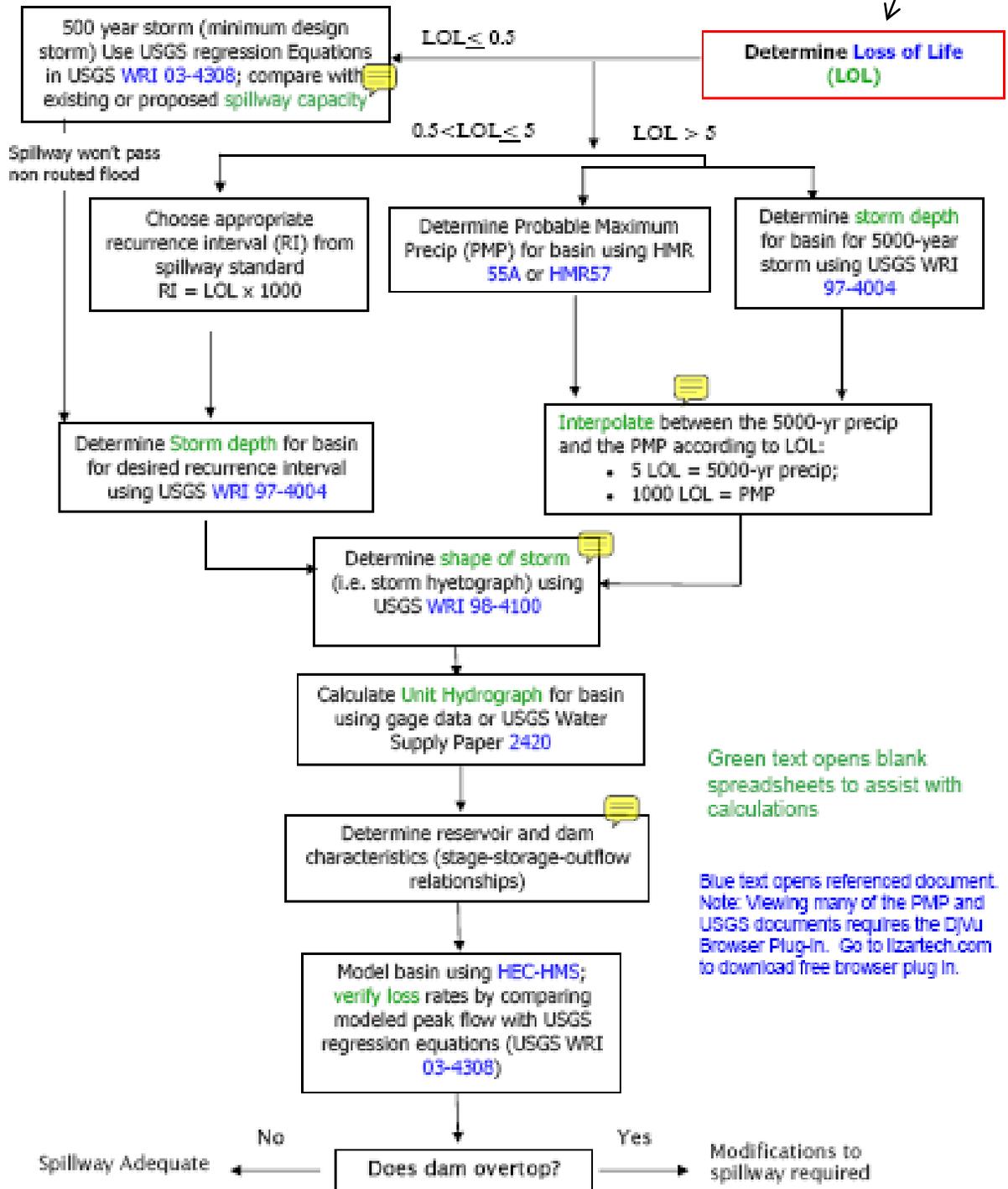
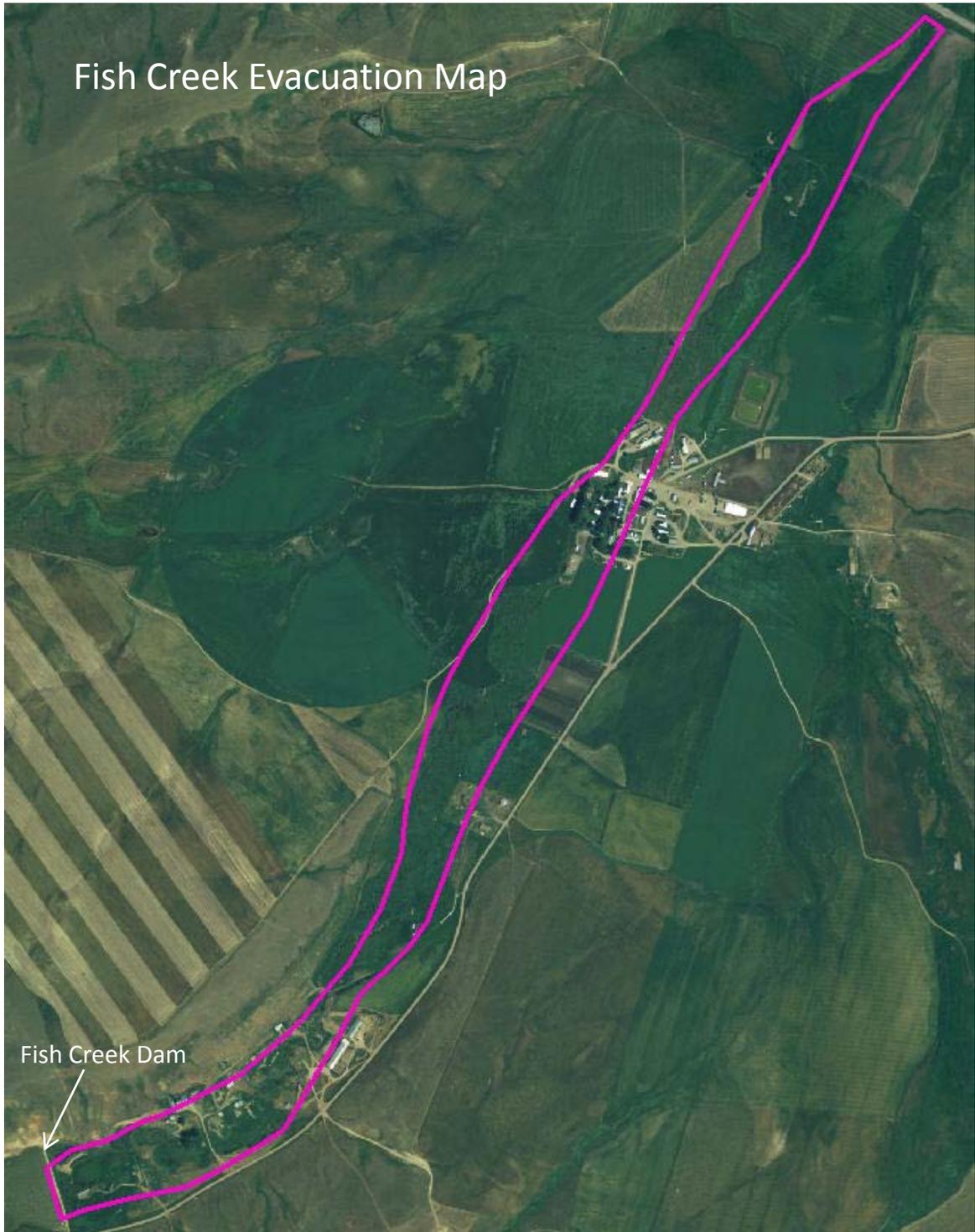


Determine Loss of Life (LOL) using the Graham Method (TN2 SEC 5.0)

Procedure for Determining Spillway Adequacy



Step 1 - Determine Population At Risk (PAR) within the dam's breach flood area. Simplified Evacuation Mapping is described, in more detail, in Technical Note 3.



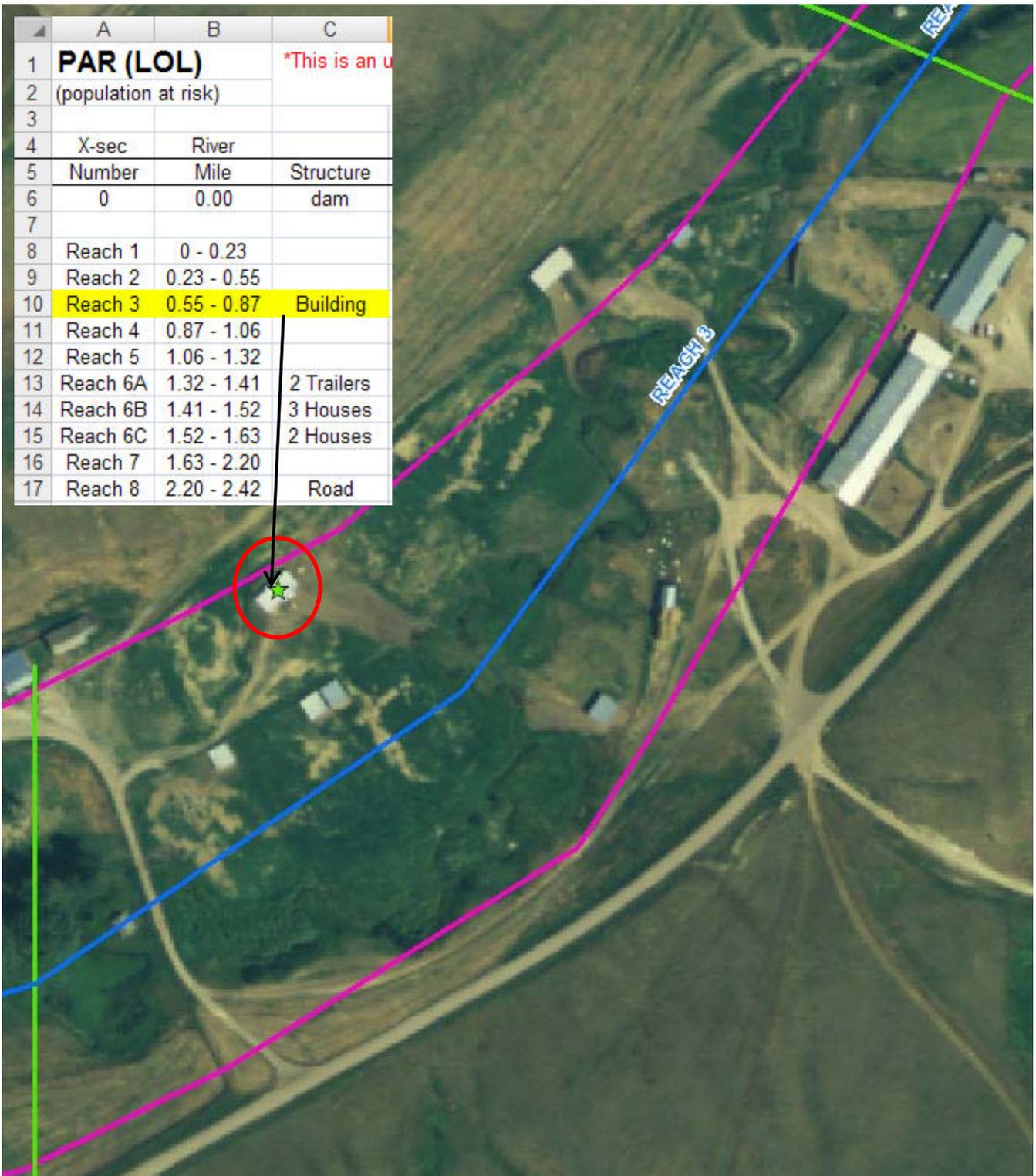
Using the PAR worksheet, start from the dam and work downstream, counting the number and types of structures through each downstream reach.

Reach 1 and 2



NOTE: You may have to make an onsite visit to determine whether or not the structures that lie within the dam breach flood area are actually inhabited. As shown here, from Reach 1 to Reach 2, there are several structures that lie within the flooded area, but from an onsite visit it was determined that these structures were not inhabited (no PAR).

Reach 3



NOTE: Onsite visit showed that Reach 3 had 1 building with potential for PAR

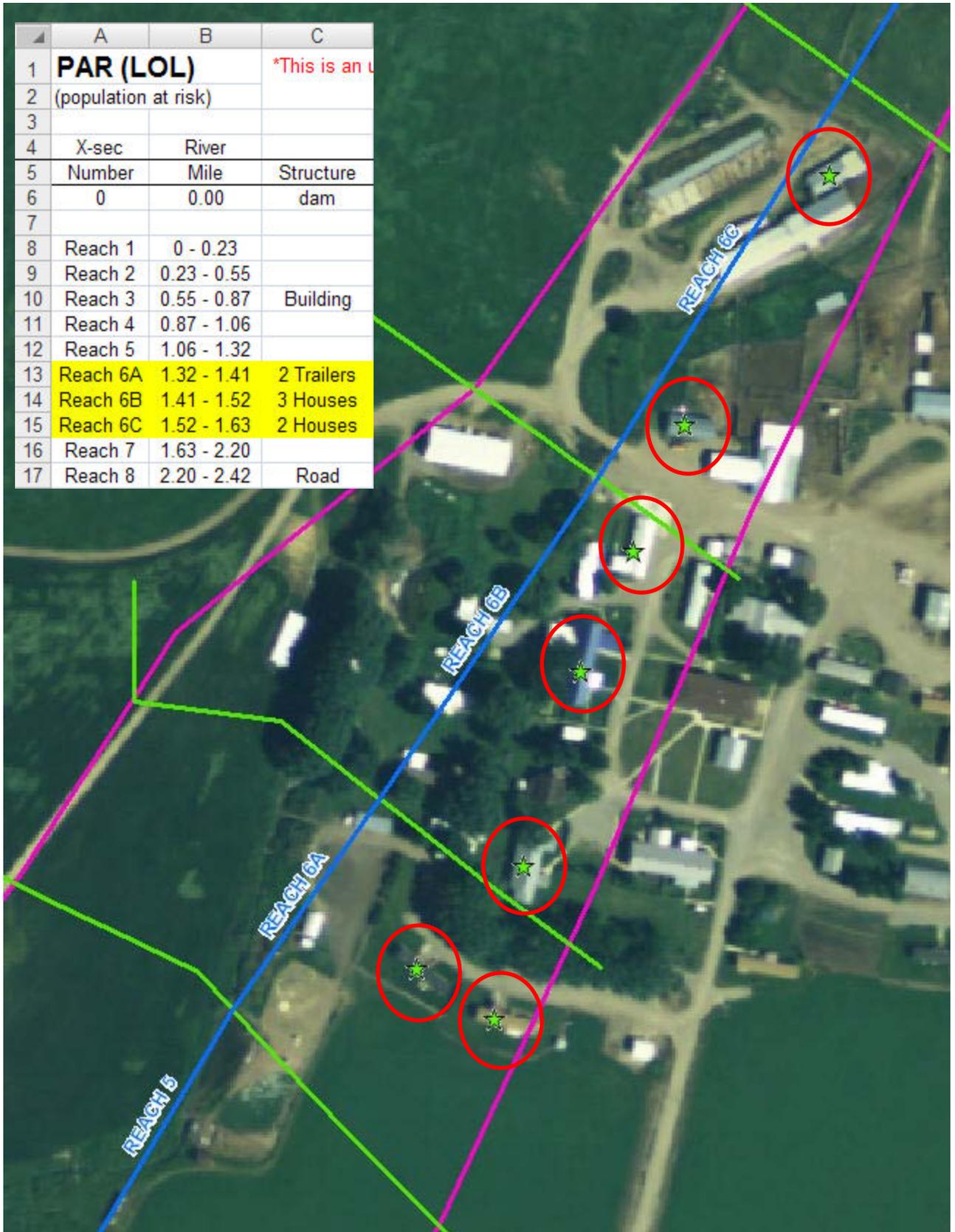
Reach 4 and 5



NOTE: Onsite visit showed that Reaches 4 and 5 had no buildings with PAR

Reach 6

	A	B	C
1	PAR (LOL)		*This is an u
2	(population at risk)		
3			
4	X-sec	River	
5	Number	Mile	Structure
6	0	0.00	dam
7			
8	Reach 1	0 - 0.23	
9	Reach 2	0.23 - 0.55	
10	Reach 3	0.55 - 0.87	Building
11	Reach 4	0.87 - 1.06	
12	Reach 5	1.06 - 1.32	
13	Reach 6A	1.32 - 1.41	2 Trailers
14	Reach 6B	1.41 - 1.52	3 Houses
15	Reach 6C	1.52 - 1.63	2 Houses
16	Reach 7	1.63 - 2.20	
17	Reach 8	2.20 - 2.42	Road



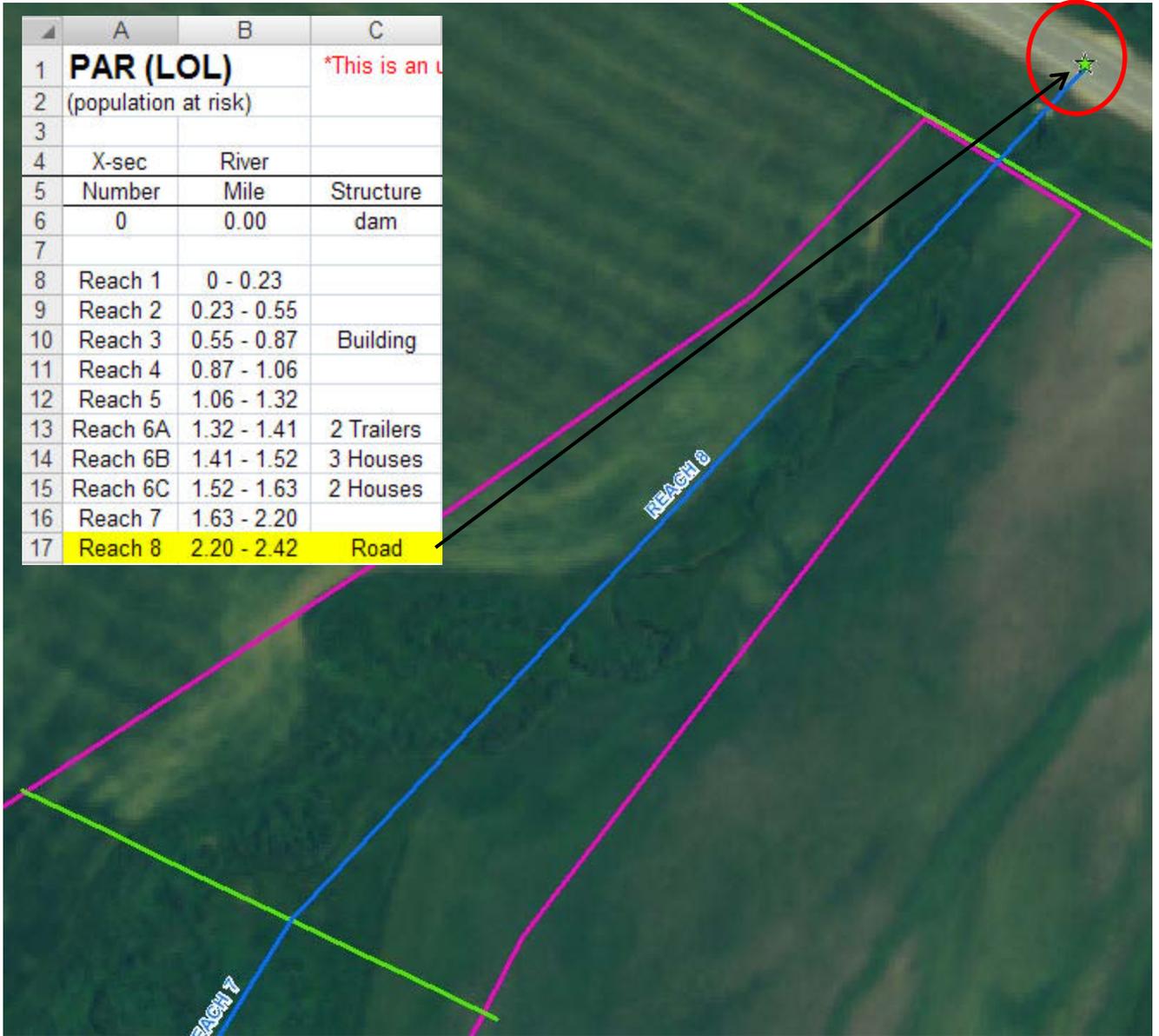
NOTE: Reach 6A, 6B and 6C, were determined to have several houses with potential for PAR. From TN2 Table 5-1, each house is assigned a PAR of 3

Reach 7



Reach 7, no PAR

Reach 8



NOTE: The road was considered part of Reach 8

Step 2 – Determine Warning Time

See TN 2 Sec. 5.2

	A	B	C	D	E	F	G	H	I	J	K
1	PAR (LOL)		*This is an unprotected sheet with formulas, see NOTE below for more details					Graham (1999) Loss of Life			
2	(population at risk)							Flood			
3			Warning time					Severity		Fatality	Loss of
4	X-sec	River		Water	PAR			Flood	Warning	Rate	Life
5	Number	Mile	Structure	(minutes)	Depth at	census	Comments	(assumed)	Time	Flood	Flood
6	0	0.00	dam								
7											
8	Reach 1	0 - 0.23		0				low	0	0.0100	0.0000
9	Reach 2	0.23 - 0.55		0				low	0	0.0100	0.0000
10	Reach 3	0.55 - 0.87	Building	0	1	3		low	0	0.0100	0.0300
11	Reach 4	0.87 - 1.06		0				low	0	0.0100	0.0000
12	Reach 5	1.06 - 1.32		0				low	0	0.0100	0.0000
13	Reach 6A	1.32 - 1.41	2 Trailers	0	1	6		low	0	0.0100	0.0600
14	Reach 6B	1.41 - 1.52	3 Houses	0	1	9		low	0	0.0100	0.0900
15	Reach 6C	1.52 - 1.63	2 Houses	0	1	6		low	0	0.0100	0.0600
16	Reach 7	1.63 - 2.20		0				low	0	0.0100	0.0000
17	Reach 8	2.20 - 2.42	Road	0		3		low	0	0.0100	0.0300
18											

Figure 5-1 Table 2 (next slide) from TN 2 shows Graham’s estimates for when warning time begins

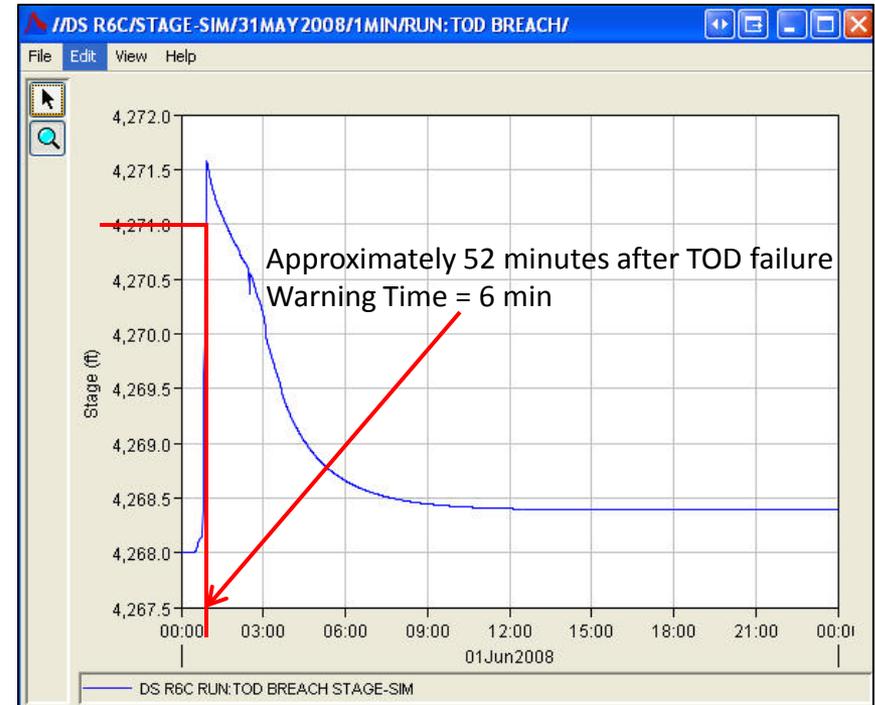
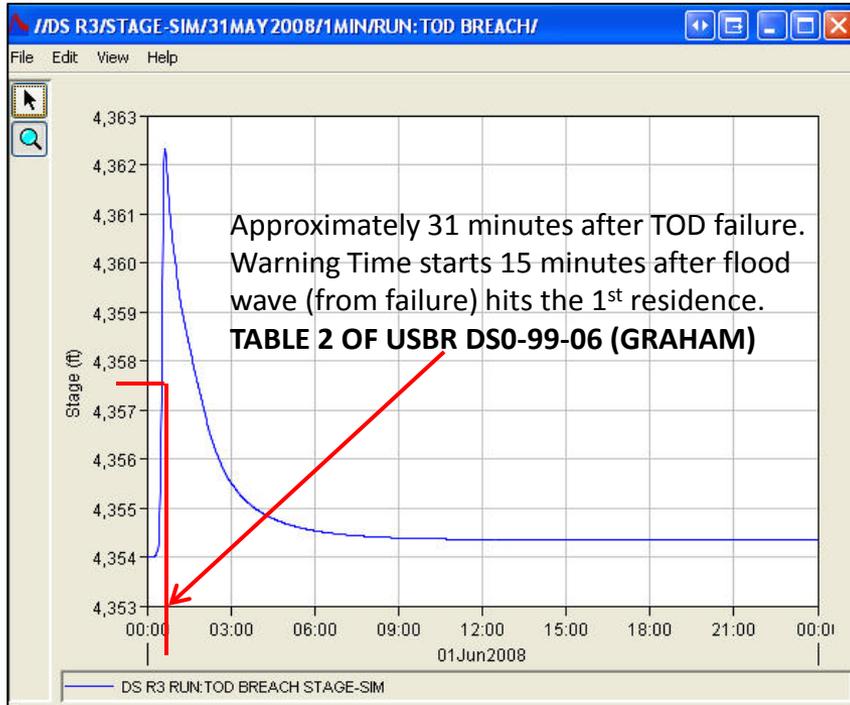
For this example we have a top of dam breach, during the day, with no observers at the dam.
 An initial 0.25 hrs after the flood wave reaches the first house is added to when the actual warning time would start.

FIGURE 5-1. TABLE 2 OF USBR DS0-99-06 (GRAHAM), ESTIMATES FOR WHEN WARNING TIME BEGINS

Table 2. Guidance for Estimating When Dam Failure Warnings Would be Initiated (Earthfill Dam)					
Dam Type	Cause of Failure	Special Considerations	Time of Failure	When Would Dam Failure Warning be Initiated?	
				Many Observers at Dam	No Observers at Dam
Earthfill	Overtopping	Drainage area at dam less than 100 mi ² (260 km ²)	Day	0.25 hrs. before dam failure	0.25 hrs. after fw reaches populated area
		Drainage area at dam less than 100 mi ² (260 km ²)	Night	0.25 hrs. after dam failure	1.0 hrs. after fw reaches populated area
		Drainage area at dam more than 100 mi ² (260 km ²)	Day	2 hrs. before dam failure	1 hr. before dam failure
		Drainage area at dam more than 100 mi ² (260 km ²)	Night	1 to 2 hr. before dam failure	0 to 1 hr. before dam failure
	Piping (full reservoir, normal weather)		Day	1 hr. before dam failure	0.25 hrs. after fw reaches populated area
			Night	0.5 hr. after dam failure	1.0 hr. after fw reaches populated area
	Seismic	Immediate Failure	Day	0.25 hr. after dam failure	0.25 hr. after fw reaches populated area
			Night	0.50 hr. after dam failure	1.0 hrs. after fw reaches populated area
		Delayed Failure	Day	2 hrs. before dam failure	0.5 hrs. before fw reaches populated area
			Night	2 hrs. before dam failure	0.5 hrs. before fw reaches populated area

Notes: "Many Observers at Dam" means that a dam tender lives on high ground and within site of the dam or the dam is visible from the homes of many people or the dam crest serves as a heavily used roadway. These dams are typically in urban areas. "No Observers at Dam" means that there is no dam tender at the dam, the dam is out of site of nearly all homes and there is no roadway on the dam crest. These dams are usually in remote areas. The abbreviation "fw" stands for floodwater.

The results from HechHMS can be used to determine when the flood wave reaches the first house.



Reach 3 is where the first building lies. It can be assumed that the initial response to the flood would start when the flood wave was about 3 to 4 feet deep at the 1st residence.

Reach 6C is the last reach with a house in it. They would have approximately 6 min of warning time.

Warning Time

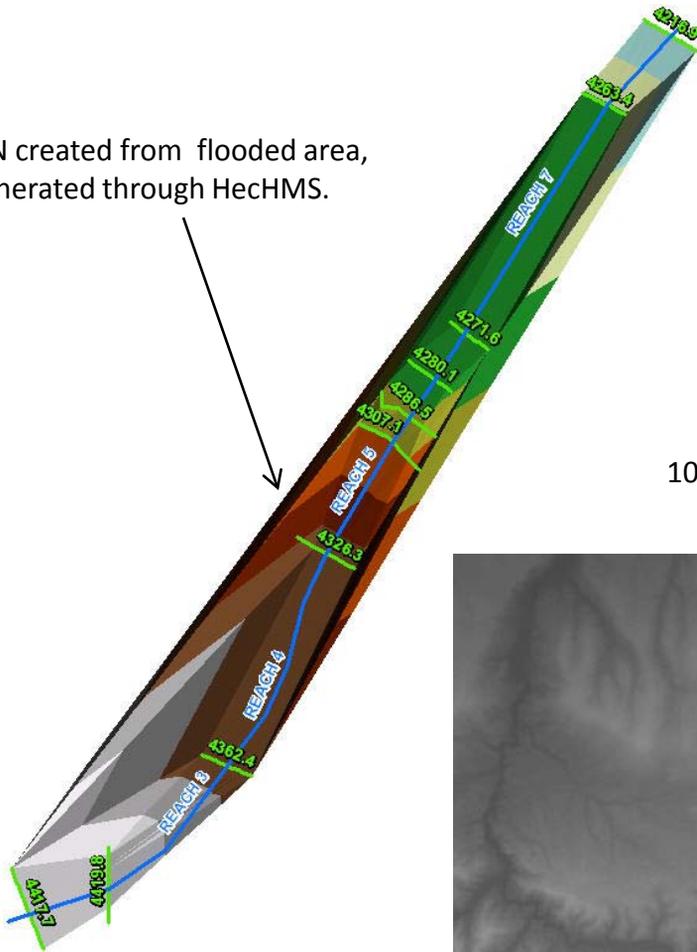
	A	B	C	D	E	F	G	H	I	J	K
1	PAR (LOL)		*This is an unprotected sheet with formulas, see NOTE below for more details					Graham (1999) Loss of Life			
2	(population at risk)							Flood			
3				Warning	Water	PAR		Severity		Fatality	Loss of
4	X-sec	River		time	Depth at	2000		Flood	Warning	Rate	Life
5	Number	Mile	Structure	(minutes)	Structure (ft)	census	Comments	(assumed)	Time	Flood	Flood
6	0	0.00	dam								
7											
8	Reach 1	0 - 0.23		0				low	0	0.0100	0.0000
9	Reach 2	0.23 - 0.55		0				low	0	0.0100	0.0000
10	Reach 3	0.55 - 0.87	Building	0	1	3		low	0	0.0100	0.0300
11	Reach 4	0.87 - 1.06		0				low	0	0.0100	0.0000
12	Reach 5	1.06 - 1.32		0				low	0	0.0100	0.0000
13	Reach 6A	1.32 - 1.41	2 Trailers	0	1	6		low	0	0.0100	0.0600
14	Reach 6B	1.41 - 1.52	3 Houses	0	1	9		low	0	0.0100	0.0900
15	Reach 6C	1.52 - 1.63	2 Houses	0	1	6		low	0	0.0100	0.0600
16	Reach 7	1.63 - 2.20		0				low	0	0.0100	0.0000
17	Reach 8	2.20 - 2.42	Road	0		3		low	0	0.0100	0.0300
18											

Although the last reach with houses has 6 minutes of warning time (WT), WT has to be ≥ 15 before it becomes a factor in LOL (TN 2 Figure 5.2 Table 7).

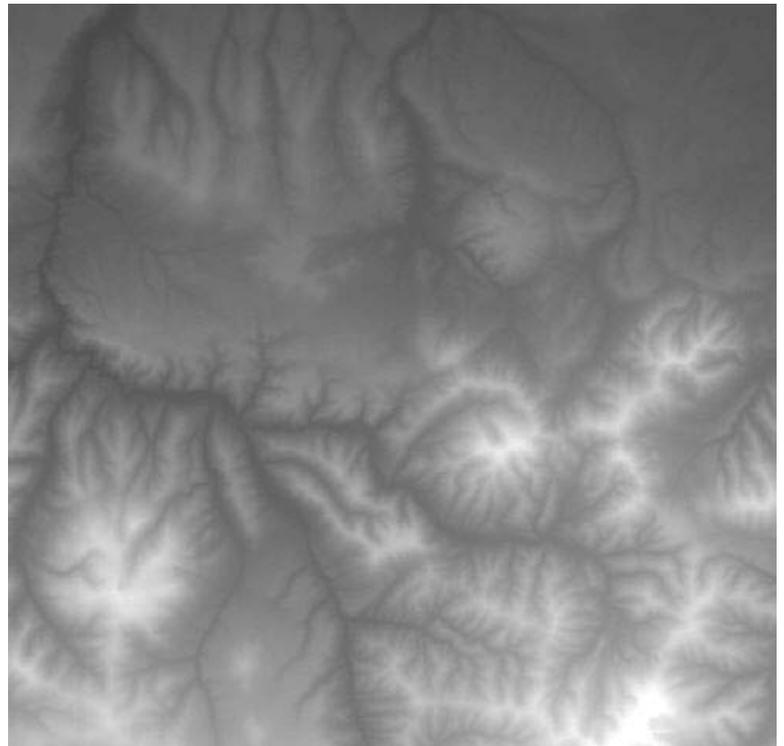
Step 3 – Determine Water Depth at Structures.

A surface model, or Triangulated Irregular Network (TIN), of the flooded area can be created using ArcGIS. This TIN, along with a Digital Elevation Model (DEM) can then be used to determine water depth at structures

TIN created from flooded area,
generated through HechHMS.



10 Meter DEM (best available
data for this area)



Using the info button in ArcGIS, the user can then select a point on the TIN and DEM to get elevation values for the ground and water surface. Subtracting the two will give you the depth of the water at that point

Determine Water Depth at Structures

	A	B	C	D	E	F	G	H	I	J	K
1	PAR (LOL)		*This is an unprotected sheet with formulas, see NOTE below for more details					Graham (1999) Loss of Life			
2	(population at risk)							Flood			
3				Warning	Water	PAR		Severity		Fatality	Loss of
4	X-sec	River		time	Depth at	2000		Flood	Warning	Rate	Life
5	Number	Mile	Structure	(minutes)	Structure (ft)	census	Comments	(assumed)	Time	Flood	Flood
6	0	0.00	dam								
7											
8	Reach 1	0 - 0.23		0				low	0	0.0100	0.0000
9	Reach 2	0.23 - 0.55		0				low	0	0.0100	0.0000
10	Reach 3	0.55 - 0.87	Building	0	1	3		low	0	0.0100	0.0300
11	Reach 4	0.87 - 1.06		0				low	0	0.0100	0.0000
12	Reach 5	1.06 - 1.32		0				low	0	0.0100	0.0000
13	Reach 6A	1.32 - 1.41	2 Trailers	0	1	6		low	0	0.0100	0.0600
14	Reach 6B	1.41 - 1.52	3 Houses	0	1	9		low	0	0.0100	0.0900
15	Reach 6C	1.52 - 1.63	2 Houses	0	1	6		low	0	0.0100	0.0600
16	Reach 7	1.63 - 2.20		0				low	0	0.0100	0.0000
17	Reach 8	2.20 - 2.42	Road	0		3		low	0	0.0100	0.0300
18											

Water depth is only used to determine Flood Severity (Low, Medium, or High).
 Water Depth < 10 Flood Severity = Low, Water Depth > 10 Flood Severity = Medium

Step 4 – Determine PAR for each reach

	A	B	C	D	E	F	G	H	I	J	K
1	PAR (LOL)		*This is an unprotected sheet with formulas, see NOTE below for more details					Graham (1999) Loss of Life			
2	(population at risk)							Flood			
3				Warning	Water	PAR					
4	X-sec	River		time	Depth at	2000		Flood	Warning	Rate	Life
5	Number	Mile	Structure	(minutes)	Structure (ft)	census	Comments	(assumed)	Time	Flood	Flood
6	0	0.00	dam								
7											
8	Reach 1	0 - 0.23		0				low	0	0.0100	0.0000
9	Reach 2	0.23 - 0.55		0				low	0	0.0100	0.0000
10	Reach 3	0.55 - 0.87	Building	0	1	3		low	0	0.0100	0.0300
11	Reach 4	0.87 - 1.06		0				low	0	0.0100	0.0000
12	Reach 5	1.06 - 1.32		0				low	0	0.0100	0.0000
13	Reach 6A	1.32 - 1.41	2 Trailers	0	1	6		low	0	0.0100	0.0600
14	Reach 6B	1.41 - 1.52	3 Houses	0	1	9		low	0	0.0100	0.0900
15	Reach 6C	1.52 - 1.63	2 Houses	0	1	6		low	0	0.0100	0.0600
16	Reach 7	1.63 - 2.20		0				low	0	0.0100	0.0000
17	Reach 8	2.20 - 2.42	Road	0		3		low	0	0.0100	0.0300
18											

TABLE 5-1. POPULATION AT RISK ESTIMATES FOR STRUCTURES OF HUMAN HABITATION

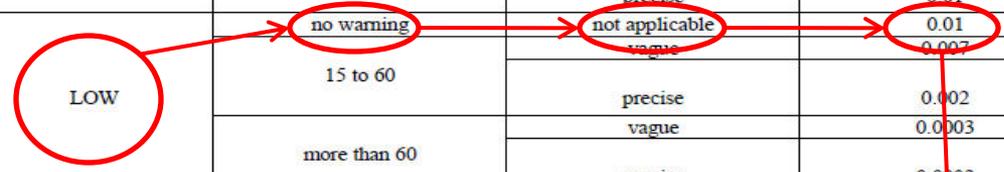
Structure	Estimated PAR
Residence	3
Farm shop building	2
Commercial building	10
Hospital	100
School	100
Municipal park	10
Campground	30
Golf course	30
Airport	30
Paved road	2
Railroad	2

NOTE: A PAR of 3 was given for the Road to be conservative

Step 5 – Determine Fatality Rates

FIGURE 5-2. TABLE 7 FROM DS0-99-06 (GRAHAM) RECOMMENDED FATALITY RATES FOR LOL ESTIMATION

Flood Severity	Warning Time (minutes)	Flood Severity Understanding	Fatality Rate (Fraction of people at risk expected to die)	
			Suggested	Suggested Range
HIGH	no warning	not applicable	0.75	0.30 to 1.00
	15 to 60	vague	Use the values shown above and apply to the number of people who remain in the dam failure floodplain after warnings are issued. No guidance is provided on how many people will remain in the floodplain.	
		precise		
	more than 60	vague		
precise				
MEDIUM	no warning	not applicable	0.15	0.03 to 0.35
	15 to 60	vague	0.04	0.01 to 0.08
		precise	0.02	0.005 to 0.04
	more than 60	vague	0.03	0.005 to 0.06
		precise	0.01	0.002 to 0.02
	LOW	no warning	not applicable	0.01
15 to 60		vague	0.007	0.0 to 0.015
		precise	0.002	0.0 to 0.004
more than 60		vague	0.0003	0.0 to 0.0006
		precise	0.0002	0.0 to 0.0004



Fatality Rate is based off of 3 factors:

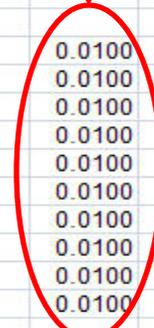
- Flood Severity – Low, Medium or High
- Warning Time
- Flood Severity Understanding

This example assumes:

- Flood Severity – Low
- Warning Time – No Warning
- Flood Severity Understanding – N/A

Fatality Rate = 0.01

	A	B	C	D	E	F	G	H	I	J	K
1	PAR (LOL)		*This is an unprotected sheet with formulas, see NOTE below for more details					Graham (1999) Loss of Life			
2	(population at risk)							Flood Severity		Fatality Rate	Loss of Life
3				Warning time	Water Depth at	PAR		Flood (assumed)	Warning Time	Flood	Flood
4	X-sec	River		(minutes)	Structure (ft)	census	Comments				
5	Number	Mile	Structure								
6	0	0.00	dam								
7											
8	Reach 1	0 - 0.23		0				low	0	0.0100	0.0000
9	Reach 2	0.23 - 0.55		0				low	0	0.0100	0.0000
10	Reach 3	0.55 - 0.87	Building	0	1	3		low	0	0.0100	0.0300
11	Reach 4	0.87 - 1.06		0				low	0	0.0100	0.0000
12	Reach 5	1.06 - 1.32		0				low	0	0.0100	0.0000
13	Reach 6A	1.32 - 1.41	2 Trailers	0	1	6		low	0	0.0100	0.0600
14	Reach 6B	1.41 - 1.52	3 Houses	0	1	9		low	0	0.0100	0.0900
15	Reach 6C	1.52 - 1.63	2 Houses	0	1	6		low	0	0.0100	0.0600
16	Reach 7	1.63 - 2.20		0				low	0	0.0100	0.0000
17	Reach 8	2.20 - 2.42	Road	0		3		low	0	0.0100	0.0300
18											



Step 6 – Calculate Loss of Life

Loss of Life = PAR X Fatality Rate

	A	B	C	D	E	F	G	H	I	J	K
1	PAR (LOL)		*This is an unprotected sheet with formulas, see NOTE below for more details				Graham (1999) Loss of Life				
2	(population at risk)						Flood				
3				Warning	Water	PAR		Severity		Fatality	Loss of Life
4	X-sec	River		time	Depth at	2000		Flood	Warning	Rate	
5	Number	Mile	Structure	(minutes)	Structure (ft)	census	Comments	(assumed)	Time	Flood	Flood
6	0	0.00	dam								
7											
8	Reach 1	0 - 0.23		0				low	0	0.0100	0.0000
9	Reach 2	0.23 - 0.55		0				low	0	0.0100	0.0000
10	Reach 3	0.55 - 0.87	Building	0	1	3		low	0	0.0100	0.0300
11	Reach 4	0.87 - 1.06		0				low	0	0.0100	0.0000
12	Reach 5	1.06 - 1.32		0				low	0	0.0100	0.0000
13	Reach 6A	1.32 - 1.41	2 Trailers	0	1	6		low	0	0.0100	0.0600
14	Reach 6B	1.41 - 1.52	3 Houses	0	1	9		low	0	0.0100	0.0900
15	Reach 6C	1.52 - 1.63	2 Houses	0	1	6		low	0	0.0100	0.0600
16	Reach 7	1.63 - 2.20		0				low	0	0.0100	0.0000
17	Reach 8	2.20 - 2.42	Road	0				low	0	0.0100	0.0100
18											
19				TOTAL PAR	=	27			TOTAL LOL	=	0.27

