An Outline Systems Analysis of the Flooding Problem in Cork City

A Plea to Re-Open The Design Process

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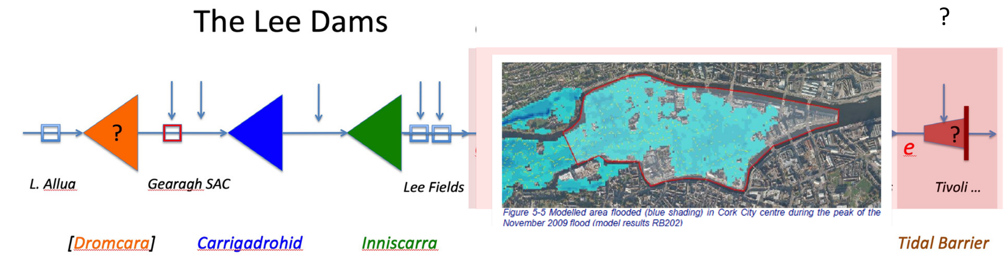
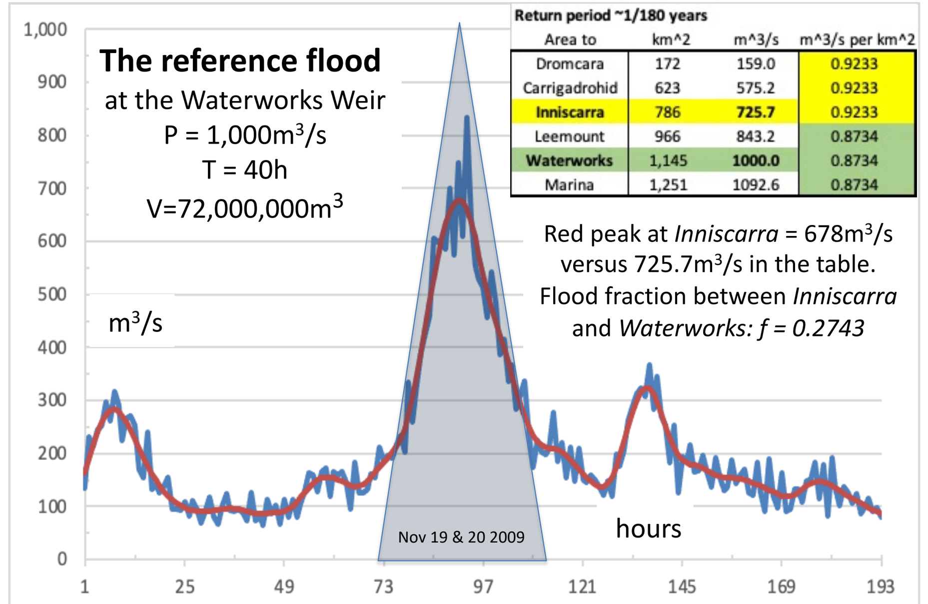
The OPW's "emerging solution" to protect Cork City from a repetition of the flood of November 2009 (plus a safety margin) consists of ground-water pumps, and 1.4m high embankments, walls, walls with 'gaps and demountables', running for 14km around the Central Island, providing 'safe' hydraulic conveyance of the design peak of 550m^3/s. This scheme will not protect the *Docklands Development,* will change irrevocably the maritime character of the city with its ancient open quays, convert the city centre into a building site for the second time in a generation, and fail to deliver 'value-for-money' mandated by Statutes of the *Oireachtas*. There are much better alternatives away from the city. If the two gated hydro-electric dams on the *Lee* are operated in a different way, using 'conjunctive e-target control' [see the companion poster for details], the risk of flooding from the river can be eliminated. No 1.4m high walls are needed, with a significant saving to the public purse. The decision of the Supreme Court in July 2020 found that the dam operator has a duty to confer on the city the benefit of flood control "in certain circumstances". Consequently, this poster calls for a new multi-disciplinary design process for protecting Cork from riverine, tidal and groundwater flooding, and justifies this public plea with an outline Systems Analysis of the problem, upstream and downstream of the city, that enhances the economic, ecological and amenity value of the waters of the river *Lee,* its catchment and estuary, while avoiding adverse impact on the commercial life and historic character of maritime Cork. A tidal barrier at or seawards of *Tivoli* deserves particular attention, similar to the *Lagan Weir and Barrier* in *Belfast*, and the *Marina Barrage* in *Singapore.*

The System

Flooding in Cork:
1. Pluvial,
2. Fluvial,
3. Tidal,
4. Groundwater.



Cork's Central Island,
November 19 & 20 2009 flood:
OPW model output



Return period ~1/180 years			
Area to	km^2	m^3/s	m^3/s per km^2
Dromcara	172	159.0	0.9233
Carrigadrohid	623	575.2	0.9233
Inniscarra	786	725.7	0.9233
Leemount	966	843.2	0.8734
Waterworks	1,145	1000.0	0.8734
Marina	1,251	1092.6	0.8734

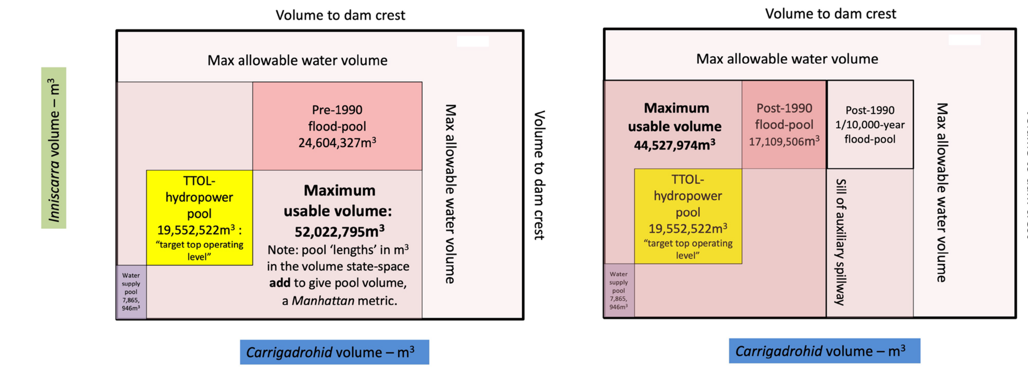
Estimated river flow [no dams] at *Inniscarra* Nov 2009 [data courtesy of the ESB]

Three storage pools at the *Lee Dams* -

the short-term flood-pool at *Carrigadrohid Dam* was halved in 1990

Pre-1990 storage

Post-1990 storage



Volumetric data on flood-, hydro-power- and water-supply-pools in each dam

Pre-1990	Carrigadrohid	Pool size	Iniscarra	Pool size		Sum of pools
Flood top	28,892,590		23,130,205		52,022,795	
		15,900,150		8,704,177		24,604,327
Hydro-TTOL top	12,992,440		14,426,028			
		10,390,231		9,162,291		19,552,522
Water-supply top	2,602,209		5,263,737			
		2,602,209		5,263,737		7,865,946
Bottom	0		0		0	
Sum		28,892,590		23,130,205		52,022,795

Post-1990	Carrigadrohid	Pool size	Iniscarra	Pool size		Sum of pools
Flood top	21,397,769		23,130,205		44,527,974	
		8,405,329		8,704,177		17,109,506
Hydro-TTOL top	12,992,440		14,426,028			
		10,390,231		9,162,291		19,552,522
Water-supply top	2,602,209		5,263,737			
		2,602,209		5,263,737		7,865,946
Bottom	0		0		0	
Sum		21,397,769		23,130,205		44,527,974

Reservoir operating procedures during a flood event

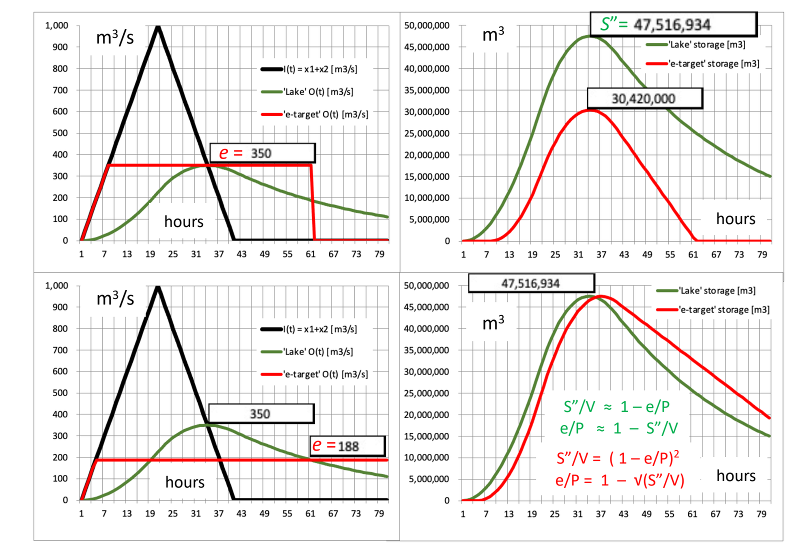
'Lake' control

- Releases proportional to volume in storage
- **"Don't worsen nature" Nollumus mutari**

'e-target' control

- Release all inflows less than *e [m^3/s]*,
  as if the dams
  were not there
- Follow the supreme court ruling to
  protect the city
  "in certain circumstances":
  when the inflow exceeds e,
  store the e-excess in the flood-pool,
  throttle releases for tributaries
  below the dams,
  balance the dams with the
  'empty-space rule', and
  empty the flood-pool at a rate *e.*

'e-target' control of the reference flood is almost twice as efficient as 'lake' control



Cases 1-3: diagnosis

Reference flood - 1/180 years P=1,000m^3/s. V=72,000,000m^3 at the Waterworks Weir	'lake' control no defenses pre-1990	'lake' control no defenses post-1990	'e-target' control no defenses post-1990
'No-flood-in-the-city' - m3/s	350	350	350
Storage volume required - m3	51,071,460	51,071,460	30,420,000
'No-flood-in-City'?	No-flood-in-City	City fooded	No-flood-in-City
flood-pool volume	24,604,327	17,109,506	17,109,506
hydro-pool volume	19,552,522	19,552,522	19,552,522
water-supply pool	7,865,946	7,865,946	7,865,946
total	52,022,795	44,527,974	44,527,974
Take from hydro-power-pool	19,552,522	19,552,522	13,310,494
Take from water-supply-pool	6,914,611	7,865,946	0
% take from hydro-power pool	100%	100%	68%
% take from water-supply pool	88%	100%	0%

Diagnosis: case 1 (pre-1990)

- When the flow in the river *Lee* exceeds 350m^3/s at the *Waterworks Weir*, riverine flooding begins.
- The *Lee* dams, **under 'lake' control**, **can** re-shape the reference flood of 72,000,000m^3 using almost the entire storage capacity of 52,022,795m^3 :
  flood-pool plus hydro-power-pool capacity
  plus 88% of the water-supply-pool capacity,
  reducing the 1,000m^3/s peak by 65% to 350m^3/s.
- Consequently, one may say **'no-flood-in-the-city'.**

Diagnosis: case 2 (post-1990)

- In 1990 the flood-pool at *Carrigadrohid* was halved, reducing the overall storage capacity at the two dams from 52,022,795 to 44,527,974m^3.
- The post-1990 dams, **under 'lake' control**, **cannot** re-shape the reference flood of 72,000,000m^3 using the reduced dam-storage capacity to attenuate the 1,000m^3/s peak to 350m^3/s.
- Consequently, one may say **'city flooded'** by the reference flood under 'lake' control post-1990.

Diagnosis: case 3 (post-1990)

- Replace the 'lake' control operating procedure with 'e-target' control.
- The *Lee* dams, under 'e-target' control, **can** re-shape the reference flood of 72,000,000m^3 using the
  entire flood-pool capacity, plus
  68% of the hydro-power-pool capacity, and nothing from the water-supply-pool capacity,
  reducing the 1,000m^3/s peak by 65% to 350m^3/s.
- Consequently, there is **'no-flood-in-the-city'** under 'e-target' control of the reference flood post-1990.

Diagnosis of the inundation of Cork in November 2009 – two causes :

- The creation in 1990 of a permanently empty flood-pool at *Carrigadrohid* for the 1/10,000-year flood, halved the short-term flood-pool at *Carrigadrohid* for the attenuation of lesser floods.
- The refusal in 1990 to change the control procedure for the operation of the dams during floods: 'don't worsen nature'; nollumus mutari.

Cases 4-7: solutions

Reference flood - 1/180 years P=1,000m^3/s. V=72,000,000m^3 at the Waterworks Weir	4: 'lake' control with defenses post-1990	5: 'e-target' control no defenses post-1990	6: 'e-target' control no defenses pre-1990 restored	7: 'e-target' control no defenses plus Dromcarra/Allua
'No-flood-in-the-city' - m3/s	550	267	267	267
Storage volume required - m3	38,718,947	38,718,947	38,718,947	38,718,947
'No-flood-in-City'?	No-flood-in-City	No-flood-in-City	No-flood-in-City	No-flood-in-City
				14,114,620
flood-pool volume	17,109,506	17,109,506	24,604,327	24,604,327
hydro-pool volume	19,552,522	19,552,522	19,552,522	19552522
water-supply pool	7,865,946	7,865,946	7,865,946	7,865,946
total	44,527,974	44,527,974	52,022,795	66,137,415
Take from hydro-power-pool	19,552,522	19,552,522	14,114,620	0
Take from water-supply-pool	2,056,919	2,056,919	0	0
% take from hydro-power pool	100%	100%	72%	0%
% take from water-supply pool	26%	26%	0%	0%
	OPW 'emerging solution'	Current ESB control?	Save Cork City	Save Cork City

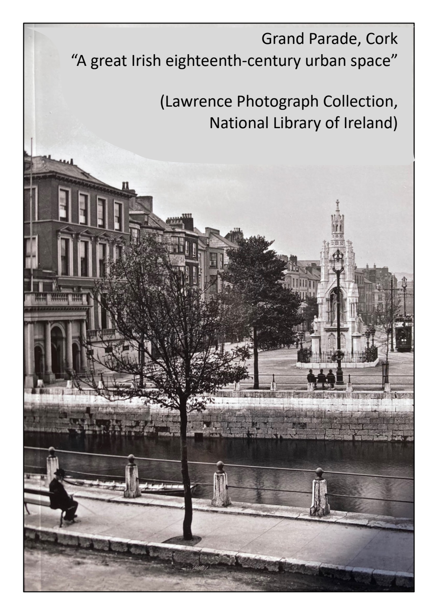
Solution: case 4 the OPW "emerging solution"

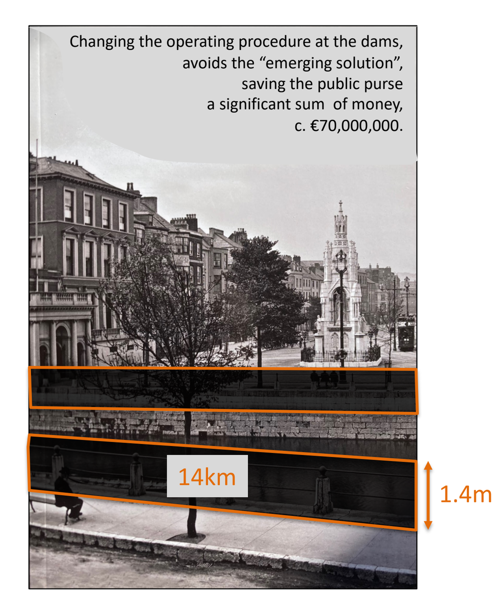
- The OPW "emerging solution" of 14km x 1.4m walls etc has a **design flow of 550m^3/s** at the Waterworks Weir, the entrance to the city.
- The reference flood of 72,000,000m^3 requires a total reservoir storage capacity of 38,718,947m^3 :
  flood-pool plus hydro-power-pool capacity
  plus 26% of the water-supply-pool capacity,
  to reduce its 1,000m^3/s peak to 550m^3/s.
- Hence, we may say **'no-flood-in-the-city'** under **'lake' control** of the reference flood post-1990**.**

Solution: case 5 'the *Lee* dams are good for big floods'

- But if **'e-target' conjunctive control** is used instead of 'lake control', the maximum flow through the city falls to **267m^3/s,** well below the 350m^3/s above which the City is flooded. *[f=0.274]*
- The reference flood is attenuated by 73% using the same total storage, 38,718,947m^3, in case 4.
- Hence, **defenses with 14km x 1.4m walls are NOT needed** to protect the Centre of Cork from the reference flood under 'e-target' control post-1990.

The "emerging solution" for Cork





Solutions: cases 6 and 7, the hydro-power and water-supply pools.

- If fuse-gates were to restore the pre-1990 flood-pool at *Carrigadrohid,* and if the third reservoir were built at *Dromcara/Allua,* there would be no 'take' from the hydro-power and water-supply pools, for the same maximum flow through the city of 267m^3/s presented in case 5 *[f=0.274]*.
- There are many other intermediate cases, and also different reference storms, that merit examination in a Systems Analysis of the full range of alternatives, (costs and benefits), for combatting riverine flooding in Cork with conjunctive 'e-target' control of the *Lee* dams.

Solutions: a tidal barrier at *Tivoli …* for tidal & groundwater flooding.

- Under an 'e-target' flow of 275m^3/s, a volume of 8,415,000m^3 will accumulate behind the barrier when it is closed for 8.5 hours starting at low tide.
- A low-head tidal pump with a capacity of 100m^3/s can remove 3,060,000m^3 in 8.5 hours, leaving 5,355,000m^3 to be stored in the North and South Channels, and on the Lee Fields, without flooding the City.
- As the location of the barrier is moved seawards, the capacity of any tidal pump that is required, declines to zero, at a location to be determined by Systems Analysis. A benefit-cost analysis will size the pump. It may be zero.