Tonkin & Taylor

Fish Passage

…an engineering perspective…

Fish Passage Symposium 2013

BRYN QUILTER

Civil & Environmental Engineer

Tonkin & Taylor Ltd

Introduction

Tonkin & Taylor

Presentation is a collection of thoughts, experiences and observations by engineers including:

- Design communication issues
- Common structures
- H&S and maintenance
- A quick look at habitat enhancement

Communication

Tonkin & Taylor

- Client needs a culvert under a road, what's an engineer to do?
  - Design criteria set as 100yr flow only
  - Simple flow calculation
  - Simple hydraulic calculation
  - **Output easy and no need to talk to anyone**

Communication

Tonkin & Taylor

- Now the culvert needs fish passage, what's an engineer to do now?
  - Design criteria now includes, low flow with low velocity and min depth plus the 100yr flow
  - Now we have multiple flow calculations, and low flow estimates typically have high error margins
  - **Calculations are at a level we don't normally work at so our 'typical' inputs don't work**
  - **Now we need to talk to someone**

Communication

Tonkin & Taylor

- Example: ramp/culvert design:

normally we only look at a single low flow point with say:

  - Low flow (say MALF) = 0.2m3/s
  - Velocity criteria < 0.3 m/s
  - Flow Depth criteria > 200mm

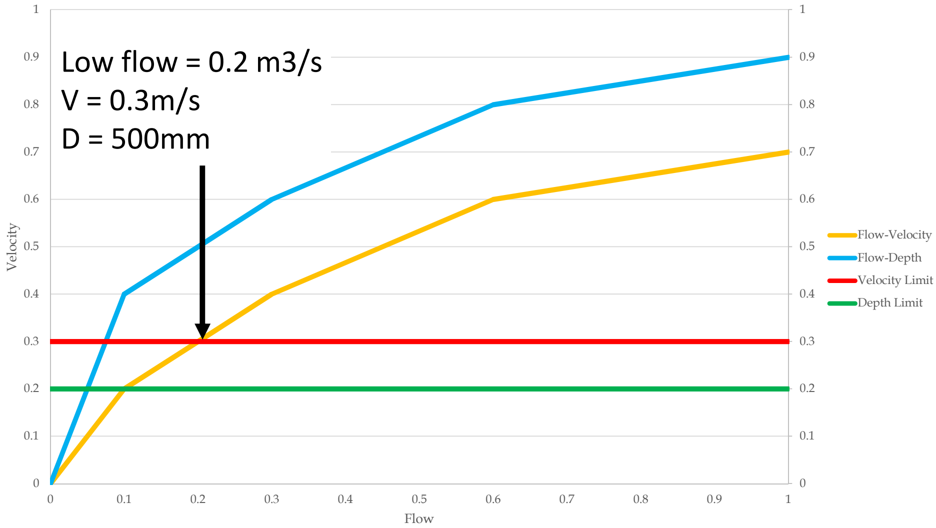
Communication

Tonkin & Taylor

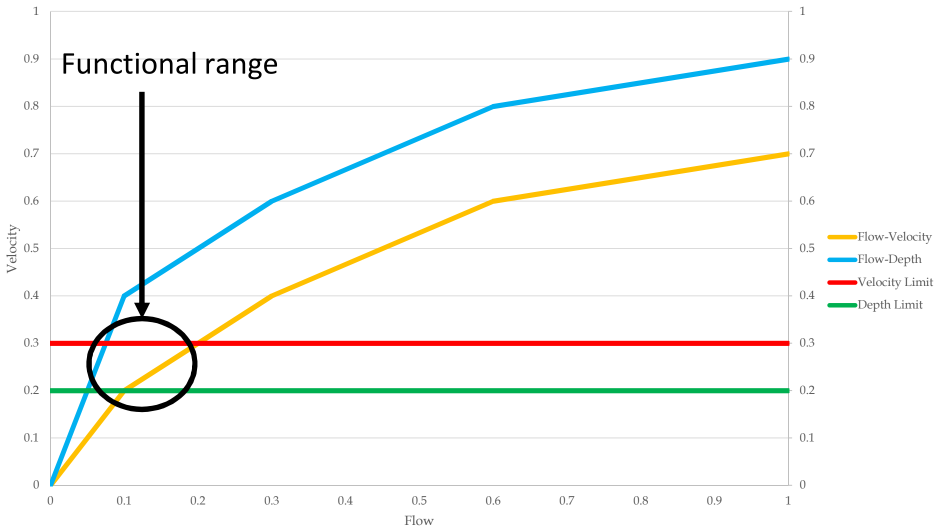
- Using a single point flow we get an answer "that works" but….**design flows are very, very critical to functional performance**

what is the *functional range* of our design?

Example design



Example design



Communication

Tonkin & Taylor

QUESTION: What design flow range?

- Establish design flow ranges, say:
  - MALF < DESIGN FLOW < 100% AEP flow
  - i.e. acknowledge when fish passage is not needed and/or not viable

Note: the selection of the upper and lower bounds here is arbitrary but not unrealistic and needs debate

Example design

Tonkin & Taylor

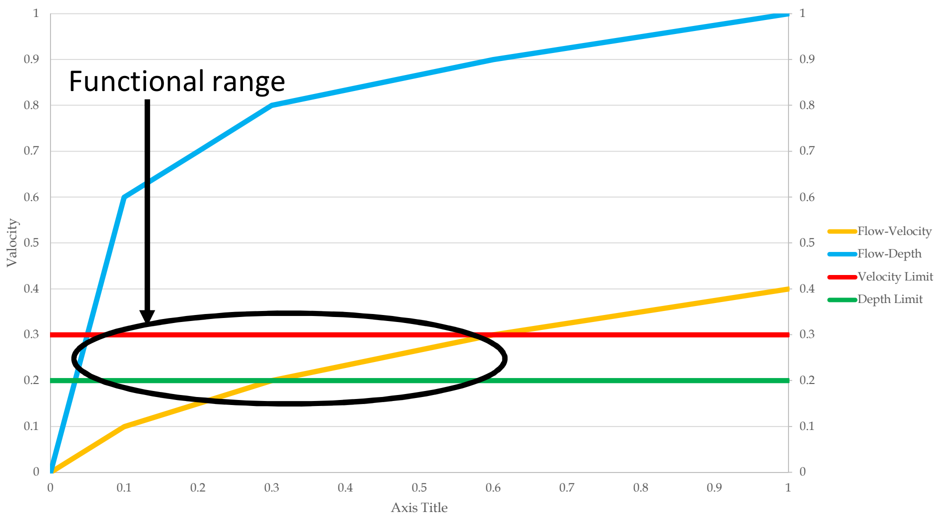
Communication

Tonkin & Taylor

- Choice of velocity limit and flow depth limit greatly influence functional range review.
- **Ecologist must tell engineer what is required**
- Given our example, how can we improve functional range?
  - Try reducing slope…

Example design with decreased slope

Tonkin & Taylor



Communication

Tonkin & Taylor

QUESTION: How far can a fish swim at higher velocities before it needs a rest?

- Ecologist need to talk to engineers about burst/prolonged speed
  - i.e. acknowledge that fish can swim at higher speeds over short distances

Communication

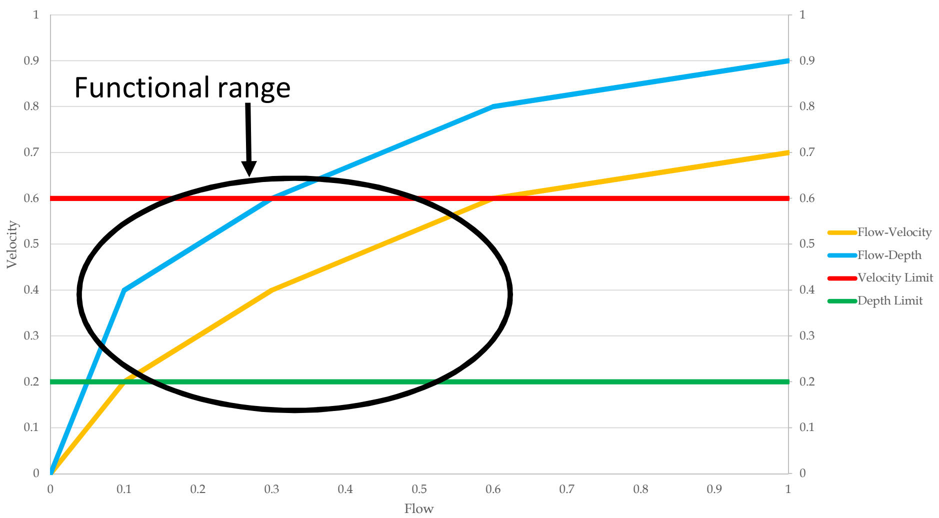
Tonkin & Taylor

- Given our example, how can we improve functional range without reducing slope?
  - Lets try reducing ramp/culvert run length, adding a rest pool and increasing the velocity limit, say:
    - 5m length sections with V max = 0.6 m/s

Note: Again numbers above are arbitrary & for debate

Example design with rest pool

Tonkin & Taylor

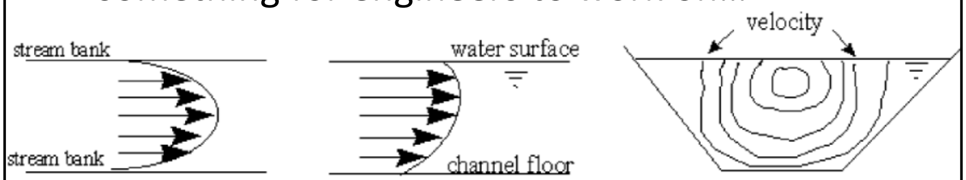


Communication

Tonkin & Taylor

NOTE ON VELOCITY

- Engineers report velocity as an average
- Actual velocities will vary from zero (or even negative) to say 2 or 3 x average
- Determining velocity range not that easy and something for engineers to work on…



Communication

Tonkin & Taylor

QUESTION: Is connectivity available? under what constraints?

- Tidal outfalls – is it realistic to expect connectivity at low tide?
  - Perhaps only mid to high tides are appropriate?
- Channels – can fish get to the barrier? Can they get anywhere from it?
  - Consider upstream and downstream access?

Communication

Tonkin & Taylor

Example design summary: need to consider

- flow range criteria
- burst/prolonged speed criteria
- ‘functional range’ of design
- tidal access limitations
- stream access upstream and downstream

Communication

Tonkin & Taylor

- Pro-forma for debate
- Covers
  - Flows
  - Flow depths
  - Length-velocity (burst speed) criteria
  - Connectivity

Communication

Tonkin & Taylor

FISH PASSAGE DESIGN COMMUNICATION TABLE		
Flows (m3/s)		
What flow points are to be estimated:		
	Flows (m3/s)	
MALF	0.2	MALF estimated only
3 month	0.5	Approximated 1/3 of 2yr event
1 year	0.9	Calculated
Minimum flow depth required (mm)		
200		
Length-Velocity criteria (m-m/s)		
How fast can fish swim over various lengths (burst speed)		
m	m/s	
20	0.15	
10	0.3	
5	0.6	
Upstream & Downstream Connectivity		
Tidal	YES/NO	
Tidal access	ALL/>MHW/etc	
Stream works	YES/NO	
Rest pools	top/middle/bottom	
Min pool depth	300 mm	
Min pool length	1500 mm	

Communication

Tonkin & Taylor

Flows (m3/s)

What flow points are to be estimated:

Flow event	Flows (m3/s)	
MALF	0.2	ave 'dry weather' flow
3 month (400% AEP)	0.5	say, occurs 4x per year
1 year (100% AEP	0.9	say, occurs 1x per year

Communication

Tonkin & Taylor

Minimum flow depth required (mm)

200

Length-Velocity criteria (m-m/s)

m	m/s
20	0.15
10	0.3
5	0.6

Communication

Tonkin & Taylor

Upstream & Downstream Connectivity		
Tidal	YES/NO	
Tidal access	ALL/>MHW/etc	
Stream works	YES/NO	
Rest pools	Top/middle/bottom	
Min pool depth	300	mm
Min pool length	1500	mm

Communication

Tonkin & Taylor

- Communication summary:
  - Key criteria need to be discussed and agreed
  - Establishment of key criteria can make it easier for engineer to design works and improve outcomes
  - Reporting of constraints, issues and success can be more clear

Common structures

Tonkin & Taylor

- Culverts
- Weirs
- Ramps
- Flood/flap gates

Common structures

Tonkin & Taylor

- **Culverts & mussel spat rope**
  - Suitable for pipes < 1.8m i.e. install & maintenance access issues are eliminated
  - Good for mitigation in disjointed pipes
  - Lead-in and exit lengths to extend beyond channel constrictions, often 5-10x pipe size
  - Long lead-in and exit lengths can cause rope to lift out of flow
  - Fix rope at key points to prevent lifting

Suitable for pipes < 1.8m i.e. install & maintenance access issues are eliminated

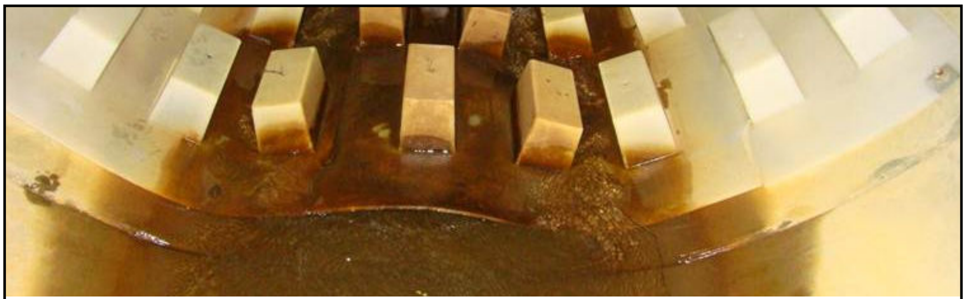
Lead-in and exit lengths to extend beyond channel constrictions and high velocity zones, often 5-10x pipe size

Long lead-in and exit lengths can cause rope to lift out of flow, need regular fixings

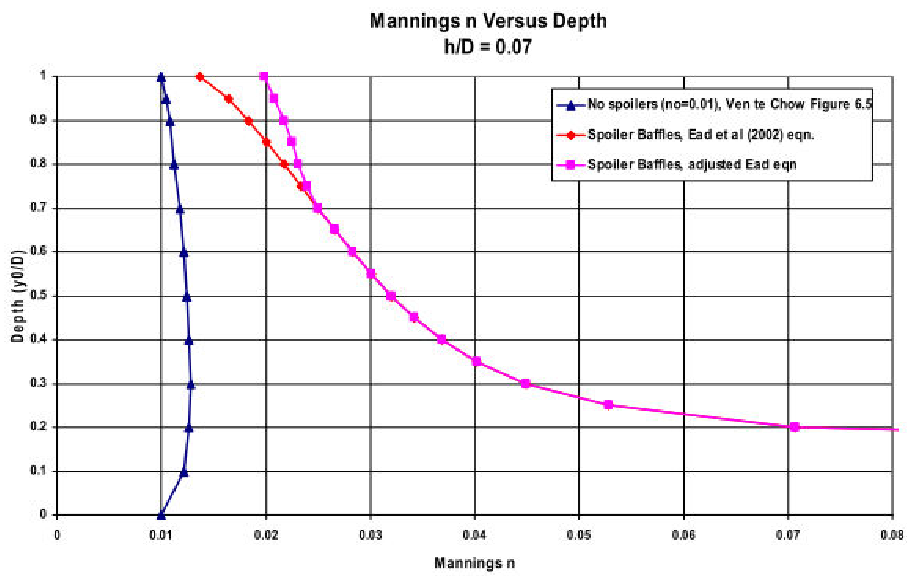
Common structures

Tonkin & Taylor

- **Culverts & baffle/rock substrates**
  - Suitable for pipes > 1.8m i.e. install & maintenance access issues are less significant
  - Baffle insert and maintenance access is still quite constrained in pipes < 2.3m
  - Fixing and sealing of baffles to prevent underflow and eventual uplift an issue
  - Manning's roughness changes with depth, little good design guidance – see T&T et al papers
  - Consider apron details



Fixing and sealing of baffles to prevent underflow and eventual uplift an issue, use stainless steel fixings and grout mortar pads with galvanised wire mesh



T&T et al paper on Northern Gateway stormwater design - useful design aid

Consider apron details…and visit site during construction

Consider apron low flow channels, especially for swimmers

Locate control (i.e. weir) beyond channel constriction, often 5-10x pipe size.
Can fish get through the control? – see WEIRS & RAMPS

Common structures

Tonkin & Taylor

- **Weirs**
  - **Low flow small diameter culverts** can often be used below weir overtopping height – need to assess how culvert discharge affects water levels
  - Smooth transition roll-over type weir design is required to avoid 'water falls' and reduce velocity step changes
  - Ramps – see RAMPS

Smooth transition roll-over type weir design is required to avoid 'water falls' and reduce velocity step changes

Common structures

Tonkin & Taylor

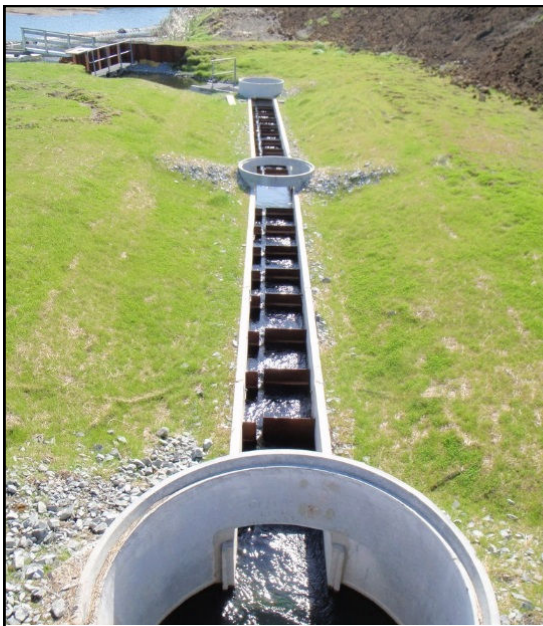
- **Ramps**
  - 'Ramps' and 'ladders' are called channels in an engineers world
  - **Providing flow depth and low velocity for swimmers is challenging**

Channel shape and substrate are key issues
Providing a wet margin only for climbers simplifies design

Common structures

Tonkin & Taylor

- **Ramps**
  - Asymmetric channels can provide a trade off in achieving flow depth, low velocity zones and a wet margin
  - **Substrate choice significantly affects calculations**
  - **Manning's roughness numbers can change significantly with depth** - **refer T&T et al papers**
  - Manning n (trapezoidal channel) with rock up to 150mm and depth up to 300mm = 0.11 -0.16



T&T et al paper on ramp flume testing is useful design aid and proven for vertical slot baffle at Taharoa

Big rocks/gabions can limit fish passage, often need designed low flow path

Asymmetric low flow channels can provide a trade off in achieving flow depth, low velocity zones and a wet margin

Common structures

Tonkin & Taylor

- Flood/flap gates
  - Again look at **functional range**.
  - Functional range is xxx? – can we improve range?

If there is water flowing, the gate will be open a bit: issues are **velocity, water depth, opening size and time open**

Common structures

Tonkin & Taylor

- Water depth and velocity can be managed by looking at:
  - Outlet water level control i.e. weirs
  - Low flow bypass using small diameter culverts or ramps
    - Operational range of stored water level may be critical
    - Water retaining structures (dams etc) may require floating, pumped or siphon flow intakes for ramps

LOW TIDE: meagre low flow with poor/nil connection to water line

MID TIDE: Good connection to water line but gate closed due to insufficient flow/water depth upstream

Common structures

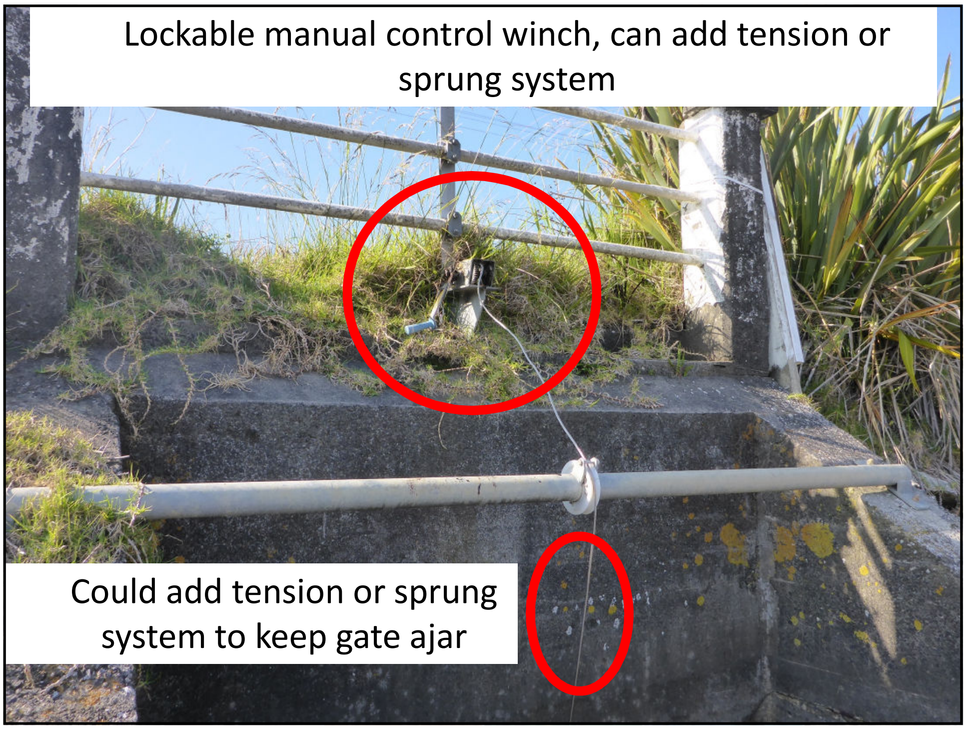
Tonkin & Taylor

- Functional range limited by:
  - Poor low tide connectivity
  - Flat upstream topography and small low flow cannot generate enough head to open gate, even at mid tide
- Functional range time about 1-2 hours per tide cycle

Common structures

Tonkin & Taylor

- Improve functional range by:
  - Lower culvert invert
  - Add ramp to low tide level
  - Use balanced/tensioned openings
  - Adopt manual control i.e. leave gate open and adopt emergency response plan



Common structures

Tonkin & Taylor

- Flood/flap gates – balanced/tensioned
  - Counter-weight mass or **spring/strap tension is critical** – monitor/adjust after installation
  - Build up and release of flow can cause **cycling of system and can lead to mechanical fatigue**

H&S and maintenance

Tonkin & Taylor

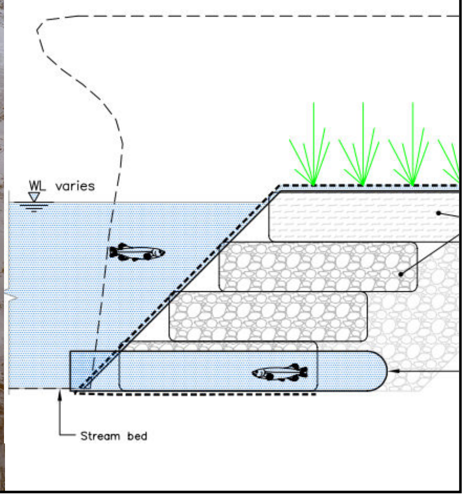
- Current proposed legislation indicates that all parties involved MUST consider through all stages **'safety in design'**
- Confined space (e.g. small culvert and manhole) entries may be **'notifiable hazards'**
- Culverts with substrate installation must **consider practicalities of culvert size in construction, inspection and maintenance**

Habitat Enhancement

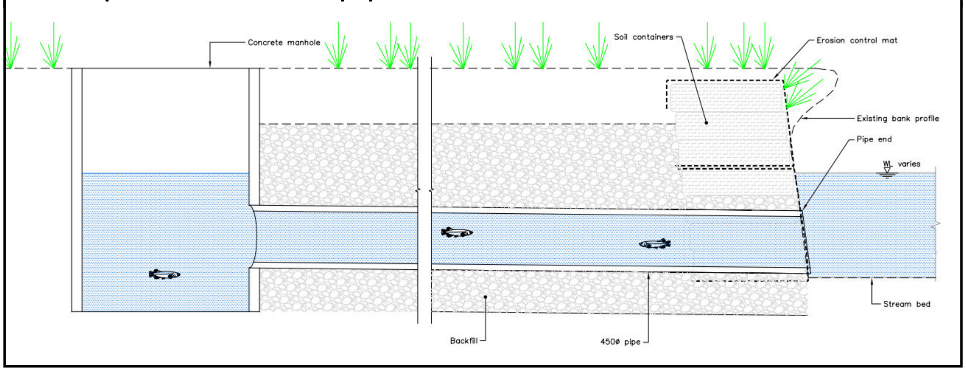
Tonkin & Taylor

- T&T has designed and implemented:
  - Small and large diameter **pipe habitats**
  - Log overhang habitats
  - Woody weirs, pool/riffle sequencing and bank slope variations for **flow diversity**
  - **T&T et al papers useful design aids**

"Tuna townhouse" 150mm flexible pipe in u-shaped lengths set in stream bank was **simple and cheap**



"Kokopu Condo" 450 pipe and manhole habitat in Hamilton



Summary

Tonkin & Taylor

- Fish passage design issues are complex
- Scientist-engineer communication and interaction is critical
- Design discussion and review needed at
  - Concept stage
  - Design development stage
  - Detailed design stage
  - **Construction stage**

Acknowledgements

Tonkin & Taylor

- Peter West, Bay of Plenty PRC
- Ghassan Basheer, Waikato RC
- Peter Mitchell, Auckland Motorways
- Conal Summers, Whangarei DC

Acknowledgements

Tonkin & Taylor

- Auckland
  - Simon Croft
  - Tim Fisher
  - Ben Chester
  - Tom Basset
  - Brett Ogilvie
  - Liza Inglis
- Hamilton
  - Dean Miller
- Tauranga
  - Mark Pennington
- Wellington
  - Ed Breese
- Nelson
  - Neville Laverick
- Christchurch
  - Tim Morris

T&T et al engineering papers

- P. Roan et al: *Using woody debris for in-stream habitat restoration – the Olympic Park project*, 2007 NZ Stormwater Conference Proceedings
- D. Leong et al: *Alpurt B2 – Stormwater design and environmental enhancements*, 2007 NZ Stormwater Conference Proceedings
- T. Fisher et al: *Mangakotukutuku Stream diversion – environmental design in action*, 2007 NZ Stormwater Conference Proceedings
- D. Leong et a: *Creating fish habitat: mitigating the impacts of long culverts*, 2007
- S. Coleman et al: *Flow characteristics of two exemplar fish pass designs*, 2009

Questions?

Bryn Quilter

Tonkin & Taylor Ltd

Phone: 64-7-834 7320

Email: bquilter@tonkin.co.nz

Website: www.tonkin.co.nz