THE TOTAL FLOOD WARNING SYSTEM ASSESSMENT TOOL

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Abstract

To date, our ability to answer questions that revolve around “how good is a flood warning system” and “is it sufficient or fit for purpose” has been subjective at best. We struggle to quantify the level of service provided by a flood warning system or determine the level of service required for an at-risk community.

Logically, the level of service provided by a flood warning system would be in direct proportion to the severity of the potential consequences: service would respond to or reflect need. For that to occur, the link between what is required and what is provided or available needs to be established. Quantifying or scoring flood risk on a scale relative to flood warning system service levels provides that link.

A flood risk assessment methodology that builds on the Rapid Assessment Method for Floodplain Management (Read Sturgis, 2001) and uses available flood and asset information to assess flood likelihood and consequences, provides flood risk scores.

The Total Flood Warning System (TFWS) Assessment Tool uses schema that utilise measurable, scalable and relevant data for sub-factors that feed into each of the TFWS elements together with the flood risk assessment results. A 5-tier service level classification framework that delivers quantifiable (i.e. deterministic) discrimination between the service level tiers facilitates the identification of locations where the TFWS, as a whole and by individual element, is either appropriately developed or in need of upgrade. The Tool also provides guidance on the comparative priority for that upgrade.

Introduction

What an achievement if communities at risk from flooding were serviced by flood warning systems that were appropriate to the risk and the perennial questions of “how good is the flood warning system, is it sufficient, is it fit for purpose” could be answered objectively?

While the TFWS Assessment Tool (“the Tool”) introduced through this paper doesn’t provide all the answers, the authors believe it is a major step in the right direction.

The Tool was developed following successive refinements of the model originally developed by Michael Cawood & Associates Pty Ltd (MCA) to facilitate a review of TFWS components across each of the river basins within Victoria as part of the 2005 review of flood warning system development priorities (VFWCC, 2005). That model considered each element of the TFWS on a river basin basis. The key output was a report card that summarised assessment results and provided guidance on the relative priority for improving each of the TFWS elements within each river basin.

As part of the State’s response[i] to recommendations put forward by the Victorian Floods

Review (Comrie, 2011) and as a feed-in to the preparation of the Victoria Floodplain Management Strategy, the former Victorian Department of Environment and Primary Industries (DEPI) set about answering the following key questions:

- How do we determine local TFWS requirements (i.e. the level of service required)? and
- How do we determine which parts, if any, of the TFWS need to be improved so that the system better meets those requirements on an equitable basis?

In 2013 following initial upgrades to some TFWS elements across the State, DEPI engaged MCA to review the 2005 model.

At around the same time, DEPI introduced a service level framework for the TFWS. A draft Total Flood Warning System Service Level Framework (the “Framework”) was developed in early 2014.

DEPI also initiated work to assess flood risk on a community or river reach basis that delivers a flood risk score for each area considered.

Following rework of the Framework in 2015, the MCA team made additional changes to the Tool which included its disaggregation into at-risk locations and river reaches. It is this version of the Tool and its application to Victorian communities that is the focus of this paper[ii].

The TFWS Assessment Tool

Overview of the Model Developed in 2005

Each TFWS element was considered individually across a basin in order to gain an appreciation of ‘how sufficient’ it was in contributing to the delivery of flood warning services. The individual assessments were then summed (without any weighting – all elements were considered of equal importance) to produce an overall TFWS assessment score. That score provided an initial indication of relative basin priorities for TFWS upgrade activity with the score from individual TFWS elements providing guidance on where effort should be directed.

The overall TFWS assessment score for each basin was then combined with damage data, adjusted by a measure of the population affected by flooding on an average annual basis in order to obtain a relative ranking of “need to” versus “value of” improving services within each basin as a whole.

2013 Version of the Tool

The 2013 version of the Tool built on and improved the 2005 model. It did not use any ‘performance’ data (e.g. measures of how close flood forecasts came to actual flood peak heights and times). Instead, it relied only on data that estimated the flood risk and the robustness of each TFWS building blocks while having greater regard for matters that contribute to an effective flood warning service. In addition, the Tool was extended to allow sub-basin scale analysis. There was also a concentrated effort to source and use hard rather than surrogate data in order to provide a more representative objective assessment.

The relationship between the building blocks and factors that drive the Tool is shown in Table 1.

TFWS elements	Tool factors
Data collection and collation	Factor A - Data Collection Network
Flood forecasting (i.e. detection and prediction)	Factor B - Forecasting
Interpretation (i.e. what forecast level means for you)	Factor E - Interpretation
Message construction	Factor C – Dissemination / Communications
Message dissemination (i.e. comms and alerting)	
Response planning and response	Factor F - Response Planning
Education and Awareness	Factor D - Awareness and Education
Review	
	Factor G - Social & Economic Impacts

Table 1: Relationship between TFWS elements and Tool factors

Current 2015 Tool – Version 3P

Version 3P of the Tool is a major rework of the two previous versions. Using essentially the same range of data, this version disaggregates the basins (shown in Figure 1) into specific at-risk locations and river reaches. The locations and river reaches are as advised by the relevant Catchment Management Authority (CMA) and align with the at-risk locations and river reaches for which flood risk data is derived.

Figure 1: Major River Basins in Victoria

This means that the Tool now provides a comparative and service level based assessment of the status of TFWS elements at a location or river reach scale. This is a major change from the earlier versions of the Tool which considered the TFWS only at a basin or sub-basin level. The Tool is also aligned with the TFWS Service Level Framework and delivers an estimate of the current level of service (in terms of the maximum service level[iii]) being achieved by each TFWS element, as well as the TFWS as a whole. These service levels are compared against the assessed risk as indicated by a flood risk score[iv]. Guidance is also provided on the priority for development or upgrade of TFWS elements.

All elements and components of the TFWS in place are assumed to work perfectly and / or as well as can be expected.

The Tool has been developed in MS-Excel as a series of workbooks. Each catchment (or basin) is assigned a workbook. Data is entered into three 'catchment' worksheets and summarised in four results worksheets.

The three data entry worksheets or 'tabs' and their data are as outlined below:
- Catchment1 - data collection network and forecasting information;
- Catchment2 - gauge elevation and distance; and
- Catchment3 - communication, dissemination, at risk locations and related information.

The four results worksheets comprise for each location and reach being analysed:
- A RAW SCORES worksheet that presents the raw scores for each of the Tool factors (i.e. TFWS elements).
- A STANDARDISED SCORES worksheet that presents:
  - Standardised scores for each of the Tool factors (i.e. TFWS elements);
  - A score for the TFWS as a whole (i.e. factors A to F inclusive).
- A SERVICE LEVEL REPORT CARD that provides:
  - A service level tier for each TFWS element considered;
  - A service level tier for the TFWS as a whole;
  - The assessed flood risk rating tier (Factor G);
  - A colour coded summary that highlights where the TFWS as a whole and for individual TFWS elements, is less developed than considered necessary for the assessed flood risk[v].
- A PRIORITY RATING REPORT CARD that provides:
  - A comparative assessment of or rating for each TFWS element considered;
  - A 'rolled-up' assessment for the TFWS;
  - A comparative assessment of or rating for the social and economic impacts factor (Factor G);
  - A priority rating that has regard for the TFWS assessment and the social and economic impacts factor.

Critical to a meaningful assessment is a common time base for data used in the Tool. This facilitates analysis of improvement over time and enables the calculation of time decay, an important element for a number of the sub-factors. Further, there is need for consistency in how data is formulated. It is therefore essential that there is an understanding of the definitions that underlie the data so that like is combined and compared with like.

A User Manual describes the essential features of the Tool together with the schema developed to enable it to be used to deliver an assessment of the TFWS services. It is aimed at assisting users of the Tool:
- Appreciate the range and scope of data required;
- Better understand how the driving schema are configured and how input data are used;
- Be aware of assumptions and limitations; and
- Make use of the assessment results in an informed manner.

Background reports prepared by the MCA team describe the alignment of the Tool with the TFWS Service Level Framework and document the changes to the Tool through its development as well as the effect of these changes on results.

The TFWS Service Level Framework

A TFWS service level can be thought of in terms of the complexity, adequacy or completeness of the information provided (or available) to an agency and / or community about an impending flood. This can be reflected in the spatial resolution (e.g. local to regional to state) and the temporal resolution (e.g. hourly to 12 hourly to daily) of that information.

The appropriate TFWS service level tier for a location or river reach should mirror the severity of the likely consequences (i.e. social and economic impacts): there is need for a clear link between what is required and what is provided or available. Flood risk provides that link and can be used to reflect community needs[vi] and as a measure of the appropriate service level.

The Framework comprises five (5) service level tiers – from zero (0) to four (4) where zero designates a very low or basic level of service and four designates a very high level of service.

Both the Framework and the Tool are constructed around the TFWS elements or building blocks using a six (6) element (or factor) model. The alignment of the TFWS elements (or factors) used in the Framework with those used in the Tool is shown in Table 2 along with related sub-factors[vii].

The Framework descriptors for each factor deliver a broad level narrative of the features / level of development / sophistication expected to be present for each of the service level tiers. Factor tier descriptors are also provided for the sub-factors (see Table 2) with due regard for what is measurable, scalable, relevant and appropriate. The descriptors facilitate a quantifiable (deterministic) discrimination between the service level tiers.

The TFWS Assessment Tool Factors

Introduction

The Tool assesses the seven (7) factors as shown in Table 1 and described in the following paragraphs.

The factors are determined for each location in order to obtain the status of each TFWS element for that location. A rating or service level is then applied to each TFWS element and an overall TFWS rating or service level determined. The overall rating or service level is then compared against the need as reflected by the flood risk rating (i.e. the social and economic impacts of flooding as determined through Factor G).

Factor A: Data Collection Network (DCN)

The DCN is the network of rain and stream gauges across a catchment that provides the base data to support flood forecasting and warning activities.

Service Level Framework Factors	Assessment Tool Factors	Tool Sub-Factors
Data Collection Network	**A** Data Collection Network	Rain gauge
		Event-reporting rain gauge
		Stream gauge
		Rated site
		Elevation sub-factors #1 & #2
		Distance sub-factors #1 & #2
Prediction	**B** Forecasting	Forecast
		Model
		FWS Charter
		Significant Storages
Dissemination	**C** Dissemination & Communication	Dissemination
Community Education & Awareness	**D** Awareness & Education	Time since last major flood
		FloodSafe Program
		Planning Scheme
		Individual Property Flood Chart
Interpretation & Consequence Assessment	**E** Interpretation	Flood Study
		Mapping
Flood Response	**F** Response Planning	MFEP

Table 2: Service Level Framework and Assessment Tool relationship

Factor A accommodates information about the DCN. A distinction is made between telemetered and manually read gauges and the timeliness of data receipt (e.g. event reporting as against polled telemetry). The factor provides a measure of the DCN's utility and coverage and thus ultimately its appropriateness and capacity to provide essential data that is able to adequately inform the forecasting process for a location or river reach. For example:

- The number and type of rain and river gauges and their whereabouts with respect to the location or reach being assessed;
- Whether individual gauging sites have been telemetered or rated;
- Consideration of the number of tributaries and distributaries within the catchment; and
- The elevation difference and distances between the most remote rain gauge, forecast locations and at-risk locations.

Factor B: Forecasting

The "Forecasting" factor provides an indication of the sophistication of the flood prediction element of the TFWS for the location or river reach and for locations upstream and downstream. It has regard for:

- The type of forecast that is routinely issued, if at all, (i.e. quantitative, qualitative, general or informal);

- In generic terms, the type of model used to produce flood forecasts (e.g. rainfall-runoff model, qualitative / analogue or informal);
- Whether a Flood Warning Service Charter[viii] (or similar) exists; and
- The presence of major storages upstream of a location and whether flood forecasts are issued for downstream locations ahead of gate operations or spills.

Factor C: Dissemination and Communication

This factor considers the dissemination and communication arrangements in place for flood information for each at-risk location. The effectiveness of those arrangements, especially in relation to communication between stakeholders and communities, is not a part of the consideration. It is assumed that all existing arrangements work perfectly and / or as well as can be expected.

Similarly, while it would seem sensible to have regard for how often and how comprehensively agencies test and update their information / warning dissemination processes, such a measure is not included. The rationale for this is founded on the view that the BoM is the only stakeholder in Victoria that has specifically tested flood information dissemination facilities and processes. VICSES does test its facilities through routine use on any number of occasions throughout the year while at the same time Municipalities confirm their ability to receive and respond to information passed to them in this way. In view of this, it was considered that including consideration would not add any discriminating value to the analysis.

Factor D: Flood Awareness and Education

Education and awareness (and thus experience) of flood risk can have a significant positive influence on flood damage reduction and thus on the efficacy of flood warning systems. Hence the calculation of Factor D is informed by the history of flooding in the catchment (with decay factors for time since last major flood) along with those things that are being done to raise awareness of flooding within the at-risk community. The more common approaches and products used within Victoria to raise community flood awareness are accommodated including:
- Implementation of flood controls across flood prone areas through Municipal Planning Schemes;
- Development and distribution of FloodSafe brochures / Local Flood Guides; and
- Development and distribution of individual property flood charts.

Factor E: Interpretation

Effective response requires an interpretation of a forecast (or actual reported) height at a gauge into likely flood extents, local depths and impacts within the at-risk community. This requires contemporary detailed information collected during recent floods and / or extracted from mapping and related intelligence. The latter is normally delivered through flood and other studies. Factor E picks up on the availability of flood intelligence to facilitate the translation of a forecast flood height into areas and assets at risk with an appropriate decay or discount for age. It does not consider whether and where the translation could, should or does occur.

Factor F: Response Planning

There are a number of elements to response planning and to actual response during a flood. However, very few are quantifiable in a way that discriminates between locations.

The Municipal Flood Emergency Plan (MFEP) acts as a repository for the flood intelligence that can inform local and community flood response planning activities. As institutional response to a flood emergency is embedded in various statutory functions and procedures, the key variable with respect to response is generally the availability of local flood intelligence (the MFEP) and event specific information (as captured through Factors A to E). Factor F reflects the availability and scope of local flood intelligence. The value of this factor is discounted for age: maximum value is achieved through the availability of contemporary flood intelligence.

Factor G: Social Impacts

Factor G reflects the social impacts associated with flooding. Although not a physical or procedural element of the TFWS, understanding the social impacts of flooding within an at-risk location assists the determination of needs within and relative priorities between locations. Social impacts are determined with due regard for:

- The potential impacts of flooding on key / essential infrastructure;
- Vulnerable areas of the community;
- Access / egress issues that may limit safe evacuation or resupply; and
- Risk metrics that cover absolute average annual damages, population affected[ix] and damage density[x].

The Report Cards

Overview

The Tool produces four results worksheets:

- A RAW SCORES process worksheet;
- A STANDARDISED SCORES process worksheet;
- A SERVICE LEVEL REPORT CARD.
- A PRIORITY RATING REPORT CARD; and

The raw scores worksheet is self-explanatory. These raw scores are then standardised in a way that prevents any of the factors from skewing the results (by exerting a disproportional influence) so that results can be combined and compared. Both the raw scores and the standardised scores worksheets are essentially process worksheets: they act as parking lots and assist build of the two report cards.

Service Level Report Card

The service levels achieved for each TFWS element are determined within the Tool using the raw scores and / or standardised scores for each factor in conjunction with the TFWS Service Level Framework.

The Service Level Report Card presents a summary and comparison of the service levels for each factor (i.e. each TFWS element) and for the TFWS as a whole[xi] against the flood risk tier for each location.

The risk level is determined by standardising the scores for Factor G as a percentage of the maximum possible score.

The report card (see Figure 2) is formatted to automatically highlight those locations where the risk level exceeds the service level for the TFWS as a whole and also for the individual factors.

Priority Rating Report Card

Using the standardised scores, each factor and the overall basin score are separated into quintile ranges and a rating assigned. A colour is assigned to the quintile ranges in order to emphasise the priorities and needs for each location and TFWS element.

Reporting on the basis of percentiles enables the needs of a location to be demonstrated relative to other locations across the State without introducing bias. This aids an objective identification of locations that require an improvement in the TFWS. Prioritisation follows.

The report card summarises results for each of the factors (and thus for each TFWS element) and provides a rating for the TFWS as a whole along with an indication of relative priority for TFWS development or upgrade on a location by location basis. The approach adopted for determining final priorities is consistent with risk assessment methodologies. An example Priority Rating report card together with the quintile rating and priority rating schema tables is provided as Figure 3.

Risk Level Colour Coding
TFWS Element Service Level is less than Level of Risk
Overall TWFS Service Level is greater than the Level of Risk
Overall TWFS Service Level is equal to the Level of Risk
Overall TWFS Service Level is less than the Level of Risk

Standardised Score and Risk Level Range	Service or Risk Level
0	0
0-24	1
25-49	2
50-74	3
75-100	4

SERVICE LEVEL REPORT CARD

Month and Year of Data= June 2012 (Do not amend date here - refer to Raw Scores)

Location/ River Reach	Service Levels A DCN	B Forecasting	C Dissemination & Communication	D Awareness & Education	E Interpretation	F Response Planning	Service Level Tier (Factors A-F)	Factor G Risk Level Tier	Location/ River Reach
Coojar	1	0	0	0	0	0	1	0	Coojar
Balmoral	1	1	0	0	0	0	1	0	Balmoral
Harrow	1	1	0	2	0	0	1	1	Harrow
Nareen	1	1	0	0	0	0	1	0	Nareen
Chetwynd	1	1	0	0	0	0	1	1	Chetwynd
Upper Glenelg	1	1	0	0	0	0	1	1	Upper Glenelg
Dergholm	1	1	0	2	0	0	1	0	Dergholm
Mid Glenelg	1	1	0	0	0	0	1	1	Mid Glenelg
Casterton	2	1	0	3	4	0	2	2	Casterton
Dunkeld	0	0	0	0	0	0	1	0	Dunkeld
Penshurst	1	0	0	0	0	0	1	0	Penshurst
Yatchaw	0	0	0	0	0	0	1	0	Yatchaw
Hamilton	1	0	0	2	4	4	2	2	Hamilton
Grange Burn	0	0	0	0	0	0	1	1	Grange Burn
Upper Wannon	0	0	0	0	0	0	1	0	Upper Wannon
Coleraine	1	0	0	2	0	0	1	2	Coleraine
Lower Wannon	0	0	0	0	0	0	1	1	Lower Wannon
Sandford	2	1	0	0	0	0	1	2	Sandford
Strathdownie	0	0	0	0	0	0	1	1	Strathdownie
Dartmoor	1	1	0	0	0	0	1	1	Dartmoor
Lower Glenelg	1	1	0	0	0	0	1	1	Lower Glenelg
Nelson	2	1	0	2	0	0	1	0	Nelson
Basin 39	0	0	0	0	0	0	1	1	Basin 39

Figure 2: The formatting schema with an example Service Level report card

QUARTILE RATINGS							
Service Level Subfactor Quartile Ratings						Service Level Rating	Social & Economic Impact Quartile Rating
Very Poor						Very Poor SL	Very High Need
0-20	0-20	0-20	0-20	0-20	0-20	0-20	0-20
Poor						Poor SL	High Need
20-40	20-40	20-40	20-40	20-40	20-40	20-40	20-40
Fair						Fair SL	Moderate Need
40-60	40-60	40-60	40-60	40-60	40-60	40-60	40-60
Good						Good SL	Low Need
60-80	60-80	60-80	60-80	60-80	60-80	60-80	60-80
Excellent						Excellent SL	Very Low Need
80-100	80-100	80-100	80-100	80-100	80-100	80-100	80-100

LOCATION PRIORITY RATING					
Service Level Rating	Needs (Social and Economic Impact Rating)				
	Very Low(1)	Low(2)	Moderate (3)	High (4)	Very High (5)
Very Poor (5)	Medium Priority	High Priority	High Priority	Highest Priority	Highest Priority
Poor (4)	Medium Priority	Medium Priority	High Priority	High Priority	Highest Priority
Fair (3)	Low Priority	Medium Priority	Medium Priority	High Priority	High Priority
Good (2)	Lowest Priority	Low Priority	Medium Priority	Medium Priority	High Priority
Excellent (1)	Lowest Priority	Lowest Priority	Low Priority	Medium Priority	Medium Priority

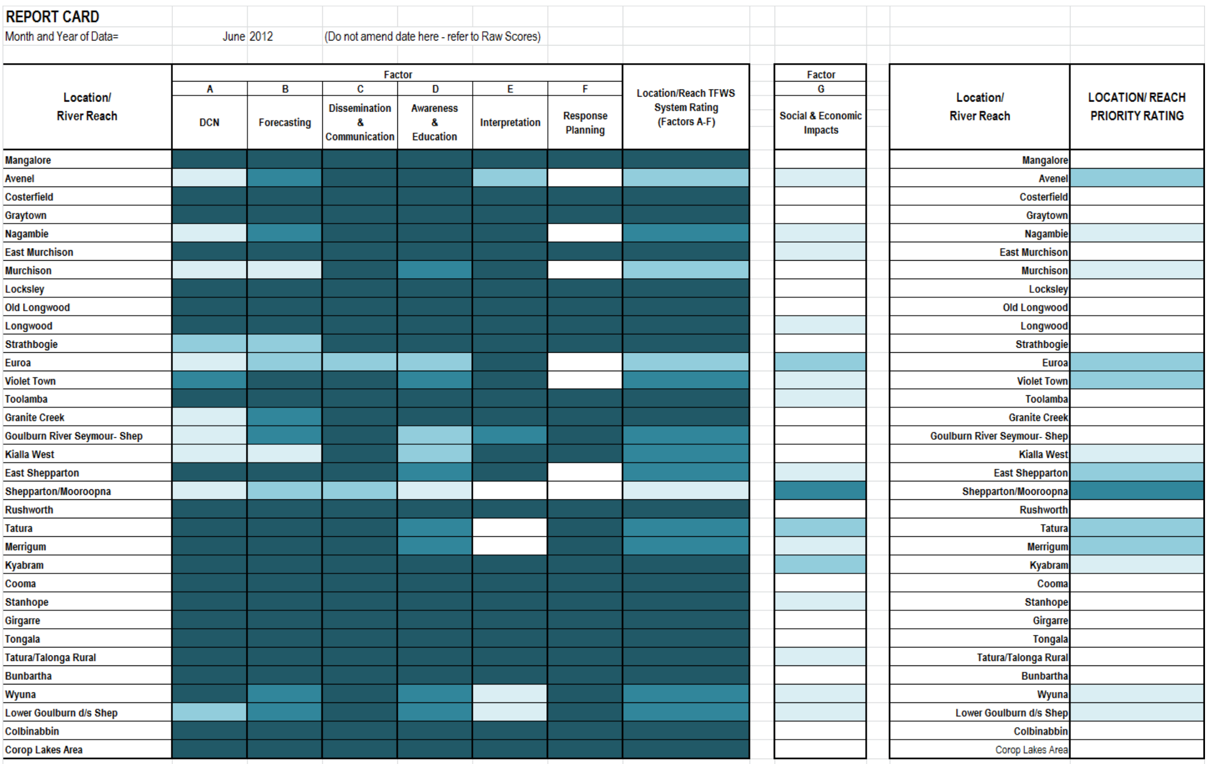

Figure 3: Example Priority Rating report card.

Interpreting the Results

It is not possible in this paper to provide a full discussion on how to interpret Tool results or to even present a full interpretation of the above example report cards. However, key takeaways are:

- The Service Level report card is showing that for the subject basin as at June 2012:
  - Substantial upgrade of the TFWS should be considered for two at-risk locations (the overall TFWS service level score is lower than the risk score);
  - That while many of the at-risk locations were assessed as being adequately (or better) serviced by the TFWS, many of the TFWS elements were in need of upgrade in order to meet the required service level (the overall TFWS service level

scores are equal to or higher than the risk score at many of the at-risk locations: but many individual TFWS element service levels scores are lower than the risk score).

- The Priority Rating report card is showing that for the subject basin as at June 2012:
  - None of the at-risk locations were assessed as having a high flood risk;
  - There was a mismatch between the available TFWS and assessed flood risk indicating some need for TFWS element upgrade work;
  - Benefits of work undertaken in selected locations prior to June 2012 and aimed at particular elements of the TFWS were evident (lowest priority); and
  - That while many of the at-risk locations were assessed as being high priority for TFWS element upgrade, only one location was identified as having a medium or more urgent priority for full TFWS upgrade.

In summary, the Tool provides a good indication of where the TFWS as a whole and its various elements need to be upgraded or expanded in order to meet the local community's needs for flood warning services. Similarly, the Tool provides guidance on the relative priorities for initiating works aimed at achieving those upgrades or expansions.

Closing Comments

The Tool provides a comparative as well as service level based assessment of the status of elements of the TFWS for locations or river reaches. It also provides guidance on the priority for TFWS development or upgrade. It does this by considering various aspects of the TFWS in conjunction with the assessed flood risk for those communities and river reaches under investigation.

The use of a comparative approach enables the assessment to drive a process of continuous improvement across all TFWS elements at a location, across basins and across multiple basins.

The Tool does not attempt to determine "how good" delivery is against each of the TFWS elements. Neither does it concern itself with the quality of the data for any of the factors or the proficiency and effectiveness of its application. It is assumed that if the element exists, it works as well as it can.

It is acknowledged that there are some data gaps in the current version of the Tool. It is further acknowledged that the Tool does rely on some subjectivity and that this may not resonate with all users. The Tool does not appear to be overly sensitive to the components being considered within each of the factors. Nevertheless, it is acknowledged that a small change in a factor's value can shift the rating, if the factor value for a location is close to a delimiter value.

It is further acknowledged that the schema that drive the Tool could well be formulated or constructed in an alternative manner. Indeed, a number of variations of the schema were trialled. In some cases limitations on the availability of required data curtailed formulation[xii] while in others a need for adequate discrimination and an assessment of what appeared to be 'reasonable' acted as constraints. Care has also been exercised to guard against double counting.

In order to understand how to lift the score or service level of a poorly scoring factor (or TFWS element), the user will need to have a sound understanding of how the individual elements / sub-factors contribute to the factor score. That could be achieved by breaking down the formulae used to calculate the raw scores and perusing the data sheet for each basin to determine weaknesses. Alternatively, it could be achieved through 'gaming' or ‘trial and error’ use of the Tool with updated inputs (e.g. to reflect the outcome of programs to update or expand particular elements of the TFWS).

The Tool is to some extent a ‘work in progress’. It will no doubt continue to mature as understanding of the factors that influence the ‘health’ of the TFWS improves along with ability to measure or develop surrogates for those influencing factors. Further changes may arise from resolution of the vexatious issue of how to deal effectively with inadequate and / or missing data.

In Victoria, the Tool will provide the CMAs and Melbourne Water with a means to consistently and systematically assess the TFWS service needs of and the existing TFWS services provided to flood-prone communities in their respective areas of responsibility as part of the development of regional floodplain management strategies. In turn and consistent with the Victorian Floodplain Management Strategy, these assessments will inform the preparation of an equitable rolling three-year State TFWS services development plan by DELWP.

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[i] The Victorian Government’s response (Victorian Government, 2012) made DEPI accountable for the planning and coordinating of the TFWS: in effect the “champion” for the TFWS in Victoria. DEPI has interpreted this “champion” role with a focus on the planning and co-ordination aspect into the following responsibilities:

a) Leading the establishment and maintenance of a framework for the assessment of TFWS service needs.
b) Establishing service levels for each TFWS element to meet agreed community needs for a given flood risk.
c) Leading consultation with CMAs, Local Government Authorities and VICSES to assess TFWS service needs across regional Victoria.

d) Leading consultation, through the VFWCC, with other agencies to address TFWS service delivery.
e) Leading ongoing review of TFWS service needs and delivery requirements, in the context of the need to align service needs and delivery arrangements.

ii It is assumed that the reader is familiar with the TFWS model as described in EMA (2009) and also with the jurisdictional boundaries that apply across the TFWS within and between the Australian States and Territories as described in BoM (2015).

iii A service level of four (4) indicates a high level of service while zero (0) indicates that there is either no data or insufficient data available and that as a result a service level tier cannot be determined.

iv Data on the social and economic impacts of flooding is sparse in Victoria although there are a few exceptions as a direct result of efforts following recent major floods. However, these data are not sufficiently detailed or complete to facilitate an analysis robust enough to support the Tool. The flood risk score is therefore determined via an approach that builds on the Rapid Assessment Method for Floodplain Management (Read Sturgis, 2001) and uses available flood and asset information to assess flood likelihood and consequences. The approach delivers a score for each location considered.

v The TFWS service level is highlighted red when the service level tier is less than the level of risk, yellow when the service level tier is the same as the level of risk and green when the service level tier is greater than the level of risk. In addition, individual TFWS elements are highlighted pink when the service level for that TFWS element (or factor) is less than the level of risk.

vi This is consistent with Emergency Management Australia Manual 21 Flood Warning (EMA, 2009).

vii Sub-factors are the more detailed measurable features of the TFWS within each element (or building block). Each factor contains one or more sub-factors. The service level tier value for each of the factors (or TFWS elements) within the Tool is obtained by combining and manipulating the scores for each of the relevant sub-factors. The combined scores for each of the TFWS elements are then grouped into score bands that represent the five service level tiers.

viii Flood Warning Service Charters generally contain detailed forecasting and flood warning information aimed at improving the focus and utility of flood forecasts issued for the location / community.

ix The population affected is calculated as the AAPA divided by the population of the location.

x The damage density is calculated as damages per area of inundation at the 1% AEP event.

xi The service level for the TFWS as a whole is calculated as the average of the sum of the service levels for each factor.

xii For example, counts of properties flooded over-ground and above-floor by nominated AEP events is limited. Including this information in the Tool without the ability to infill or use a surrogate with confidence would introduce significant skew. While the work done by GHCMA in 2011 (Little and Cawood - unpublished) provides some initial thinking on how this data might be used, the issue of whether a small number of properties flooded over-floor at the 10% event but representing a high proportion of properties in the community is more 'worthy' than a large number at the 1% AEP event in a large town remains unresolved. Resolving that issue and how to infill for missing or unavailable data are key to using such data successfully within the Tool.