APPENDIX

G. RISK EVALUATIONS

TABLE OF CONTENTS

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G.1 Risk Evaluation

All designs with floodplain encroachments should include an evaluation of the inherent flood-related risks to the highway facility and to the surrounding property. In the traditional design process, the level of risk is seldom quantified, but is instead implied through the application of predetermined design standards. For example, the design frequency, backwater limitations, and limiting velocity are parameters for which design standards can be set.

Two other approaches, however, are available that quantify risk on projects involving highway facilities designed to encroach within the limits of a floodplain. These are risk assessment and economic analysis.

Consideration of capital costs and risks should include, as appropriate, a risk analysis or risk assessment that includes:

- The overtopping flood or the base flood, whichever is greater
- The greatest flood that must pass through the highway drainage structure(s), where overtopping is not practicable

G.1.1 Risk Assessment

A risk assessment is a subjective analysis of the risks engendered by various design alternatives, without detailed quantification of flood risks and losses. It may consist of developing the construction costs for each alternative and subjectively comparing the risks associated with each alternative. A risk assessment usually is more appropriate for small structures or for structures whose size is highly influenced by non-hydraulic constraints. There are no well-defined procedures or criteria for performing risk assessments. However, an attempt should be made to screen projects and determine the level of analysis required. Some items to consider are:

- Backwater
    a. Is the overtopping flood greater than the design flood (100-year)?
    b. Is the overtopping flood greater than the check flood (500-year)?
    c. Is there potential for major flood damage from the overtopping flood?
    d. Could flood damage occur even if the roadway crossing wasn't there?
    e. Could flood damage be significantly increased by the backwater caused

by the proposed structure?

f. Could flood damage occur to offsite property owners?

- Traffic-Related Losses
  a. If the design flood is exceeded and the roadway is overtopped, is there a detour available?
- Roadway and/or Structure Repair Costs
  a. Is the overtopping flood greater or less than the design flood (100-year)?
  b. Is the embankment constructed from erosion-resistant material, such as a clay type soil?
  c. Does the embankment have good erosion-resistant vegetation cover?
  d. How long will the duration of overtopping be?
  e. Will the cost of protecting the roadway and/or structure from damage exceed the cost of providing a relief structure?
  f. Is there damage potential to the structure caused by scour, debris, or other means during the lesser of the overtopping flood or the design flood (100-year)?

If the risk assessment indicates the risks warrant additional study, a detailed analysis of alternative designs and associated costs is necessary to determine the design with the least total expected cost (LTEC) to the public.

G.1.2 Economic Analysis

An economic analysis (sometimes called risk analysis) encompasses a complete evaluation of all quantifiable flood losses and the costs associated with them for each structure alternative. This can include damage to structures, embankments, surrounding property, traffic-related losses, and scour or stream channel change.

The level of expense and effort required for an economic analysis is considerably higher than for a risk assessment, and selection of the process to be used should be based on the size of the project and the potential risk involved.

Further details of the economic analysis process and procedures for using it have been documented in HEC-17 (USDOT, FHWA, 1981). The full-scale detailed risk analysis described in HEC-17 would not be necessary for normal stream crossings, but would apply to unusual, complex, or high-cost encroachments involving substantial flood losses.

An example of a simple risk analysis follows.

G.2 SAMPLE RISK ANALYSIS

An existing double 10-foot x 4-foot concrete box culvert (CBC) crossing is the subject for this analysis.

G.2.1 Alternatives Considered

Alternative 1: Extend existing double 10-foot x 4-foot CBC (60 feet total length) with no change to road. Overtops at about a 17-year frequency; flooding at the site has not caused any accidents.

Alternative 2: New quad 10-foot x 5-foot CBC (60 feet total length). Raise road to meet FDOT 50-year HW (Headwater) criteria and closely match existing 100-year HW. Overtops at frequencies greater than 50 years.

Alternative 3: Bridge

Table G-1: Alternatives Data

	Alternative 1	Alternative 2	Alternative 3
Annual Capital Costs $ (i.e., Construction Costs)			
Annual Risks Costs $			
Total Costs $			

G.2.1.1 Calculations for Alternative 1

(A) Capital Costs

Quantities are from the Department's Culvert Design Program.

Extend 20 feet right	Concrete	43.1 CY	Steel	6,622 lbs
Extend 8 feet left		23.5 CY		3,283 lbs
Total quantity	Concrete	66.6 CY	Steel	9,905 lbs
Unit prices			$477/CY	$0.53/lb
Total capital cost = $37,018 =		$31,768	+ $5,250	

To convert to annual capital cost, use capital recovery factor (CRF) based on a discount rate of 7 percent and a 20-year design life.

$$CRF = \frac{i}{1-(1+i)^{-n}}$$ where: n = 20 and i = 0.07

Annual capital costs = $37,018 x 0.0944 = $3,494

(B) **Additional Economic Costs**

The following discussion estimates the additional losses associated with extending the existing culvert and allowing the road to overtop. The losses usually consist of embankment (and pavement), backwater, and traffic.

No embankment losses are expected. The existing road and culvert overtop, but there is no history of embankment or pavement loss.

There will not be any additional backwater losses compared to Alternative 2. Both Alternative 1 and Alternative 2 have essentially the same backwater characteristics.

There may be additional traffic losses associated with Alternative 1 when compared with Alternative 2, which would raise the road to reduce overtopping potential. Traffic-related costs consist of running time costs, lost time costs, and accident costs. Running time costs were estimated, lost time costs were ignored (detour length added only 1 mile to the travel distance), and accident costs were estimated but were found to be insignificant.

Assume traffic would have to be detoured:

1 day for 25-year storm event (roadway tops at about a 17-year event)
2 days for 50-year storm event
3 days for 100-year storm event
4 days for 200-year storm event

The additional detour distance is 0.5 mile on a two-lane undivided roadway and 0.5 mile on a four-lane divided roadway.

<u>Additional running costs</u> = Cost per mile x ADT x additional detour length (miles)
Assume cost per mile = $0.35/mile

$\$_{25\ yr}$ = $0.35 x 27250 vpd x 1.0 mi x 1 day = $9,538

$\$_{50\ yr}$ = $0.35 x 27250 vpd x 1.0 mi x 2 days = $19,075

$\$_{100\ yr}$ = $0.35 x 27250 vpd x 1.0 mi x 3 days = $28,615

$\$_{200\ yr}$ = $0.35 x 27250 vpd x 1.0 mi x 4 days = $38,150

<u>Additional accident costs</u>: These are additional costs due to increased travel distance due to the need to detour.

Additional detour length is 0.5 mi on a two-lane undivided roadway and 0.5 mi on a four-lane divided roadway.

Accident cost = crash rate x vehicle miles x cost per crash

Vehicle miles = ADT x additional detour distance x number of days of detour

Get the crash rate and the cost per crash from the FDOT Safety Office.

Crash rate =	1.9 crashes/million vehicle miles for urban, two-lane, undivided roadways
	0.8 crashes/million vehicle miles for urban, four-lane, divided roadways
Cost per crash =	$28,000 for urban, two-lane, undivided roadways
	$26,000 for urban, four-lane, divided roadways

$\$_{25}$ = ($28,000 x [27,250 x 0.5 x 1] x 1.9) + ($26,000 x [27,250 x 0.5 x 1] x 0.8)
$\$_{25}$ = $1,008.25

Using the same method, with 50-year detour = 2 days, 100-year detour = 3 days, and 200-year detour = 4 days:

$\$_{50} = \$2,016.50$
$\$_{100} = \$3,024.75$
$\$_{200} = \$4,033.00$

Traffic losses in the following table are the sum of increased running costs and increased accident losses.

Table G-2: Summary of Economic Losses

Frequency (yr)	Losses ($)			Total Losses ($)
	Embankment & Pavement	Backwater	Traffic	
5	0	0	0	0
10	0	0	0	0
15	0	0	0	0
25	0	0	9,538 + 1,008.25 = 10,546.25	10, 546.25
50	0	0	21,091.50	21,091.50
100	0	0	31,639.75	31,639.75
200	0	0	42,183.00	42,183.00

Table G-3: Summary of Annual Risk Costs

Freq. (yr)	Exceed. Prob.	Losses ($)	Average Loss ($)	Delta Prob.	Annual Risk Costs ($)
5	0.2	0			
10	0.1	0			
15	0.07	0			
			5,273.13	0.03	158.19
25	0.04	10,546.25			
			15,818.88	0.02	316.38
50	0.02	21,091.50			
			26,365.63	0.01	263.66
100	0.01	31,639.75			
			36,911.38	0.005	184.56
200	0.005	42,183.00			
			42,183.00	0.005	210.92
	0	42,183.00			
Total Annual Risk Costs					**1,133.71**

G.2.1.2 Calculations for Alternative 2

Replace with quad 10’ x 5’ CBC

(A) Capital Costs

Concrete (from box culvert program) = 219.7 CY @ $477/CY = $104,797
Steel (from box culvert program) = 42,251 lbs @ $0.53/lb = $22,393

(B) **Rebuild 400’ of Roadway**

Structural Course (2’ x 24’) = 1,067 SY @ $3.40/SY = $3,628
Base group 9 = 1,067 SY @ $6.16/SY = $6,573
Neglect earthwork costs

Total Capital Costs = $137,391

Annual Capital Cost = Total x CRF = $12,970

This alternative would overtop at frequencies greater than the 50-year storm event and would, therefore, have some annual risk costs. These risks were not calculated because the annual cost alone is greater than the total cost for Alternative 1. If the capital costs for Alternative 2 were less than the total cost for Alternative 1, it would be necessary to calculate the other costs associated with this alternative.

G.2.1.3 Calculations for Alternative 3

57-foot-long x 44-foot-wide flat slab bridge

(A) Capital Costs

57 feet x 44 feet x $40/sf = 2,508 sf x $40/sf = $100,320

Annual cost using CRF = 0.0944 = $9,470

(B) Costs Not Estimated

Roadway fill and new base and asphalt. At a minimum, 900 feet of roadway would have to be rebuilt to raise the grade to meet the bridge. (Bridge would be raised to meet FDOT drift clearance requirements.)

Standard 1H:2V front slopes encroach into roadside ditches. Since the upstream roadside ditch conveys substantial flow, it may not be possible or wise to reduce its capacity. Vertical walls and/or additional right of way may be necessary.

Miscellaneous factors include driveway connections within the raised roadway section, and the aesthetics of the raised road and bridge.

Table G-4: Cost Comparisons

Cost Item	Alternative 1	Alternative 2	Alternative 3
Annual Capital Costs (i.e., Construction Costs)	$3,494	$12,970	$9,740
Annual Risks Costs	$1,134	>0	>0
Total Costs	$4,628	>$12,970	>$9,740

Alternative 1 is the most economical alternative and the most desirable when considering other impacts.