RISK MANAGEMENT OF WATERWAYS: IMPACT DETERMINATION OF BARRIER WORKS FOR FISH PASSAGE IN QUEENSLAND

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The Queensland Department of Agriculture and Fisheries (DAF), Australia has a statutory role in the assessment of the impacts a proposed development may have upon fish passage. The decision on the importance of a waterway to fish passage (a waterway determination) was previously made on a case-by-case basis. Although the definition of a waterway is consistent, the characteristics of an individual waterway and their importance to fish passage have been interpreted differently by DAF staff and applicants. In March 2013, DAF released a spatial layer with a waterway determination for every waterway across the State that is considered to be important to fish passage. These waterway determinations are coded into five colours depending on how instream development impacts upon fish passage, ranging from Purple (major impacts) down to Green (low impacts). The Department now uses this spatial layer to trigger and assess Development Approvals and its use has streamlined the waterway determination process, providing a transparent and definitive determination both in-house and for the wider community. The spatial layer has also enabled a major redefinition of a set of waterway barrier works self-assessable codes that are used for fish passage under minor works. The codes outline a set of acceptable development risks that the Department is satisfied can occur without the need for a development approval or further fish passage mitigation. With the use of this spatial layer, the codes are now better attuned to the impacts development (waterway barriers) could have upon fish passage in all five colour-coded waterways.

1 BACKGROUND

The requirement to provide fish passage has been in Queensland legislation since 1945, but implementation was patchy until the introduction of the *Fisheries Act (1994)*. Prior to the implementation of the Act, fish passage was still considered to be important, but most fishways were installed voluntarily. Of those fishways built in Queensland (before the Act), all were modeled after those constructed in Europe and the United States of America (USA) designed for Salmon; a method that did not suite the biology of Queensland's native fish and were essentially ineffective. The realization in the early 1990's that these fishways were neither practical nor effective set about the transformation of approach to fish passage in Queensland.

With the introduction of the *Fisheries Act 1994* a number of definitions came into effect to help distinguish what is a waterway and what is waterway barrier works. The Act describes a waterway as: - *a waterway includes a river, creek, stream, watercourse or inlet of the sea* [1]. This definition is broad and open to interpretation to those within the Development Approval industry. The Queensland Department of Agriculture and Fisheries (DAF) expanded on this definition, bringing into policy an extended version of what is a waterway that included the physical and hydrological attributes of what is considered to be a waterway. The following is an extract from departmental policy documents: - for DAF purposes, features relevant to fisheries resources, such as the physical and hydrological attributes are considered. These are:

- Defined bed and banks
    - The bed and banks need to be continuous upstream and downstream of the site rather than isolated and broken sections of a depression

- Extended (or permanent) period of flow
    - Flow must continue beyond the duration of a rain event and have some reliability commensurate with rainfall. Distinguish between channels just funneling immediate localised rainfall and waterways that have flow arising from upstream catchment.
- Flow adequacy
    - The flow must be sufficient to sustain basic ecological processes and habitat and to maintain biodiversity within or across the feature. Adequacy depends on the ecological function of the channel e.g. waterways that connect to fish habitat like a wetland or waterhole may only need infrequent and short-duration flows to provide connectivity for fish.
- Fish habitat at or upstream of the site
    - Most instream features would provide habitat for fish under adequate flow conditions or, in the case of pools, during dry periods, so it is important to have some knowledge of the fish species for the site and their habitat usage, particularly in headwater streams. Periodic connections to upstream, offstream fish habitat would also count [2].

Although this policy position better defined a waterway, this comprehensive definition (of a waterway) was still open to interpretation and differs from the Queensland Department of Natural Resources and Mines' (DNRM) definition of a watercourse, which includes upstream and downstream limits. DNRM regulates water use between the upstream and downstream limits for services such as water licenses and sediment removal and quarrying. These limits do not apply to DAF's definition for waterway determinations, but despite this they were being incorrectly applied by some clients and stakeholders, often excusing their own works from assessment. The second issue with the revised DAF definition was the difference in DAF staffs' range of knowledge of fish biology. The Impact Management and Assessment team within DAF has staff across Queensland all with Fisheries experience, but few with more specific knowledge of freshwater fish. This meant the definition of a waterway could still be interpreted differently depending on each staff member's own level of experiences with freshwater fish. Unfortunately this then created the possibility of clients and stakeholders 'office shopping' to gain the waterway determination that most suited their needs.

The use of this waterway definition was maintained by DAF up until early 2013, when the *Queensland Waterways for Waterway Barrier Works* spatial layer was released. This layer identifies all the waterways in Queensland that are important to fish passage and has them mapped and colour coded. Any waterway not coloured on this layer is not considered of significant importance to fish passage (in relation to development) in Queensland by the Department, and instream works do not require assessment from DAF with respect to impacts they may have to fish passage (it is important to note that works in freshwater wetlands are subject to other state and federal legislation) [3]. The spatial layer is coded into five different colours that represent the level of risk waterway barrier development impacts on fish passage: purple (major impact), red (high impact), amber (moderate impact), green (low impact) and grey (tidal waterways, major impact). The spatial layer is publically available on a number of websites and can be used with very little training. This has helped greatly to remove inconsistencies in interpretation of the definition of a waterway and streamlined the waterway determination process for clients, stakeholders and DAF staff. The layer can be downloaded for ArcGIS from the Queensland Spatial Catalogue – QSpatial website[1] or accessed online vial the Queensland Department of Infrastructure, Local Government and Planning (DILGP) website[2].

All waterway determinations by the Department are now finalised using the spatial layer. The comprehensive definition of a waterway under the *Fisheries Act 1994* still forms part of the determination process, but is now mostly used to confirm or refute potential errors in the spatial layer mapping.

2 THE LAYER:

The *Queensland waterways for waterway barrier works* spatial layer was created over an 18 month period, utilising Departmental staff with extensive knowledge of freshwater fish biology and ArcGIS mapping skills. The spatial layer was born from a joint project between the DAF and the Queensland Department of Transport

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[1] http://qldspatial.information.qld.gov.au/catalogue/custom/index.page (search Queensland Waterways for Waterway Barrier Works, to download the dataset

[2] http://dilgp.qld.gov.au/planning/development-assessment/da-mapping-system.html (Under SARA Layers, economic growth, then fish habitat areas in the Legend)

and Main Roads (DTMR) after a large scale waterway determination project was required for road reconstruction, following major flooding in Queensland in 2010-2011. DTMR engaged the services of DAF and two staff members were made available to liaise between the two departments on all waterway barrier works development applications, and make waterway determinations until the spatial layer was finalised, to ensure the impacts to fish passage were minimised during their large scale flood recovery waterway barrier works projects.

Creating the layer started with a review of all existing Queensland stream mapping datasets; this review highlighted that much of the information available in these datasets was incomplete. However, combining these datasets provided a basis for the mapping for the waterway spatial layer. The gaps in the data were filled using three different products [3]:

- One second SRTM Derived Hydrological Digital Elevation Model (DEM-H) Version 1.0. The 1 second SRTM derived DEM-H Version 1.0 is a 1 arc second (~30m) gridded digital elevation model (DEM). The DEM-H captures flow paths based on SRTM elevations and mapped stream lines, and supports delineation of catchments and related hydrological attributes [3]. This dataset was used to create an ordered stream network for western and north-western draining streams that did not drain into the Eastern Queensland coast.
- Ordered Drainage 100K—Queensland. This dataset is based on the GeoScience Australia 1:100,000 drainage network of Queensland (where 1:100,000coverage exists) and has streams connected and directionalised, and ordered using the Strahler method of stream ordering [3]. This dataset was used to create an ordered stream network for streams draining to the east coast of Queensland.
- Queensland Wetland Data Version 3.0—wetland areas. This dataset provides mapping of the 2009 extent and type of wetlands at 1:100,000 scale across Queensland [3]. This data set was used to define the estuarine area.

The combination of these datasets provided an ordered stream network and estuarine wetland boundaries for the whole state what could be further analysed to derive the Waterway Barrier Works classification. To appropriately categorise the stream network and estuary datasets required GIS analysis using three different systems..

These three systems were: -

- ArcGIS (ESRI)—to perform analysis and mapping.
- Global Mapper—to enable a detailed analysis of the slope characteristics of the all waterways in Queensland.
- RivEX—to achieve the quality control of river networks, to apply attributes to the network (including stream order) and for analysis of the network [3].

These systems were used to determine colour coding for the waterways, and then ground surveyed to determine their accuracy in a real world application. The main dataset was split into two groups, freshwater waterways and tidal waterways. This decision was for policy and legislative reasons, whereby the potential development impacts upon freshwater and tidal areas is different in Queensland and requires separate assessment.

The potential impacts to fish passage in tidal waterways are considered to be major and as such were assigned the colour code of Grey. The freshwater data layer was then considered separately and categorised into the four impact colours - purple, red, amber and green that each represents a different level of risk of instream waterway barrier works to fish passage, with purple being the highest risk and green being the lowest. To define the risk level of each of these colour-coded waterways, an analysis of fish biology, locational geography and stream topography was undertaken. Existing research from both within and outside the Department was used to create mapping characteristics according to risk, which considered the following:

- All streams within the two stream networks were equalised to ensure that in different locations throughout that state that streams would be of the same size and characteristics. This was required as each of the datasets contained variable levels of detail from 1:25,000 to 1:250,000. Streams were standardised at a 1:100,000 level of detail.
- As it is known that in upper catchments the number of fish species is reduced and the fish present have greater swimming capabilities, it was deemed that barriers built on 1st and 2nd order streams are lower in risk than those streams lower down in the catchment. This then allocated streams lower in the catchment as higher risk categories than those in the upper catchment as they contained more species and more fish that were likely to be impacted by waterway barriers. All 4th to 9th order streams were

allocated to the purple category, while those in 1st to 3rd order streams were in lower risk categories based on slope.

- In 1st to 3rd order streams, the slope of the stream was determined to be the limiting factor in the suitability of fish habitat and fish access to that habitat. Streams with steeper slopes were deemed low risk, whereas smaller/shallower slopes were deemed to be of a higher risk. Stream slope was determined by draping the stream network over a digital elevation model of Queensland and allocating a slope to each stream segment. After field assessments were conducted to validate relevant slopes, each segment in stream orders 1 to 3 was allocated a fish passage risk category (colour) based on their slope. First (1st) order streams greater than 6% slope were discarded, while those with slopes between 0.5% and 6% were allocated to the green category and those with slopes less than 0.5% were allocated to the amber category. Second (2nd) order streams greater than 6% slope were allocated to the green category, while those with slopes between 0.5% and 6% were allocated to the amber category and those with slopes less than 0.5% were allocated to the red category. Third (3rd) order streams greater than 1% slope were allocated to the amber category, while those with slopes between 0.2% and 1% were allocated to the red category and those with slopes less than 0.2% were allocated to the purple category.
- As the inland streams of Queensland have very different flow regimes from coastal streams, with most having intermittent flows at best, it was determined that the risk categories of these systems would be different. As such the categorisation of these streams was further modified to take into account their arid nature. The categorisation of streams in these regions was only determined by the stream order of the stream, with all 1st order streams discarded from the categorisation. Stream orders 2, 3 and 4 were categorised as green, amber and red streams respectively, while stream orders 5 to 9 were categorised as purple streams.
- These categorisations were all backed up but the knowledge accumulated within Fisheries Queensland of the distribution of fish species in the streams of Queensland. The number and type of species present in each of the stream types directly contributed to the category the stream was allocated to. This knowledge, along with the knowledge of individual species swimming abilities, allowed the relationship between stream order, slope and fish populations to be resolved, which allowed the categorisation of streams. In general low species diversity streams with strong swimming species were deemed to be a low risk, while streams with a diverse fish community poor swimming species were deemed to be a higher risk.

In all 1.4million kilometres of Queensland streams were categorised into the four colours. Purple waterways are identified as being a major risk, as they are large stream orders, with smaller low slopes, extended flow periods and maintain good quality habitat, both riparian and instream, and fish species in these areas are very diverse with both weak and strong swimmers (juveniles to adults, small and large fish). They therefore require a strict assessment to ensure fish passage can be provided for the whole fish community and on a variety of flows to ensure fish passage is not impeded.

Red waterways are identified as a high risk, they are similar to purple waterways in that they are larger stream orders, but can be smaller in size, they have extended flood periods and maintain good quality habitat, and these systems have diverse fish species in number, size and community (both weak and strong swimmers). Comprehensive assessment is required for red waterways, but allowances have been made in the self-assessable codes for certain developments.

Amber waterways are identified as a moderate risk to fish passage. They tend to be higher in the catchment with less gentle slopes, they have smaller stream orders, contain moderate to good instream habitats, and their species diversity is generally less and the swimming ability of those species is greater than that of a Red waterway. Assessment of these systems is mostly undertaken via the self-assessable codes.

Green waterways have been given the lowest risk for works that may impact upon fish passage, they are generally smaller in size, are smaller stream orders, their slopes are greater, have faster flows which can cease quickly, they are generally in the top of the catchment, and the species of fish in these areas are usually strong swimmers, which means they require less assessment as development impacts are much lower than the other colour codes. The majority of works in green systems is undertaken using the self-assessable codes (Figure 1).

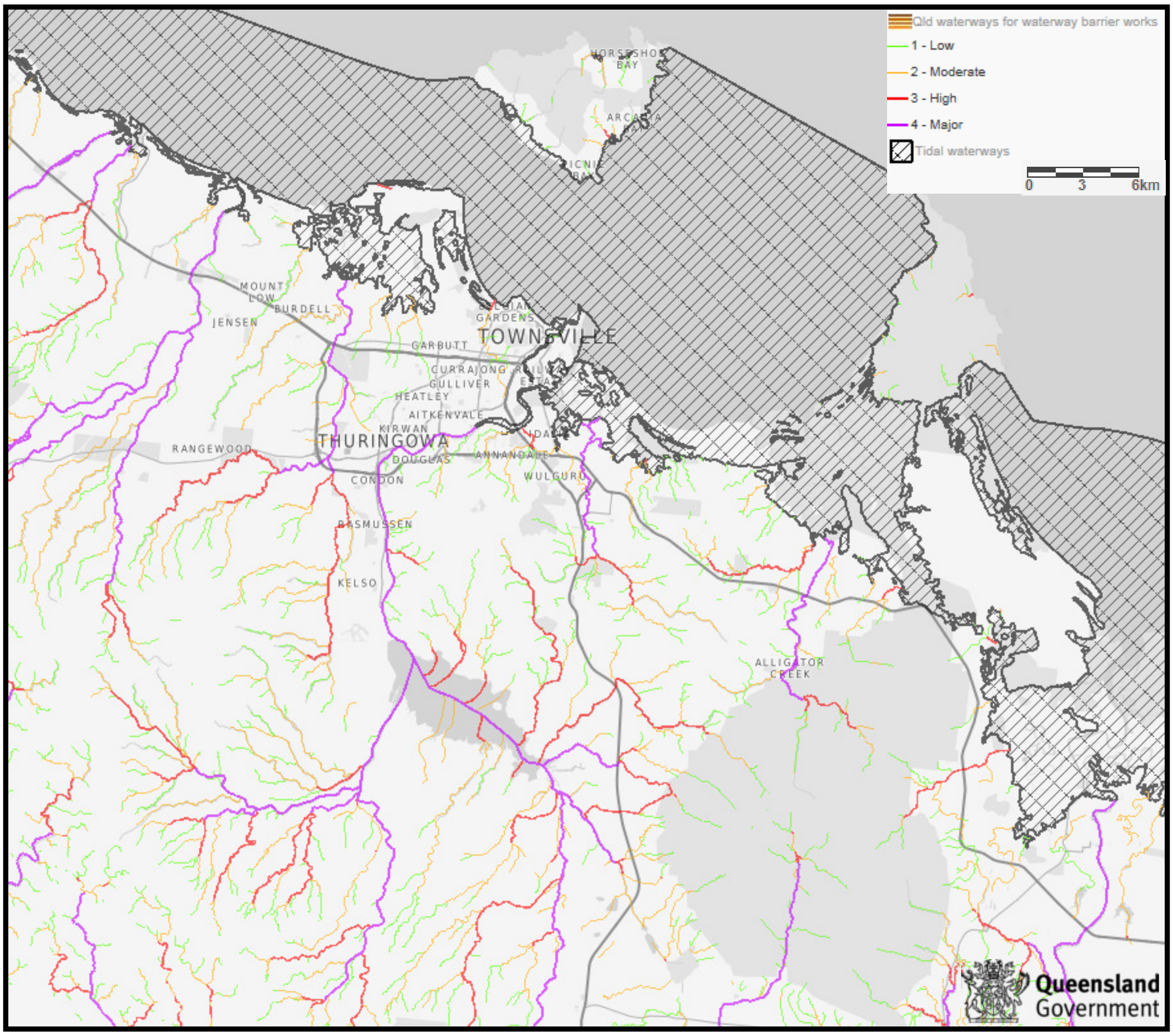

Figure 1 Colour coded waterways surrounding the city of Townsville, Queensland in Australia, as mapped by the '*Queensland waterways for waterway barrier works*' spatial layer.

The layer's classifications were ground-truthed in a variety of location (both coastal and inland waterways) to ensure there was an accurate representation of risk [3]. This coding and risk then provided a solid base for determining the risk assessment of waterway barrier work impacts on fish passage in Queensland waterways.

The Department also released a public document which is used in conjunction with the spatial layer that explains the intent and background of the layer along with a user's guide [3].

3 WATERWAY BARRIER WORKS

The *Fisheries Act* (*1994)* defines waterway barrier works (in relation to construction of) as: – a dam, weir or other barrier across a waterway if the barrier limits fish stocks across and movement along a waterway [1]. This definition ensures that the construction of any physical structure that could act as a barrier to fish passage, either temporary or permanent, is captured as waterway barrier works. Chemical or (water) temperature barriers that are not physical structures may still affect fish passage, however they are not considered to be waterway barrier works by the DAF.

Physical structures include dams, weirs, stream crossings such as causeways and culvert crossings, full or partial bunds (temporary or permanent), flow control structures (floodgates etc.), pollution control devices (trash racks etc.), silt curtains, levee banks, riffle structures, revetment walls, abutments etc. Instream structures within waterways, such as bridge piles, pile driving pads or partial bunds, which narrow the width of the waterway, have the potential to increase water velocities and act as barriers to fish movement, [2]. The Department also considers maintenance of existing structures as waterway barrier works, this includes like-for-like replacement of culverts and pipes, apron repairs or replacements, installation of scour protection, lengthening of culverts, increasing deck heights for flood mitigation, end wall/wing wall and/or head wall replacements etc.

A series of fact sheets were released by the Department in 2014 that provide examples of what does and does not constitute waterway barrier works. The examples in these fact sheets (*What is a waterway barrier work*, and *What is not a waterway barrier work*) are based on the risk management of different types of development in different coloured waterways[3].

4 SELF-ASSESSABLE CODES

Self-assessable codes (SAC) were first introduced into Fisheries legislation in 2005 as a result of new state planning legislation. They are a series of documents that address lower risk development that the Department does not deem necessary to be formally assessed via a Development Approval (DA). The codes are prepared under both the *Fisheries Act 1994* and the *Sustainable Planning Act 2009* (SPA); under SPA, waterway barriers (temporary or permanent) are considered to be development [4] Self-assessable works do not require a development approval as long as the works are completed to the standards listed in those codes. The self-assessable codes cover minor works (low impact weirs and dams, replacement of floodgates, culvert crossings, and bed level crossings), temporary works and regularly rebuilt works (sand dams).

Since their introduction, the SAC's have undergone a number of reviews to better define and broaden the scope of works allowable as self-assessable. Prior to the spatial layer introduction, the codes were constrained to general information (either a single stream order or a single set of design criteria) that needed to be applied to all waterways. This included width and height restrictions, fish passage culvert cell dimensions, scour protection and apron extent, and certain maintenance restrictions. The introduction of the waterways spatial layer enabled an update of the SAC's to tailor the design requirements for the waterway barrier works to match the risk level of the waterway. Where the risk to fish passage is high or major (purple, grey and red), design provisions for fish passage for fish passage is more comprehensive than were the risk is deemed lower (green or amber).

Four of the six SAC's were updated in 2013 to include the spatial layer colour coding, (the remaining two are site specific codes that don't rely on the spatial layer). One SAC, (WWBW01, Part 3: Culvert crossings), excludes all new works in Purple waterways, as the Department considers generic design criteria to be too much of a compromise and the risk unacceptable. Instead any new culvert works in a purple waterway require assessment of site specific fish passage provisions, through a development approval process.

Two of the SAC's do allow some new works within Purple waterways, The SAC for temporary works (WWBW02)addresses the major risk level of purple waterways by constraining the duration of the works. Bed level crossings (WWBW01 Part 4) can address the risk and are considered sufficiently conservative to allow these crossings to be built under the SAC in purple waterways.

On the other end of the spectrum, green waterways have been given the lowest risk for works that may impact upon fish passage. The requirements under the codes for works in green waterways are broad due to the scoping of the layer; an example of the requirements for '*the construction new of replacement of existing culverts on low impact (green) waterways'*: -
5.4.1 - Works must commence and finish within a maximum time of 360 calendar days and instream sediment and stream silt control measures associated with the works must be removed in this period
5.4.2 – In all crossings the minimum (combined) culvert aperture width must be 1.2m or span 100% of the main channel width.
5.4.3 – All new or replacement culvert cells must be installed at or below bed level.
5.4.4 – The culvert must be installed at no steeper gradient than the waterway bed gradient
5.4.5 - Apron and stream bed scour protection must be as per 5.2.4 and 5.2.5 (i.e. no drops in elevation across the structure and at the stream gradient)
5.4.6 - Where aprons are at bed level, it is desirable but not mandatory that they be roughened throughout to approximately simulate natural bed conditions [5].

Stakeholder consultation has been a key driver in the evolution of the SACs. While client input was sought in the writing of the earliest versions of the codes, there was limited engagement and a fundamental disconnect in the understanding of the biologists and the engineers when it came to setting out design codes. However, after

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[3] These can be found on the Departments website: https://www.daf.qld.gov.au/fisheries/habitats/policies-and-guidelines/fish-habitat-factsheets.

embedding biologists within DTMR, Fisheries gained a better understanding of the drivers and constraints of developers and the terminology and processes that the codes needed to encapsulate. An inter-departmental working group saw close collaboration between biologists, design engineers and environmental managers in the writing of the codes. This was complimented by equally productive dialogue with the utility company, Powerlink through a series of site visits and also with regional councils providing constructive feedback on the practicalities of code implementation. Improved take-up and ownership of the codes by their target audience reflects this more realistic and accessible product.

5 RESULTS

The introduction of the waterway spatial layer and revision of the SAC's bought about a significant increase in the use of the codes. Since the introduction of the revised SAC's, aligned to the waterways layer (2013 to 2015), 1705 waterway barrier work self-assessable code notifications have been received. A breakdown of the number of notifications received since their introduction in 2005 is listed in Table 1.

Table 1: Self-assessable code notifications 2005 to 2015

Years for SAC code notifications	**Number of notifications received**
01/07/2005 – 30/06/2007	0
01/07/2007 – 30/06/2009	23
01/07/2009 – 30/06/2011	253
01/07/2011 – 30/06/2013	1048*
01/07/2013 – 30/06/2015	1705 **

Numbers taken from the DAF Development Licensing System (DLS)
*2011 the waterway barrier works code was separated out into the four parts we currently use.
**2013 the waterway barrier works codes were updated to use the spatial waterway layer.

An increase in SAC notifications has also come with a reduction in DA's, see Table 2. The dramatic increase in SAC's is considered to be new works being generated through a much more comprehensive but easier self-assessment process. This increase may also be due to waterways that in the past were given a non-waterway determination by DAF staff, and are now considered to be waterways. The standardized mapping process has removed much of the human error in waterway determinations and these areas will now be covered by appropriate design requirements when maintenance is required.

Table 2: Development Approvals 2005 to 2015

Development Approvals (years)	Number of approvals
01/07/2005 – 30/06/2007	58
01/07/2007 – 30/06/2009	99
01/07/2009 – 30/06/2011	203 *
01/07/2011 – 30/06/2013	229
01/07/2013 – 30/06/2015	180**

Numbers taken from DLS and DAF's internal recording system RDB2.
*2009 the *Sustainable Planning Act 2009* replace *the Integrated Planning Act 1997* (IPA)
** 2013 the introduction of the spatial waterways layer and the updated codes.

The reduction in DA's is a good indication that the Department has reduced a significant amount of 'Red Tape' for certain development. Although there is still a large number of waterway barrier work DA applications, those applications are generally restricted to those waterways where development works potentially have a major impact to fish passage.

The implementation of this system has seen a significant increase in the number of fish passage compliant structures installed in Queensland and has likely made a small, but rapidly increasing, dent in the reduction of barriers to fish migrations. Further research into the benefits of using the layer and revised self-assessable codes is needed to determine the impact these requirements are having upon fish passage and the reduction to barriers to migration.

6 WHAT'S NEXT

A small number of errors have been found within the spatial layer since its introduction, and a number of alternative determination (change to the risk level to a waterway) requests from external users have been made to the Department. All errors and review of alternative determinations are assessed annually and any changers to the layer will be uploaded to the websites in an annual layer upgrade.

The spatial layer has been widely accepted and used and has streamlined the waterway determination process. Further proposed improvements to the spatial layer include: -

- Inclusion of freshwater wetlands for development impact risk management.
- Filtering inland braided systems into different more appropriate colour codes (rather than them all being purple, as currently mapped)
- Improving the (grey) tidal waterways layer to increase the impact management of green waterways that directly adjoin grey waterways. Development in these green systems often has a far greater impact upon fish passage (i.e. tidal barriers) than those of green systems higher up in the catchment; and
- Fine-tuning the layer to increase the risk management of coastal waterways. Development often has a higher impact to fish passage along the coast than those waterways inland.

From the initial roll out, the spatial waterway layer, combined with the updated self-assessable codes have better attuned management of the impacts development has upon fish passage in all five colour-coded waterways. By streamlining the process it has improved compliance and eased assessment of minor development. This systems approach has proven to have significant benefits in reducing cumulative impacts to fish passage.

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