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River system modelling for the Flinders and Gilbert Agricultural Resource Assessment case study analysis

A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy

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Citation

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Flinders and Gilbert Agricultural Resource Assessment acknowledgments

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The Strategy was guided by two committees:

(i) the **Program Governance Committee**, which included the individuals David Crombie (GRM International), Scott Spencer (SunWater, during the first part of the Strategy) and Paul Woodhouse (Regional Development Australia) as well as representatives from the following organisations: Australian Government Department of Infrastructure and Regional Development; CSIRO; and the Queensland Government.

(ii) the **Program Steering Committee**, which included the individual Jack Lake (Independent Expert) as well as representatives from the following organisations: Australian Government Department of Infrastructure and Regional Development; CSIRO; the Etheridge, Flinders and McKinlay shire councils; Gulf Savannah Development; Mount Isa to Townsville Economic Development Zone; and the Queensland Government.

This report was reviewed by Daren Barma (Barma Water Resources), Alex Loy (QLD Department of Science, Information Technology, Innovation and the Arts (DSITIA))

Director's foreword

Northern Australia comprises approximately 20% of Australia's land mass but remains relatively undeveloped. It contributes about 2% to the nation's gross domestic product (GDP) and accommodates around 1% of the total Australian population.

Recent focus on the shortage of water and on climate-based threats to food and fibre production in the nation's south have re-directed attention towards the possible use of northern water resources and the development of the agricultural potential in northern Australia. Broad analyses of northern Australia as a whole have indicated that it is capable of supporting significant additional agricultural and pastoral production, based on more intensive use of its land and water resources.

The same analyses also identified that land and water resources across northern Australia were already being used to support a wide range of highly valued cultural, environmental and economic activities. As a consequence, pursuit of new agricultural development opportunities would inevitably affect existing uses and users of land and water resources.

The Flinders and Gilbert catchments in north Queensland have been identified as potential areas for further agricultural development. The Flinders and Gilbert Agricultural Resource Assessment (the Assessment), of which this report is a part, provides a comprehensive and integrated evaluation of the feasibility, economic viability and sustainability of agricultural development in these two catchments as part of the North Queensland Irrigated Agricultural Strategy. The Assessment seeks to:

- identify and evaluate water capture and storage options
- identify and test the commercial viability of irrigated agricultural opportunities
- assess potential environmental, social and economic impacts and risks.

By this means it seeks to support deliberation and decisions concerning sustainable regional development.

The Assessment differs from previous assessments of agricultural development or resources in two main ways:

- It has sought to 'join the dots'. Where previous assessments have focused on single development activities or assets – without analysing the interactions between them – this Assessment considers the opportunities presented by the simultaneous pursuit of multiple development activities and assets. By this means, the Assessment uses a whole-of-region (rather than an asset-by-asset) approach to consider development.
- The novel methods developed for the Assessment provide a blueprint for rapidly assessing future land and water developments in northern Australia.

Importantly, the Assessment has been designed to lower the barriers to investment in regional development by:

- explicitly addressing local needs and aspirations
- meeting the needs of governments as they regulate the sustainable and equitable management of public resources with due consideration of environmental and cultural issues
- meeting the due diligence requirements of private investors, by addressing questions of profitability and income reliability at a broad scale.

Most importantly, the Assessment does not recommend one development over another. It provides the reader with a range of possibilities and the information to interpret them, consistent with the reader's values and their aspirations for themselves and the region.

Peter Stone

Dr Peter Stone, Deputy Director, CSIRO Sustainable Agriculture Flagship

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Shortened forms

AEM	airborne electromagnetics
AHD	Australian Height Datum
APSIM	Agricultural Production Systems Simulator
AWRC	Australian Water Resources Council
CGE	Computable General Equilibrium
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	digital elevation model
GCMs	global climate models
GCM-ES	global climate model output empirically scaled to provide catchment-scale variables
IPCC AR4	the Fourth Assessment Report of the Intergovernmental Panel on Climate Change
IQQM	Integrated Quantity-Quality Model – a river systems model
Landsat TM	Landsat Thematic Mapper
MODIS	Moderate Resolution Imaging Spectroradiometer
NQIAS	North Queensland Irrigated Agriculture Strategy
NRM	natural resource management
ONA	the Australian Government Office of Northern Australia
OWL	the Open Water Likelihood algorithm
PAWC	plant available water capacity
PE	potential evaporation
RCP	representative concentration pathway
Sacramento	a rainfall-runoff model
SALI	the Soil and Land Information System for Queensland
SLAs	statistical local areas
SRTM	shuttle radar topography mission
TRaCK	Tropical Rivers and Coastal Knowledge Research Hub
WRON	CSIRO’s Water Resource Observation Network

Units

MEASUREMENT UNITS	DESCRIPTION
GL	gigalitres, 1,000,000,000 litres
keV	kilo-electronvolts
kL	kilolitres, 1000 litres
km	kilometres, 1000 metres
L	litres
m	metres
mAHD	metres above Australian Height Datum
MeV	mega-electronvolts
mg	milligrams
ML	megalitres, 1,000,000 litres

Preface

The Flinders and Gilbert Agricultural Resource Assessment (the Assessment) aims to provide information so that people can answer questions such as the following in the context of their particular circumstances in the Flinders and Gilbert catchments:

- What soil and water resources are available for irrigated agriculture?
- What are the existing ecological systems, industries, infrastructure and values?
- What are the opportunities for irrigation?
- Is irrigated agriculture economically viable?
- How can the sustainability of irrigated agriculture be maximised?

The questions – and the responses to the questions – are highly interdependent and, consequently, so is the research undertaken through this Assessment. While each report may be read as a stand-alone document, the suite of reports must be read as a whole if they are to reliably inform discussion and decision making on regional development.

The Assessment is producing a series of reports:

- Technical reports present scientific work at a level of detail sufficient for technical and scientific experts to reproduce the work. Each of the 12 research activities (outlined below) has a corresponding technical report.
- Each of the two catchment reports (one for each catchment) synthesises key material from the technical reports, providing well-informed but non-scientific readers with the information required to make decisions about the opportunities, costs and benefits associated with irrigated agriculture.
- Two overview reports – one for each catchment – are provided for a general public audience.
- A factsheet provides key findings for both the Flinders and Gilbert catchments for a general public audience.

All of these reports are available online at <http://www.csiro.au/FGARA>. The website provides readers with a communications suite including factsheets, multimedia content, FAQs, reports and links to other related sites, particularly about other research in northern Australia.

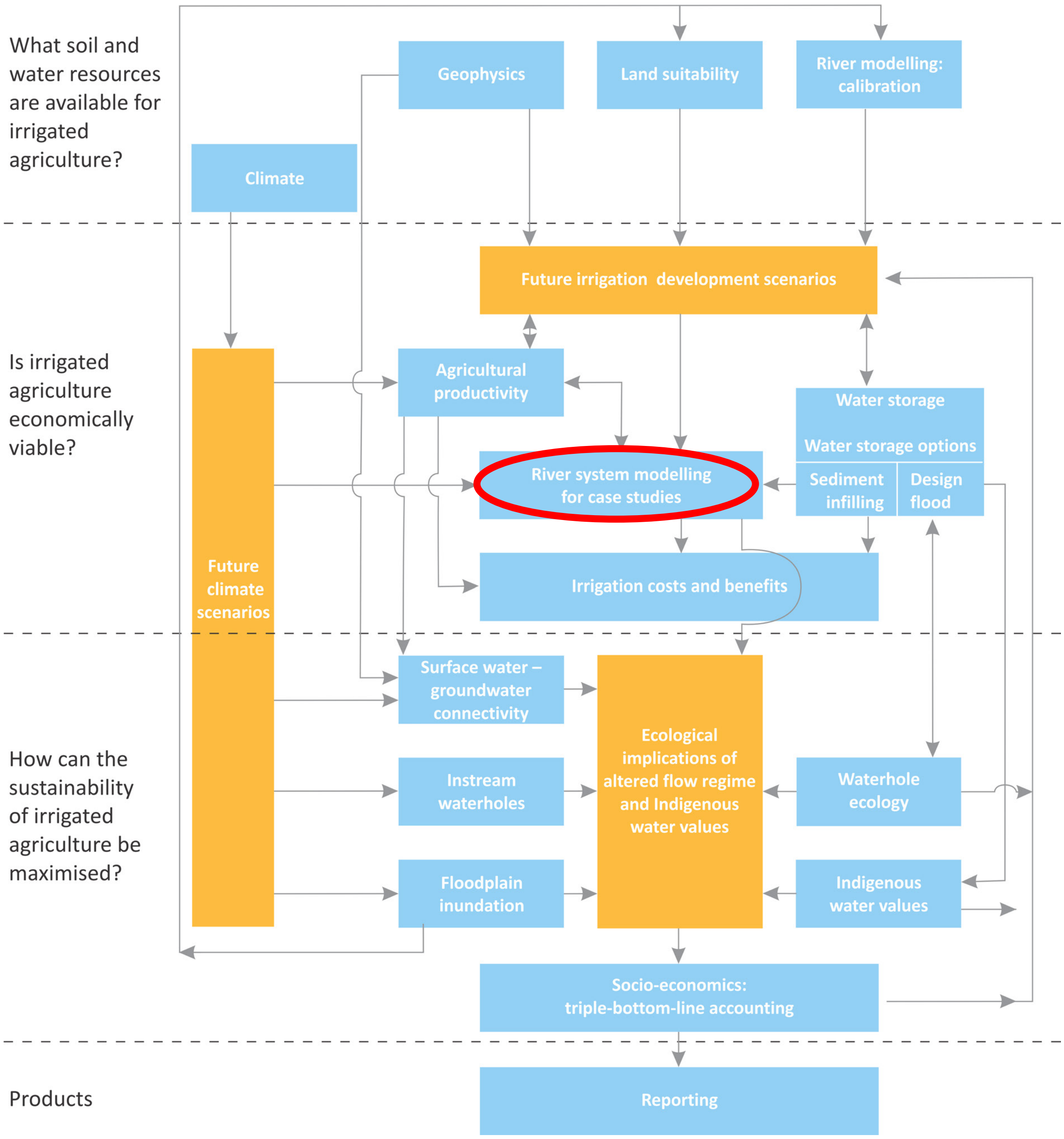
The Assessment is divided into 12 scientific activities, each contributing to a cohesive picture of regional development opportunities, costs and benefits. Preface Figure 1 illustrates the high-level linkages between the 12 activities and the general flow of information in the Assessment. Clicking on an 'activity box' links to the relevant technical report.

The Assessment is designed to inform consideration of development, not to enable particular development activities. As such, the Assessment informs – but does not seek to replace – existing planning processes. Importantly, the Assessment does not assume a given regulatory environment. As regulations can change, this will enable the results to be applied to the widest range of uses for the longest possible time frame. Similarly, the Assessment does not assume a static future, but evaluates three distinct scenarios:

- Scenario A – historical climate and current development
- Scenario B – historical climate and future irrigation development
- Scenario C – future climate and current development.

As the primary interest was in evaluating the scale of the opportunity for irrigated agriculture development under the current climate, the future climate scenario (Scenario C) was secondary in importance to scenarios A and B. This balance is reflected in the allocation of resources throughout the Assessment.

The approaches and techniques used in the Assessment have been designed to enable application elsewhere in northern Australia.



Preface Figure 1 Schematic diagram illustrating high-level linkages between the 12 activities (blue boxes)

This report is a technical report. The red oval in Preface Figure 1 indicates the activity (or activities) that contributed to this report.

The orange boxes indicate information used or produced by several activities. The red oval indicates the activity (or activities) that contributed to this technical report. Click on a box associated with an activity for a link to its technical report (or click on 'Technical reports' on <http://www.csiro.au/FGARA> for a list of links to all technical reports). Note that the Water storage activity has multiple technical reports – in this case the separate reports are listed under the activity title. Note also that these reports will be published throughout 2013, and hyperlinks to currently unpublished reports will produce an 'invalid publication' error in the CSIRO Publication Repository.

Executive summary

The Flinders and Gilbert Agricultural Resource Assessment (the Assessment), of which this report is a part, provides a comprehensive and integrated evaluation of the feasibility, economic viability and sustainability of agricultural development in these two catchments as part of the North Queensland Irrigated Agricultural Strategy. The Assessment includes detailed analysis of six case studies. These case studies represent an integrated evaluation of the scale of opportunity of irrigation in key geographic areas of the catchment, and enable an assessment of the viability of irrigation and its sustainability.

This report is the companion report to Lerat et al. 2013, which described the configuration and calibration of eWater Source river models for the Flinders and Gilbert catchments. The focus of this report is to describe the approaches by which these models were used to assess the reliability of supplying water to potential irrigation developments in the Flinders and Gilbert catchments and examine the potential impacts on streamflow and existing entitlements.

Potential irrigation development was assessed in the form of case studies, there being three case studies each for the Flinders and Gilbert catchments as follows:

Flinders catchment case studies:

- Cave Hill Dam and irrigated sorghum
- O'Connell Creek off-stream storage and irrigated rice
- Irrigation mosaics and a variety of irrigated crops

Gilbert catchment case studies:

- Green Hills dam and irrigated three-crop rotation
- Dagworth and Green Hills dams and irrigated sugarcane
- Kidston Dam and irrigated Rhodes grass

For each case study, sensitivity testing was undertaken to assess the viability of an irrigation development under a range of possible development options. For each case study, the eWater Source results were used to evaluate crop yield in conjunction with the Agricultural Production Systems Simulator (Keating et al., 2003) model.

The profitability of each of the irrigation developments was then evaluated in terms of both gross margins and net present value as is reported in the Flinders and Gilbert Catchment Reports (Petheram et al., 2013a and b). On the basis of this, a single development option was selected for each case study for further detailed analysis.

Each case study has been evaluated with consideration given to downstream impacts. The case study assessments included an allowance to avoid impacts on the reliability with which existing entitlement holders could extract water. The exception to this is O'Connell creek; for this case study no allowance was made on the basis that it was desired to undertake the most generous assessment possible to determine whether the scheme has any chance of being viable.

The initial assessment of each case study did not provide any allowance for environmental flow rules. The proposed method was that potential rules would be evaluated in the event that any of the irrigation developments appear to be viable; no such assessments were deemed to be required. This is because the incorporation of environmental flow rules would have the effect of further reducing the reliability of water supply, making the investment less profitable.

The selected development options evaluated for Green Hills and Dagworth resulted in the most reliable systems. O'Connell creek off-stream storage and Cave Hill dam result in the least reliable systems. For the Flinders water harvesting case study, water availability is poor by 1st January but significantly improves by

the 1st February. For most sites the full entitlement assigned to the site can be extracted in a high percentage of years for the smallest new entitlement release examined (80GL) however reliability is decreased with increasing new entitlement release.

For all of the case studies, river reaches immediately downstream of the irrigation development would experience a moderate impact to median flow (i.e. median streamflow quotient typically between 0.6 and 0.8). None of the case studies resulted in a large change in the median flow at the end of system.

The initial river system modelling undertaken for each case study includes a number of uncertainties and assumptions that could influence the viability of a particular case study. Climate change also provides a potential threat to the future viability of each case study. Consequently, in the event that any of the schemes appeared to be viable, the case studies were to be further examined to consider the impact on supplied irrigation water reliability of these uncertainties, assumptions and future climate. The evaluated schemes are not viable from a scheme scale economic analysis perspective (see Flinders and Gilbert Catchment Reports (Petheram et al., 2013a and b)). A supplied irrigation water reliability assessment has thus only been conducted for one case study (Dagworth – Green Hills sugarcane). The largest impact was a 10% reduction in average annual volumes supplied to the crop as a result of low scheme efficiency. Note however, that impacts during dry periods are more significant. The impacts due to climate change were of similar magnitude to the impacts of scheme efficiency. The largest increase in average annual volumes supplied was 5%. Potential increases may be more significant in other case studies where water availability is less reliable. The report did not assess impacts on crop yield modelling and this would be an informative area of future work.

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1 Introduction

1.1 Context

The Flinders and Gilbert catchments in north Queensland have been identified as potential areas for further agricultural development. The Flinders and Gilbert Agricultural Resource Assessment (the Assessment), of which this report is a part, provides a comprehensive and integrated evaluation of the feasibility, economic viability and sustainability of agricultural development in these two catchments as part of the North Queensland Irrigated Agricultural Strategy. The Assessment includes a series of technical and synthesis reports as detailed in Appendix A. A key activity in the Assessment is understanding the hydrology of these two catchments.

Previous studies (Petheram et al., 2009) have shown that large volumes of runoff (> 2000 GL/year) occur in both catchments. However, the spatial distribution of water within the catchments and its inter-annual and within-year variability imposes constraints on the availability of water and is an important consideration in the design of water storages and irrigation developments.

To better understand these opportunities and constraints this report describes a robust framework under which climate and potential irrigation development can be evaluated. At the heart of this framework are hydrological models. These models can simulate natural hydrological processes, including runoff generation, flow routing (i.e. the timing and attenuation of flow along a river reach), river reach evaporation and transmission losses. They are also capable of incorporating the effects on water flows of dams and weirs, extractions, diversions, irrigation return flows and complex operating rules and environmental flow conditions.

In the context of the Assessment, river models are useful to help answer the following questions:

- How much water is in the river at different locations and different times, under the historical climate and current levels of development?
- How much water is available and at what reliability of supply for irrigated agriculture at different locations and different times, under current and future climate and potential development scenarios?
- How might potential development scenarios be optimised to maximise economic return?
- How may streamflow change downstream of potential development if the development went ahead?

This report is the companion report to Lerat et al. 2013, which described the configuration and calibration of eWater Source river models ((Carr & Podger, 2012; Welsh et. al., 2012) for the Flinders and Gilbert catchments. The focus of this report is to describe the approaches by which these models were used to assess the reliability of supplying water to potential irrigation developments in the Flinders and Gilbert catchments and examine the potential impacts on streamflow and existing entitlements.

To this end the Assessment examined potential future irrigation development in the form of six case studies. These case studies represent an integrated evaluation of the scale of opportunity of irrigation in key geographic areas of the catchment, and enable an assessment of the viability of irrigation and its sustainability. Each evaluates particular crops and their needs, additional investment requirements and ecological impacts. There are three case studies each for the Flinders and Gilbert catchments as follows:

Flinders catchment case studies:

- Cave Hill dam and irrigated sorghum
- O'Connell Creek off-stream storage and irrigated rice

- Irrigation mosaics based on water harvesting (i.e. no headwater storage)

Gilbert catchment case studies:

- Green Hills dam and irrigated three-crop rotation
- Dagworth and Green Hills dams and irrigated sugarcane
- Kidston Dam and irrigated Rhodes grass

A number of sensitivity analyses are presented in this report to test for different development scenarios. Each of these sensitivity tests were evaluated in terms of economic viability as reported in Petheram et al. (2013a and b). This economic assessment was used to determine a single development option for each case study which underwent further detailed analysis. This report is limited to presenting results relating to water availability, crop yield and impacts on flow and existing entitlements. The focus of the initial assessment was to determine whether any of the irrigation developments appear to be viable. Given this focus, the model assumptions adopted have at times been generous (i.e. in favour of irrigation development) such that the assessment provides an over-estimate of water yields. Further detail is provided in the report. This approach was adopted such that if the initial sensitivity testing resulted in irrigation developments appearing to be unviable then no further assessment would be required under more conservative assumptions.

1.2 Objective

The objectives of this report are as follows:

- Describe the development of the river models for each of the case studies
- Describe how crop yield and river system impacts were evaluated using the outputs from the river system models
- Illustrate the results obtained for each case study in terms of reliability of supply, crop yield and impacts on flow and existing entitlements
- Assess impacts on the reliability of supplied irrigation water due to streamflow uncertainty, different supply efficiencies and future climate.

The remainder of the report is structured as follows. A more detailed introduction to the study site is provided in Section 2. The methods used in the Assessment are detailed in Section 3. Section 4 provides supporting information which informs the choice of methods for assessing the impact of climate change. This section also contains information supporting assumptions made about storage, distribution and application losses in each of the case studies. The details of each case study are presented in Section 5 as are the results and discussion. Conclusions are presented in Sections 6.

Appendix A provides the complete citations for all reports produced by the Assessment.

Appendix B provides the results of a simple spreadsheet water harvesting analysis.

Appendix C shows the Crop k-c parameters used by the Source river system model for the case study crops.

Appendix D provides a graphical presentation of key hydrological metrics at all streamflow gauging stations for each case study development. An ecological interpretation of these metrics is provided in the case study chapters (8 to 10) in Petheram et al. (2013a and b).

2 Site description

2.1 Location of the catchments

The Assessment area encompasses the Flinders and Gilbert catchments, which are located in the Gulf region of North Queensland (Figure 2.1).

The Flinders catchment has an area of 109,000 km^2 and a population of about 6,000 people. The Flinders River is the main river in the Flinders catchment. It rises in the Great Dividing Range, 100 km north-east of Hughenden. The river flows from north to south, until it reaches Hughenden where it tracks west across the flat and treeless Mitchell grass plains. After flowing through the town of Richmond, it continues towards the north-west before flowing north and draining into the Gulf of Carpentaria. The Flinders River has five major tributaries. These are the Dutton River, the Stawell River, Alick Creek, the Cloncurry River and the Saxby River. The largest tributary is the Cloncurry River, which accounts for half of the catchment area at the confluence between the Cloncurry and Flinders rivers. Large increases in catchment area occur where these large tributaries join the Flinders River. The Cloncurry River has four main tributaries: the Malbon River, the Gilliat River, Julia Creek and the Dugald River.

The Gilbert catchment has an area of 46,354 km^2 and a population of about 1,200 people. The Gilbert catchment is comprised of two major rivers, the Gilbert and the Einasleigh. Although the Gilbert catchment shares a name with the Gilbert River (named after the explorer Gilbert), the Einasleigh River has the larger streamflow volume of the two rivers. The flow characteristics of the two rivers are quite different, with the Einasleigh River and some of its upper tributaries draining the basalt country in the eastern parts of the Gilbert catchment. This results in extended flows during the dry season in some reaches of the Einasleigh River and its tributaries. In contrast the Gilbert River and Etheridge River (a major tributary of the Einasleigh River) are highly ephemeral and do not flow for more than half the year on average. Downstream of Strathmore Station the Gilbert and Einasleigh rivers converge before entering the Gulf of Carpentaria.

Both catchments have a maximum elevation of about 1,050 m. While the Gilbert catchment is undulating in its mid-to-upper reaches the Flinders catchment is predominantly flat (Figure 2.1). The land use in the two catchments is mainly cattle grazing; only a small part is being used for cropping.

2.2 Climate

The Flinders and Gilbert catchments have a semi-arid tropical climate. The mean and median annual rainfall spatially averaged across the Flinders catchment is 492 mm and 454 mm, respectively. However, the historical annual rainfall series for the Flinders catchment shows considerable variation between water years (Figure 2.2). The mean and median annual rainfall spatially averaged across the Gilbert catchment is 775 mm and 739 mm, respectively. Spatially, mean annual rainfall varies from about 1,050 mm at the coast to about 650 mm in the south-east of the catchment.

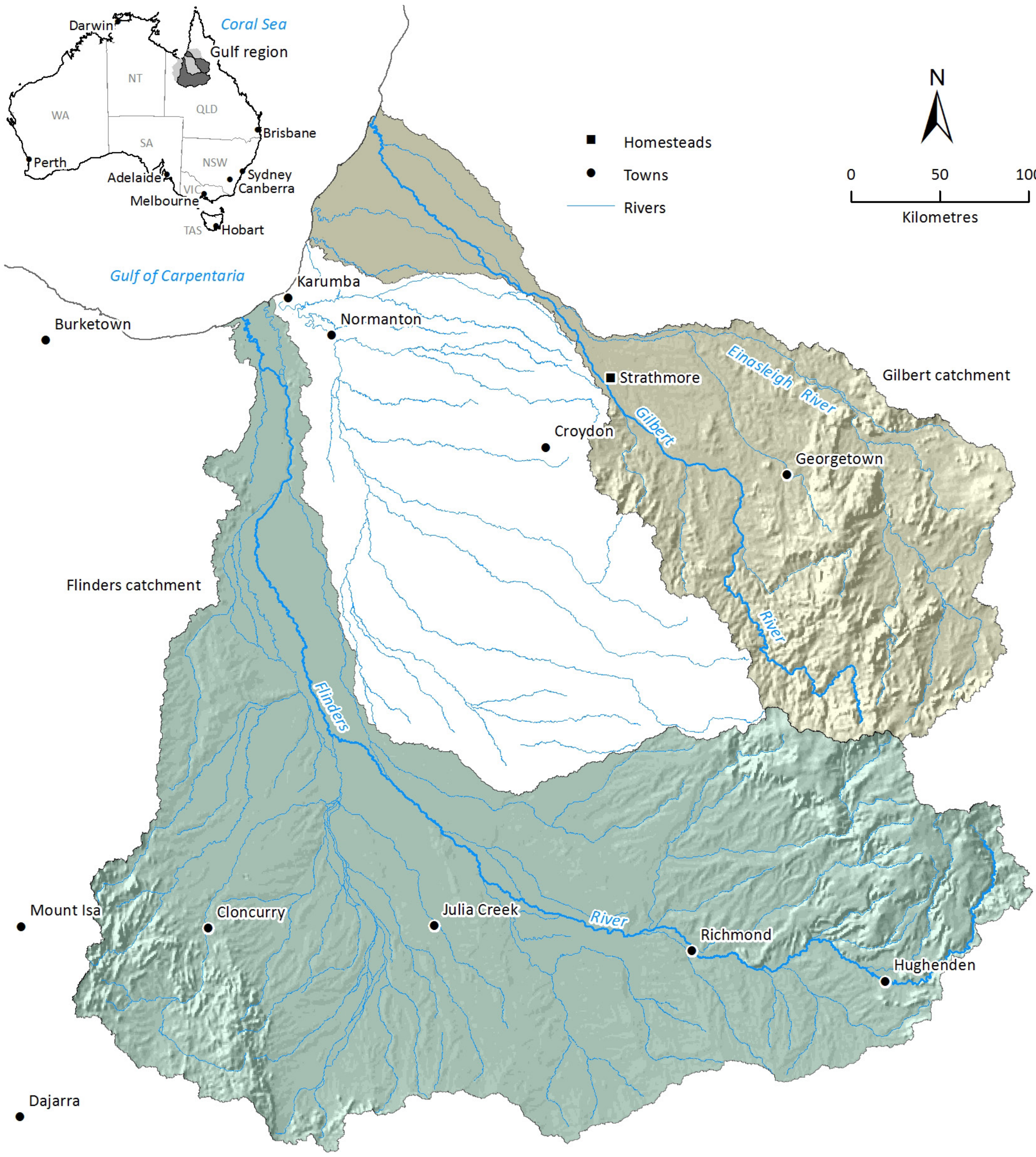

Figure 2.1 A shaded relief map of the Flinders and Gilbert catchments. The Flinders and Gilbert catchments, the Gulf region is shown in the small thumbnail map in top left corner

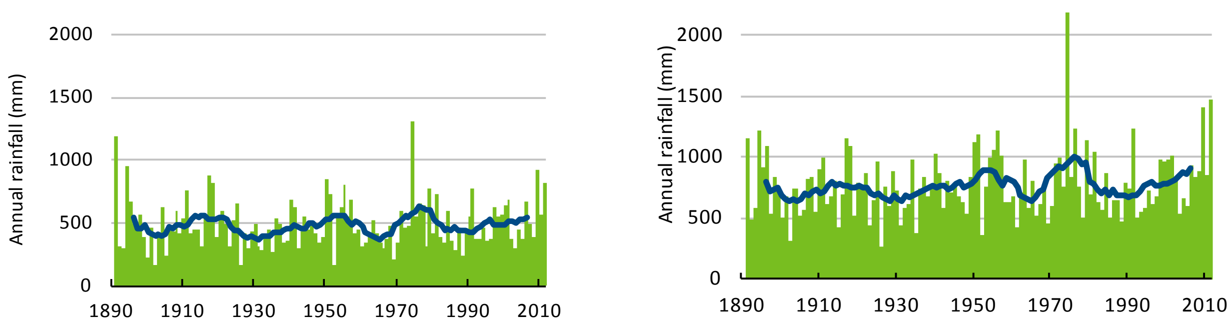

Figure 2.2 Historical annual rainfall averaged over the Flinders (left) and Gilbert (right) catchments. The low-frequency smoothed line is the 10 year running mean

A defining characteristic of the Flinders and Gilbert catchments’ climate is the seasonality of rainfall with more than 80% of rainfall (88% in the Flinders and 93% in the Gilbert) occurring during the wet season (November to April inclusive) (Figure 2.3). The highest median monthly rainfall in the two catchments

occurs during the months of January and February (~100 mm in Flinders and ~ 200 mm in Gilbert). The months with the lowest median rainfall are July and August (~ 0.5 mm) (Petheram and Yang, 2013).

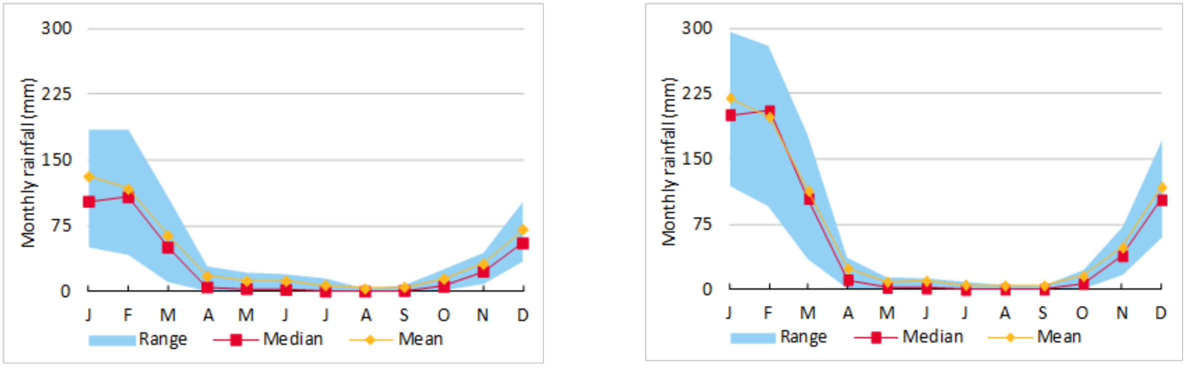

Figure 2.3 Historical monthly rainfall averaged over the Flinders (left) and Gilbert (right) catchments (A range is the 20th and 80th percentile monthly rainfall)

Areal potential evaporation in the two catchments exceeds 1800 mm in most years. The Flinders catchment has a mean annual potential evaporation of 1862 mm. Mean wet and dry season potential evaporation are 1115 mm and 762 mm respectively. The Gilbert catchment has a mean annual potential evaporation of 1868 mm. Mean wet and dry season potential evaporation is 1067 mm and 815 mm respectively (Figure 2.4). Potential evaporation in the two catchments exhibits a strong seasonal pattern, ranging from 200 mm per month during the build up and the wet season (October to January), to about 100 mm per month during the middle of the dry season (June to July) (Figure 2.5). The majority of the Flinders and Gilbert catchments experience a mean annual rainfall deficit of greater than 600 mm. Consequently, both catchments have a high proportion of landscape with a semi-arid climate (Petheram and Yang, 2013).

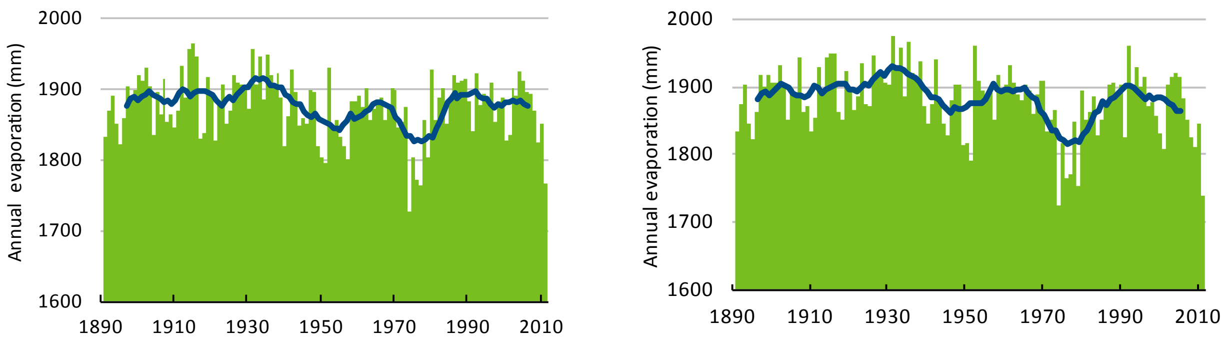

Figure 2.4 Historical annual areal potential evaporation averaged across the Flinders (left) and Gilbert (right) catchments. The low-frequency smoothed line is the 10 year running mean

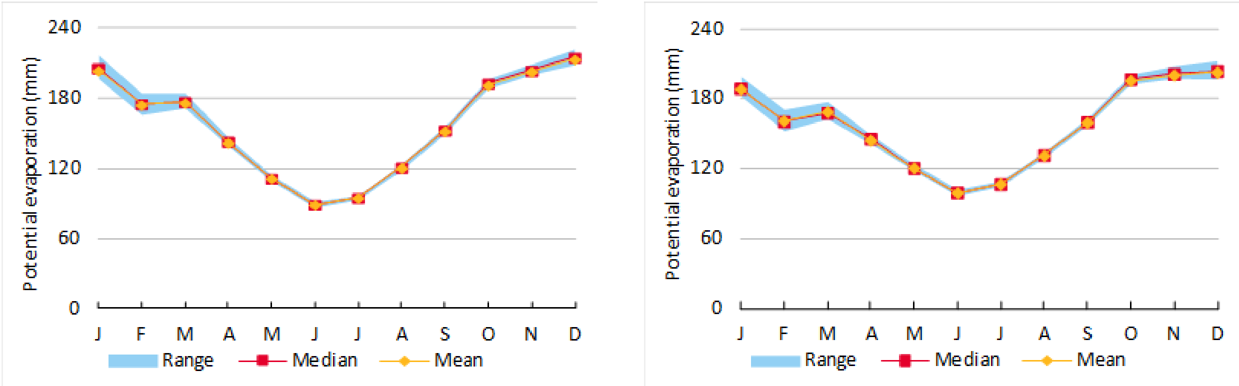

Figure 2.5 Monthly potential area evaporation averaged over the Flinders (left) and Gilbert (right) catchments between 1965 and 2011(A range is the 20th and 80th percentile monthly potential areal evaporation)

2.3 Soils

Flinders

The physical environment of the Flinders catchment provides both opportunity and challenge for potential developers. While soils are suitable for agriculture the topography and geology do not favour the construction of large headwater dams.

The dominant soils in the Flinders catchment (68%) are cracking clays derived from the fine-grained sedimentary rocks of the Great Artesian Basin Rolling Downs Group. These soils store a moderately large amount of water and can grow a range of annual crops but not deep-rooted perennial or tree crops. The risk of secondary salinisation is high for these soils and they require careful management.

The soils most suitable for irrigated agriculture in the Flinders catchment are the alluvial soils adjacent to the Flinders and Cloncurry rivers and their larger tributaries. The alluvial soils are less prone to salinity issues and have moderate to high nutrient levels.

Gilbert

The Gilbert contains alluvial soils suitable for a variety of cropping near to suitable sites for large dams. About 20% of the Gilbert catchment contains soils that are at least moderately suitable for irrigated agriculture. The most suitable are the recent alluvial soils adjacent to the Gilbert and Einasleigh rivers upstream of their confluence. These soils are deep (greater than 1.5 m) and generally extend about 1 km from the river. Elsewhere in the Gilbert catchment the agricultural potential is low.

For further information refer to the technical report about land suitability (Bartley et al., 2013).

3 Methods

3.1 Key concepts

3.1.1 WATER YEAR AND WET AND DRY SEASONS

The Gulf region experiences a highly seasonal climate, with the majority of rain falling between December and March. Unless specified otherwise the wet season is defined as being the six-month period from 1 November to 30 April and the dry season is the six-month period from 1 May to 31 October. All results in the Assessment are reported over the 'water year', defined as the period 1 July to 30 June and which allows each individual wet season to be counted in a single 12-month period, rather than being split over two calendar years (i.e. counted as two separate seasons). This is the best option for reporting climate statistics in northern Australia and from a hydrological and agricultural assessment viewpoint.

3.1.2 SCENARIO DEFINITIONS

The Assessment, considered three different scenarios of climate and surface water, groundwater and economic development, as used in the *Northern Australia Sustainable Yields Project* (CSIRO, 2009a & b):

- Scenario A – historical climate and current development
- Scenario B – historical climate and future irrigation development
- Scenario C – future climate and current development

As the primary interest was in evaluating the scale of the opportunity for irrigated agriculture development under the current climate, the future climate scenario (Scenario C) was secondary in importance to scenarios A and B. This balance is reflected in the allocation of resources throughout the Assessment.

Scenario A

Scenario A included historical climate and current development. The historical climate data were of 121 years (water years from 1 July 1890 to 30 June 2011) of observed climate (rainfall, temperature and potential evaporation for water years). All results presented in this report are reported over this period unless specified otherwise. Historical tidal data were used to specify downstream boundary conditions for flood modelling undertaken by the Assessment.

Current development is the current level of surface water, groundwater and economic development that was defined as that of 1 July 2013. This scenario assumes full use of entitlements which were allocated prior to 2013. The recent release of entitlements is not represented in this scenario. Scenario A was used as the baseline against which assessments of relative change in streamflows were made.

The river model simulation period extended from 1 July 1889 to 30 June 2011, with the first year being used as a model warm up period.

Scenario B

Scenario B included historical climate and future irrigation development (see the case studies in chapters 5), undertaken by the Assessment through discussion with stakeholders. Scenario B used the same historical climate data as Scenario A. Future irrigation development is described by each case study storyline, and river inflow and agricultural productivity were modified accordingly.

The case studies models were developed from scenario B0. This differs to scenario A in that the recent release of entitlements is included in Scenario B0 but not Scenario A. Scenario B0 was used to assess impacts on existing entitlements.

Scenario C

Scenario C included future climate and current development. It was based on a 121-year climate data sequence scaled for ~2060 conditions. These climate data were derived from a range of global climate model (GCM) projections for a 2 °C global temperature rise scenario which encompassed different GCMs for this single global warming scenario – the projections were then used to modify the observed historical daily climate sequences. The current level of surface water, groundwater and economic development were assumed. Tidal level data were manipulated to reflect a ~2060 sea-level rise (i.e. the median date at which the GCMs reach a 2 °C global temperature rise).

3.2 Overview of methods

The river models developed for the Assessment were built within the eWater Source modelling platform, hereafter referred to as Source (Carr & Podger, 2012; Welsh et. al., 2012). It is a flexible package that can be used to represent both the physical and management characteristics of a river system. Welsh et. al. (2012) summarise its capability as follows:

> *"It is designed and developed to provide a transparent, robust and repeatable approach to underpin a wide range of water planning and management purposes. It can be used to develop water sharing plans and underpin daily river operations, as well as be used for assessments on water quantity and quality due to changes in: i) land-use and climate; ii) demands (irrigation, urban, ecological); iii) infrastructure, such as weirs and reservoirs; iv) management rules that might be associated with these; and v) the impacts of all of the above on various ecological indices."*

A separate Source model was developed for each case study with each potential irrigation development evaluated using 121 years of climate data as further detailed in Section 3.3. The development of the case study models was preceded by the development of the calibration and baseline models as further detailed in Sections 3.3.1 and 3.3.2 respectively.

Each case study has a unique cropping system which has been simulated in Source using the Irrigator Demand Model (Bethune & Podger. 2013). The choice of parameter values for this model has been informed through the development of Agricultural Production Systems Simulator (APSIM) (Keating et al., 2003) models as detailed in Section 3.4. APSIM is a biophysical process agricultural model and as such it provides superior capability to predict crop yields in comparison to the conceptual model provided in Source. APSIM does not however have the capability to assess water availability to the crop. Hence, a joint approach has been adopted where Source is used to assess water availability to the crop and these results are used to re-run APSIM to determine crop yield. Crop yields were in some cases also initially assessed with a regression model as is further detailed below in Section 3.4.3.

For each case study, an analysis was undertaken to explore water supply reliability and crop yield for irrigation developments of scheme area (Section 3.3.4). One scheme area was then selected and a more detailed analysis undertaken.

For the purposes of the initial explorative analysis, it was necessary to estimate crop yield using a statistical crop yield model, where a model could be reliably developed. The reason for this is that it is not practical to re-run APSIM numerous times using water supply data from the Source river model, so as to assess a large number of scheme areas. The regression models were developed based on APSIM results (see Section

3.4.3). In the event that a reliable regression model could not be developed, the exploratory analysis was undertaken using APSIM. The results of the sensitivity testing were evaluated using an economic assessment as reported in the Flinders and Gilbert Catchment Reports (Petheram et al., 2013a and b). The economic assessment was used to select a scheme area to assess in more detail. For each case study where an initial yield analysis was based on a regression model, the yield for the selected development option was re-assessed using APSIM in the more detailed analysis.

The initial river system modelling undertaken for each case study includes a number of uncertainties and assumptions that could influence the viability of a particular case study. Climate change also provides a potential threat to the future viability of each case study. Consequently, in the event that any of the schemes appeared to be viable, the case studies were to be further examined to consider the impact on supplied irrigation water reliability of these uncertainties, assumptions and future climate. The evaluated schemes are not viable from a scheme scale economic analysis perspective (see Flinders and Gilbert Catchment Reports (Petheram et al., 2013a and b)). A supplied irrigation water reliability assessment has thus only been conducted for one case study (Dagworth – Green Hills sugarcane) as is detailed in Section 3.3.5. This assessment enables comparison of the impacts of streamflow uncertainty, different supply efficiencies and future climate on the reliability of irrigation water supplied to crops.

Each case study has been evaluated with consideration given to downstream impacts. For each, rules have been developed to avoid impacts on existing entitlements as is further detailed in Section 3.3.3. Impacts on the flow regime have also been evaluated as detailed in Section 3.4.

The data inputs for the calibration model, new storages evaluated in case studies and crop modelling for proposed new scheme areas were as follows:

- Rainfall - gridded SILO climate data (Jeffery et al. 2001)
- Potential Evaporation (APET) - Morton evaporation from gridded SILO data used for storages
- Potential Evaporation (PE-PT) – Priestly-Taylor PE used for crop modelling in both Source and APSIM.

The adopted method is summarised in Figure 3.1, including linking of Source modelling with other analysis methods.

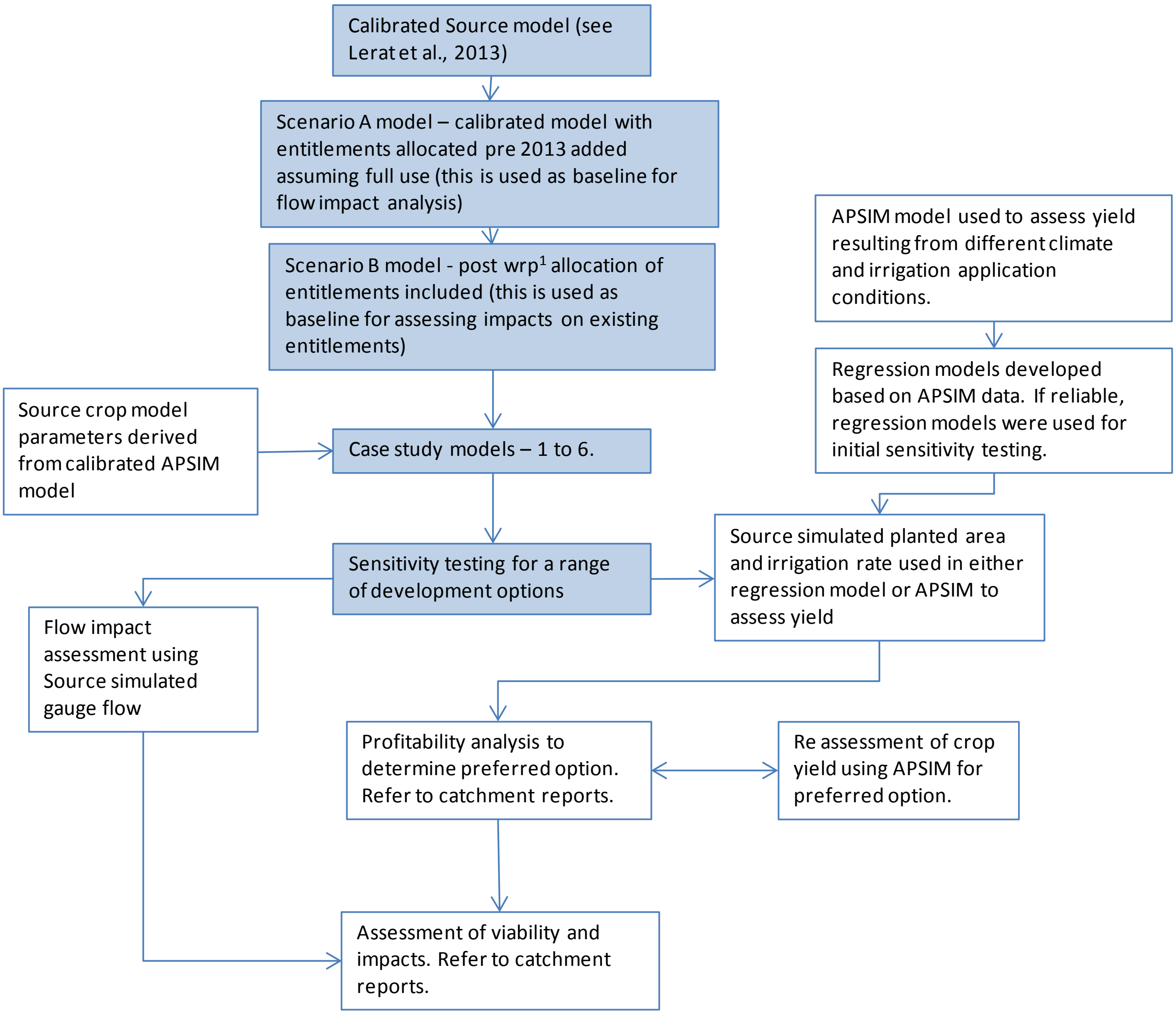

Figure 3.1 River system modelling methodology (blue boxes represent assessment undertaken using eWater Source).
1 Water resource plan

3.3 River system modelling methods

This section provides a brief overview of the calibration model for each of the Flinders and Gilbert catchments, reported in Lerat et al., (2013). It is then followed by a description of the methods uses to modify the calibration model to develop the baseline model (Section 3.3.2).

3.3.1 CALIBRATION MODEL

The technical report (Lerat et al., 2013) provides full details on the calibration of the Flinders and Gilbert Source models however a brief re-cap follows.

The calibration model was initially developed by transferring the existing IQQM models into Source. The IQQM models were developed by the Queensland Government to support the Gulf Water Resources Plan. The IQQM and the Source river models were run in parallel to ensure that the model was translated faithfully. Additional model nodes were then incorporated in the Source models to improve their spatial resolution in key areas (particularly in the vicinity of the potential irrigation areas and dam sites). The models were subsequently recalibrated using gridded SILO climate data (Jeffrey et al., 2001) and also using

the most recent streamflow data, provided by the Queensland Government. The calibration period varied for each river reach on the basis of available data as reported in Lerat et al. (2013).

Model calibrations were undertaken using an automated search algorithm that jointly calibrated rainfall-runoff, routing and loss model parameters. In the Gilbert catchment the search algorithm used an objective function that combined a bias constraint and the mean squared error on root square transform of the flow. In the Flinders catchment the highly ephemeral nature of the streamflow was particularly challenging to simulate and resulted in the use of an alternative objective function that combined a bias constraint, the mean squared error on root square transform of the flow and a constraint on the flow duration curve.

This model is called the baseline model and was calibrated using the above approach and streamflow discharge data provided by Queensland Government (i.e. based on rating curve relationship developed by Queensland Government hydrographers).

To better understand the influence of rating curve uncertainty on model calibration, 50 equally plausible streamflow replicates were generated. These replicates were generated using a regression model based on variation in the flow gauging measurements. The model was subsequently calibrated to each of the 50 replicates and results obtained. This innovative approach provides a means of understanding the associated uncertainty in the model so that modellers can advise whether the model is providing a meaningful answer within the context of the uncertainty that is inherent in the observed streamflow data. These models, which were calibrated using the same method as the baseline model but against different streamflow discharge data, are referred to as the ensemble of models.

The calibration models reproduced the historical monthly and annual streamflows well at most stations (Nash Suttcliffe Efficiency (NSE) > 0.9) and in many cases the models performance was considered excellent (NSE > 0.95). However, the calibration was less reliable for low flows and as such the models may not be a robust tool for assessing how potential climate and potential irrigation development may perturb very low flow regimes.

3.3.2 SCENARIO B0 MODEL

The Flinders and Gilbert calibration models did not include extractions from existing entitlements due to a lack of available data; the exception was that extractions from Kidston Dam (officially known as the Copperfield River Gorge Dam) were simulated in the Gilbert model. This approach was considered defensible as the extractions are relatively small. Assuming full use of existing entitlements, the use of water relative to the mean annual flow at the catchment outlet has been assessed as 1.4% for the Gilbert and 3.5% for the Flinders (Lerat et al., 2013).

The calibration model was therefore updated to represent the existing entitlements which were modelled assuming full utilisation as per the IQQM WRP model (DNRM, 2006). This update was necessary as one of the requirements of the Assessment is to evaluate impacts on existing entitlements.

The baseline model differs from the version reported in Lerat et al. (2013) in several respects:

- Agricultural entitlements in the baseline model have been modelled with on farm storages rather than just a pattern. This change better reflects the method used in IQQM.
- Recent allocations (2013) in the Flinders and Gilbert have been included in the Source model as per advice from the QLD Department of Science, Information Technology, Innovation and the Arts (DSITIA). This included approximately 14 GL in the Gilbert catchment and 80GL in the Flinders catchment. All entitlements are modelled under full use assumptions as per the method used by DSITIA.

- The IQQM WRP model includes a number of nodes which represent use of unallocated entitlement. These have not been included in the final Source baseline models
- A new tributary has also been defined for the Gilbert as per advice from DSITIA. The addition of the Rocky Creek inflow was required so that a new entitlement on the tributary could be represented in the model. This addition does result in a small impact on the mass balance of the model; however, no attempt has been made to recalibrate the model. The impact is relatively small; median end of system flows were increased by less than 2%. None of the case studies have development below this tributary inflow hence it is not considered significant for the case study assessments.

These changes have altered the location and method of simulating the existing entitlements. Changes in average annual diversions are reported in Table 3.1.

Table 3.1 Average annual diversions parameterised in different Source models

	Calibration report baseline and ensemble models (GL/yr)	Scenario B0 baseline and ensemble models (GL/yr)
Flinders catchment	89	95
Gilbert catchment	51	51

3.3.3 CASE STUDY MODELS

The Scenario B0 model was used as the basis for each of the case study river models. For each case study the Scenario B0 model was modified to reflect the case study 'storyline'. This involved incorporating and parameterising:

- one or more water storages;
- conveyance and field application efficiencies;
- one or more 'irrigator' nodes; and
- a 'resource assessment'.

These are discussed below.

Water storage parameters

The water storage parameters adopted in Source were derived as follows. See the storage options technical report (Petheram et al., 2013) for further information.

- Storage depth - volume – area relationships were derived using the hydrological corrected Shuttle Radar Terrain Model (SRTM-H)
- Seepage based on expert judgement from a geologist, except for O'Connell which was estimated using a simple groundwater calculations
- Dead storage based on 2% FSL except for Kidston which was based on the existing IQQM value

Storage, distribution and application efficiency

In all irrigation systems water is required to be diverted from rivers or dams through artificial and or natural water distribution systems before ultimately being used on-field for irrigation purposes. Some proportion of the water diverted for irrigation is ultimately lost during conveyance to the field and before it can beneficially be used by a crop to meet its water requirement needs. These losses, or efficiency of irrigation delivery, need to be taken into account when planning potential irrigation systems and developing likely irrigated cropping areas.

Source has been configured to represent storage, distribution and application efficiencies. Some of these efficiencies are modelled based on the calibrated loss parameters (e.g. natural river losses), some are based on explicit representation of the physical process (e.g. evaporation from the surface area of a water body) and some are represented through a fixed percentage loss parameter. For the latter, the efficiency values adopted for each case study are detailed in Section 5. These parameter values were selected based on a review of available data as presented in Section 4.

Natural river losses were configured in the Source calibration model (Lerat et al., 2013). The resolution of these loss components was not suitable however to represent the losses due to conveying water from in-stream storages to the potential irrigation development. The paucity of streamflow data in the Assessment area is a limiting factor in improving the resolution of the loss parameters. Furthermore the natural river loss term was jointly calibrated with the routing and rainfall-runoff model parameters during the calibration process and operational losses (i.e. operational surpluses) were not taken into account.

Given these limitations, it was considered necessary to create an alternate representation of river conveyance efficiency for case studies which include an in-stream storage. For these studies, the river conveyance efficiency was estimated by examining the allocated losses in other regulated river systems in Queensland (see Section 4.2.2). In each case study, the existing loss values in Source between the storage and the irrigation development were very small compared to the losses that are likely to occur during regulated flow. Hence, the adopted conveyance efficiency was represented as an additional loss at the proposed irrigation node in Source (referred to as water user node). This means that the additional loss only applies to water ordered for the irrigation area. This approach was adopted such that the effect on the model calibration was minimised.

The other loss components; channel distribution efficiency, on farm distribution efficiency and field application efficiency all relate to losses defined at the irrigation node. Note that losses relating to storage evaporation and seepage are modelled explicitly in Source using the modelled surface area of the storage. This applies to in-stream, off-stream and on farm storages.

Crop models

The eWater Source model includes a conceptual model for simulating cropping systems. The parameters used in the model either need to be calibrated, estimated using expert knowledge, adopted from the literature, or derived using a calibrated biophysical process agricultural model. The latter approach has been adopted for the Assessment using the Agricultural Production Systems Simulator (APSIM) (Keating et al., 2003). A brief description of APSIM follows, however, further information on the parameterisation of the APSIM models can be found in the companion technical report on agricultural productivity (Webster et al. 2013).

APSIM contains an array of modules that simulate – on a daily time step – the growth, development and yield of crops. These modules simulate physiological processes in response to daily weather data, soil characteristics and crop management actions including irrigation application. Simulated physiological response principles are the same for all crops, and response rates and thresholds are specific to crop and cultivar. Simulated physiological processes include crop phenology, biomass, canopy (leaf) development, roots, senescence, water uptake, and nitrogen and phosphorous assimilation and distribution. These physiological processes respond to temperature and photoperiod, and to soil water, nitrogen and phosphorous. Observations from farmer managed fields (e.g. soil physical and chemical properties, local climate data etc) are used to further parameterise and validate APSIM modelling.

One of the strengths of physically based models is that they can be parameterised without calibration by experienced users. For example where local measurements of soil physical properties were unavailable,

APSIM soil parameters were adopted from similar soils from elsewhere in Queensland. These APSIM models were used to derive crop parameters for Source (see Section 3.4.2) and to also calculate crop yields. Source includes a simple conceptual model to predict crop yield as a function of water stress, however, it needs to be calibrated (e.g. based on APSIM results). This is a new feature in Source and as such was not used in the Assessment. Instead, a joint approach was adopted where Source was used to assess water availability for the crop and assess how much of the scheme-area was planted each year; these data were then used to calculate crop yield through either a statistical crop yield model or APSIM as described in Section 3.2. Refer to Section 3.4.3 for further information on the development of the statistical crop yield models.

Source includes the ability to define an annual planting decision which was configured independently of APSIM. For annual crops, the area planted in Source varies each year on the basis of an expression defined by the modeller. The expression defines the area to plant as a function of the available water resource (e.g. volume in resource assessment account, volume in on farm storage).

Resource assessment

For all regulated case studies, except O'Connell, the Assessment used annual accounting order debit schemes. A daily assessment period was defined such that any new available resource was made available at every time step. In this system, any water remaining in an account is debited at the end of the water year and a new assessment is made at the start of the water year. Any remaining assessments in that water year can only add water to the account. The account is debited for any water ordered. In practise the Resource Assessment system should account for storage and delivery losses, however, no attempt has been made to determine what this allowance should be. This will affect annual planting decisions (i.e. planted area is larger than it should be) however the planting decision sensitivity testing can make some compensation for this. This will also mean that where results report reliability on the basis of account volumes, these will be an overestimate.

The Resource Assessment system retains a reserve in the water storage to avoid impacts on downstream water harvesters. The reserve is used to supply water to those downstream existing entitlements which are impacted by the dam. They are now in effect supplied water from the dam.

Resource assessment was not used for the O'Connell Creek off-stream storage case study because it involves an off-stream storage that is used entirely by the associated irrigation development.

For the Flinders Water Harvesting case study, access to water is defined through a combination of commence to pump flow thresholds and annual limits on the volume of wafer that can be extracted. The annual limit is defined by the volume of the entitlement assigned to each 'irrigator', where an irrigator may be one or more landholders within a river reach. Conceptually it does not matter.

3.3.4 CASE STUDY SENSITIVITY TESTING

The viability of a particular scheme is dependent on a number of management decisions. As such, a number of sensitivity tests were undertaken for each case study. This included sensitivity to the following:

- Water sharing arrangements
- Maximum area of irrigated crop
- Annual planting decisions
- Irrigation infrastructure (select case studies)

Uncertainty in the physical characteristics of the system also affects the assessment of scheme viability as discussed in Section 3.3.5.

The viability of an irrigation development depends on the particular water sharing arrangements assumed. As such, two alternatives were investigated for each case study to give an indication of the potential range in outcomes (Table 3.2). The first was the ‘Impact’ alternative, which does not consider the impacts of the irrigation development on existing downstream entitlements. The ‘No Impact’ alternative makes adjustments to the water supplied to the irrigation development, either through commence to extract thresholds or through a resource assessment system, to avoid impacting existing entitlement holders. The ‘Impact’ alternative simulates the most generous conditions (i.e. upper end) in terms of potential crop yield from the irrigation development and hence can be used to determine whether the irrigation development has any likelihood of being financially viable. The ‘No Impact’ alternative does not necessarily represent the lowest possible crop yield from the irrigation development as it does not consider any additional environmental flow rules that may be required. Environmental flow rules were only to be evaluated in the Assessment if the initial analysis of the irrigation development indicated that it may be viable. In addition, this report only considers the changes to long term average diversions of existing entitlements resulting from the ‘No Impact’ alternative; in practise more stringent conditions may be required such that the spatial and temporal variability of impacts is suitable.

Table 3.2 Baseline simulations

Simulation	Description
Impact	Irrigation development is simulated without consideration for impact on downstream existing water harvesting entitlements.
No Impact	Irrigation development operating rules are configured to avoid impacts on downstream existing entitlements

For each case study, sensitivity testing was also undertaken to assess the viability of each irrigation development under a range of assumptions about the size of area developed for cropping and the area that is planted in any one year. The area of the irrigation sites was progressively increased to assess the impact of the system characteristics on the reliability of supply.

Two commonly used terms in this section are ‘scheme area’ and ‘crop area decision’. Scheme area refers to the size of the irrigation development and represents the maximum area that can be planted in any one year. The annual area planted is a function of water available at the time of planting (e.g. in Resource Assessment account or in on farm storage). At sowing, the area planted is nominally equal to the water in the storage minus conveyance and application losses, divided by the crop area decision (e.g. 3ML/ha). This means that for a given volume of water in the storage, the lower the crop area decision, the larger the area that could be planted. It then follows that a 2 ML/ha crop area decision will result in a larger area planted than a 4 ML/ha decision. The actual amount of water needed by the crop will be determined by the crop water requirements and climate during the growing season. It is independent of the crop area decision. The greater the divergence of the crop area decision below the actual crop water requirement, the higher the risk of crop failure. The greater the divergence of the crop area decision above the actual crop water requirement, the more water is stored in the reservoir for the following year.

The crop area decision may be different to the irrigation requirement of the crop for the following reasons:

- The crop area decision may be larger than the rate of irrigation required as storage and delivery losses need to be allowed for.

- The crop area decision may be smaller than the rate of irrigation required if a 'risky' decision is suitable. For example, if the water availability is expected to increase significantly after the date of planting.
- If there is a non-linear relationship between irrigation and crop yield it may be feasible that the highest total yield is obtained with a crop area decision which results in some water stress

For those case studies involving a perennial crop, it was assumed that the cropped area was equivalent to the developed area over the entire simulation period (i.e. there is no benefit in adjusting the planted area based on the amount of water in the storage in any one particular year). For annual crops, a range of planting decisions, from conservative to high risk, were evaluated.

Further sensitivity testing was undertaken for some case studies to determine how sensitive the results were to the type of irrigation system (e.g. drip, spray or furrow). For the Kidston Dam case study, additional analysis was undertaken to determine viability with and without supplementation with water harvesting and with and without raising Kidston dam.

For the Cave Hill, O'Connell Creek and Green Hills case studies, the Source results were used to evaluate crop yield using a statistical crop yield model as described in Section 3.4.3. The profitability of the irrigation development was then evaluated in terms of both gross margins and net present value at the scheme and farm scale. These are reported in the Flinders and Gilbert catchment reports (Petheram et al., 2013a and b). Based on the results of this exploratory analysis a scheme area and crop area decision was selected for a more detailed financial analysis. This report does not present any results of the financial analysis, however, some references are made to these results. Further detail about each of the sensitivity tests follows.

3.3.5 IRRIGATION SUPPLY RELIABILITY ASSESSMENT

The initial river system modelling undertaken for each case study includes a number of uncertainties and assumptions that could influence the viability of a particular case study. Climate change also provides a potential threat to the future viability of each case study. Consequently, in the event that any of the schemes appeared to be viable, the case studies were to be further examined to consider the impact on supplied irrigation water reliability of these uncertainties, assumptions and future climate. The evaluated schemes are not viable from a scheme scale economic analysis perspective (see Flinders and Gilbert Catchment Reports (Petheram et al., 2013a and b)). A supplied irrigation water reliability assessment has thus only been conducted for the Dagworth – Green Hills dams and irrigated sugarcane case study. This assessment enables comparison of the impacts of streamflow uncertainty, different supply efficiencies and future climate on the reliability of irrigation water supplied to crops (Table 3.3).

Table 3.3 Irrigation supply reliability assessment criteria for Dagworth and Greenhills sugarcane scenario

ASSESSMENT CRITERIA	DESCRIPTION
1. Streamflow uncertainty	Assessing the impact of streamflow uncertainty due to the inherent uncertainty in rating curves, based on 50 model ensembles.
2. Future climate	Assessing the impact of climate change including an upper (C_{dry}), median (C_{mid}) and lower (C_{wet}) impact case
3. Scheme supply efficiency	Assessing the impact of scheme efficiency (storage, distribution and application efficiencies) including a high and low loss case impact

Hydrologic modelling inherently contains a degree of uncertainty. Modelling work in the Northern Australia Sustainable Yields Project (Petheram et al., 2009) indicated that hydrological modelling is challenging in northern Australia. The considerable uncertainty in modelling results is thought to be primarily due to the large uncertainties in observed streamflow data. A majority of flow records in the Flinders and Gilbert catchments show more than 50% of the total volume occurring above the maximum gauged height, as shown in Figure 5.1 for the Flinders catchment (Figure from Petheram et al., 2009). Petheram et al. (2009) present a similar figure for the Gilbert catchment. This suggests a high level of uncertainty in flows that exceed gauged levels and that quantification of uncertainty associated with streamflow data should be a critical component of the river modelling activity.

Other sources of uncertainty that can affect river system models include limited data availability, inappropriate model formulation and uncertainty in model parameters. Five rainfall-runoff model structures were compared by Petheram et al., (2012) in northern Australia with no significant difference in performance. A similar conclusion was reached by Vaze et al. (2010) when modelling runoff in south-eastern Australia. Consequently, the impact of the rainfall runoff model formulation is expected to be small compared to the uncertainty in streamflow that these models are calibrated against. As a result, the Assessment will focus on the uncertainty in streamflow data.

Model uncertainty due to the impact of flow data uncertainty has been based on the 50 ensemble models described in Lerat et. al. (2013). Briefly, the ensembles represent equally plausible alternate models calibrated to random perturbations of streamflow data. This analysis was undertaken as many of the gauges in the Flinders and Gilbert catchments have limited streamflow measurements resulting in uncertainty in the relationship between stream height and flow (i.e. the rating curve). Hence each of the 50 ensemble models is based on calibration to 50-equally statistically plausible time series of streamflow data for each gauging station by introducing a random perturbation in the original streamflow dataset.

Potential impacts due to climate change have also been assessed. Further detail about the methods used in the climate change assessment can be found in Section 4.1.

Assessments are also made assuming different storage, distribution and application efficiencies; this in part reflects uncertainty about the physical characteristics of the system but also reflects uncertainty about what management actions would be taken to improve efficiency.

Each assessment has been made individually for the purposes of comparing the significance of each criteria related to infrastructure and management decisions and uncertainty in the physical environment.

Beyond the river system modelling, an assessment of impacts on the crop modelling and associated derivation of yield would be informative but is beyond the scope of this report. The relationship between the yield regression models and APSIM is presented to provide an indication of the reliability of yield estimates derived in the initial sensitivity analysis. Future analysis would be required to investigate uncertainty in both Source and APSIM crop modelling and in the linking of the two. Some investigation was undertaken to ensure that the Source generated irrigation pattern was reasonable given APSIM generated demands. This was only undertaken for full supply conditions (i.e. no shortfalls in available water). An analysis for periods where water availability is restricted would also be useful.

3.4 Modelling crop requirements and yield

3.4.1 INTRODUCTION

As outlined in Section 3.2, a joint approach was used with APSIM and Source to simulate crop requirements and yield.

The calibrated APSIM models were used to derive crop parameters for Source as further detailed in Section 3.4.2.

A statistical crop yield model was developed based on APSIM results as is detailed in Section 3.4.3. This model was used to post-process Source results to estimate crop yield for the purposes of the initial sensitivity analysis which evaluated a range of scheme areas and planting decisions. The Source daily time series for water applied to crop and area irrigated were used in the statistical model to derive annual crop yield time series data for each case study. This approach was used for the Cave Hill dam and irrigated sorghum, O'Connell Creek off-stream storage and irrigated rice and the Green Hills dam and irrigated three-crop rotation case studies.

APSIM was used to provide a final estimate of crop yield once a scheme area and in some cases a crop area decision had been selected. This final analysis used the same outputs from Source; daily time series for water applied to crop and area irrigated. Dagworth and Green Hills dams and irrigated sugarcane and Kidston Dam and irrigated Rhodes grass case studies did not use statistical crop yield models for calculating crop yield for different scheme areas. For these case studies, APSIM was used to calculate crop yield for all scheme areas.

3.4.2 APSIM DERIVATION OF SOURCE CROP MODEL PARAMETERS

The Source Crop model uses the FAO 56 method (Allen et al, 1998) of crop water requirement for calculation of irrigation demands. This calculation requires a crop coefficient (Kc) that is unique to each crop and its stage of growth from sowing to maturity. Crop demand is calculated as follows;

$$ET_c = K_c * ET_o$$

where ET_c is the crop evapotranspiration (mm d^{-1}), $ET_o$is the reference crop evapotranspiration (mm d^{-1}) and K_c is the crop coefficient (dimensionless) for the specific crop growth stage. This is a widely accepted method for determining crop water requirements in a simple way. However obtaining realistic values for $K_c$is not simple especially where crops are to be grown in environments where few measurements have been made in relation to crop water use.

In the case of the FGARA project K_c values were obtained for each crop for specific sowing dates using outputs from the APSIM model in the following way;

$$K_{c,i} = \frac{\sum_{y=1}^{122}(T_{c,i}(y) + E_{c,i}(y))/ET_{o,i}(y)}{122}$$

where $K_{c,i}$ was the crop coefficient for crop *c*, on the ith day after sowing, $T_{c,i}$ was crop extraction of soil water (mm) on the ith day after sowing, $E_{c,i}$ was evaporation of soil water (mm) on the ith day after sowing and $ET_{o,i}$ was the Priestly-Taylor reference evapotranspiration (mm) on the ith day after sowing. Each APSIM simulation was 122 years in duration, giving 122 replicates for each day after sowing i. Such a technique ensured that a full range in climatic extremes were experienced and encapsulated in the $K_c$estimates. An average of the 122 replicates was taken obtain a 365 day pattern which was then used in Source.

APSIM was also used, in combination with expert knowledge, to derive additional Source parameters listed in Table 3.4. The parameter values adopted are listed for each case study in Section 5. Refer to Source technical documentation for further detail on the Source crop model and parameters used[1].

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[1] https://ewater.atlassian.net/wiki/display/SD35/Irrigator+Demand+Model+-+SRG

Table 3.4 Source Crop Model Parameters

PARAMETER	COMMENT
Soil moisture Capacity (%)	The difference in volumetric soil water content between field capacity and permanent wilting point
Fallow depth (mm)	Depth of soil that soil water will deplete due to evaporation.
Depth of roots (mm)	Depth of soil profile that water is extracted for ET.
Crop Depletion factor (%)	Percentage of total available water that a crop can extract from the root zone without suffering water stress
Target soil depletion (mm)	The target soil water depletion that irrigation attempts to maintain. Negative values used for ponded crops.

3.4.3 YIELD REGRESSION ANALYSIS

The sensitivity testing conducted using Source resulted in a significant number of model runs which needed to be evaluated in terms of crop yield. It was not feasible to re-run APSIM for every scheme area and crop area decision combination, hence it was necessary to use an empirical approach to estimate crop yield. APSIM was run using a range of water allocations under Scenario A (historical climate). This generated crop yield predictions, which were matched to inputs such as water supplied, rainfall, evaporation, radiation and temperature. This data was then used to train statistical models to predict crop yield. These models all had an annual time step; hence they used annual totals of water supplied for irrigation and an annual metric for climate data. These models were then used to predict crop yield based on the same environmental data they were trained on but with the water supplied replaced by output from SOURCE model. Some case studies contained more than one crop type and/or planting dates. APSIM models were configured for each situation and separate models constructed for each. Finally, the models performance was tested by comparing their predictions to crop yields from APSIM model runs using the water supplied by SOURCE.

Two types of model were used on each of the case studies: Generalised Additive Models (hereafter referred to as GAM)) and random forests. The best performing model in terms of variance explained was chosen, as summarised in Table 3.5. Overall the random forest approach produced the best model in terms of predictive capacity but the GAM proved optimal in some cases.

Note that both the APSIM and regression estimation of yield represents an upper limit and actual yields are likely to be lower and to vary considerably from year to year. The results are modelled production potential under optimum management, i.e. nutrients are not limiting, and there is no damage to the crop due to disease, pest, flood, cyclone or poor management practise.

For the Kidston and Dagworth-Green Hills sugarcane case studies, all reported results are based on APSIM data as the regression model was found to be unreliable for perennial crops. This was because in simulating a perennial the timing of water application becomes increasingly important, and an annual crop yield regression model cannot distinguish between the affect on crop yield of applying the same amount of water at different times of the year. This was not a problem for the annual crops because the largest volume of water available was at the time of planting and decreased through the growing season. The application of multiple regression models based on water application at different times of the year did not result in a notable improvement, mostly likely because there was no memory from one regression model to the next. For this reason crop yields for sugarcane and bambasti were simulated using APSIM for all scheme

areas. It is feasible that for perennial systems the Source model for predicting yield may be more reliable than a regression model hence this could be evaluated in future work.

Table 3.5 Crop Yield Regression Models

CASE STUDY	REGRESSION MODEL USED	PERCENTAGE VARIANCE EXPLAINED OF CALIBRATION DATA
O'Connell	Random forest	-February 15 planting date: 95.4% -January 15 planting date: 94.1%
Kidston	GAM	-Bambatsi : 87.3%
Dagworth	GAM	-Sugar Cane Dagworth: 81.7% -Sugar Cane Greenhills: 86.5%
Greenhills	Random Forest	-Cotton: 90.8% -Peanuts: 97.8% -Sorghum: 88.5%
Flinders Water Harvesting	Random Forest	-Cotton: 94.6%
Cave hill	GAM	-Sorghum: 92.7%

All yield results are reported in 30-year windows, as this was the selected investment time frame (see the companion technical report about irrigation costs and benefits (Brennan McKellar et al., 2013) for a discussion on the choice of investment planning period). Annual yield time series data was converted to a mean 30-year time series. Each value in the mean 30-year time series represents the mean yield over the preceding 30 years. The median of the mean 30-year time series is then reported as M30M.

3.5 Streamflow Impacts

Ecosystems in the study catchments have adapted to the prevailing and highly seasonal flow characteristics of these rivers. Alterations to these flow conditions could further stress the ecology in this region.

The exploratory analysis only evaluated the impacts of irrigation development in terms of median annual flows:

$$\text{Median annual streamflow quotient } = \frac{\text{Median annaul flow (case study)}}{\text{Median annual flow (Scenario A)}}$$

A more detailed analysis was undertaken using a wide range of hydrological metrics for the selected development option for each case study. These results are presented graphically in order to assess the impacts of development on ecologically important flows. This was undertaken using a set of consistent metrics based on low and high flows and flow seasonality. Metrics were calculated for key river modelling nodes within the selected reaches and results were illustrated relative to historic conditions. The change in monthly average flows is reported in text. The remaining metrics are reported in Appendix D. These metrics are as follows:

- median first day median no zero - this is the day that non-zero flow occurs. This assumes that the year starts at the beginning of the water year.
- annual flow (mean)- mean annualised flow. The daily time series is converted to an annual one and the mean flow calculated.

- annual flow (median) - median annualised flow. The daily time series is converted to an annual one and the median flow calculated.
- annual flow (coefficient of variation) - coefficient of variation (C) is the ratio of the standard deviation (σ) of flow to the mean (μ) of the flow

$$C = \sigma/\mu$$

- wet-season flow, November to April (median) - this is the median of flow in the wet season. The wet season starts on the 1st of November and ends on the 30th of April. Daily time series were converted to wet season time series and the median calculated
- dry-season flow, May to October (median) - this is the median of flow in the dry season. The wet season starts on the 1st of May and ends on the 1st of October. Daily time series were converted to wet season time series and the median calculated
- Base Flow Index using the method of Lyne and Hollick.
- max annual zero flow spell (median) - daily time series were converted to annual series of the maximum length of zero flow days for each year. The median of this maximum annual zero flow was then calculated.
- max zero flow spell - max zero flow is the maximum period in days of no flow over the entire period. In other words it is the all-time record for days with no flow
- monthly flow (is the pdf showing mean or median?) - the daily time series is converted to a monthly time series. The monthly mean flows is then calculated for each calendar month.
- daily flow exceedence - daily flow exceedence is the probabilities from 0 to 1 that a flow level will be exceeded.

The above hydrological metrics were calculated using output from each of the 50 ensemble of river models (Section 3.3.1) for each gauging station in the catchment. The range in hydrological metric values provides an indication of the uncertainty in the metric results as a result of uncertainty in the streamflow stage – discharge relationship at each gauging station.

4 Supporting information for case study development

4.1 Runoff under a future climate

Selection of AR4 global climate models

A commonly held premise of hydrological prediction is that models that are better able to simulate the past are more likely to accurately simulate the future. In an Australia-wide assessment of rainfall simulations using 23 GCMs, Chiew et al., (2009) found that there was no clear difference in future rainfall projections across northern Australia between the better and poorer performing GCMs and that the use of weights to favour the better GCMs gave similar rainfall results to modelling using all the 23 GCMs. The use of palaeo-observations to determine which, if any, GCMs have the proper sensitivity in tropical regions is also of little value because tropical oceanic and terrestrial palaeo-climate proxies are conflicting (Rind, 2008).

To consider the uncertainty in future climate predictions and simulate the range of future runoff predictions, future climate projections from a large range of archived GCM simulations were downloaded from the Program for Climate Model Diagnosis and Intercomparison (PCMDI) website <http://www-pcmdi.llnl.gov>. Of the 23 GCMs examined by Chiew et al., (2009b), 15 have readily available daily rainfall data. These 15 GCMs were used in the Assessment. For more details see Petheram and Yang 2013.

Overview of method

The empirical scaling method employed here utilised the output from 15 GCMs to scale the 121 years of historical daily rainfall and potential evaporation (PE) sequences, to construct the 15 by 121-year future daily rainfall and PE sequences. The method comprised two broad steps: the first considered changes in the mean 'seasonal' values of rainfall and APET, and the second step considered changes to the daily distribution of rainfall within each 'season'. This was undertaken using an empirical scaling method (ES). A brief overview of the method is provided below, see the companion technical report on climate scaling, Petheram and Yang 2013.

For each catchment the Sacramento rainfall-runoff model was run using the daily climate series for Scenario C. This provided 15 series of 121 years of modelled daily runoff (one series from each of the 15 GCM-ES). For each catchment a Cdry, Cmid and Cwet scenario was evaluated. Scenarios Cdry, Cmid and Cwet corresponded to the 10th, 50th and 90th percentiles of mean annual runoff (i.e. obtained from the 14th, 8th and 2nd wettest GCM). The GCM selected for Cdry, Cmid and wet in Table 4.1 and

Table 4.2 are in bold.

The Source river system models were then run by replacing the Sacramento generated Scenario A inflows with the Sacramento Cdry, Cmid and Cwet inflows. Climate data from the same GCM's were used to calculate net evaporation from the potential reservoirs.

Table 4.1 Mean annual runoff spatially averaged across the Gilbert catchment generated using input climate data from 15 GCM-ES. GCM-ES ranked in order of increasing runoff

GCM	RUNOFF (MM)	RUNOFF (% CHANGE)
Scenario A (historical climate)	139.97	NA
csiro	54.06475	-61%
mri	**98.1307**	**-30%**
giss_aom	106.6164	-24%
cnrm	115.2595	-18%
inmcm	116.0411	-17%
iap	121.1697	-13%
ipsl	132.741	-5%
ncar_ccsm	**133.4595**	**-5%**
mpi	138.4477	-1%
miroc	151.737	8%
gfdl	157.6447	13%
ncar_pcm	176.7078	26%
miub	181.755	30%
cccma_t47	**223.9683**	**60%**
cccma_t63	233.9601	67%

Table 4.2 Mean annual runoff spatially averaged across the Flinders catchment generated using input climate data from 15 GCM-ES. GCM-ES ranked in order of increasing runoff

GCM	RUNOFF (MM)	RUNOFF (% CHANGE)
Scenario A (historical climate)	34.71	
csiro	16.09	-54%
giss_aom	**23.24**	**-33%**
mri	25.19	-27%
iap	27.80	-20%
inmcm	28.98	-17%
mpi	30.68	-12%
cnrm	31.19	-10%
gfdl	**35.64**	**3%**
cccma_t47	36.01	4%
ipsl	36.13	4%
ncar_ccsm	36.53	5%
ncar_pcm	43.20	24%
miroc	49.69	43%
miub	**49.96**	**44%**
cccma_t63	55.19	59%

4.2 Review of scheme losses

4.2.1 INTRODUCTION

In all irrigation systems, water needs to be diverted from rivers or dams through artificial and/or natural water distribution systems before ultimately being used on-field for irrigation. Some water diverted for irrigation is ultimately lost during conveyance to the field, before it can be used by a crop. These losses need to be taken into account when planning irrigation systems and developing irrigated areas. This section contains information about these losses, hence informs the assumptions made for each of the case studies.

The amount of water that is lost during conveyance depends on the:

- river conveyance efficiency, from the water storage to the irrigation scheme
- channel distribution efficiency (within an irrigation scheme), from the river offtake to the farm gate
- on-farm distribution efficiency, in getting water from the farm gate to the field
- field application efficiency, which is the efficiency to which water can be delivered from the edge of the field to the crop.

Little previous irrigation system research has previously been undertaken in the Assessment area. Time frames of this Assessment did not permit on-ground research into irrigation systems to be undertaken. Consequently, a brief discussion of the above items is provided based on relevant literature from Australia and overseas. Table 4.3 summarises the broad range of efficiencies and costs associated with each of the above components. The total conveyance efficiency of the delivery of water from water storage to the crop will be related to all these four components.

Further detail regarding background information for each efficiency component can be found in Sections 4.2.2 to 4.2.5. The parameter values adopted area detailed separately for each case study in Section 5.

Table 4.3 Summary of conveyance efficiencies and costs (capital, operation and maintenance)

COMPONENT	TYPICAL EFFICIENCY (%)
River conveyance efficiency	50 to 90%*
Channel distribution efficiency	50 to 95%
On-farm distribution efficiency	80 to 95%
Field application efficiency	60 to 90%

* River conveyance efficiency varies with a range of factors (including distance) and may be lower than the range quoted here. Under such circumstances, it is unlikely that irrigation would proceed. It is also possible for efficiency to be 100% in gaining rivers, but there are no gaining rivers in the Flinders catchment.

4.2.2 RIVER CONVEYANCE EFFICIENCY FROM STORAGE TO IRRIGATION AREA

The conveyance efficiency of rivers is difficult to measure and even more difficult to predict. Although there are many methods for estimating groundwater discharge to surface water, there are few suitable methods for estimating the loss of surface water to groundwater. In the absence of existing studies for northern Australia, conveyance efficiency as nominated in Water Resource Plans and Resource Operation Plans for four irrigation water supply schemes in Queensland was examined collectively. The results are summarised in Table 4.4.

Water resource plans and resource operations plans prepared under the provisions of the Queensland *Water Act 2000* define the allocation volumes and priority of supplies provided from each water supply scheme in a catchment. Additionally, the plans detail water sharing rules which determine the allocation to be provided in those years when the available supply is insufficient to provide the full volume of allocation. The determination in each case takes into account the volume of storage at the particular time and losses such as evaporation from storages and distribution and operational losses (i.e. operational surplus).

It should be noted that the conveyance efficiencies listed in Table 4.4 are from the water storage to the farm gate and that these are nominated efficiencies, largely based on expert judgement. These data can be used to estimate conveyance efficiency of rivers.

Table 4.4 Water distribution and operational efficiency as nominated in water resource plans for four irrigation water supply schemes in Queensland

WATER SUPPLY SCHEME IN QUEENSLAND	TOTAL ALLOCATION VOLUME (ML)	RIVER AND CHANNEL CONVEYENCE EFFICIENCY* (%)	COMMENT
Burdekin Haughton	928,579	78%	The primary storage is the Burdekin Falls Dam (1860 GL), approximately 100 km upstream of Clare Weir, the major extraction point. The Bowen River, a major unregulated tributary of the Burdekin River, joins the Burdekin River downstream of Burdekin Falls Dam. This may assist in reducing transmission losses between the dam and Clare Weir.
Lower Mary	34,462	93.8%**	The Lower Mary irrigation area is supplied from two storages, a barrage on the Mary River and a barrage on Tinana Creek. Water is drawn directly from the barrage storages to irrigate areas riparian to the streams. Water distribution is predominantly via pipelines.
Proserpine River	87,040	72%	The scheme has a single source of supply, Peter Faust Dam (491 GL). At various distances downstream of the dam, water is extracted from the river bed sands and is distributed to urban communities, several irrigation water supply boards and individual irrigators.
Upper Burnett	26,870	68%	The Upper Burnett is a long run of river scheme with one major storage (Wuruma Dam (165 GL)) and four weir storages. The total river length supplied by the scheme is 165 km.

* Ignores differences in efficiency between high and medium priority users and variations across the scheme zone areas.

** Channel conveyance efficiency only

An analysis of streamflow data from across northern Australia as part of the Assessment did not identify any relationships that could be used to predict river conveyance efficiency. An analysis of a number of river reaches confirmed that the percentage loss of streamflow is higher for low streamflow values. Inflow from ungauged tributaries is one of the major confounding factors in trying to compute river conveyance efficiency between upstream and downstream gauging stations.

4.2.3 CHANNEL DISTRIBUTION EFFICIENCY

Across Australia, the average water conveyance efficiency from the river to the farm gate has been estimated to be 71% (Marsden Jacobs Associates, 2003). On the heavier textured soils found in the Flinders catchment, and for well-designed irrigation distribution systems, conveyance efficiencies are likely to be higher.

In the absence of larger scheme-scale irrigation systems in the Flinders catchment, it is useful to look at the conveyance efficiency of existing irrigation areas in order to estimate the conveyance efficiency of irrigation developments in the catchment. Australian conveyance efficiencies are generally higher than those found in similarly sized overseas irrigation schemes (Bos and Nugteren, 1990). Therefore, Australian data should be used in preference.

The most extensive review of conveyance efficiency was undertaken by the Australian National Commission on Irrigation and Drainage, which tabulated system efficiencies across irrigation areas of Australia (ANCID, 2001). Conveyance losses were reported as the difference between the volume of water supplied to irrigation customers and the water delivered to the irrigation system. For example, if 10,000 ML of water is diverted to an irrigation district and 8,000 ML is delivered to irrigators, then the conveyance efficiency is 80% and the conveyance losses are 20%.

Figure 4.1 shows reported conveyance losses across irrigation areas of Australia between 1999 and 2000, along with the supply method used for conveying irrigation water and the associated irrigation deliveries. There is a wide spread of conveyance losses both between years and across the various irrigation schemes. Factors identified by Marsden Jacob Associates (2003) which affect the variation include delivery infrastructure, soil types, distance that water is conveyed, type of agriculture, operating practices, infrastructure age, maintenance standards, operating systems, in-line storage, type of metering used and third-party impacts such as recreational, amenity and environmental demands. Differences across irrigation seasons are due to variations in water availability, operational methods, climate and customer demands.

Based on these industry data, Marsden Jacob Associates (2003) concluded that on average 29% of water diverted into irrigation schemes is lost in conveyance to the farm gate. However, some of this 'perceived' conveyance loss may be due to meter underestimation (about 5% of water delivered to provider (Marsden Jacob Associates, 2003)). Other losses were from leakage, seepage, evaporation, outfalls, unrecorded usage and system filling.

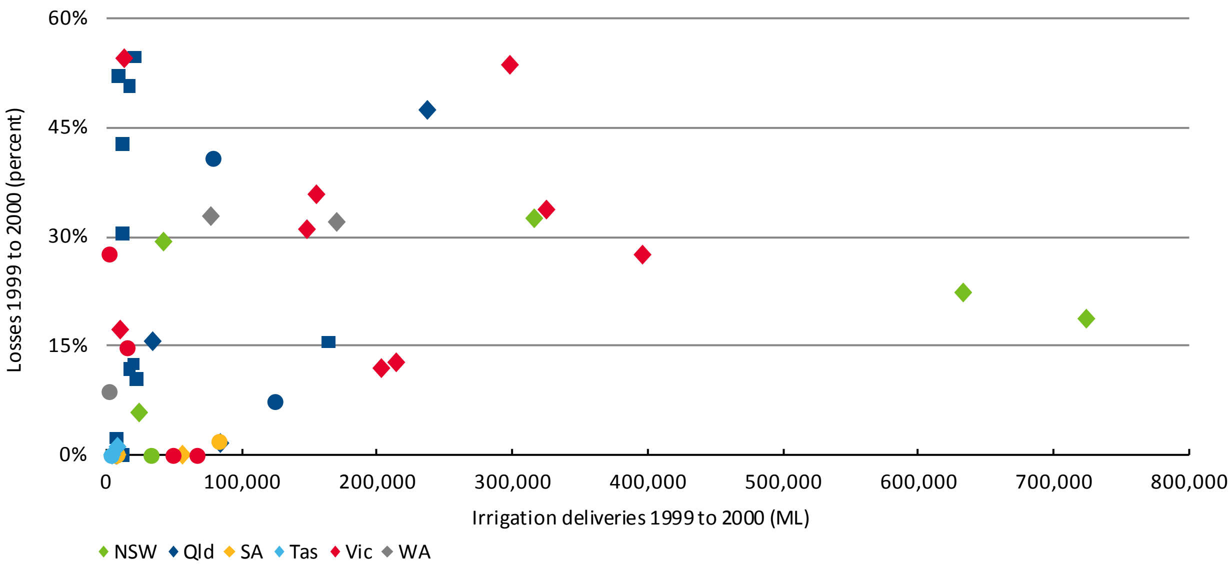


Figure 4.1 Reported conveyance losses from irrigation systems across Australia (ANCID, 2001)
The shape of the marker indicates the supply method for the irrigation scheme: square (▪) indicates natural carrier, circle (•) indicates pipe, and diamond (♦) indicates channel. The colour of the marker indicates the location of the irrigation system (by state), as shown in the legend

4.2.4 ON-FARM DISTRIBUTION EFFICIENCY

On-farm losses are the losses that occur between the farm gate and delivery to the field. These losses usually take the form of evaporation and seepage from on-farm storages and delivery systems. Even in irrigation schemes where water is delivered to the farm gate in a channel, many farms have small on-farm storages (i.e. less than 250 ML for a 500 ha farm). These on-farm storages enable the farmer to have a reliable supply of irrigation water with a higher flow rate, and also enable recycling of tailwater. Several studies have been undertaken in Australia on on-farm distribution losses. Meyer (2005) estimated an on-farm distribution efficiency of 78% in the Murray and Murrumbidgee regions, while Pratt Water (2004) estimated on-farm efficiency to be 94% and 88% in the Coleambally Irrigation and Murrumbidgee Irrigation areas respectively. On nine farms in these two irrigation regions, however, Akbar (2000) measured channel seepage to be less than 5%.

Irrigation areas which primarily rely on unregulated water (e.g. water harvesting and floodplain harvesting) typically have larger on farm storages. As such the losses due to on farm storage will be higher in these areas (e.g. see estimates in MDBA 2010).

4.2.5 FIELD APPLICATION EFFICIENCY

Once water is delivered to the field, it needs to be applied to the crop using an irrigation system. The application efficiency of irrigation systems typically varies between 60% and 90%, with more expensive systems usually resulting in higher efficiency.

There are three types of irrigation systems that can potentially be applied in the Flinders catchment: surface irrigation, spray irrigation and micro irrigation. Irrigation systems applied in the Flinders catchment need to be tailored to the soil, climate and crops that may ultimately be grown in the catchment and matched to the availability of water for irrigation. System design will also need to consider investment risk in irrigation systems as well as likely returns, degree of automation, labour availability, and maintenance and operation costs (e.g. the cost of energy).

Irrigation systems have a trade-off between efficiency and cost. Table 4.5 summarises the different types of irrigation systems, including their application efficiency and their limitations. Across Australia the ratio of areas irrigated using surface, spray and micro is 83:10:7, respectively. Irrigation systems that allow water to be applied with greater control, such as micro, cost more and as a result are typically used for irrigating higher value crops such as horticulture and vegetables. For example, although only 7% of Australia's irrigated area uses micro irrigation, it generates about 40% of the total value of produce produced by irrigation (Meyer, 2005).

Table 4.5 Application efficiencies for surface, spray and micro irrigation systems
Application efficiency is the efficiency with which water can be delivered from the edge of the field to the crop.

IRRIGATION SYSTEM	TYPE	APPLICATION EFFICIENCY (%)	LIMITATIONS
Surface	Basin	60 to 85%	Suitable for most crops; topography and surface leveling costs may be limiting factor
	Border	60 to 85%	Suitable for most crops; topography and surface leveling costs may be limiting factor
	Furrow	60 to 85%	Suitable for most crops; topography and surface leveling costs may be limiting factor
Spray	Centre pivot	75 to 90%	Not suitable for tree crops; high energy requirements for operation
	Lateral move	75 to 90%	Not suitable for tree crops; high energy requirements for operation
Micro	Drip	80 to 90%	High energy requirement for operation; high level of skills needed for successful operation

5 Case study set up, results and discussion

5.1 Flinders water harvesting

5.1.1 SCHEME CHARACTERISTICS

Water harvesting refers to a practice where water is extracted during flow events and either applied directly to a crop, or more commonly, held in an off-stream storage on a property for later use. The Flinders water harvesting case study evaluates the potential for storing water in on-farm dams. An assessment was made at several locations in the Flinders catchment such that variability in water availability could be assessed. The distribution of the new entitlements was undertaken with consideration given to the following factors:

- Land suitability
- Proximity to significant existing entitlements
- Water availability

The possibility of land constraints was evaluated in terms of soil suitability for cropping and suitability for constructing off stream storages. For the Flinders, it was determined that there were no constraints within the scope of allocations that are being considered. However, it should be noted that, at the higher new catchment entitlements (scenario B400 and B560) finding land that is not susceptible to flooding will become a constraint. For more detail on the land suitability assessment methods and results see the companion technical report, Bartley et al. 2013.

In regions where there was significant existing entitlement, new irrigation area was placed upstream of the existing entitlement such that the potential for impacts on existing entitlements could be conservatively evaluated. New irrigation areas were also placed below gauging stations. A total of ten new irrigation areas were adopted after removing some duplications and also removing one node which had a zero median flow at the nearest gauge. The approximate location of these sites is illustrated in Figure 5.1. Note that these irrigation areas are all hypothetical and may represent either one or multiple users on that one river reach.

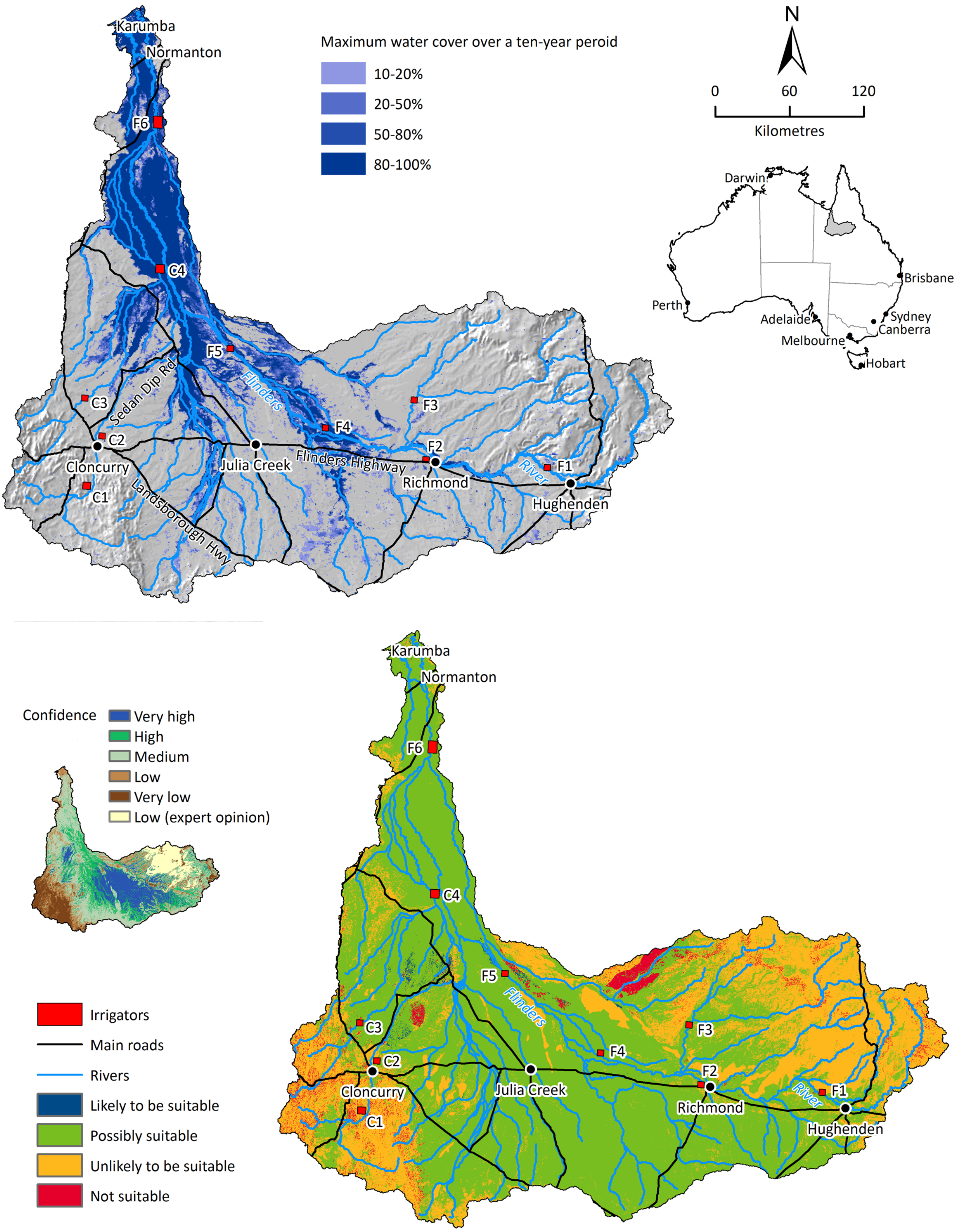


Figure 5.1 Location of new irrigation areas (a) Relief and broad scale flood inundation map and (b) off-stream water storage suitability map of the Flinders catchment

Data used to develop flood map was captured using MODIS satellite imagery. This figure illustrates the maximum percentage of MODIS pixel inundated between 2000 and 2010. For more detail see Dutta et al. (2013).

On farm water storage suitability map is only based on digital soil mapping data in top 1.5 m. It does not take into consideration subsurface strata below 1.5m, distance from river, and availability of water or flood risk.

In this case study five different scenarios regarding new entitlement release were examined:

- 80 GL new entitlement – corresponding to Scenario B80
- 160 GL new entitlement – corresponding to Scenario B160
- 240 GL new entitlement – corresponding to Scenario B240
- 400 GL new entitlement – corresponding to Scenario B400
- 560 GL new entitlement – corresponding to Scenario B560

These volumes are in addition to existing entitlement. This means that the volumes are in addition to the 80 GL of water that was released in 2013.

The proposed new entitlement was distributed to the ten hypothetical locations based on an assessment of water availability at the time of planting cotton. This assessment was undertaken using a spreadsheet analysis of flows which is further detailed later in this section.

It has been assumed that the on-farm dam capacity at each proposed irrigation area is equal to the entitlement assigned to that area. This is on the assumption that the most of the required irrigation occurs after the wet season has ended.

It has been assumed that all on-farm dams can be filled to a depth of 5m. It is possible that deeper storages may be built however levee banks higher than 8m might be less common due to the need to undertake a failure impact assessment if the storage also exceeds 500ML (Barrett, 2007).

It has been assumed that the on farm dams have a flat bottom profile. This means that low volumes still result in large surface areas. It also means that no dead storage has been assumed.

A seepage rate of 2mm per day has been assumed. Whilst the possible range of seepage rates can be high, Wigginton (2012) undertook an analysis of losses for 136 storages across all Australian cotton regions and found that there was a mean seepage rate of 2.3mm/day. The soil suitability mapping (Figure 5.1) identified that the majority of the area had soils possibly suitable for construction of on farm storages. Hence whilst a well designed storage has potential for seepage rates lower than 2mm/day, lower values have not been evaluated at this stage.

It has been assumed that 2 storage cells are developed per irrigation area. The assumption is that water would be preferentially withdrawn from one cell before withdrawing water from the second. This has the effect of reducing the surface area during periods when the storage volume is low, which in turn reduces evaporative losses.

It has been assumed that pumping is required into all on-farm dams. The volume that can be harvested is highly sensitive to the assumed pump capacity [see Appendix B] hence a simple spreadsheet analysis has been undertaken to determine suitable pump sizes. This analysis used daily flow data for each gauging station to estimate the potential harvestable volume and the impact of the following decisions at a system level:

- Total entitlement and capacity of on-farm dam (assumed equivalent)
- Total daily diversion capacity
- Impact of flow threshold rules.

This analysis was undertaken individually for each gauge and did not attempt to account for cumulative impacts down the system. The results are sensitive to the flow threshold assumed; as such this was based on flow thresholds slightly greater than occurs for existing nearby entitlement. The flow analysis results

were subsequently used to undertake a simple system level profitability analysis for the purposes of determining the most suitable pump capacities for the case study. It was assumed that the capital cost of pumps was $850 per ML per day capacity[2].

On the basis of the spreadsheet profitability assessment, a 'storage to pump capacity ratio' of 5 was used for each new irrigation area. This means that it is assumed that the pump is sized such that if it were operating at full capacity it would take 5 days to fill the on-farm storage. This appears to be a lower ratio than occurs in other irrigation areas however the ratio was considered suitable given the intermittent flows in the system. Some sensitivity analysis is undertaken with smaller pump sizes (or larger ratio values) for comparison (see Section 5.1.5)

The spreadsheet analysis was also used to determine water availability at the end of January and hence the distribution of entitlement to the ten new irrigation areas. This assessment was based on an entitlement of 15 GL at each gauge, a pumping capacity of 3 GL per day and the estimate of the required commence to pump flow threshold. Based on these assumptions, the average volume which could be harvested at the end of January was calculated for each gauge. Recall that this assessment was undertaken for each gauge individually and did not account for impacts of upstream development. The distribution of these volumes was used as the basis for assigning new entitlement to the ten irrigation areas.

The parameters applied to each new irrigation area are summarised in Table 5.1 and Table 5.1.

[2] This was on the basis of an average of two estimates. SunWater (2009) data for 8000ML storage in Flinders estimated cost at $1157/MLperday capacity. Mason pers. Comm. (2012) data for 500ha cotton case study which I used to derive an estimate of $550/MLperday capacity.

Table 5.1 Storage details for each new water harvesting irrigation area

STORAGE PARAMETERS	
Capacity	Equivalent to entitlement
Dead storage volume (GL)	0
Depth of storage (m)	5
Storage seepage (mm/day)	2
Number of cells per irrigation area	2
Storage to pump capacity ratio	5

Table 5.2 Percentage Distribution of New Entitlement to each Irrigation Area

IRRIGATION AREA	COTTON SCENARIO (%)
F1	14%
F2	11%
F3	8%
F4	9%
F5	9%
C1	11%
C2	9%
C3	6%
C4	12%
F6	11%

Table 5.3 lists the conveyance efficiency assumptions used in this analysis. In total, the conveyance and application efficiency from the storage to the crop is about 63% excluding the simulation of evaporation and seepage from the on farm storage. Including an estimate of these losses for a 6 month period results in a total efficiency of 55%. This means that approximately 45% of water extracted from the river is lost before it can be used by the crop. In Source, water is typically stored for longer than 6 months hence the overall efficiency will be slightly lower.

Table 5.3 Efficiencies for the irrigation scheme associated with Flinders Water Harvesting

COMPONENT	EFFICENCY	COMMENT
River conveyance	100%	All losses as per baseline model. Efficiency is calculated from the point of river extraction.
Supply channel to storage	90%	Representative of losses from river to storage
Evaporation and seepage estimate from on farm storage	75%[1]	Representative of off-stream storage net evaporation and seepage loss holding water for about 6 months. *Note that Source models this component explicitly hence this factor is not applied in Source.*
Supply channel to field	95%	Representative of losses from storage to field (assumes close proximity)
Field application (surface/furrow)	85%	Furrow irrigation – assumes no tail water recycling
Overall efficiency	55%	

[1] In Source, water is typically stored for longer than 6 months hence the overall efficiency will be slightly lower

5.1.2 CROPPING SYSTEMS

This case study primarily assessed cotton. The parameters used in the Source crop model are detailed in Table 5.4 and Table 5.5. See Section 3.4.2 for parameter definitions. A daily pattern has been defined for the crop factor (see Appendix D).

Table 5.4 Characteristics of crops used in Flinders Water Harvesting Case Study

Crop	Planting date	Planting decision sensitivity testing (ML/ha)	Depth of roots (mm)	Target soil depletion (mm)
Cotton	30th January	4 to 14 ML/Ha	136	91

Table 5.5 Other crop model parameters used for Flinders Water Harvesting Case Study

PARAMETER	VALUE
Soil moisture Capacity (%)	15
Fallow depth (mm)	300
Fallow Depletion factor (%)	100
Crop Depletion factor (%)	50
Soil description	Grey vertosol Richmond-X

Source determines the area to plant each year by dividing the volume of water in the on farm storage by a planting decision. A number of sensitivity tests were undertaken to determine the viability of different planting decision, as detailed in Table 5.6. Note that these were not repeated for all scenarios regarding new entitlement release. One of the sensitivity tests evaluated whether a minimum area should be planted every year. This test was conducted as the availability of water in January is significantly lower than that available later in the season hence it may be suitable to adopt some risk in the planting decision.

Table 5.6 Sensitivity testing (cotton only scenarios)

Scenario	Scenarios evaluated
Planting decision testing, no minimum area defined	B80GL for No Impact scenario only.
Test to see whether a minimum area should be defined.	B80GL for No Impact scenario only.
Plant a fixed area every year. Test for different fixed areas.	All case studies

APSIM was run for a number of different water supply scenarios using historical environmental data to generate a relationship with crop yield (Figure 5.2). This data was then used to train statistical models to predict crop yield. These results are modelled production potential under optimum management hence represent an upper limit.

Maximum yields of January-planted cotton (>7.5 bales/ha) require a median of 3 ML/ha, and yield reductions are more or less linear with decreasing water below that maximum. The regression model which was built for the initial sensitivity testing had a relatively good relationship with APSIM (Figure 5.5).

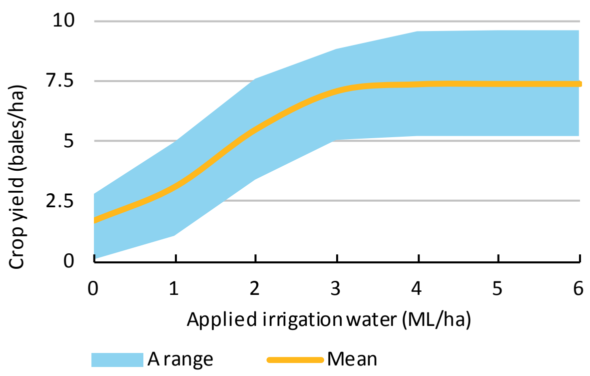


Figure 5.2 APSIM Yield Results

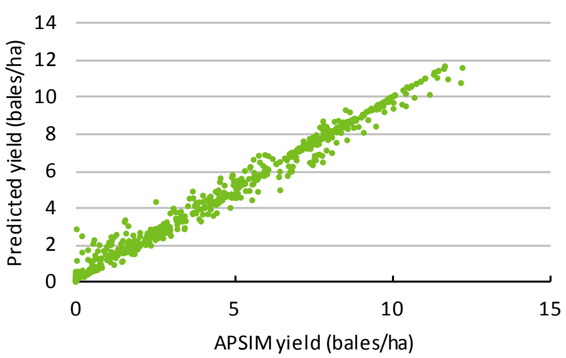


Figure 5.3 Comparison of APSIM and regression predicted specific yield

5.1.3 COMMENCE TO PUMP FLOW THRESHOLD RULES

The flow threshold at which any new water harvesting entitlement can commence to extract needs to be determined with consideration of both existing entitlements and environmental flow objectives.

For the “No Impact” scenario [see Section 3.3.3] the streamflow thresholds for new irrigators has been assigned so that there is a reduced impact on existing downstream entitlement holders. This has been achieved in Source through two components; a fixed threshold has been defined as per existing nearby entitlements and an additional variable daily time series threshold has also been defined based on the baseline model simulation of additional requirements to meet downstream demands. Note that the variable component was calculated using the Source ordering methodology which means that forecasted inflows on major tributaries are accounted for, hence the variable component may be less than the sum of the downstream orders. This method has been chosen for the base case for the ease of implementation in the model in comparison to determining a suitable fixed flow threshold.

The adopted variable threshold approach could be considered an approximation of a rostering system. Hence, while a variable threshold is obviously not practical for implementation, a rostering system may have similar impacts. An alternative approach to managing impacts on existing entitlement may be to adopt higher thresholds for any new entitlement released however this has not been examined in this report.

Table 5.7 Flow threshold rules for new water harvesting entitlements

NEW IRRIGATION AREA	FLOW THRESHOLD RULE (ML/DAY)
1	Variable time series +100
2	Variable time series +150
3	100ML (branch)
4	Variable time series +1800
5	Variable time series +1800
6	Variable time series +100
7	Variable time series +500
8	Variable time series +500
9	Variable time series +1800
10	Variable time series +1800

5.1.4 AREA AND PLANTING DECISION OPTIMISATION RESULTS

Note: for other case studies the catchment report details the economic analysis resulting from the area and planting decision sensitivity analysis. The water harvesting chapter in the Flinders catchment report did not include these results however as a general discussion was desired rather than focusing on cotton. This section makes some references to the economic outcomes resulting from the sensitivity analysis but no results are presented.

Planting decision testing, no minimum area defined

An analysis was undertaken for scenario B80 to determine the impact of different planting decision. No minimum area was defined. Total yield increases with a smaller planting decision (Figure 5.4). Accounting for distribution, storage and application loss, a stored volume of around 9ML/ha is required to meet an irrigation requirement of 4ML/ha. However, the water availability is significantly less at the time of planting cotton in comparison to later in the season (see Section 5.1.5) hence higher risk scenarios achieve better median yields.

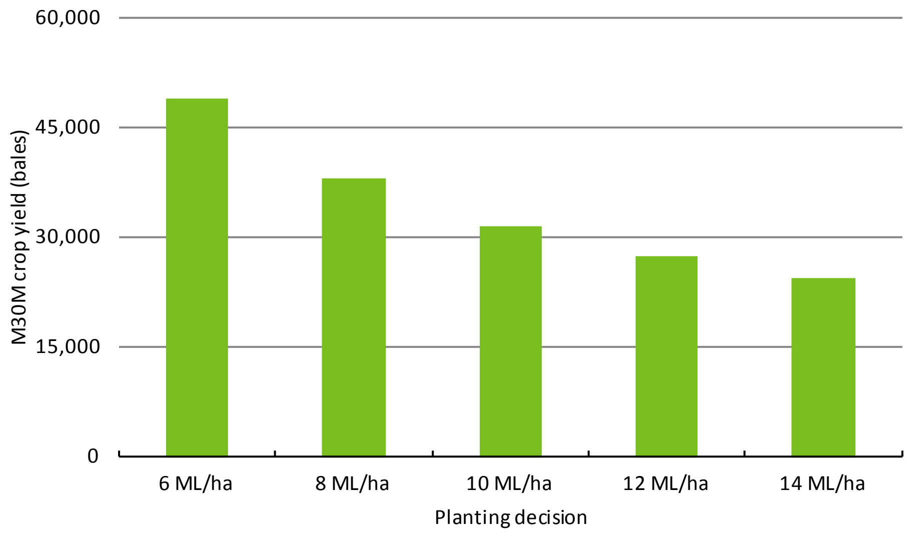


Figure 5.4 Median of the 30-year mean values (M30M) for annual crop yield under Scenario B: total of all ten irrigation areas.

Test to see whether a minimum area should be defined

A analysis test was undertaken for scenario B80 to determine whether a minimum area should be planted. This test was conducted as the availability of water in January is significantly lower than that available later in the season (see Section 5.1.5) hence it may be suitable to adopt some risk in the planting decision.

This test used a combination of a planting decision and a minimum area as follows:

Planted area = MAX((volume in on farm storage)/8 , entitlement**percent*/8) [1]

This analysis was undertaken for percentage values ranging from zero to 100% which means respectively that no minimum area was planted or that a maximum area was planted every year. Despite the potential for increased water stress with an increased minimum area, the results indicate that yield increases with the percentage value (Figure 5.4). The net present value results also indicate the same trend with the best results obtained when the same maximum area is planted every year. This trend can be linked to the timing of water availability (see Section 5.1.5) with availability being significantly greater after the cotton planting date hence planting only on the basis of volume in storage will be unnecessarily conservative. For higher entitlement scenarios (e.g. B400 and B560) the reliability of extractions is decreased hence a more conservative planting approach may be required.

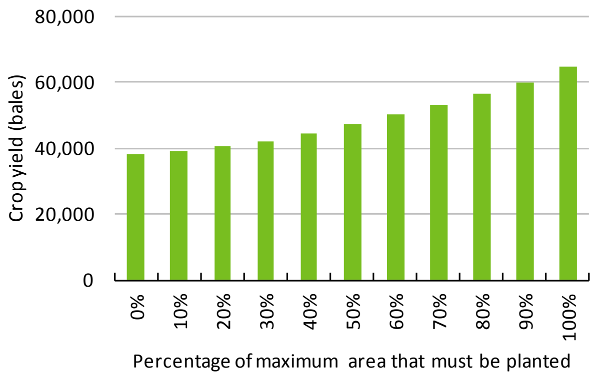
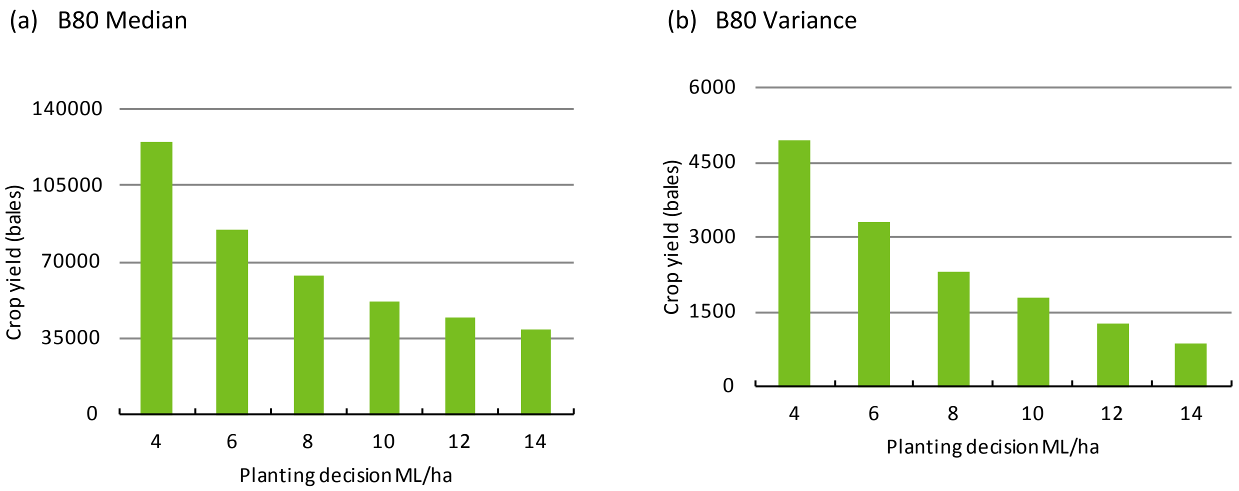


Figure 5.5 Total yield result for various minimum area scenarios
The planting decision represents the percentage of developed area defined as a minimum.

Test for different fixed areas

Assuming an approach of planting a fixed area every year, regardless of volume available in storage, a number of sensitivity tests were conducted to determine the viability of different planted areas. The total yield, mean and variance is illustrated in Figure 5.6 for various decisions about what the fixed area should be. The set area is determined by dividing the irrigator entitlement by a planting decision as illustrated in the graphs. Hence a smaller planting decision results in a larger fixed area to be planting each year (see Table 5.8).

Whilst the mean yield increases with area, the variance also increases. The net present value results indicate that in determining what the fixed area should be, a conservative approach should be adopted with a smaller fixed area giving better returns. Taking into account distribution, storage and application losses you need to extract around 9 ML/ha so that a crop requirement of 4ML/ha is met. A fixed area based on 8ML/ha would be feasible given that yield appears to be relatively insensitive to a small reduction water application (see Figure 5.2).



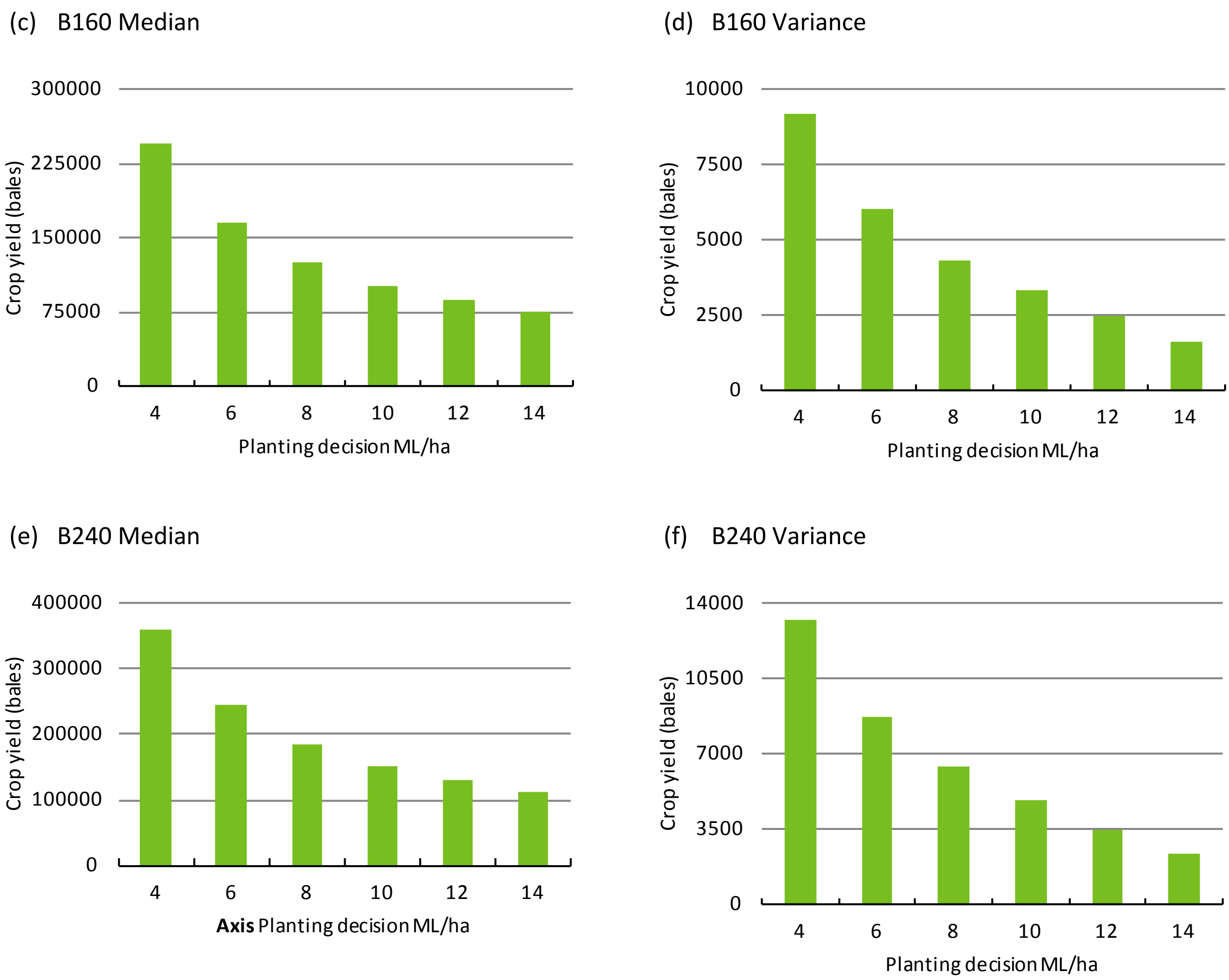


Figure 5.6 Median Total Annual Yield and variance for B80, B120GL and B240GL for various fixed areas. The fixed area is determined by dividing the total entitlement by the specified planting decision.

Table 5.8 Fixed areas (ha) for each scenario derived from new evaluated entitlement divided by a planting decision

SCENARIO	New entitlement evaluated	4 ML/ha	6 ML/ha	8 ML/ha	10 ML/ha	12 ML/ha	14 ML/ha
B80	**80GL**	20,000	13,333	10,000	8,000	6,667	5,714
B160	**160GL**	40,000	26,667	20,000	16,000	13,333	11,429
B240	**240GL**	60,000	40,000	30,000	24,000	20,000	17,143

Conclusion regarding the option selected for further investigation

For all other case studies, one development option has been selected for further analysis on the basis of the economic analysis (Petheram et al., 2013a and b). For the water harvesting case study however, the economic analysis presented in the catchment report was of a general nature rather than specific to the cotton case study. Hence a single option was not chosen.

5.1.5 RELIABILITY OF SUPPLY

Figure 5.7, Figure 5.8 and Figure 5.9 show for each of the ten hypothetical irrigators the percentage of years that volumes of water can be extracted by a particular date. In each case, the volume extracted is limited to the irrigator's entitlement volume. It is important to note that each irrigator is representative of the cumulative extraction/entitlement of all 'water users' in that reach (i.e. there may be multiple farms in a reach).

In each of these figures, when the graphed lines are horizontal this means that the full annual entitlement has been extracted. The percentage of years that the annual entitlement is extracted is referred to as the reliability of extractions.

Figure 5.7 shows that the reliability of new irrigators extracting their annual entitlement under Scenario B80 before 1 January is low (less than 10 and 20% of years). For example, in this figure the reliability (i.e. percentage of years) that irrigator C4 can extract their entire entitlement under Scenario B80 is 22%.

Figure 5.8 shows that there is a notable improvement in the reliability with which irrigators can extract their annual entitlement by the start of February (increased to between 40 and 60% of years for Scenario B80). Figure 5.9 shows that the reliability of extracting their annual entitlement increases further by the end of the wet season (increases to between 70 and 90% of years for scenario B80).

These figures also show that as the new catchment entitlement increases, the reliability of new irrigators extracting their annual entitlement decreases. For example under Scenario B560, the reliability with which irrigators can extract their annual entitlement by the end of the wet season decreases to between 30 and 60% for most irrigators (Figure 5.9).

Whilst the analysis used thresholds higher than existing nearby entitlements, there were still some impacts on existing entitlements (see Section 5.1.6). Hence it is possible that more stringent licence conditions may be attached to new catchment entitlements. If this were to occur the reliability of extractions for the ten hypothetical irrigators would be reduced.

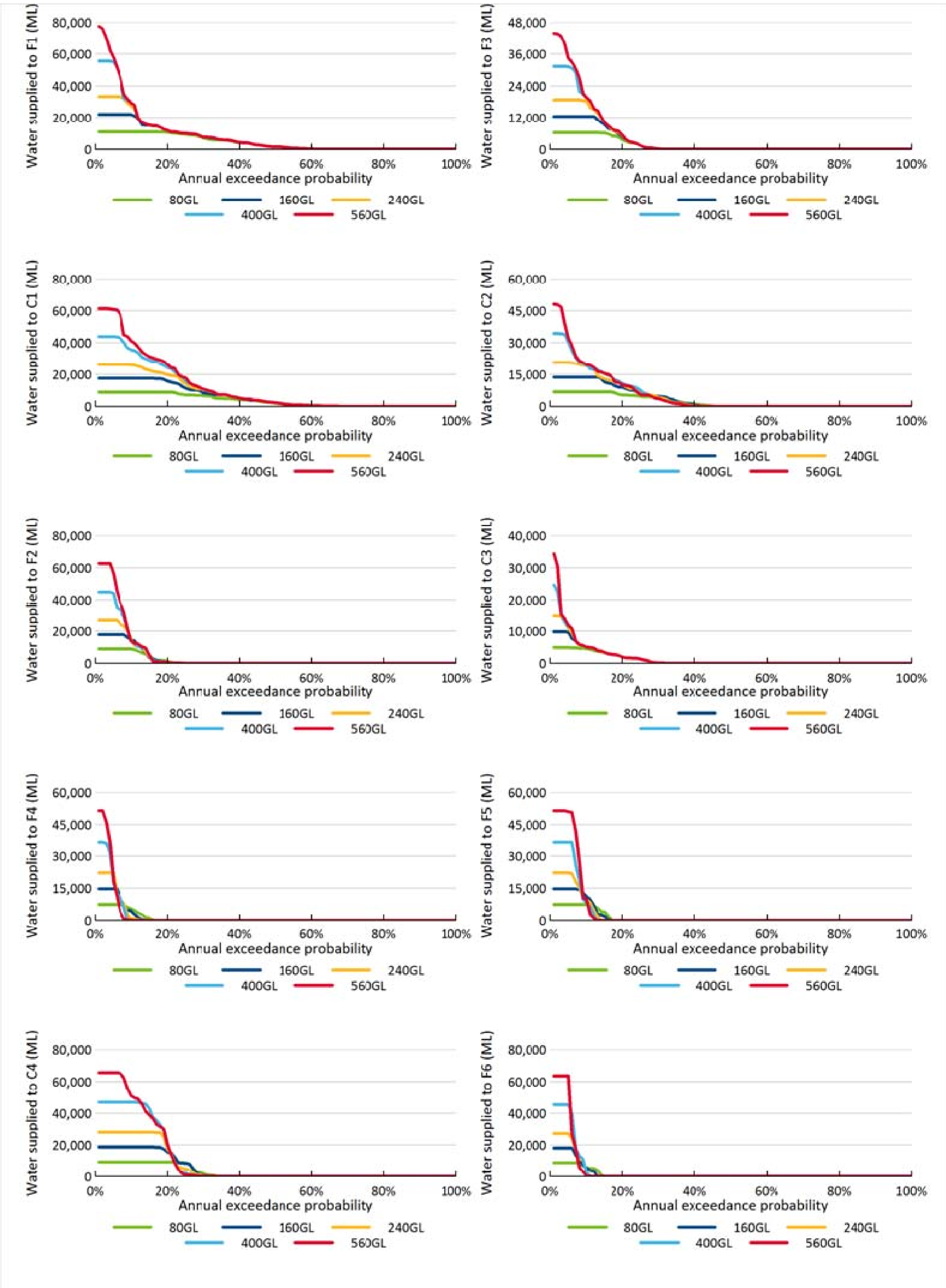


Figure 5.7 The 1st January reliability of extracting water up to the entitlement for 10 water harvesting users under Scenario B

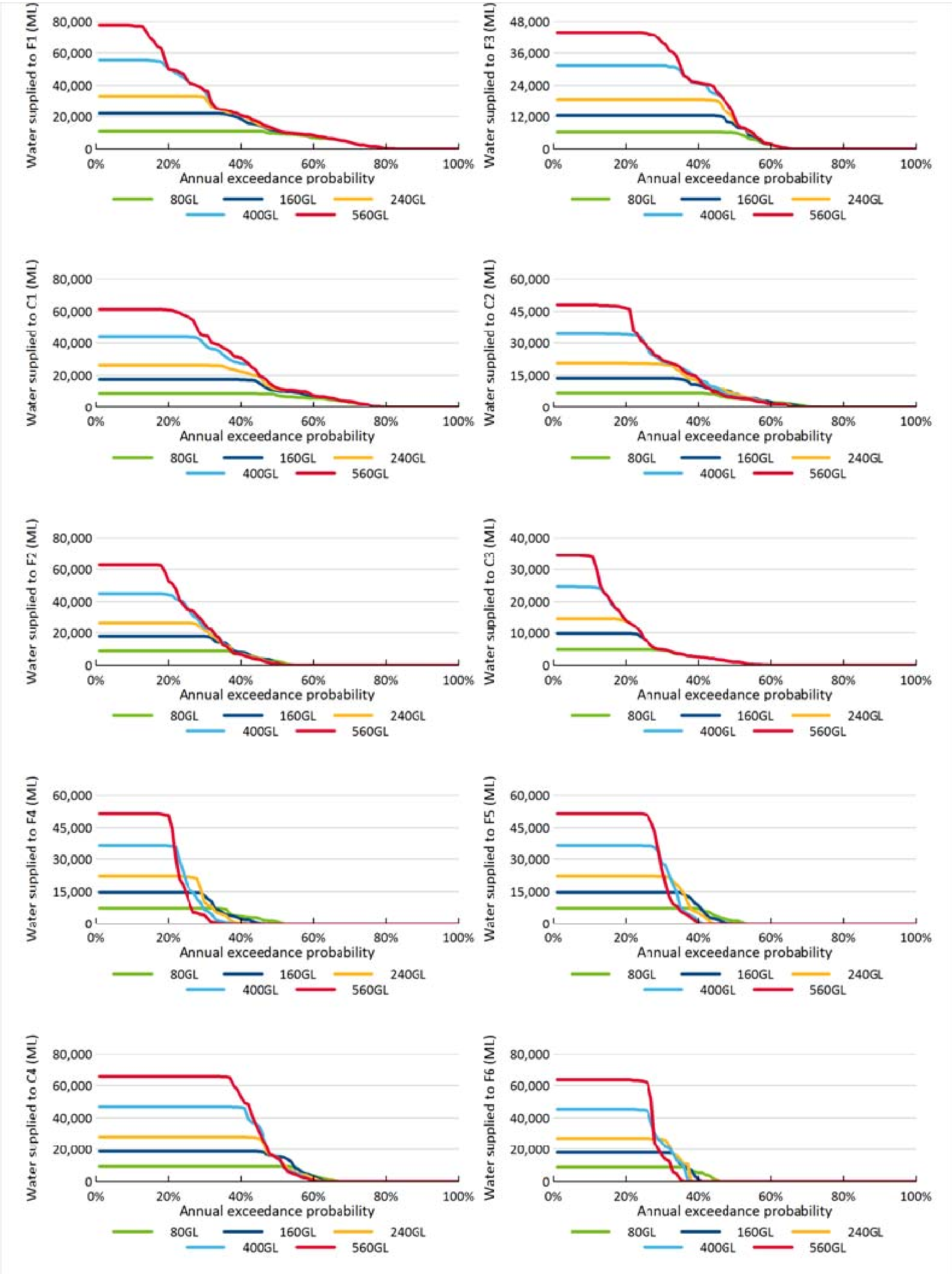


Figure 5.8 The 1st February reliability of extracting water up to the entitlement for 10 water harvesting users under Scenario B

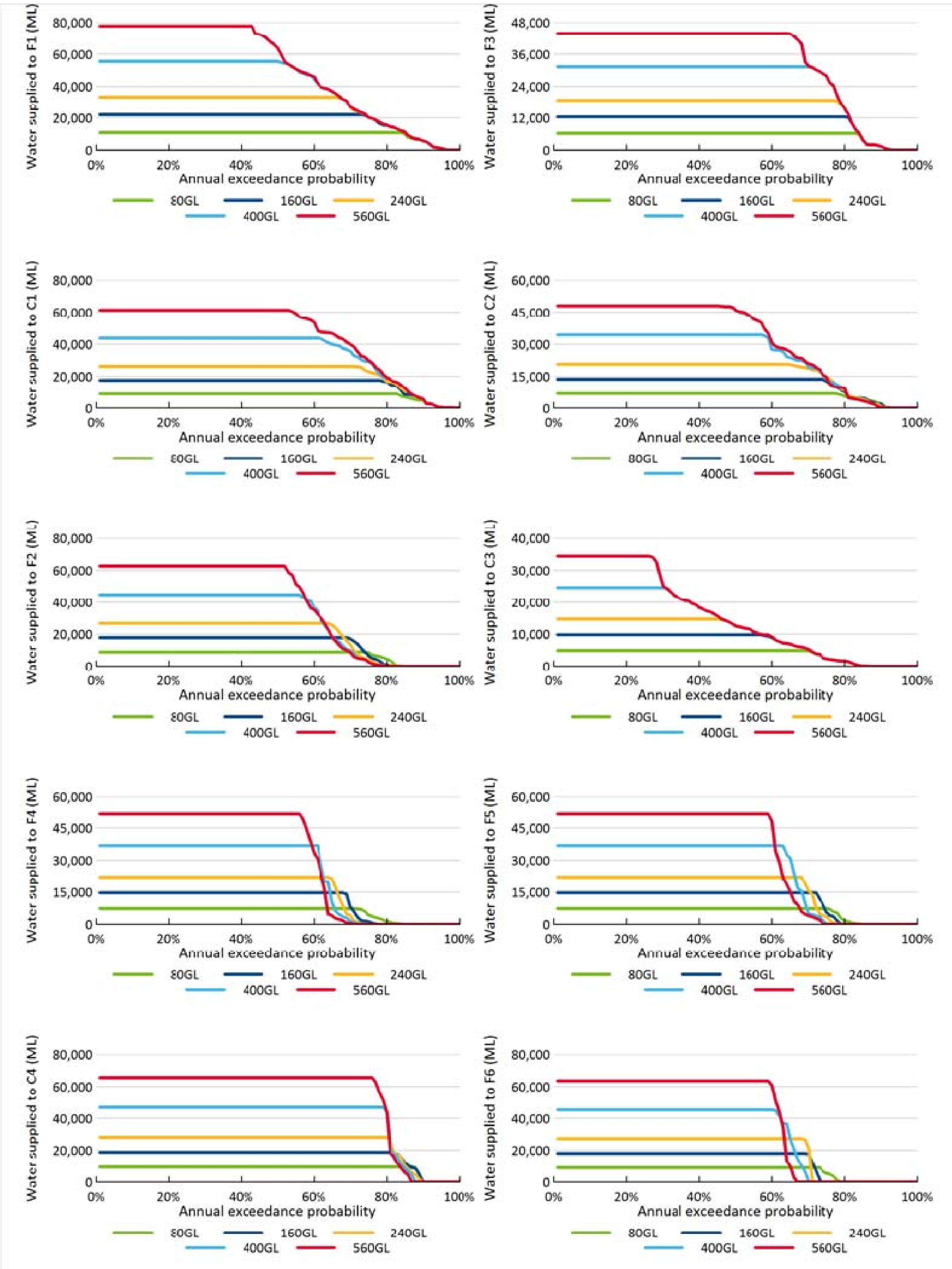


Figure 5.9 The 30th June reliability of extracting water up to the entitlement for 10 water harvesting users under Scenario B

Impact of different assumed pump capacities

The case study assumed a storage to pump capacity ratio of 5; this means that if pumps are operating at full capacity, it takes 5 days to fill the off-stream storage. The impact of smaller pumps is evaluated in this section. Storage to pump ratios of 10 and 20 are evaluated and the reliability of extractions compared in Figure 5.10 (extraction for water year up to 1st February) and Figure 5.11 (total water year extraction). Both graphs relate to the Scenario B320.

Both figures show clear differences between the three pump capacities. Larger pumps (smaller storage to pump ratios) result in a significant increase in the number of years in which the full entitlement can be extracted. For example in Figure 5.10 new irrigator F3 can extract their annual entitlement of water by 1 February in 45% of years with a SSEPC ratio of 5 and can extract their annual entitlement of water in 35% of years with a SSEPC ratio of 10.

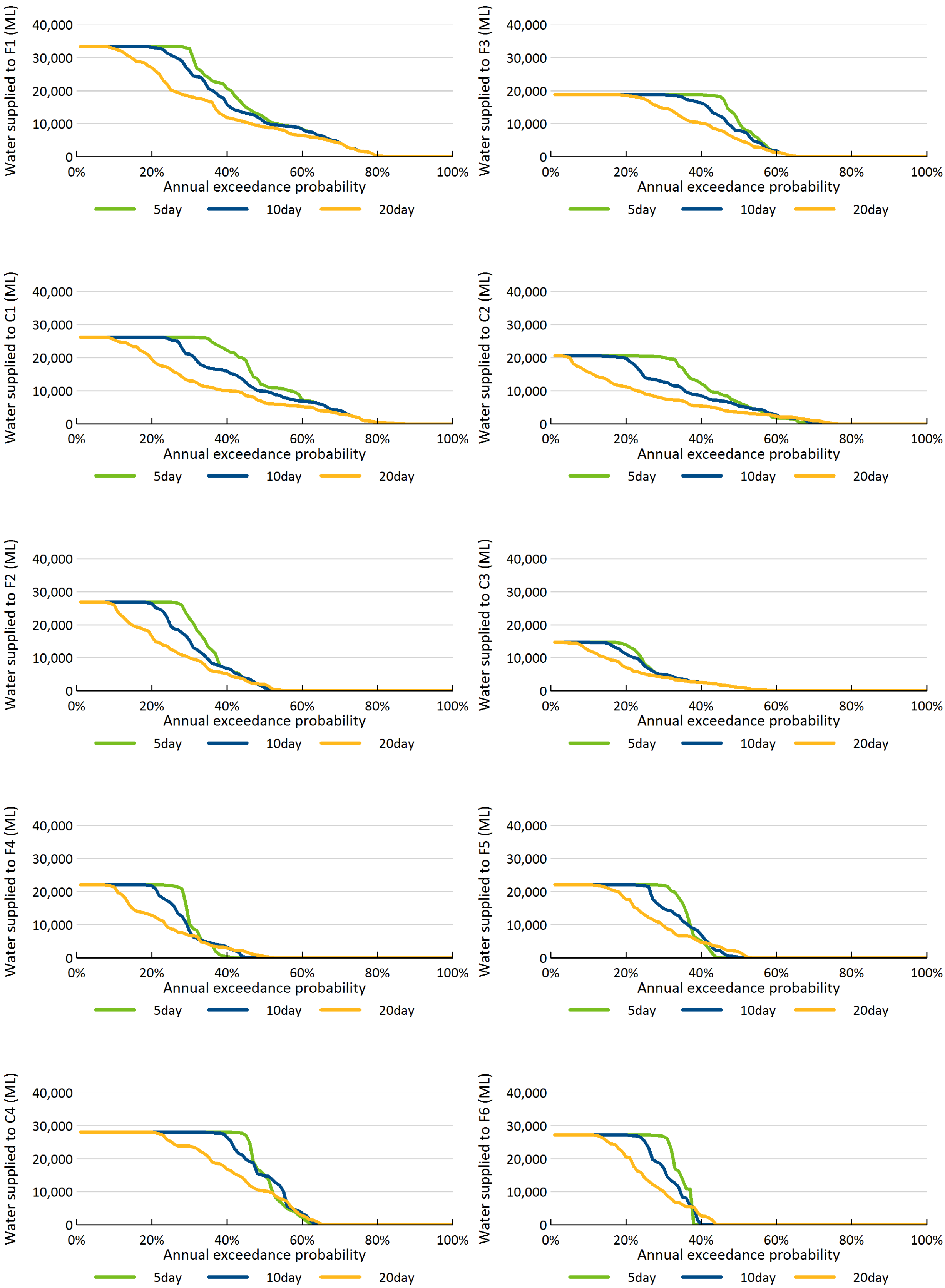


Figure 5.10 Reliability of extracting water up to the annual entitlement for ten water harvesting users for three 'storage size to entitlement-to-pump capacity' (SSEPC) ratios (5, 10 and 20) by 1 February under Scenario B320.

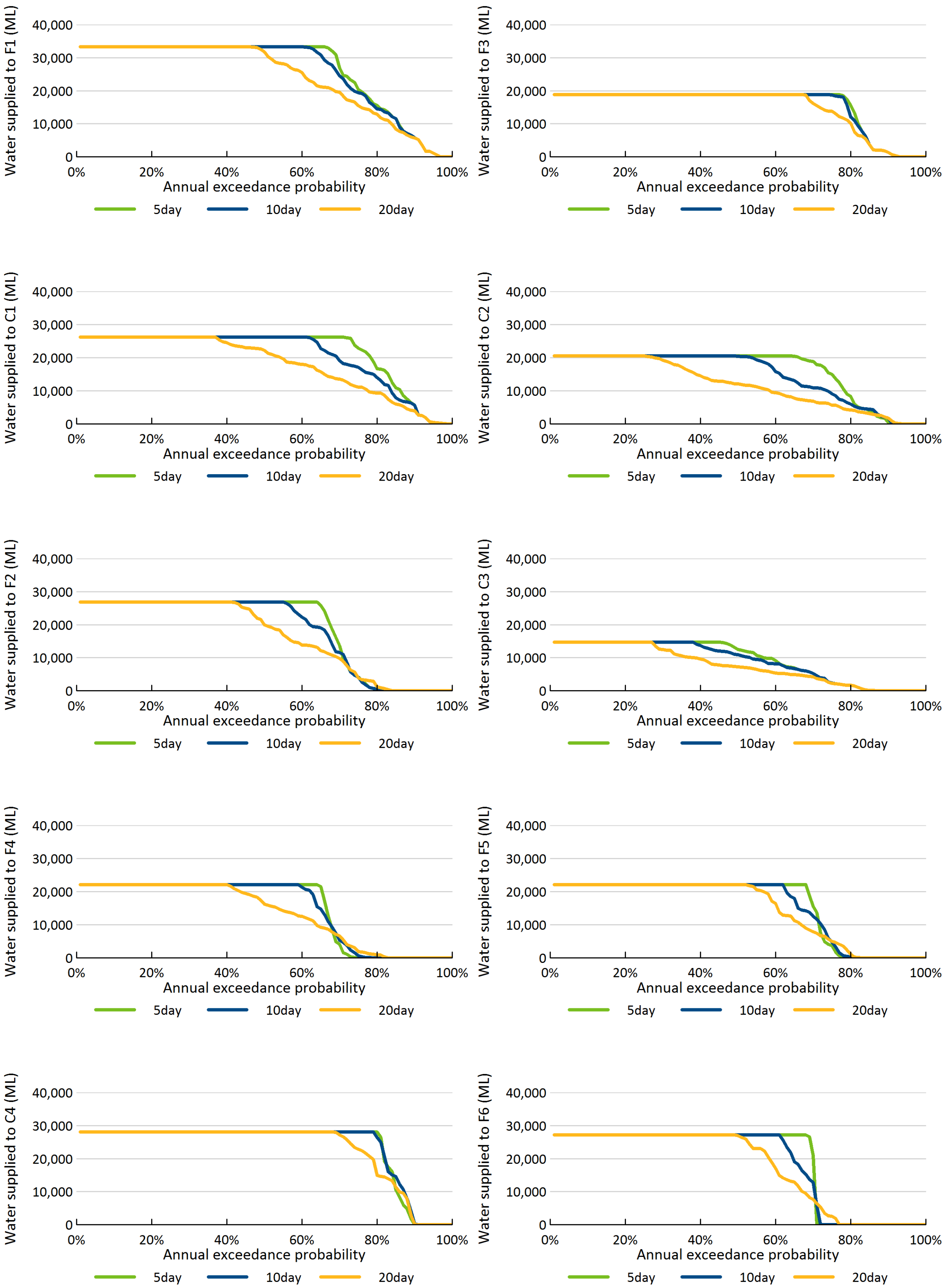


Figure 5.11 Reliability of extracting water up to the annual entitlement for ten water harvesting users for three ‘storage size to entitlement-to-pump capacity’ (SSEPC) ratios (5, 10 and 20) by 1 July under Scenario B320

5.1.6 IMPACTS ON EXISTING ENTITLEMENTS

The 'No Impact' cotton case studies do have some impact on total long term average extractions for existing entitlements (see Table 5.9). However, this impact is primarily restricted to the upper Flinders due to extractions from F1 and F2. Note that the impacts that would occur during any one season may be greater than the long term average.

Table 5.9 Percentage reduction in total diversions for existing entitlements. All assume a fixed planted area based on 8ML/ha

SCENARIO	PERCENTAGE CHANGE – TOTAL AVERAGE ANNUAL EXISTING DIVERSIONS (%)
B80	-2%
B160	-4%
B240	-6%
B400	-8%
B560	-9%

5.1.7 STREAMFLOW IMPACTS

Figure 5.12 illustrates the median annual streamflow quotient at several gauges throughout the catchment as well as for the last node in the model (EOS). All sites result in increased impact with higher new entitlement scenarios. The impact at EOS is relatively small but localised impacts are greater. For example gauge 915203A results in significant changes (0.72 for the 240GL scenario). Monthly average flows are reduced, primarily from December to March (Figure 5.13and Figure 5.14).

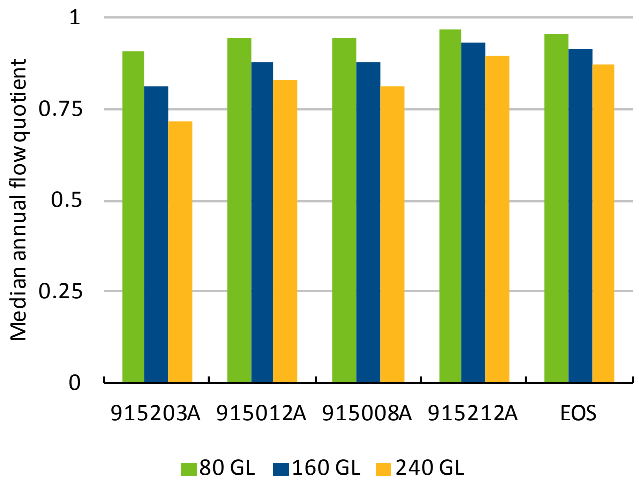


Figure 5.12 Median annual streamflow quotient at for various gauges

Median annual streamflow quotient is the median annual streamflow under Scenario B divided by the median annual streamflow under Scenario A. Scenario A is the historical climate (1890 to 2011) and current development. Scenario B is the historical climate (1890 to 2011) with irrigation development.

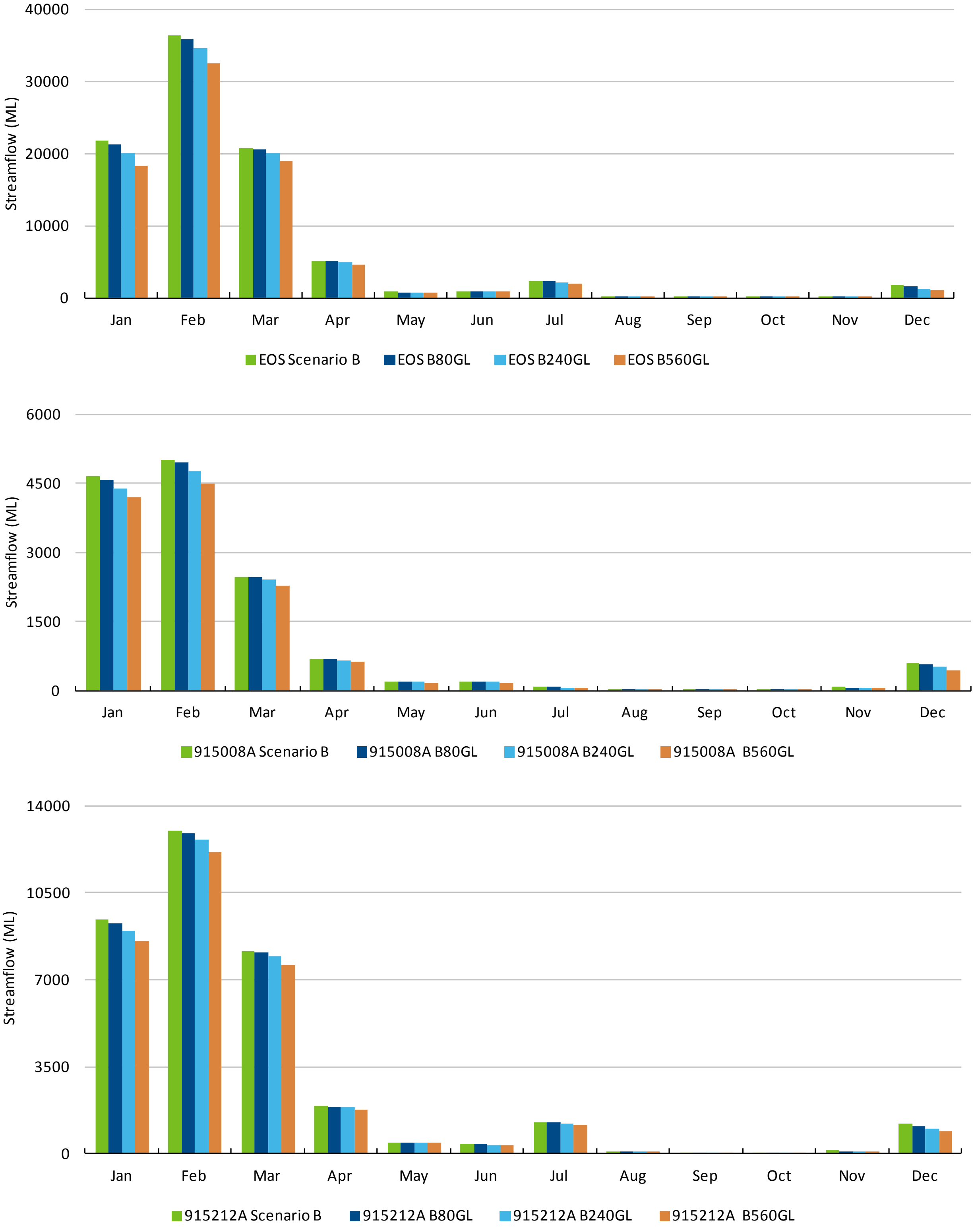
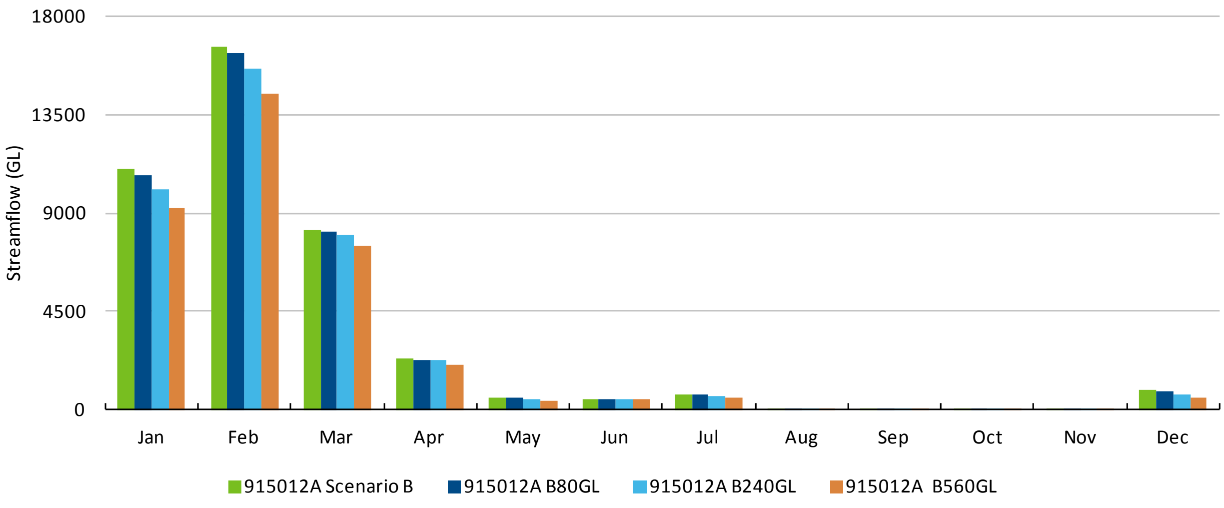


Figure 5.13 Change in monthly average flows for scenario B80 assuming fixed area planted every year based on 1 hectare per 8ML of entitlement



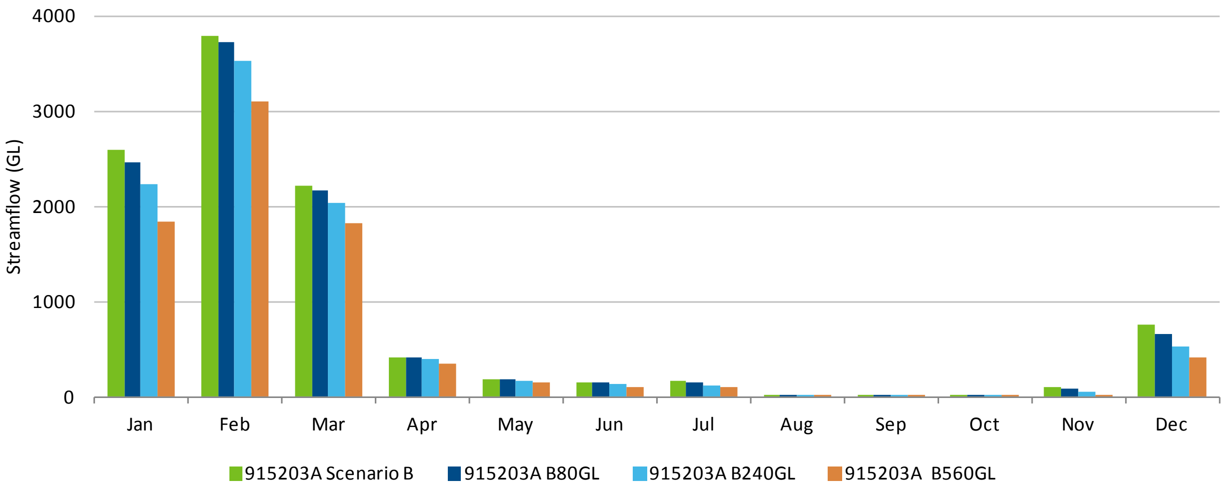


Figure 5.14 Change in monthly average flows for scenario B80 assuming fixed area planted every year based on 1 hectare per 8ML of entitlement

5.2 Cave hill

5.2.1 SCHEME CHARACTERISTICS

The potential Cave Hill dam is an earth embankment dam located on the Cloncurry River about 18 km upstream of Cloncurry. Key dam characteristics are detailed in Table 5.10 and the relationship between water depth, volume and area is presented in Figure 5.15. The valve has not been designed and as such a relatively unconstrained outlet capacity was adopted with a cross sectional area of 10m^2 assumed.

Table 5.10 Parameters for Cave Hill dam

TYPE OF DAM	CATCHMENT AREA (km^2)	HEIGHT (m)	CAPACITY (GL)	FULL SUPPLY LEVEL (m)	DEAD STORAGE (GL)	SEEPAGE (MM/DAY)
Earth embankment	5264	16	248	224	4.96	0

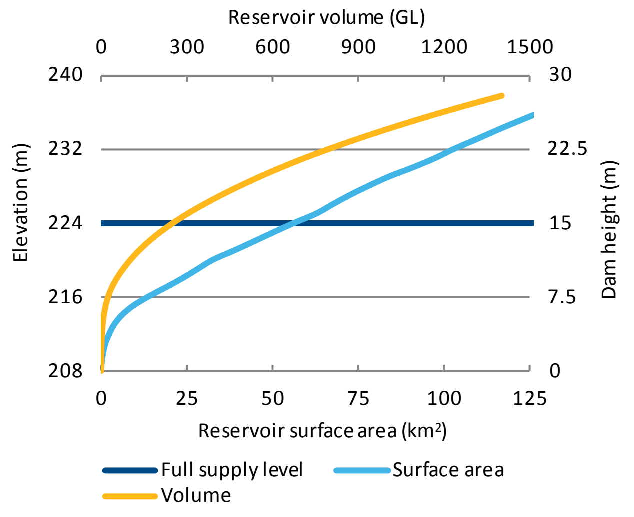


Figure 5.15 Storage volume area relationship – Cave Hill

Under this nominal configuration, water would be released from the Cave Hill dam to a re-regulating structure 32 km downstream of the dam. The weir would have limited storage capacity and would primarily serve as a pool from which to pump hence for this reason it has not actually been represented in Source as it would be small enough that it would not be relevant to the model.

Irrigation water is assumed to be distributed within a farm (i.e. from the farm gate to the field) using open channels. No on-farm storage is simulated. Once at the field, water is applied using spray irrigation, more specifically lateral move sprinklers. Lateral move sprinklers are used to optimise irrigation productivity from the limited water supply and minimise accessions to groundwater which have the potential to cause secondary salinity problems in the area. Well-managed spray irrigation generates very little tailwater runoff (i.e. water leaving the field following an irrigation event), except during large rainfall events which may occur immediately after irrigation on full soil profiles. In this case study, irrigation occurs during the dry season, and it is assumed that there is no need for on-farm tailwater recycling and on-farm water storages.

Runoff generated from heavy rainfall events during the wet season would not be captured but rather allowed to run off into neighbouring areas that are not being irrigated or directed back into the river system if water quality parameters were met.

Table 5.11 lists the conveyance efficiency assumptions used in this analysis. In total, the conveyance and application efficiency from the storage to the crop is about 56%. Losses from the Cave Hill storage were simulated by Source explicitly as evaporation and seepage (see 5.2.1). Note that on an optimistic farm distribution efficiency has been evaluated as it has been assumed that there is no on farm storage.

Table 5.11 Assumed conveyance efficiencies for the irrigation development associated with the Cave Hill dam

COMPONENT	EFFICENCY (%)	COMMENT
Channel distribution efficiency	90%	Representative of evaporation loss from re-regulation structure and channel loss between river and farm gate. Assumed best practice
Field application efficiency (spray)	85%	Lateral move sprinklers
Conveyance efficiency between storage and irrigation area	75%	Distance between dam and re-regulating structure is about 50 km. Long distance, relatively low volumes. The advantage is that the first releases of water occur towards the end of the wet season when the bed sands are already near saturation.
Evaporation and seepage estimate from on farm storage	100%	Case study does not include on farm storages
On-farm distribution efficiency	97%	Representative of on-farm evaporation and seepage loss from farm gate to edge of field. Assumed best practice
Overall efficiency	56%	

5.2.2 CROPPING SYSTEMS

In this case study, the development would enable sorghum (grain) to be supplied to newly established local feedlot and abattoir facilities. Crop parameters are detailed in Table 5.12 and Table 5.13. See Section 3.4.2 for parameter definitions. A daily pattern has been defined for the crop factor (see Appendix C).

A range of maximum areas and planting decisions were tested as detailed in Table 5.12.

Source determines the area to plant each year by dividing the volume available in the Cave Hill storage (in the Resource Assessment account) by a planting decision. A range of planting decisions from risky to conservative has been evaluated (Table 5.12).

Table 5.12 Characteristics of crops used in Cave Hill case study

Crop	Planting date	Maximum planted area sensitivity testing (Ha)	Planting decision sensitivity testing (ML/ha)	Depth of roots (mm)	Target soil depletion (mm)
Sorghum	15-Mar	4,000 to 40,000 Ha	1 to 8 ML/Ha	900	64

Table 5.13 Other crop model parameters used for the Cave Hill Case Study

PARAMETER	VALUE
Soil moisture Capacity (%)	16.5
Fallow depth (mm)	300
Fallow Depletion factor (%)	100
Crop Depletion factor (%)	50
Soil description	Moderate Grey Vertosol

APSIM was run for a number of different water supply scenarios using historical environmental data to generate a relationship with crop yield (Figure 5.16). This data was then used to train statistical models to predict crop yield. This data was then used to train statistical models to predict crop yield. These results are modelled production potential under optimum management hence represent an upper limit.

Average irrigation application greater than 4 ML/ha (400 mm) do not result in a higher crop yield, because the crop does not require any more water. At water applications less than 4 ML/ha, the crop becomes increasingly water-stressed and crop yields reduce, because the amount of water applied is insufficient to meet the crop water requirements.

There is significant scatter between the regression model and APSIM yield results (Figure 5.17) however the percentage variance explained was reasonable (92.7%) and there was only a 1 percent difference in average specific yield.

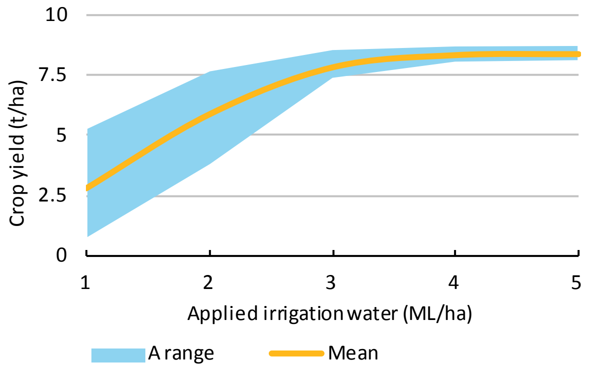


Figure 5.16 APSIM Yield Results

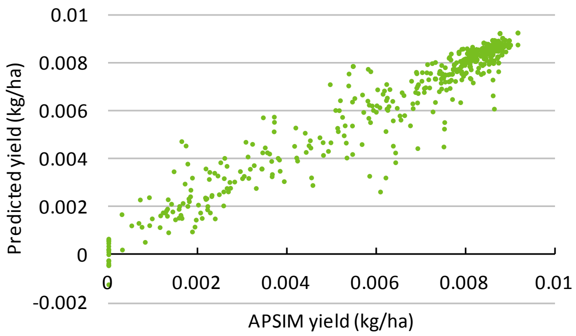


Figure 5.17 Comparison of APSIM and regression predicted specific yield

5.2.3 RESOURCE ASSESSMENT SYSTEM

An annual allocation and accounting system has been defined in Source. This system has been configured differently for the Impact and No Impact scenarios.

For the Impact scenario, downstream existing entitlements are ignored and Cave Hill is allocated 100% to the new irrigation area.

For the No Impact scenario, existing entitlements are assigned high priority shares in Cave Hill and the new irrigation area is assigned a medium priority share. This means that the existing users are assigned access to water prior to the new irrigation area in the resource assessment process. The existing entitlements were assigned a high priority account share equivalent to their existing water harvesting entitlement volume.

5.2.4 AREA AND PLANTING DECISION OPTIMISATION RESULTS

Note: Please note that the crop area decision reported in the following graphs relates to the available volume in storage at the time of planting multiplied by the efficiency factor of 0.56. Hence to convert into a relationship between volume in storage and area planted, all crop area decisions should be divided by 0.56.

Exploratory analysis

Total crop yields from a scheme area are highest for larger scheme areas and higher levels of risk (i.e. lower water allocations per ha of crop). This is because in the years the reservoir is full or nearly full, the planted area is less constrained by the scheme area. It also occurs because reducing water allocation to the crop by 50% (from the 4 ML/ha full median requirement to 2 ML/ha) reduces crop yield by only 25% (Figure 5.16). The highest total yields from a scheme are attained at higher levels of risk, and the variability in 30-year crop yields is high at large scheme areas and low crop area decisions (i.e. high risk, see Figure 5.18b).

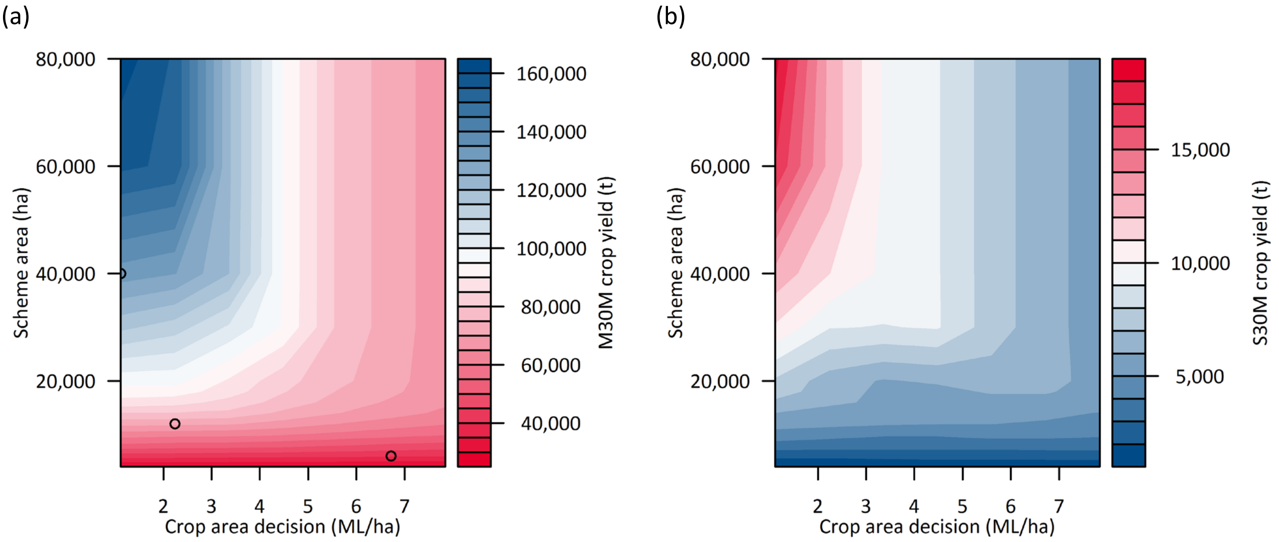


Figure 5.18 (a) Median of the 30-year mean values (M30M) for crop yield and (b) standard deviation of the 30-year mean values (S30M) for crop yield, under Scenario B for the irrigation development associated with the Cave Hill dam. Circles in a) represent the time series chosen for demonstrating crop yield variability

Results are presented as a function of scheme area and annual crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows within the period from 1890 to 2011.

The annual variability in crop yield is illustrated in Figure 5.19. Although a low area and high planting decision value results in low crop yield it results in a more reliable system than an irrigation development with a larger area and lower planting decision value.

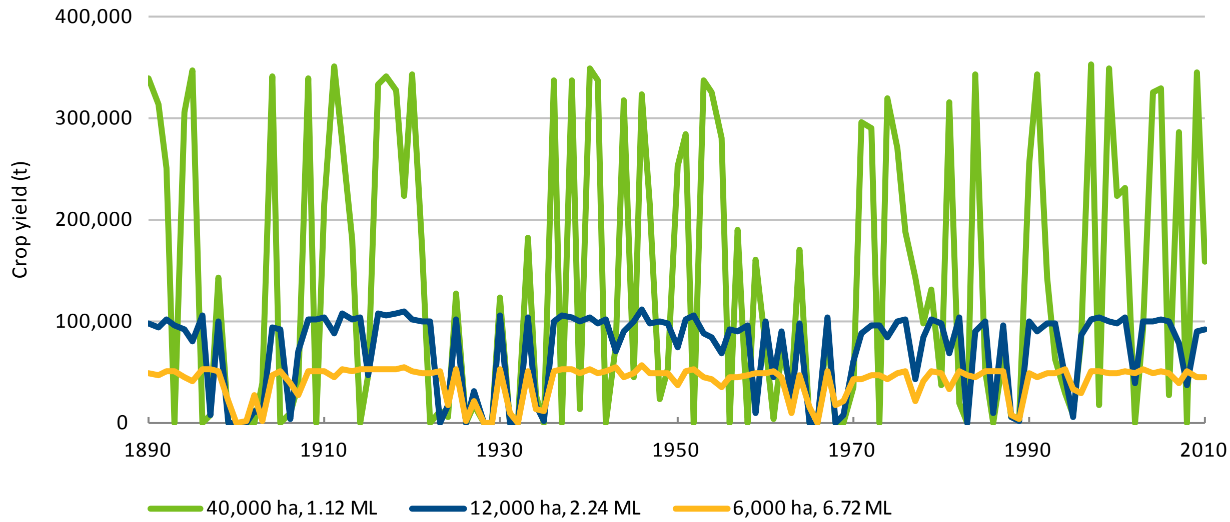


Figure 5.19 Crop yield from the total scheme area under Scenario B for three different scheme areas
Results are presented as a function of scheme area and annual crop area decision. Scenario B is the historical climate with irrigation development. Mean values are calculated for 30-year windows within the period from 1890 to 2011. The median of these 30 year windows is presented

The yield per hectare planted decreases with lower crop area decision, because there is insufficient water to meet the irrigation requirement of the crop hence it is more often under water stress (Figure 5.20a).

An analysis was conducted to determine the grain requirements of a local feedlot and abattoir and hence what area of sorghum would be required to support those developments. A feedlot supporting a 65,000-head abattoir would require about 82,500 t of grain a year (Petheram et al., 2013a). Assuming this grain is to be locally sourced, the percentage of years that 82,500 t of grain is exceeded for different scheme area and crop area decisions is presented in Figure 5.20b. Scheme areas less than 8000 ha never achieve 82,500 t of grain per year (Figure 5.20b). At high crop area decisions (i.e. greater than 2 ML/ha), the crop yields per hectare are high but the annual area planted is too low to regularly exceed 82,500 t. For high scheme areas (e.g. greater than 30,000 ha) and low crop area decisions (i.e. less than 2 ML/ha), even though the planted areas are often high, the specific crop yield is such that 82,500 t is only exceeded in about 50% of years. The combination that results in grain yields exceeding 82,500 t most often (approximately 70%) is a scheme area of about 12,000 ha and a crop area decision of 1 to 2.2 ML/ha (Figure 5.20b). Under this best-bet regime, it is not possible to achieve the 82,500-t target of scheme-level grain production 3 years in 10. This may have implications for the longer-term profitability of a combined irrigation, feedlot fattening and abattoir system. However, the abattoir will not be solely dependent on finishing cattle with other classes of cattle contributing to the 100,000-head annual throughput. The years in which grain production does not reach 82,500 t are generally below average in rainfall. Rangeland pasture production will also be below average in those years, meaning that there are likely to be more cattle needing to be sold and processed in response to forage deficits in grazed pastures.

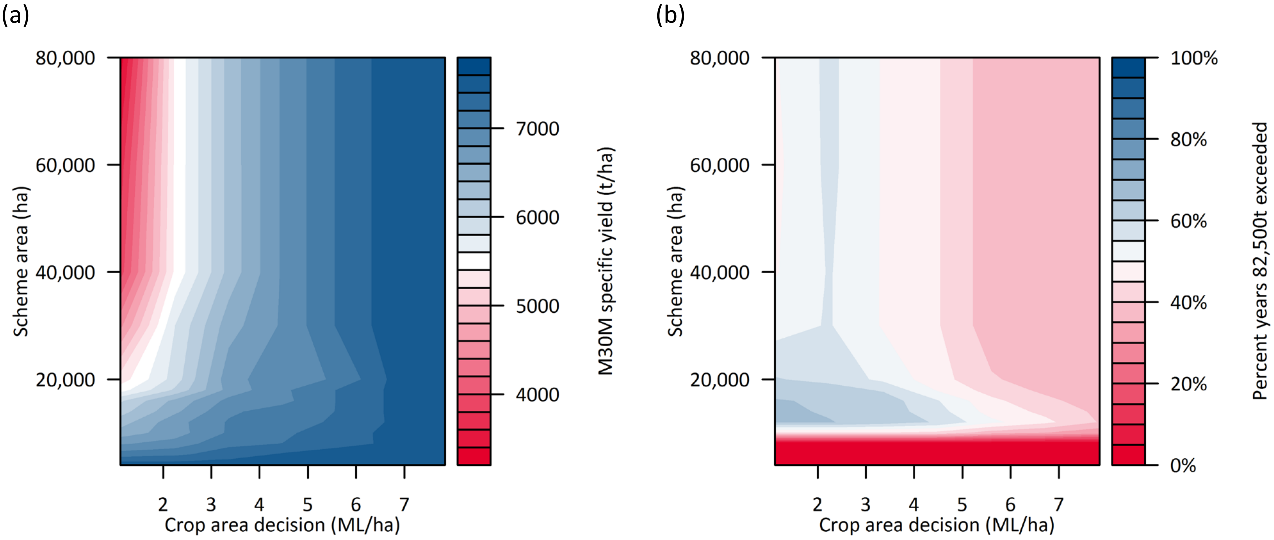


Figure 5.20 (a) Median of the 30-year mean values (M30M) for specific yield and (b) percentage of time 82,500 tonnes of grain is exceeded under Scenario B for the irrigation development associated with the Cave Hill dam
Results are presented as a function of scheme area and crop area decision. Specific yield is crop yield per hectare planted. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows within the period from 1890 to 2011. The median of the mean values for each of the 92 windows are presented. {please note the key should say kg/ha}

The water supplied per hectare decreases as scheme area increases and as the crop area decision is decreased (Figure 5.21b). Note that the applied water is generally less than the planting decision.

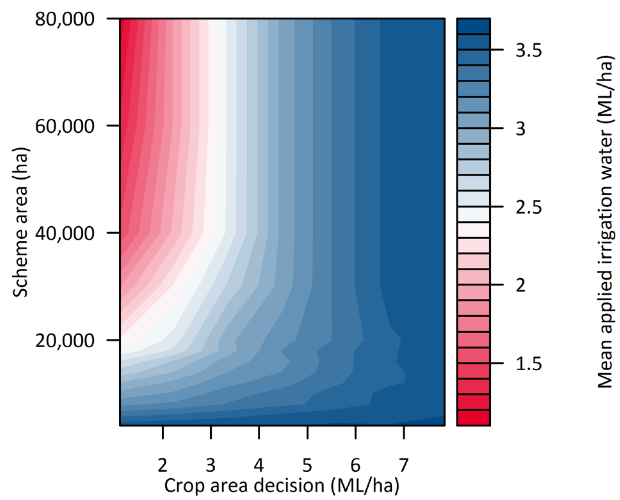


Figure 5.21 Mean annual applied irrigation water supplied to the field in ML/ha, under Scenario B for the irrigation development associated with the Cave Hill dam
Results are presented as a function of scheme area and crop area decision. Applied irrigation water is the water supplied from the dam, with the losses from river conveyance, channel distribution and field application removed. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Figure 5.22 illustrates the percentage of years that the entire scheme area is planted. Lower crop area decisions result in the scheme area being fully planted in more years.

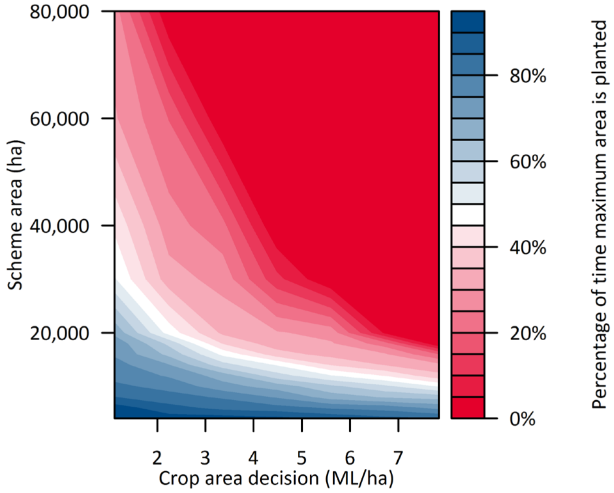


Figure 5.22 Percentage of years that the maximum area is planted, under Scenario B for the irrigation development associated with the Cave Hill dam

Results are presented as a function of scheme area and crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Conclusion regarding the option selected for further investigation

In this case study, the total crop gross margin from the scheme is not sufficient to cover the capital and overhead costs over the duration of the investment period, for any combination of scheme area and crop area decision (Petheram et al., 2013a). Given this, the minimum size of scheme required to maintain a feedlot supplying an abattoir was chosen as the option to investigate in further detail. The scheme area required to exceed 82,500 t of grain most often is about 12,000 ha, with a crop area decision of 1 to 2.2 ML/ha.

A scheme area of 12,000 ha and a crop area decision of 2.2 ML/ha was selected as the option for further investigation and additional results for this option are presented in the following sections. By dividing by 0.56 this means that for every 3.9ML available in the resource assessment account, 1 hectare is planted.

5.2.5 RELIABILITY OF SUPPLY

The reliability of water available from Cave Hill is illustrated in Figure 5.23 for both the time of planting sorghum (15th March) and for maximum available during the water year. Note that there is only a small increase in reliability between the planting date and maximum for the water year. There is also only a small difference between the maximum annual water availability under “No Impact” and “Impact” assumptions is illustrated in Figure 5.24.

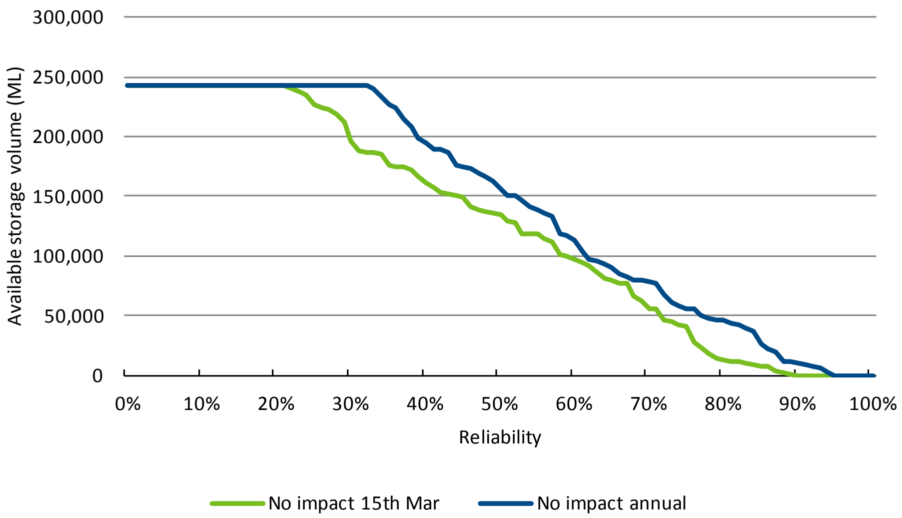


Figure 5.23 Available volume at time of planting (15th March) versus maximum annual (No Impact model - 12,000 ha option). Available volume refers volume allocated to the new scheme in the resource assessment system hence accounts for dead storage and reserves required for other users. It does not account for storage operation and delivery losses however so the results are an overestimate.

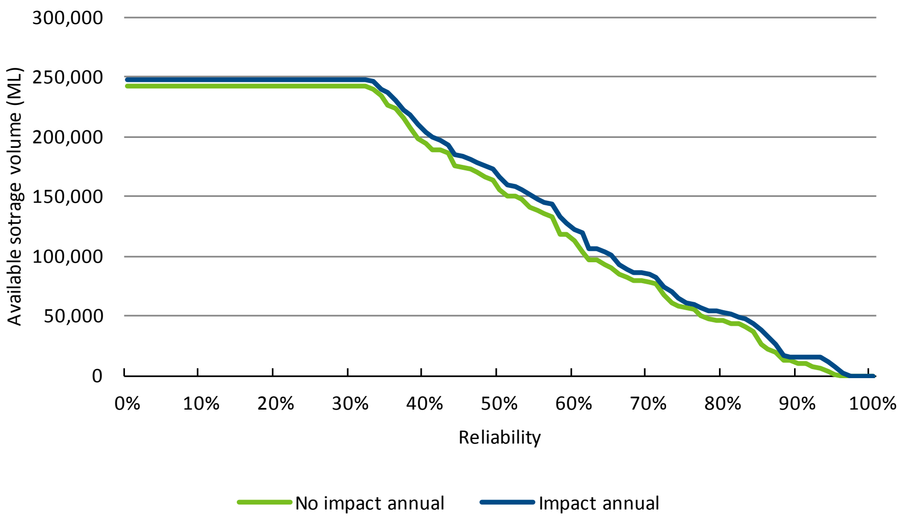


Figure 5.24 Maximum annual available volume – Comparison of Impact and No Impact Scenarios for the 12,000 ha option. Available storage volume refers volume allocated to the new scheme in the resource assessment system hence accounts for dead storage and reserves required for other users. It does not account for storage operation and delivery losses however so the results are an overestimate.

5.2.6 IMPACTS ON EXISTING ENTITLEMENTS

The 12,000 ha option selected for further analysis actually resulted in a positive impact on the immediate downstream existing entitlements under "No Impact" model assumptions. For this scenario, the average annual extractions increased by 14%. It would be possible to reduce the high priority entitlement of existing users such that average extractions are unchanged. However, this was not considered necessary as the relevant volumes are very small compared to the volume of the general security entitlement for the new irrigation area and hence have negligible impact on the assessment for Cave Hill.

5.2.7 STREAMFLOW IMPACTS

Figure 5.25 illustrates the mean annual streamflow quotient at a streamflow gauging station between the dam and the irrigation development (915203A) and near the mouth of the Flinders River (915003A). This provides an indication of the extent to which the mean annual streamflow would change under irrigation for different combinations of scheme area and crop area decision. For large scheme areas and small crop area decisions the change in mean annual streamflow is small. For small scheme areas there are moderate changes to the mean annual streamflow at station 915203A (Figure 5.25a) because more water is held in storage resulting in increased evaporation. Very little change in mean annual streamflow occurs at the mouth of the Flinders River (Figure 5.25b) because the catchment of the Cave Hill dam is small relative to the entire Flinders catchment.

For the 12,000ha development option, monthly average flows are reduced during the wet season however flows are increased from April to July at gauge 915203 (Figure 5.26). Increased autumn and winter flows occur at this gauge as it is upstream of the irrigation area and hence it reflects increased flows due to regulated releases for the irrigation area. Additional stream flow metrics for this option are illustrated in Appendix D.

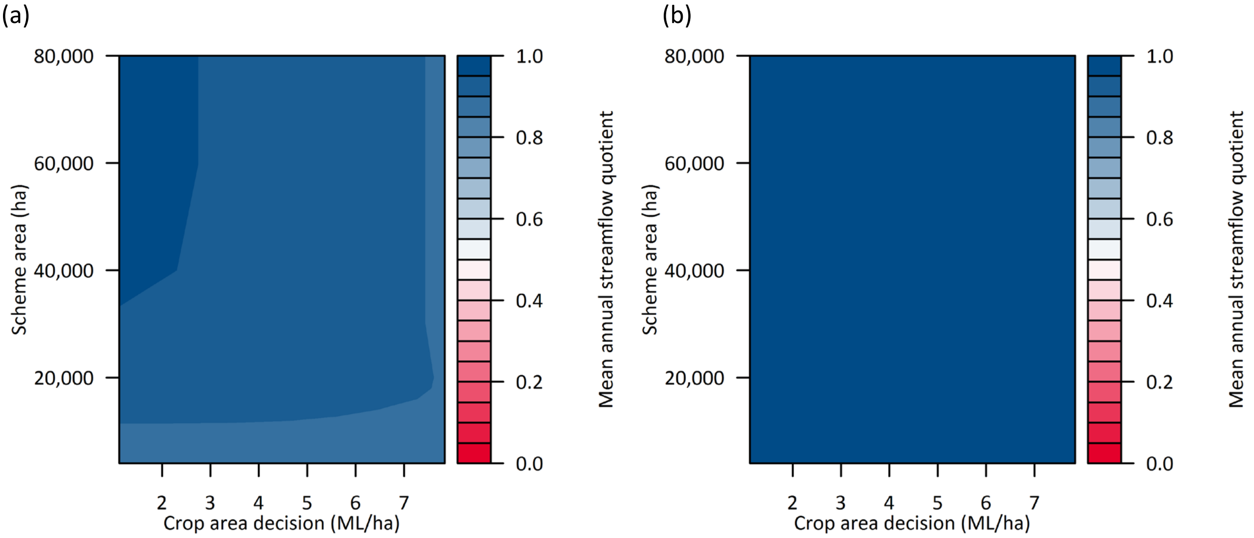
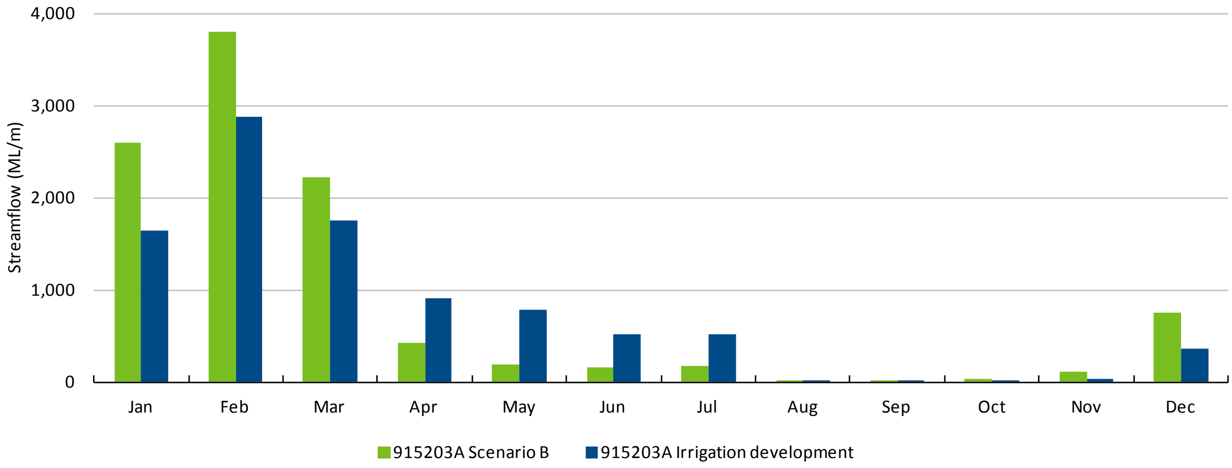


Figure 5.25 Mean annual streamflow quotient at (a) gauge 915203A and (b) gauge 915003A for the irrigation development associated with the Cave Hill dam

Median streamflow quotient is the median annual streamflow under Scenario B divided by the median annual streamflow under Scenario A. Scenario A is the historical climate (1890 to 2011) and current development. Scenario B is the historical climate (1890 to 2011) with irrigation development.



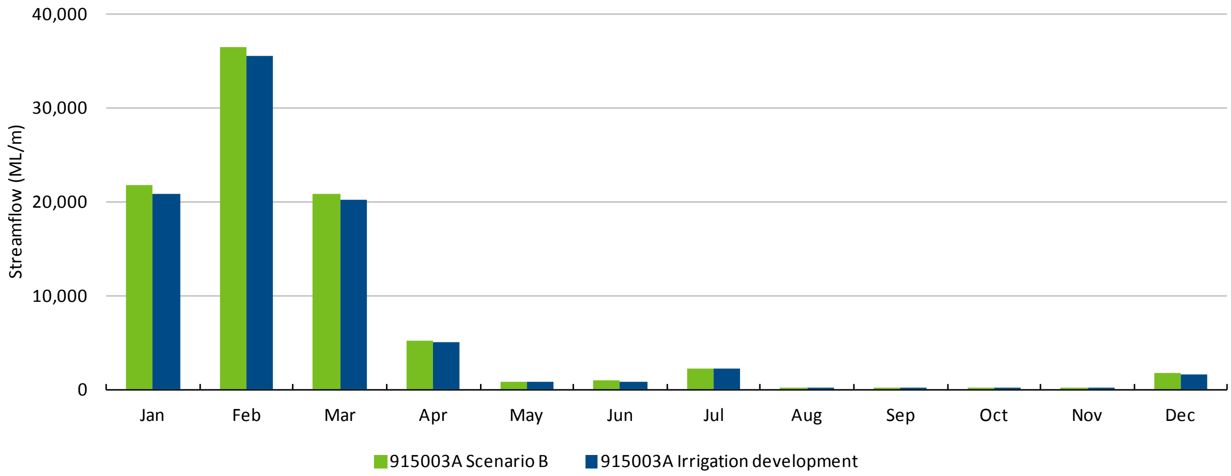


Figure 5.26 Change in monthly average flow for 12,000ha development option

5.3 O'Connell Creek Off-Stream Storage

5.3.1 SCHEME CHARACTERISTICS

The O'Connell Creek off-stream storage is the preferred large water storage option near the town of Richmond (see companion technical report Petheram et al. 2013). Key dam characteristics are detailed in Table 5.14. A feature of the storage is that it is shallow (i.e. the spillway has a height of 9 m). The O'Connell Creek storage would receive inflows from O'Connell Creek catchment and water diverted from the Flinders River downstream of Richmond. A channel capacity constraint of 150 m^3/s has been assumed for diversions from the Flinders River (because of the erodible soils the maximum design flow velocity would need to be limited to 0.4 m/s, which would require a channel bed with of 55 m, Petheram et al. 2013).

A hydraulic model is required to accurately simulate diversions from the Flinders which is dependent on high resolution elevation data. The best available elevation data at the point of diversion was a surveyed transect undertaken by AECOM (2009). There were some challenges in reconciling the surveyed transect data with the Shuttle Radar Terrain Model derived water storage levels.

Due to some uncertainty in the elevation data along the diversion channel, the approach undertaken in this case study was to assess the O'Connell Creek storage and irrigation development without the hydraulic connection and using a zero threshold (i.e. water can be diverted along the diversion channel up to 150 m^3/s regardless of the river level height and the relative level between the river and the water storage).

This will exaggerate the water yield to and from the storage and if the irrigation development is not found to be profitable under very generous assumptions it will not be profitable under more realistic assumptions. A trial hydraulic model was developed in Source and some comparisons are made to this model to give an indication of the potential reduction in reliability of the storage (see Section 5.3.5).

Table 5.14 O'Connell Creek dam parameters

DAM NAME	CATCHMENT AREA (km^2)	HEIGHT (m)	CAPACITY (GL)	FULL SUPPLY LEVEL (m)	DEAD STORAGE (GL)	SEEPAGE (MM/DAY)
O'Connell Creek Off-stream	1508	9	127	201	2.55	See Table 5.15

A simple groundwater model was developed to estimate seepage from the storage. The derived relationship between dam water level and seepage is detailed in Table 5.15.

Table 5.15 O'Connell Creek dam seepage relationship

Level (m)	Seepage (mm/day)
0	0
1	0.27
3	0.95
6	1.00
8	1.01

The relationship between water depth, volume and area is presented in Figure 5.27.

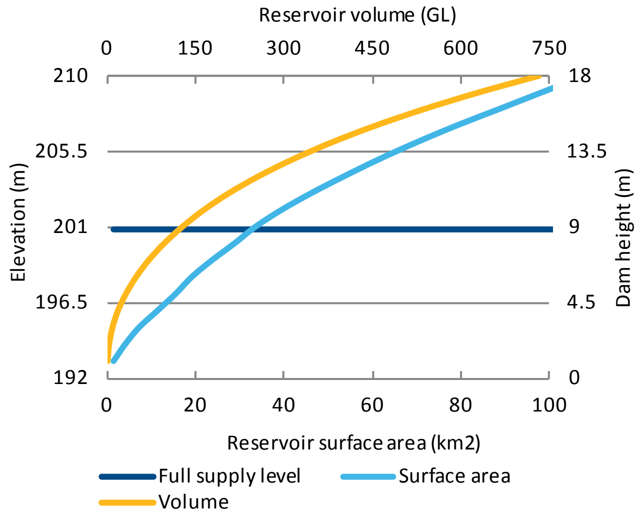


Figure 5.27 Storage volume area relationship – O'Connell

Table 5.16 lists the conveyance efficiency assumptions used in this analysis. River conveyance losses are modelled as per the baseline model. O'Connell Creek storage evaporation and seepage losses are modelled explicitly in Source (see 5.3.1).

Water would be released from the O'Connell Creek storage along a 32 km open channel to the potential irrigation development near Maxwelton. It is assumed that irrigation water is distributed within a farm (i.e. from the farm gate to the field) using open channels and the rice is grown in irrigation bays within which water is permanently ponded. No on farm storage has been simulated.

Runoff generated from heavy rainfall events would not be captured on-farm but rather diverted through an associated surface drainage network and allowed to runoff into neighbouring areas which are not being irrigated or directed back into the river system if water quality parameters were meet.

In total, the conveyance and application efficiency from the storage to the crop is about 64%. Note that optimistic farm distribution efficiency has been evaluated as it has been assumed that there is no on farm storage.

Table 5.16 Conveyance efficiencies for the irrigation scheme associated with the O'Connell Creek storage

COMPONENT	EFFICENCY	COMMENT
River conveyance efficiency between storage and irrigation area	100%	Not applicable - all losses in the river are as per the baseline calibrated model.
Channel distribution efficiency	88%	Representative of losses from storage to irrigation development – channel 32 km in length set in heavy soils
Evaporation and seepage estimate from on farm storage	100%	Case study does not include on farm storages
On-farm distribution efficiency	95%	Representative of on-farm evaporation and seepage loss from farm gate to edge of field, assumed best practice.
Field application efficiency (flood)	75%	Ponded rice. APSIM model did not simulate evaporation or deep drainage loss from ponded water. A large percentage of this field application loss is due to evaporation from open water.
Overall efficiency	64%	

5.3.2 CROPPING SYSTEMS

This case study included an assessment of rice as detailed in Table 5.17 and Table 5.18. See Section 3.4.2 for parameter definitions. A daily pattern has been defined for the crop factor (see Appendix C).

Streamflows are highest in February and are typically low and irregular during January. To make best use of favourable planting and growing conditions in the Flinders catchment two rice crops were simulated with different planting/growing windows. The first crop was planted in January, and the planted area was based on the water in the storage at the end of the month. The second crop was planted in February and the planted area based on any additional inflows since January.

A range of maximum areas and planting decisions were tested as detailed in Table 5.17. Source determines the area to plant each year by dividing the volume available in the O'Connell storage by a planting decision. The available volume in storage accounts for dead storage. No reserves are required for other users.

Table 5.17 Characteristics of crops used in O'Connell Creek Case Study

Crop	Planting date	Maximum planted area sensitivity testing (Ha)	Planting decision sensitivity testing (ML/ha)	Depth of roots (mm)	Pond depth (mm)
Rice	15/1 and 15/2	1,000 to 40,000	2 to 20 ML/ha	40	120 to 300

Table 5.18 Other crop model parameters used for the O'Connell Creek Case Study

PARAMETER	VALUE
Soil moisture Capacity (%)	10
Fallow depth (mm)	300
Fallow Depletion factor (%)[1]	100
Crop Depletion factor (%)	100
Soil description	Richmond Grey Vertosol

[1] Rice depletion factor is 100% is high but it is compensated by a shallow root depth which means it allows rice to die pretty quickly when the ponds start to dry out.

APSIM was run for a number of different water supply scenarios using historical environmental data to generate a relationship with crop yield (Figure 5.28). This data was then used to train statistical models to predict crop yield. These results are modelled production potential under optimum management hence represent an upper limit.

Average irrigation application greater than 4 to 5 ML/ha does not result in a higher yield as the rice crop does not require more water. Irrigation less than 4 ML/ha the rice crop quickly becomes water stressed and large reductions in yield occur.

There is some scatter between the regression model and APSIM yield results (Figure 5.29).

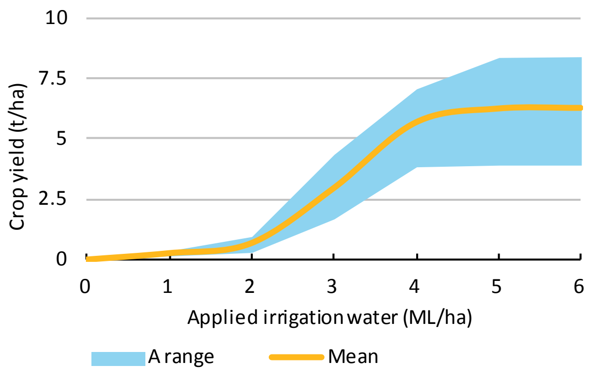


Figure 5.28 APSIM Yield Results

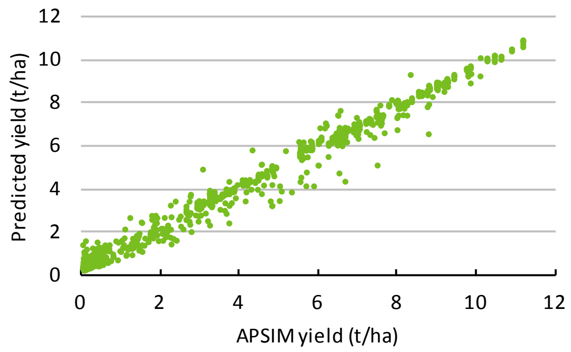


Figure 5.29 Comparison of APSIM and regression predicted specific yield

5.3.3 RESOURCE ASSESSMENT SYSTEM

Resource assessment was not used for the O'Connell case study as the storage is used entirely by the proposed new irrigation area. Hence the active volume in storage (i.e. above dead storage) was defined as the volume available at the planting date.

5.3.4 AREA AND PLANTING DECISION OPTIMISATION RESULTS

Note: Please note that the planting decision reported in the following graphs relates to the available volume in storage at the time of planting multiplied by the efficiency factor of 0.64. Hence to convert into a relationship between volume in storage and area planted, all crop area decisions should be divided by 0.64.

Sensitivity analysis results

Larger scheme-scale crop yields are attained for larger scheme areas and smaller crop area decisions (Figure 5.30). This is because, in the years the reservoir is full or nearly full, the planted area is less constrained by the scheme area. Larger scheme-scale crop yields are attained at higher levels of risk – the variability in 30-year crop yields is high at large scheme areas and low crop area decisions (i.e. high risk; see Figure 5.30b).

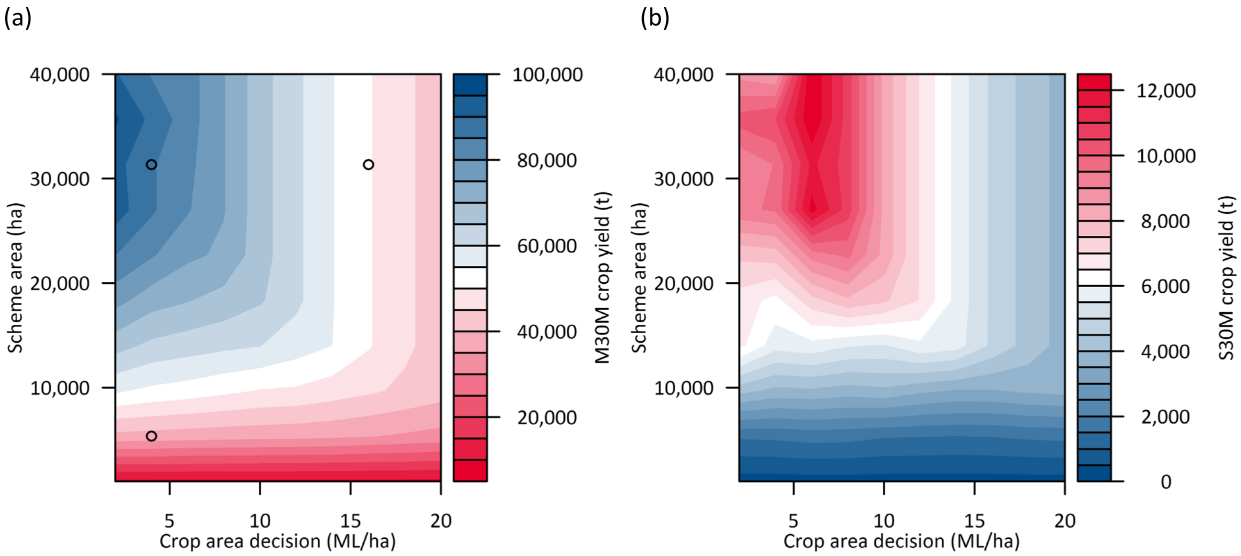


Figure 5.30 (a) Median of the 30-year mean values (M30M) for crop yield and (b) standard deviation of the 30-year mean values (S30M) for crop yield, under Scenario B for the irrigation development associated with the O'Connell Creek off-stream storage. Circles in a) represent the time series chosen for demonstrating crop yield variability
Results are presented as a function of scheme area and annual crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows within the period from 1890 to 2011. Both the median and the standard deviation of the mean values for each of the 92 windows are presented.

The higher crop yields and higher variability for larger scheme areas is illustrated in . Although the 5333 ha scheme area and 4ML planting decision scenario has the lowest total crop yield it results in a more reliable system than a scheme with larger areas.

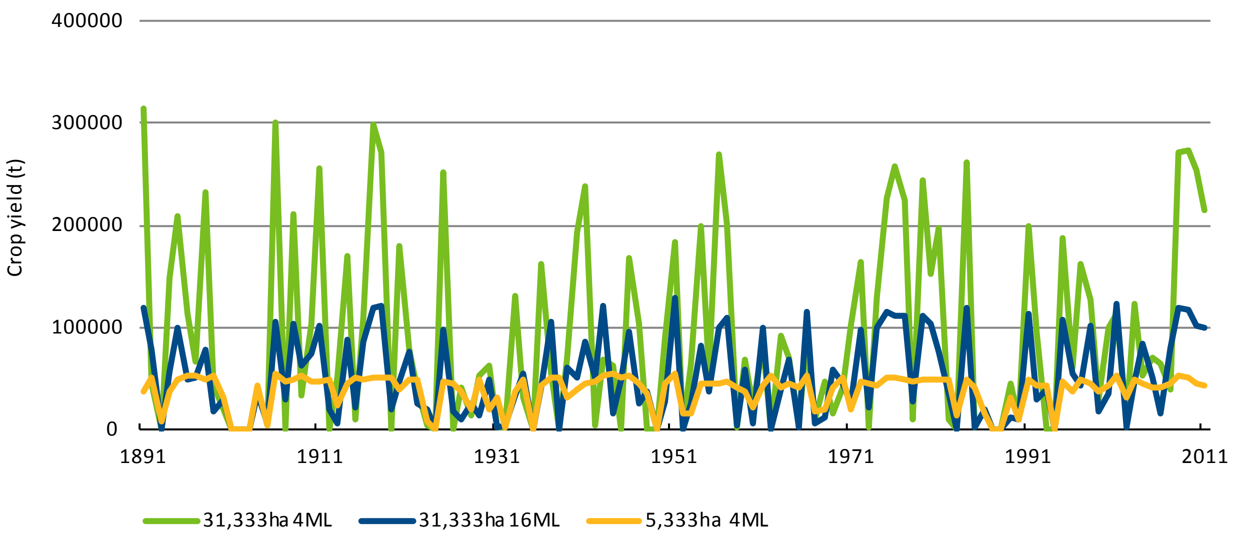


Figure 5.31 Crop yield from the total scheme area under Scenario B for three different scheme areas

Median 30-year average 'specific yield' (i.e. crop yield per hectare planted) decreases with higher planted areas and lower crop area decisions as rice crops are more often under water stress and this results in lower yields (Figure 5.31a). However, at scheme areas less than 8,000ha, the reliability of a 50,000t or more crop yield is less than 20% while above 8,000ha this crop yield will be exceeded 50% of the time.

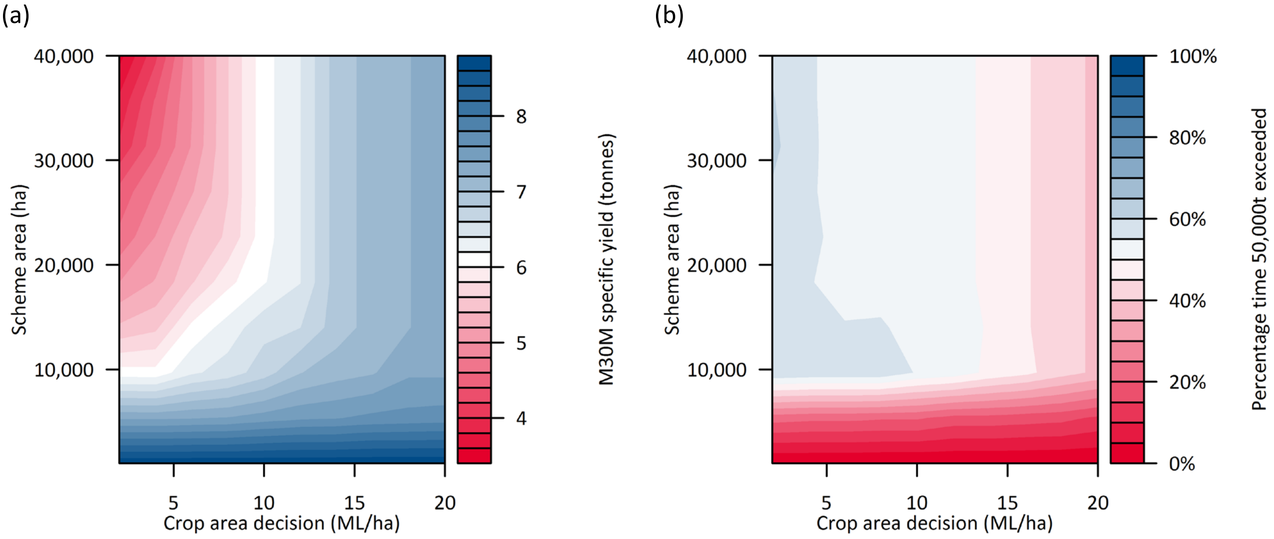


Figure 5.32 (a) Median of the 30-year mean values (M30M) for specific yield and (b) percentage of time 50,000 tonnes of grain is exceeded under Scenario B for the irrigation development associated with the O'Connell Creek off-stream storage

Results are presented as a function of scheme area and crop area decision. Specific yield is crop yield per hectare planted. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows within the period from 1890 to 2011. The median of the mean values for each of the 92 windows are presented.

The water supplied per hectare decreases as scheme area increases and as the crop area decision is decreased (Figure 5.32). Note that the applied water is generally less than the planting decision.

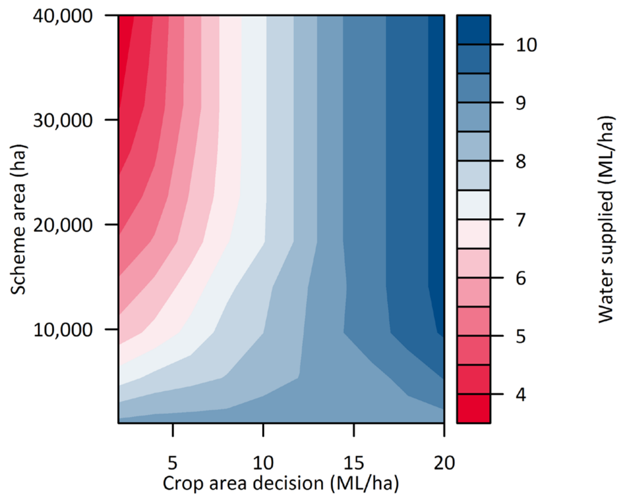


Figure 5.33 Mean Applied irrigation water supplied to the field in ML/ha under Scenario B for the irrigation development associated with the O'Connell Creek off-stream storage

Results are presented as a function of scheme area and crop area decision. Applied irrigation water is the water supplied from the dam, with the losses from river conveyance, channel distribution and field application removed. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Figure 5.34 illustrates the percentage of years that the entire scheme area is planted. Lower crop area decisions result in the scheme area being more fully planted in more years.

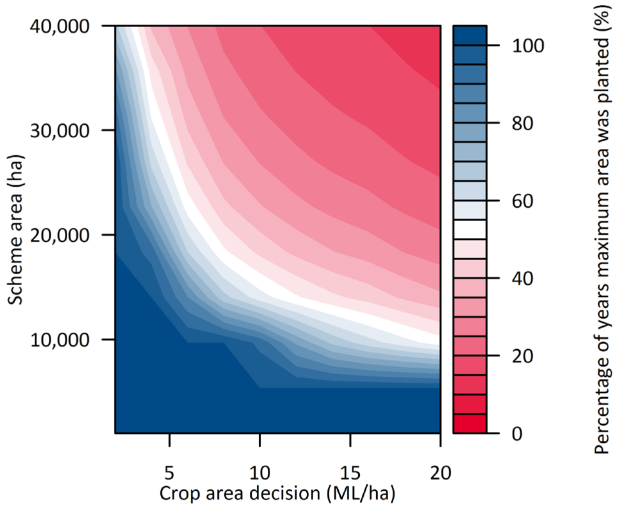


Figure 5.34 Percentage of years that the maximum area is planted, under Scenario B for the irrigation development associated with the O'Connell Creek off-stream storage

Results are presented as a function of scheme area and crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Conclusion regarding the option selected for further investigation

Based on the economic analysis of all options (Petheram et al., 2013a) a more detailed investigation was undertaken using a scheme area of 5300 ha and a planting decision of 4 ML/ha. By dividing by 0.64 this means that for every 6.25ML available in storage 1 hectare is planted.

A low scheme area was adopted so as to achieve a high degree of reliability. Further results for this scenario are presented in Section 5.3.5 and 5.3.6.

5.3.5 RELIABILITY OF SUPPLY

The reliability of water available from O'Connell storage is illustrated in Figure 5.35 for both the time of the initial rice planting (15th Jan) and for maximum available during the water year. Note that reliability is significantly reduced at the initial planting date.

An indication of the reduced annual water availability likely due to the hydraulic constrain on Flinders diversions is provided in Figure 5.36.

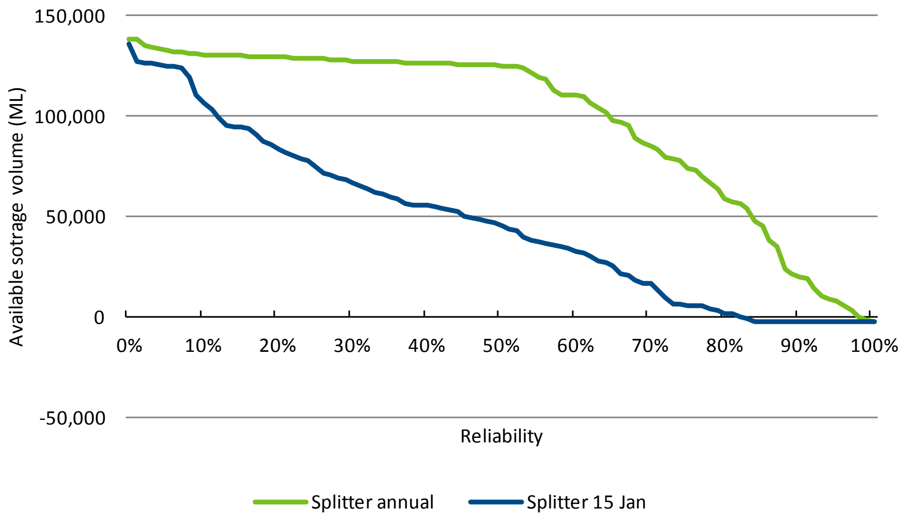


Figure 5.35 Available storage volume at time of planting (15th Jan) versus maximum annual (splitter model 5300 ha option). Available storage volume refers volume in storage above dead storage.

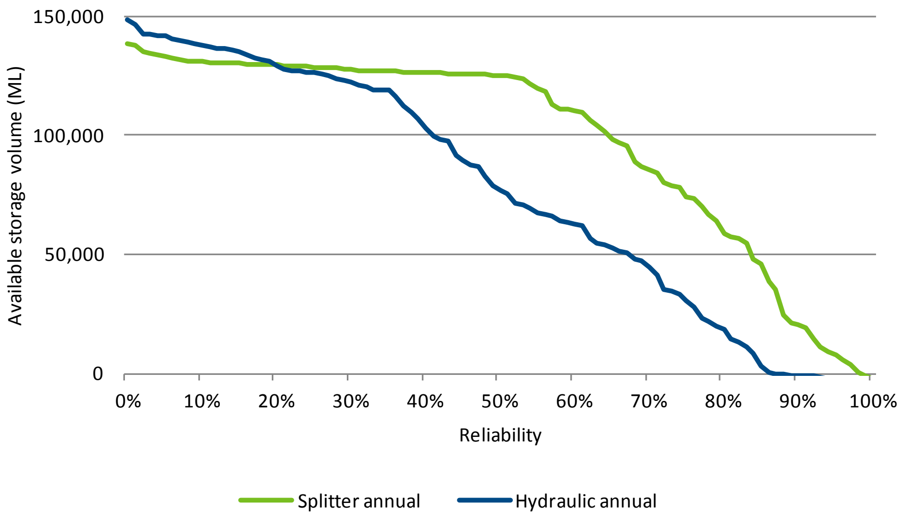


Figure 5.36 Maximum annual available volume – Comparison of Splitter and Trial Hydraulic model (zero threshold). Available storage volume refers volume in storage above dead storage.

5.3.6 IMPACTS ON EXISTING ENTITLEMENTS

A range of commence to take flow thresholds could be evaluated to assess reduced impacts on downstream existing entitlements. This has not been evaluated however. For this case study, a zero threshold was used hence all results represent an 'Impact' scenario. The splitter model for O'Connell resulted in significant impacts when a zero flow threshold was evaluated. These impacts primarily occur for existing entitlements between the O'Connell offtake and the junction with the Stawell River; a 51% decrease in average annual extractions occurred in this reach. Downstream of this junction, the impacts on existing entitlement were relatively minor.

In reality, the impacts on existing entitlement would be significantly less then that predicted by the splitter model as the hydraulic constraint on offtakes to the O'Connell storage would restrict diversions into the storage. The actual impacts would need to be assessed using a model that accounts for the hydraulic constraint on diversions from the Flinders River.

5.3.7 STREAMFLOW IMPACTS

Figure 5.37 illustrates the median annual streamflow quotient at a location downstream of the diversion weir on the Flinders River (virtual gauge 943) and near the mouth of the Flinders River (915003A). For all combinations of scheme area and crop area decision, the median annual streamflow quotient indicates a major change in median annual flow at virtual gauge 943 (0.7 or less). Note however that the impacts are likely to be exaggerated as the model overestimates the diversions that can occur from Flinders river. Very little change occurs at the mouth of the Flinders River however (gauge 915003A).

For the 5300 ha development option, monthly average flows are reduced throughout the wet season (Figure 5.38). Additional stream flow metrics for this option are illustrated in Appendix D.

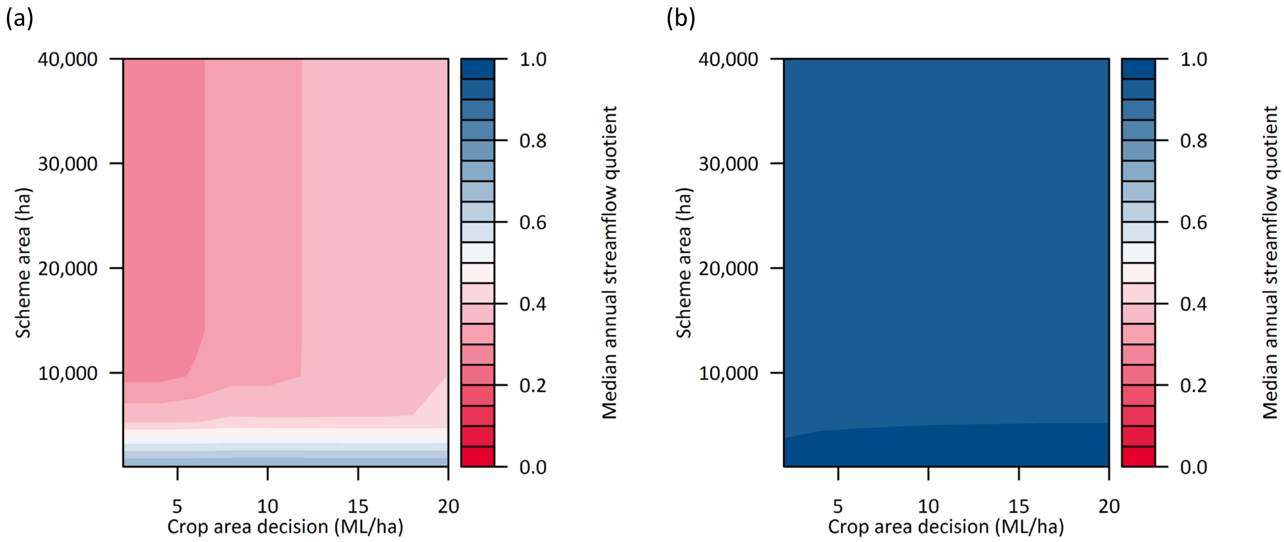
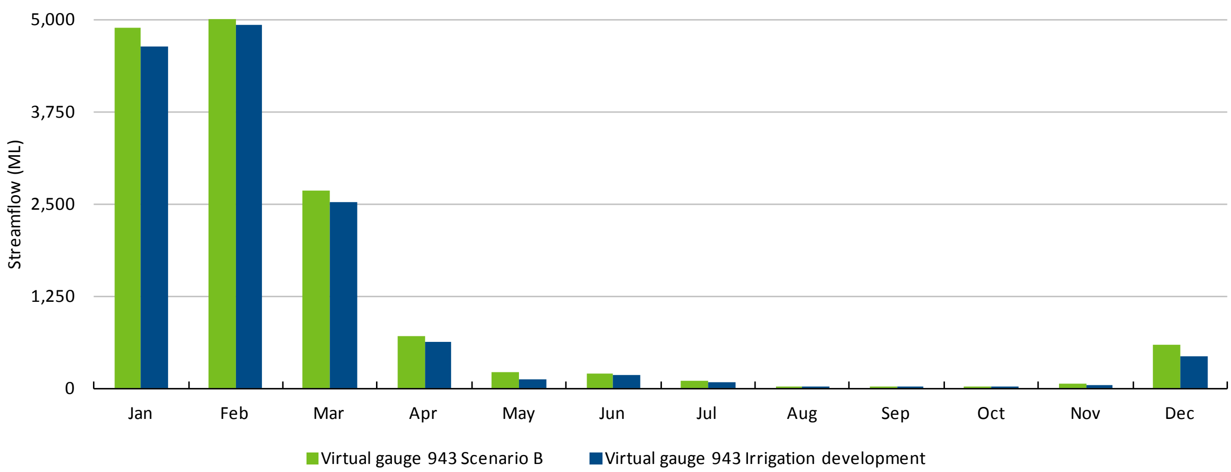


Figure 5.37 Median annual streamflow quotient at (a) dummy gauge 943 and (b) gauge 915003A for the irrigation development associated with the O'Connell creek off-stream storage. Virtual gauge 943 is a node created within the Source river model

Median annual streamflow quotient is the median annual streamflow under Scenario B divided by the median annual streamflow under Scenario A. Scenario A is the historical climate (1890 to 2011) and current development. Scenario B is the historical climate (1890 to 2011) with irrigation development.



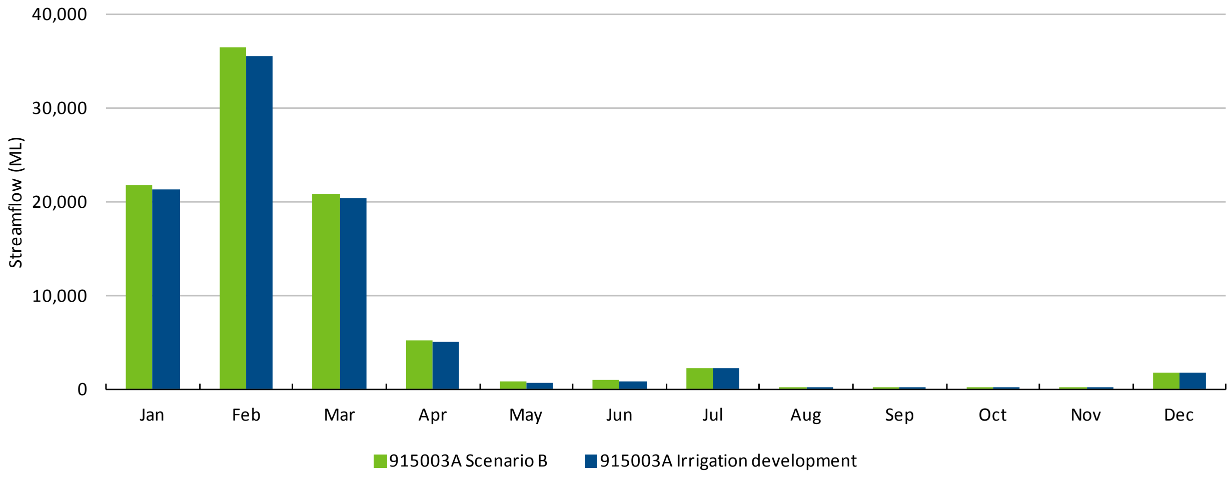


Figure 5.38 Change in monthly average flow for 5300 ha development option

5.4 Kidston Dam

5.4.1 SCHEME CHARACTERISTICS

The existing Kidston dam is a 40 m roller compacted concrete dam located on the Cloncurry River about 70 km upstream of Einasleigh. The Kidston dam has a relatively small storage capacity (25 GL) and yields a modest amount of water. For this reason various options were investigated to supplement the water supplied from the dam. One of these was raising the dam wall by 2m, which would incur modest costs, but increase the water yield from 13 to 17 GL at 85% reliability (Petheram et al., 2013b).

Another option investigated was the construction of a large ring tank (~10,000 ML capacity) on the Copperfield River, near the irrigation development. This would enable water in the Kidston dam to be saved for use during the dry season. It is possible that a ring tank could be sited on the Einasleigh River. While this may provide more water during the wet season than a ring tank on the Copperfield River, it would require more diversion infrastructure and large pumping capacity and would probably provide more water for irrigation than available land. This option was not investigated.

A combination of raising the dam wall and water harvesting with a small amount of on farm storage (100ML) was also investigated.

These options were considered in combination resulting in six options:

1. Raising the dam, no water harvesting
2. Raising the dam, water harvesting with 100ML storage
3. Raising the dam, water harvesting with 10,000ML storage
4. Existing dam, no water harvesting
5. Existing dam, water harvesting with 100ML storage
6. Existing dam, water harvesting with 10,000ML storage

Of the six options investigated number 5 was the most profitable. This option uses water from the existing dam and water harvesting (from runoff generated between the dam and the irrigation area) during the wet season for direct application to the forage crop. This option is reported in this case study.

The modelling of water harvesting is based on residual inflows below Kidston. Given the lack of available data to verify these inflows, Section 5.4.2 provides some further detail regarding the calibration on this reach and hence provides comment on the reliability of the modelled residuals.

The parameters relating to the existing dam are detailed in Table 5.19 and the relationship between water depth, volume and area is presented in Figure 5.39. Note that the dead storage defined in the IQQM model has been retained in this assessment.

Table 5.19 Kidston Dam parameters

DAM NAME	CATCHMENT AREA (km^2)	HEIGHT (m)	CAPACITY (GL)	FULL SUPPLY LEVEL (m)	DEAD STORAGE (GL)	SEEPAGE (MM/DAY)
Kidston (existing)	1244	40	20	586	1.93	0
Kidston (raised 2m)	1244	42	25	588	1.93	0

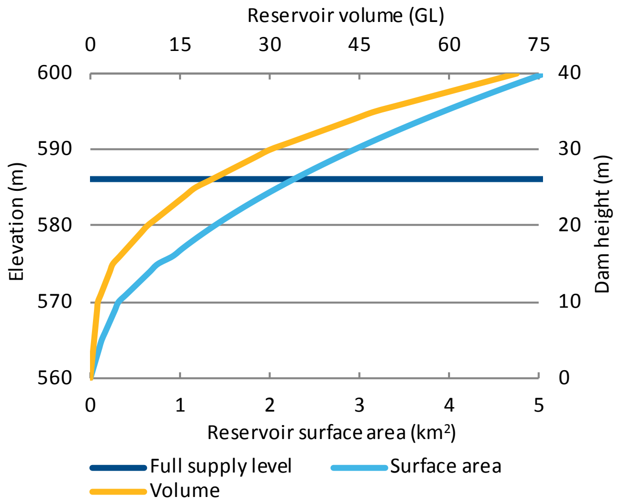


Figure 5.39 Storage volume area relationship – Kidston

Under this configuration water would be released from the Kidston dam to a series of weir re-regulating structures upstream of the town of Einasleigh. Given that these would be relatively small pumping pools, it was considered unnecessary to include them in the Source model.

It is assumed that irrigation water is distributed within a farm (i.e. from the farm gate to the field) using open channels. Once at the field, water is applied using spray irrigation, more specifically lateral move sprinklers. Lateral move sprinklers are used to optimise irrigation productivity from the limited water supply and minimise accessions to groundwater that have the potential to cause secondary salinity problems in the area. Well managed spray irrigation generates very little tailwater runoff (i.e. water leaving the field following an irrigation event), except during large rainfall events which occur immediately after irrigation on full soil profiles. In this case study area, irrigation occurs during the dry season, and it is assumed that there is no need for on-farm tailwater recycling and on-farm water storages. Runoff generated from heavy rainfall events during the wet season would be directed back into the river system.

Kidston storage evaporation and seepage losses are modelled explicitly in Source. Table 5.20 lists the conveyance efficiency assumptions used in this analysis. In total, the conveyance and application efficiency from the storage to the crop is about 56%.

Table 5.20 Conveyance efficiencies for the irrigation scheme associated with the Kidston dam

COMPONENT	EFFICENCY	COMMENT
River conveyance efficiency	75%	Distance between dam and re-regulating structure is about 70 km.
Channel distribution efficiency	90%	Representative of evaporation loss from re-regulation structure and channel loss between river and farm gate
Evaporation and seepage estimate from on farm storage	Variable depending on case study	Note that Source models this component explicitly hence this factor is not applied in Source.
On-farm distribution efficiency	97%	Representative of on-farm evaporation and seepage loss from farm gate to edge of field
Field application efficiency (spray)	85%	Lateral moving sprinklers
Overall efficiency	56%	

5.4.2 RESIDUAL INFLOWS BELOW KIDSTON

The modelling of water harvesting below Kidston Dam is based on use of residual inflows estimated in the calibration model. This estimation was based on rainfall runoff modelling from an uncalibrated model. Hence, a review of the calibration of this reach is provided here such that some comment can be made about the reliability of the residual inflow estimate.

The calibration results reported in Lerat et. al. (2013) relate to the performance of the fully assembled model. The calibration was actually conducted for each reach in isolation using gauged upstream inflow data. The calibration results achieved at the reach level are the best indication of how reliably the residual inflows have been estimated. The relevant reach spans from Copperfield River at Kidston Dam to Einasleigh River at Einasleigh. It also includes the Einasleigh from McKinnon's Creek gauge 917108. This reach had a very good calibration result as indicated through the following statistics:

- Daily r^2 = 0.87;
- Monthly r^2 = 0.96;
- Bias = 0.98.

The calibration of this reach is complicated however by the fact that it includes residual inflow estimates for both the Copperfield River and the Einasleigh River. Hence it is possible that there is some interplay between these estimates. Despite this, it was concluded that the residual inflow estimate was reasonably reliable. This is supported by the fact that the residual area below Kidston is relatively large and that the residual inflow estimate is based on actual climate data for the region (i.e. through the rainfall runoff model).

5.4.3 CROPPING SYSTEMS

This case study included an assessment of Bambatsi as detailed in Table 5.21 and Table 5.22. See Section 3.4.2 for parameter definitions. A daily pattern has been defined for the crop factor (see Appendix C). There is no planting decision as the crop is a perennial.

Table 5.21 Characteristics of crops used in Kidston Dam Case Study

Crop	Planting date	Maximum planted area sensitivity testing (Ha)	Planting decision sensitivity testing (ML/ha)	Depth of roots (mm)	Target soil depletion (mm)
Bambatsi	Perennial	200 – 10,000	N/A	2500	111

Table 5.22 Other crop model parameters used for the Kidston Dam Case Study

PARAMETER	VALUE
Soil moisture Capacity (%)	9
Fallow depth (mm)	300
Fallow Depletion factor (%)	100
Crop Depletion factor (%)	50
Soil description	Sandy-loam_180PAWC

APSIM was run for a number of different water supply scenarios using historical environmental data to generate a relationship with crop yield (Figure 5.40). These results are modelled production potential under optimum management hence represent an upper limit. Note that the relationship is relatively linear.

A regression model was developed however it was not sufficiently reliable for use. Regression models for perennial systems were unreliable as they did not take into account the effect of climate in previous years on the current year's biomass. For this case study all yields reported are based on APSIM derivation rather than from a regression model hence the regression model results are not presented.

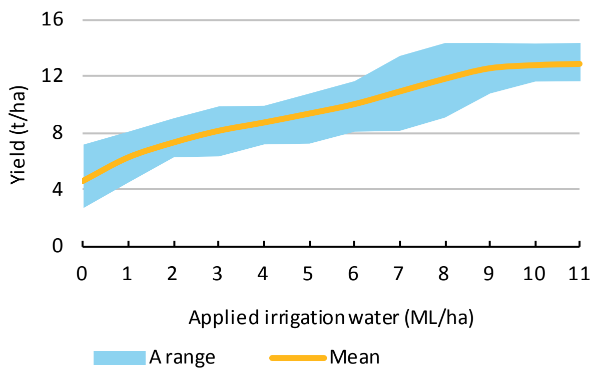


Figure 5.40 APSIM Yield Results

5.4.4 RESOURCE ASSESSMENT SYSTEM

An annual allocation and accounting system has been defined in Source. This system has been configured differently for the Impact and No Impact scenarios. Whilst for other scenarios the Impact scenario ignored existing entitlements, this was not considered suitable for the Kidston case study as there are existing users of the dam. At present there is one existing entitlement of 4,650ML. There is also an unofficial arrangement whereby releases to supplement other downstream users on the Einasleigh River. The Department of

Energy and Water Supply QLD (Pers. comm., 29 August 2013) advise that approximately 3,000ML of water is released each October for use by local farmers and the Etheridge Shire council and that additional releases have occurred at other times during extended dry conditions.

The Impact scenario therefore reserves 7650ML of water for use by the existing entitlement and the October release. This might be considered a bare minimum for meeting existing commitments. It does not account for storage losses or additional releases required in months other than October. In addition, it does not necessarily achieve the required reliability with which this annual volume can be supplied.

For the No Impact case, the reserve has been increased such that the October release rule can be achieved with high reliability and that there is negligible impact on the existing user in comparison to the baseline model. In this scenario, 13,000ML has been reserved for the existing users.

In both cases, a minimum flow requirement rule of 100ML/d has been defined for the month of October. In practise, there may be a requirement to reserve greater volumes of water to enable releases in other months during extended dry periods however this has not been evaluated.

5.4.5 AREA AND PLANTING DECISION OPTIMISATION RESULTS

Existing dam, water harvesting with 100ML storage

Total crop yields from a scheme area are highest for larger scheme areas (Figure 5.41a). This is because in the years the reservoir is full or nearly full, the planted area is less constrained by the scheme area. However, the variability in the 30-year crop yields is high at large scheme areas (Figure 5.41b).

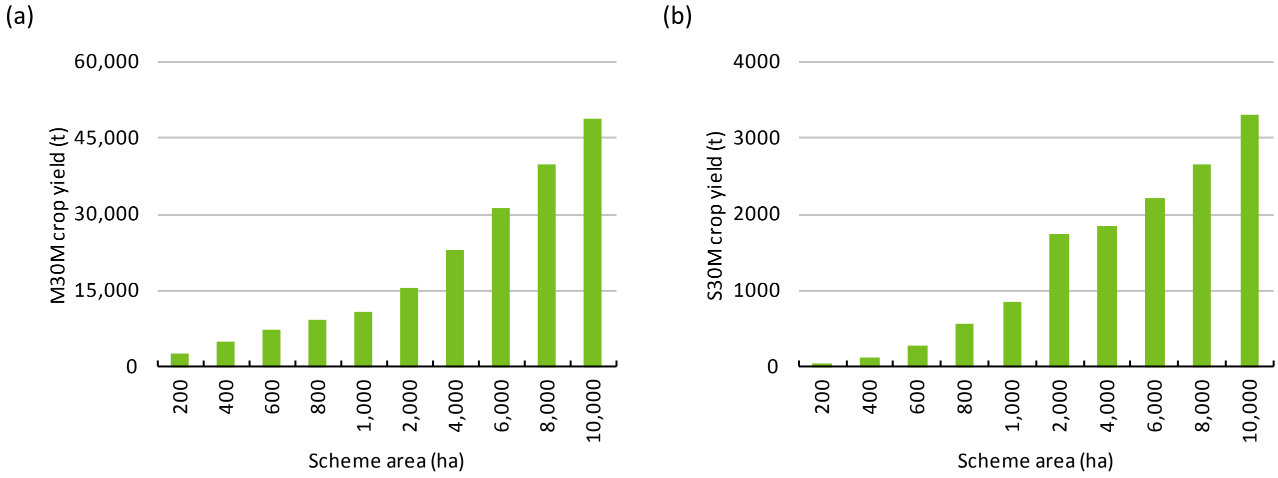


Figure 5.41 (a) Median of the 30-year mean values (M30M) for crop yield and (b) standard deviation of the 30-year mean values (S30M) for crop yield, under Scenario B for the irrigation development associated with the Kidston Dam

Scenario B is the historical climate (1890 to 2011) with irrigation development. Median values are calculated for 30-year windows within the period from 1890 to 2011. Both the median and the standard deviation of the mean values for each of the 92 windows are presented.

The higher crop yields and higher variability for larger scheme areas is illustrated in Figure 5.42. Although the 400 ha scheme area has the lowest total crop yield, there is always sufficient water in the dam to ensure there is not a complete crop failure. An irrigation development with a 6000 ha scheme area will result in a less reliable system.

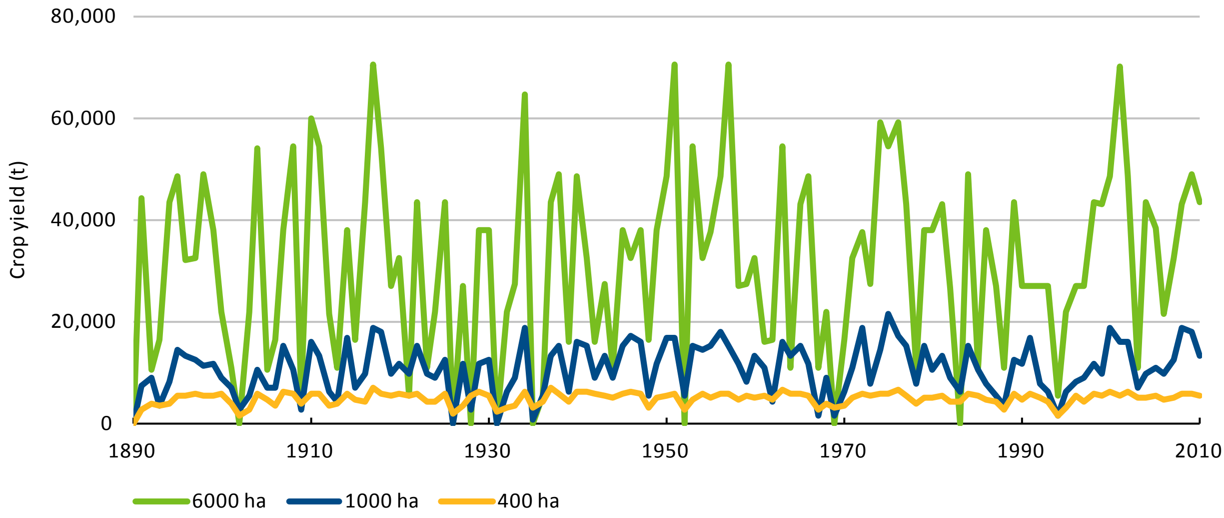


Figure 5.42 Crop yield from the total scheme area under Scenario B for thw2ree different scheme areas

The crop yield per hectare planted (specific yield) decreases with increasing scheme area, because Rhodes grass is more often under water stress resulting in lower yields per hectare (Figure 5.43a). The variability in specific yield is highest for scheme areas of 1000 and 2000 ha (Figure 5.43b). This is because at smaller areas sufficient water is supplied in most years and at larger areas, even when the Kidston Dam is full, the crop yields are severely reduced due to water stress.

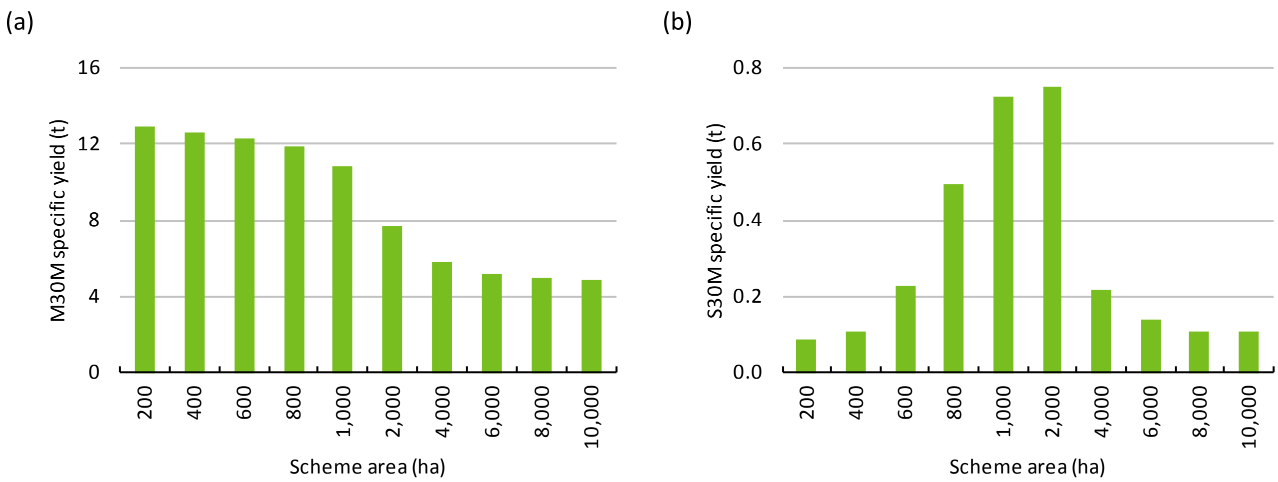


Figure 5.43 (a) Median of the 30-year mean values (M30M) for specific yield and (b) standard deviation of the 30-year mean values (S30M) for specific yield under Scenario B for the irrigation development associated with the Kidston Dam

Specific yield is crop yield per hectare planted. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows within the period from 1890 to 2011. The median of the mean values for each of the 92 windows are presented.

The larger the scheme area, the larger the total volume of water supplied to and used by the irrigation development, up until about 2000 ha (Figure 5.44a). Thereafter the mean applied irrigation water does not increase above 7,500 ML. Figure 5.44b shows that mean applied irrigation water per hectare decreases with increasing scheme area.

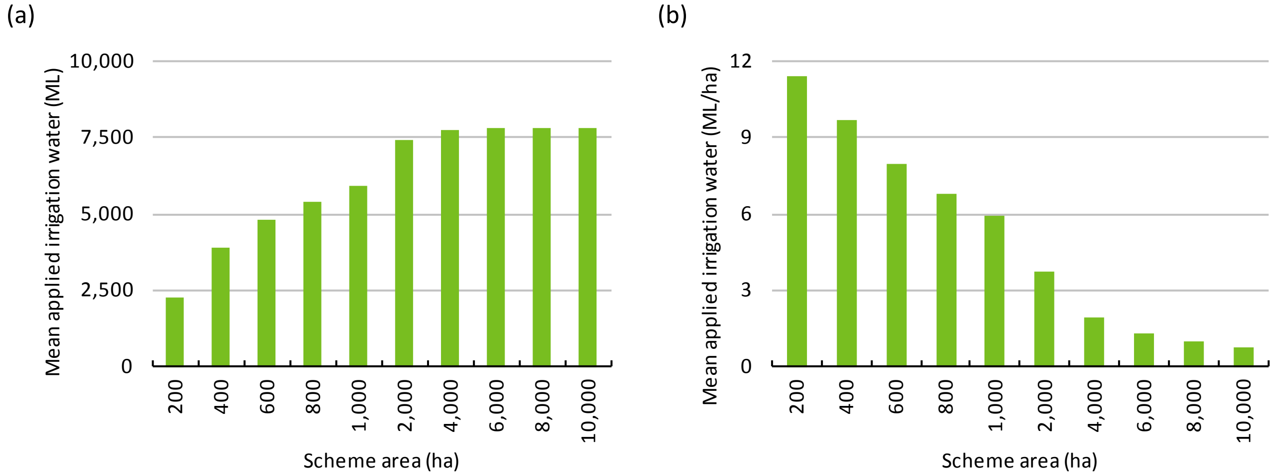


Figure 5.44 Mean annual applied irrigation water supplied to the field in (a) ML and (b) ML/ha equivalent, under Scenario B for the irrigation development associated with the Kidston Dam
Applied irrigation water is the water supplied from the dam, with the losses from river conveyance, channel distribution and field application removed. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Conclusion regarding the option selected for further investigation

Based on the economic analysis of all options (Petheram et al., 2013b) a scheme area of 1,000 ha was selected for further investigation. In this scenario, the scheme area is supplied with water from the existing dam and water harvesting (from runoff generated between the dam and the irrigation area) during the wet season for direct application to the forage crop. The scenario assumes a minor amount of on farm storage (100ML total). The use of water in Kidston is based on stored water in excess of that assessed to be required for existing users. Further results relating to this option are presented in the following sections.

5.4.6 RELIABILITY OF SUPPLY

For the 1,000 ha option, extractions due to water harvesting are larger than extractions due to regulated supply from Kidston (Figure 5.45). Total extractions are significantly increased under “Impact” assumptions (Figure 5.46). Note that there may be in practise less water available from Kidston than depicted under the ‘No Impact’ scenario as the requirements for existing users are not clear.

The option of adding a large on farm storage would significantly increase the volume of water harvesting that could occur (Figure 5.47). A larger storage increases the reliability, with which 10GL/yr can be extracted from the river for later use, from 10% to approximately 90%.

If Kidston was raised 2m this would increase the maximum annual water available from 7.5GL/yr to 12.5GL/yr as illustrated in Figure 5.48.

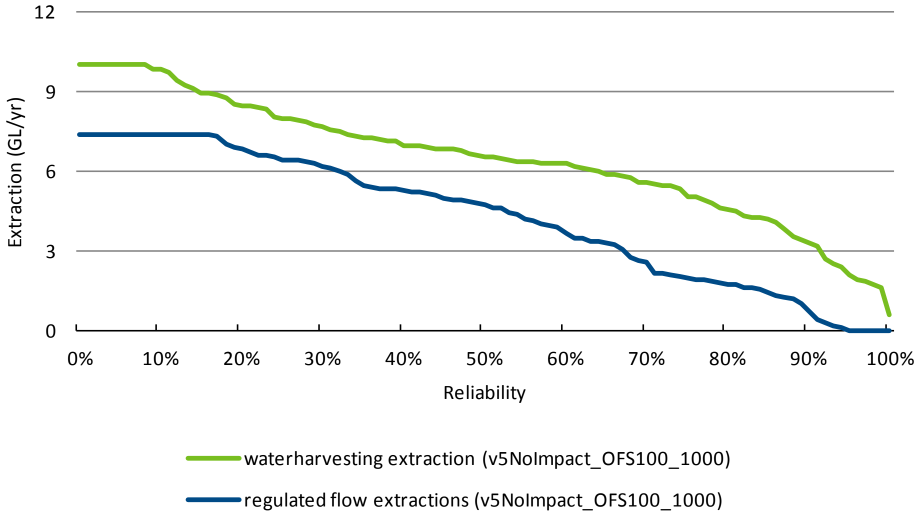


Figure 5.45 Comparison of volume extracted from water harvesting (green) and from regulated supply from Kidston (blue). (1,000 ha option, No Impact scenario).

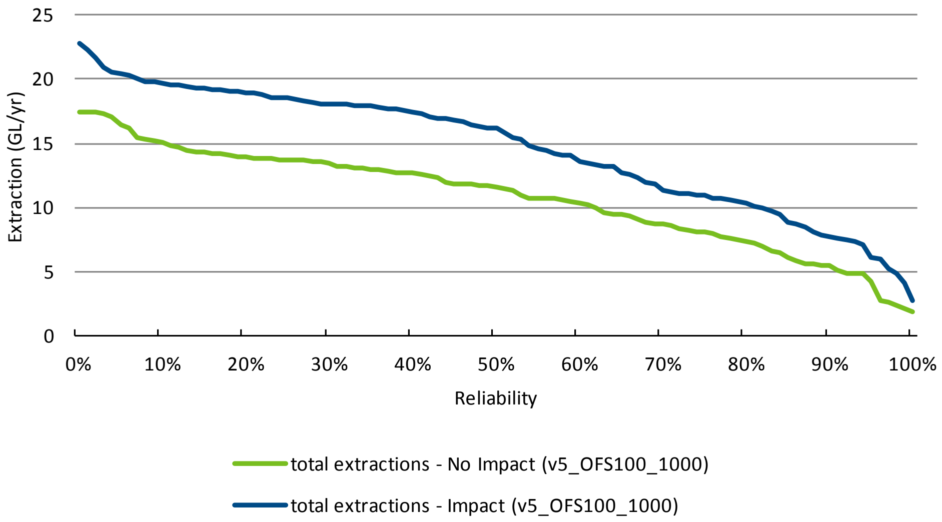


Figure 5.46 Total annual extraction volume – Comparison of Impact (blue) and No Impact (green) scenarios for the 1,000 ha option.

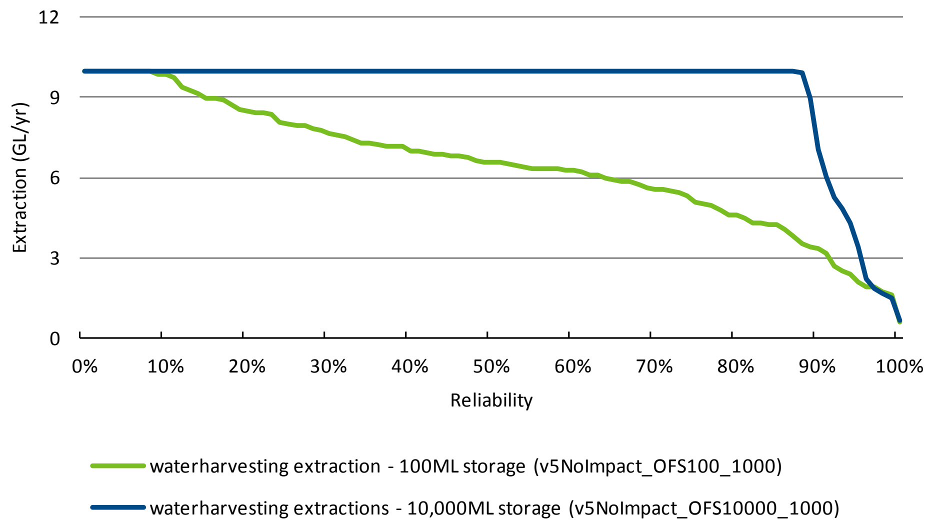


Figure 5.47 Annual extraction from water harvesting: comparison of options with small (green) and large (blue) on farm storage scenarios.

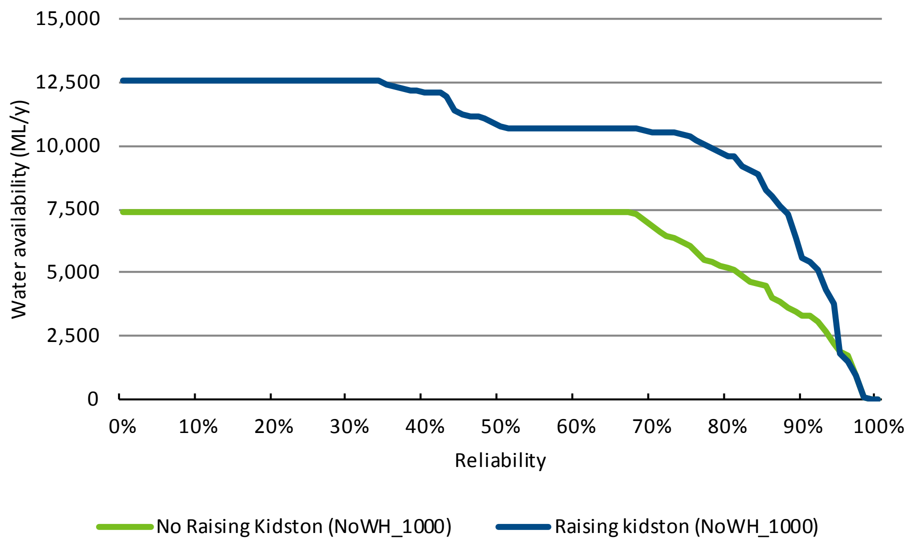


Figure 5.48 Maximum annual available water in Kidston: comparison of with (blue) and without (green) raising of the dam wall. Both scenarios are for 1000ha with no water harvesting under No Impact assumptions.
Available volume refers volume allocated to the new scheme in the resource assessment system hence accounts for dead storage and reserves required for other users. It does not account for storage operation and delivery losses however so the results are an overestimate.

5.4.7 IMPACTS ON EXISTING ENTITLEMENTS

The 1,000 ha option results in a relatively small (3%) reduction in average annual diversions for the downstream entitlement holders. There do not appear to be any impacts in long term average diversions resulting from the use of off-allocation water. Note that the impacts that would occur during any one season may be greater than the long term average.

5.4.8 STREAMFLOW IMPACTS

Figure 5.49 illustrates the median annual streamflow quotient at a streamflow gauge below both the dam and the irrigation development (917106A) and near the mouth of the Gilbert River (917009A). This provides an indication of the extent to which the median annual streamflow would change under irrigation development for different combinations of scheme area and crop area decision. For all scheme areas only a small change in the flow regime occurs at gauge 917106A, and effectively no change occurs at the lowest gauge on the Gilbert River (917009A). The reason there is very little change is that the Kidston Dam was an existing dam and under this case study the only thing that changes is its operation.

There is very little change in monthly average flows for the selected 1,000ha option (Figure 5.50). Additional stream flow metrics are illustrated in Appendix D for the option of 4000ha.

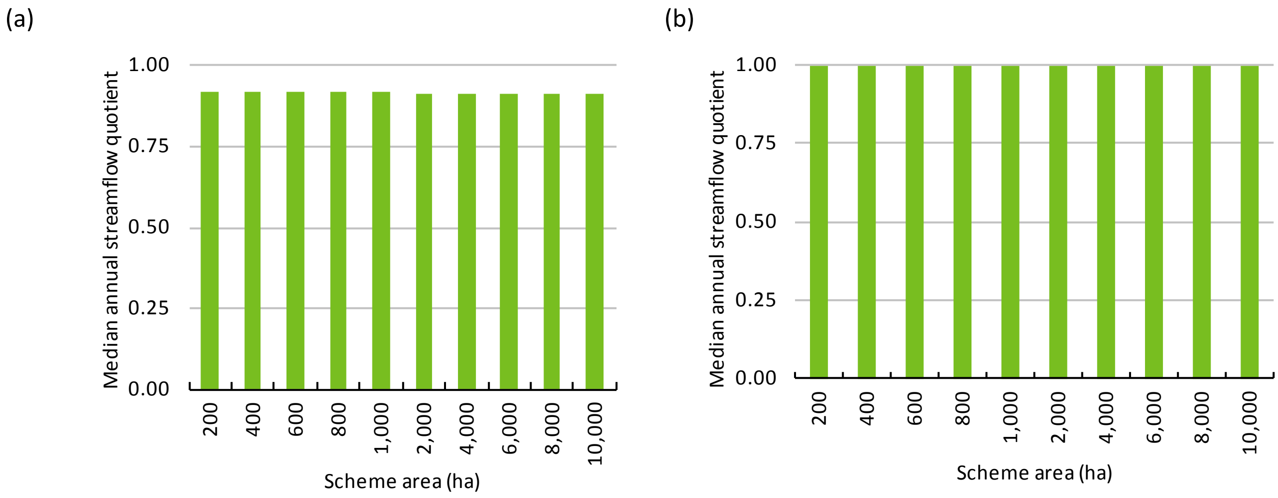
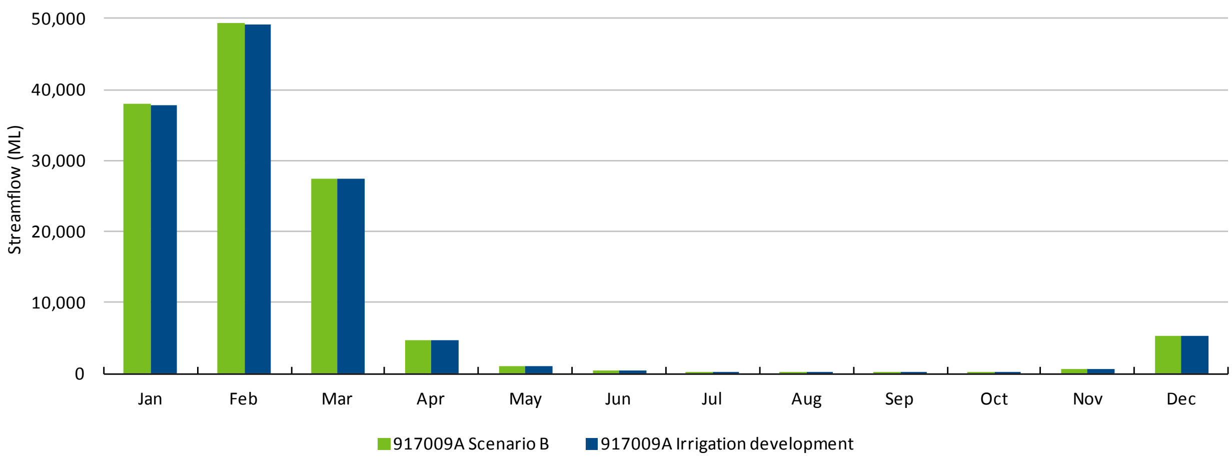


Figure 5.49 Median streamflow quotient at (a) gauge 917106A and (b) gauge 917009A under or the irrigation development associated with the Kidston Dam

Median streamflow quotient is the median annual streamflow under Scenario B divided by the median annual streamflow under Scenario A. Scenario A is the historical climate (1890 to 2011) and current development. Scenario B is the historical climate (1890 to 2011) with irrigation development.



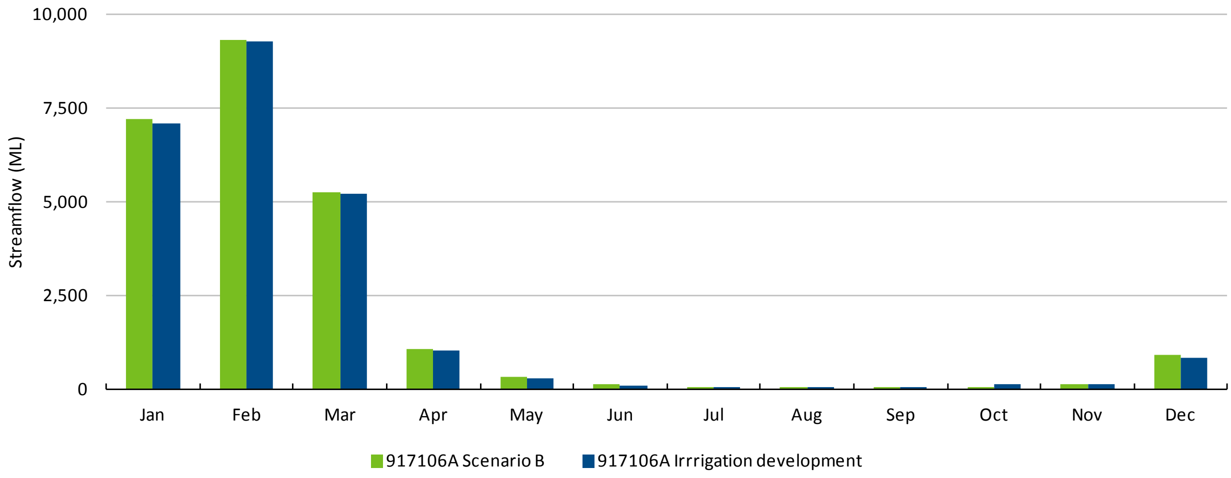


Figure 5.50 Change in monthly average flow for 1,000 ha development option

5.5 Green Hills

5.5.1 SCHEME CHARACTERISTICS

The potential Green Hills dam is a 20m high roller compacted concrete dam located on the Gilbert River. The key dam parameters are summarised in Table 5.23 and the relationship between water depth, volume and area is presented in Figure 5.51. The scheme configuration is the same as that for the Dagworth-Green Hills case study as detailed. See Section 5.6.1 for further detail.

Table 5.23 Green Hills dam parameters

DAM NAME	CATCHMENT AREA (km^2)	HEIGHT (m)	CAPACITY (GL)	FULL SUPPLY LEVEL (m)	DEAD STORAGE (ML)	SEEPAGE (MM/DAY)
Green Hills	8310	20	227	254	4,544	0

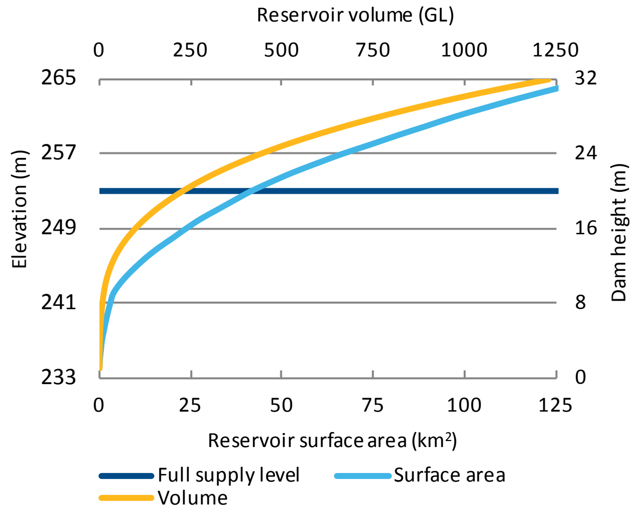


Figure 5.51 Storage volume area relationship – Green Hills

Table 5.24 lists the conveyance efficiency assumptions used in this analysis. In total, the conveyance and application efficiency from the storage to the crop is about 68%. Note that on an optimistic farm distribution efficiency has been evaluated as it has been assumed that there is no on farm storage.

Table 5.24 Conveyance efficiency assumptions for the irrigation scheme associated with the Green Hills dam

COMPONENT	EFFICENCY	COMMENT
River conveyance efficiency	85%	Distance between dam and sheet piling re-regulating structure is about 15 km.
Channel distribution efficiency	95%	Representative of evaporation loss from re-regulation structure and channel loss between river and farm gate. Channel is lined due to sandy soils[1].
Evaporation and seepage estimate from on farm storage	100%	Case study does not include on farm storages
On-farm distribution efficiency	99%	Representative of on-farm evaporation and seepage loss from farm gate to edge of field. Assumed lined channel[1].
Field application efficiency (spray)	85%	Assumed majority of loss goes to deep drainage.
Overall efficiency	68%	

[1] Poorly constructed channels will have lower conveyance efficiency than those values listed in this table.

5.5.2 CROPPING SYSTEMS

This case study assessed a rotational system including cotton, peanuts and forage sorghum. The incorporation of peanuts and fodder into a rotation with cotton complements growing season and integrated pest management requirements (see companion technical report about agricultural production (Webster et al., 2013)).

The parameters relating to each crop are detailed in Table 5.25 and Table 5.26. See Section 3.4.2 for parameter definitions. A daily pattern has been defined for the crop factor (see Appendix C).

The rotation aims to plant equal areas to each crop every year. Half of the planted area is planted each to cotton and peanuts. After cotton is harvested, sorghum is planted in that area.

The planting decision in Source is configured such that the available water is prioritised for cotton and peanut plantings. This case study undertook a sensitivity analysis with respect to the combination of all three crops rather than individually. This included the following:

- Total developed area ranging from 2,000 to 80,000 ha
- A risk factor for scaling the combined planting decision of each crop up and down. This varied from 0.1 to 2. The initial planting decision values are as follows:
  - $mlperhasorghum=3.98 ML/ha (which is subsequently halved in Source)
  - $mlperhapeanut=6.33 ML/ha
  - $mlperhacotton=3.33 ML/ha

Note that all results referring to crop area decision (ML/ha) relate to the sum of all these requirements multiplied by the risk factor. Hence, the lowest risk factor of 0.1 is presented as a requirement of 1.36 ML/ha.

Table 5.25 Characteristics of crops used in Green Hills Case Study

Crop	Planting date	Depth of roots (mm)	Target soil depletion (mm)
Cotton	1/1	2500	111
Peanuts	15/3	967	34
Forage Sorghum	15/8	1660	65

Table 5.26 Other crop model parameters used for the Green Hills Case Study

PARAMETER	VALUE
Soil moisture Capacity (%)	9
Fallow depth (mm)	300
Fallow Depletion factor (%)	100
Crop Depletion factor (%)	50
Soil description	Sandy-Loam

APSIM was run for a number of different water supply scenarios using historical environmental data to generate a relationship with crop yield (Figure 5.52). This data was then used to train statistical models to predict crop yield. These results are modelled production potential under optimum management hence represent an upper limit.

Maximum yields of January-planted cotton (>7.5 bales/ha) require a median of irrigation application of 3 ML/ha, and yield reductions are more or less linear with decreasing irrigation below that maximum. The median irrigation requirement is low because the crop is grown largely during the wet season and has access to post-wet season stored soil water. For peanuts sown in March-April, yield response to water application is more or less linear because there is a low probability of in-season rainfall or access to significant stored soil moisture. The response of sorghum (forage) to water application is curvilinear because, like cotton, it will rely on irrigation for only the dry (August- perhaps November) period of its (August-March) growing window. For each crop, the slope of the rising part of the curve provides an insight

into the relative response of the crop to irrigation, and could be used to help guide decisions about which crops and which areas of crop should preferentially receive irrigation water in the event that it is limiting.

There is some scatter between the regression model and APSIM yield results (Figure 5.29).

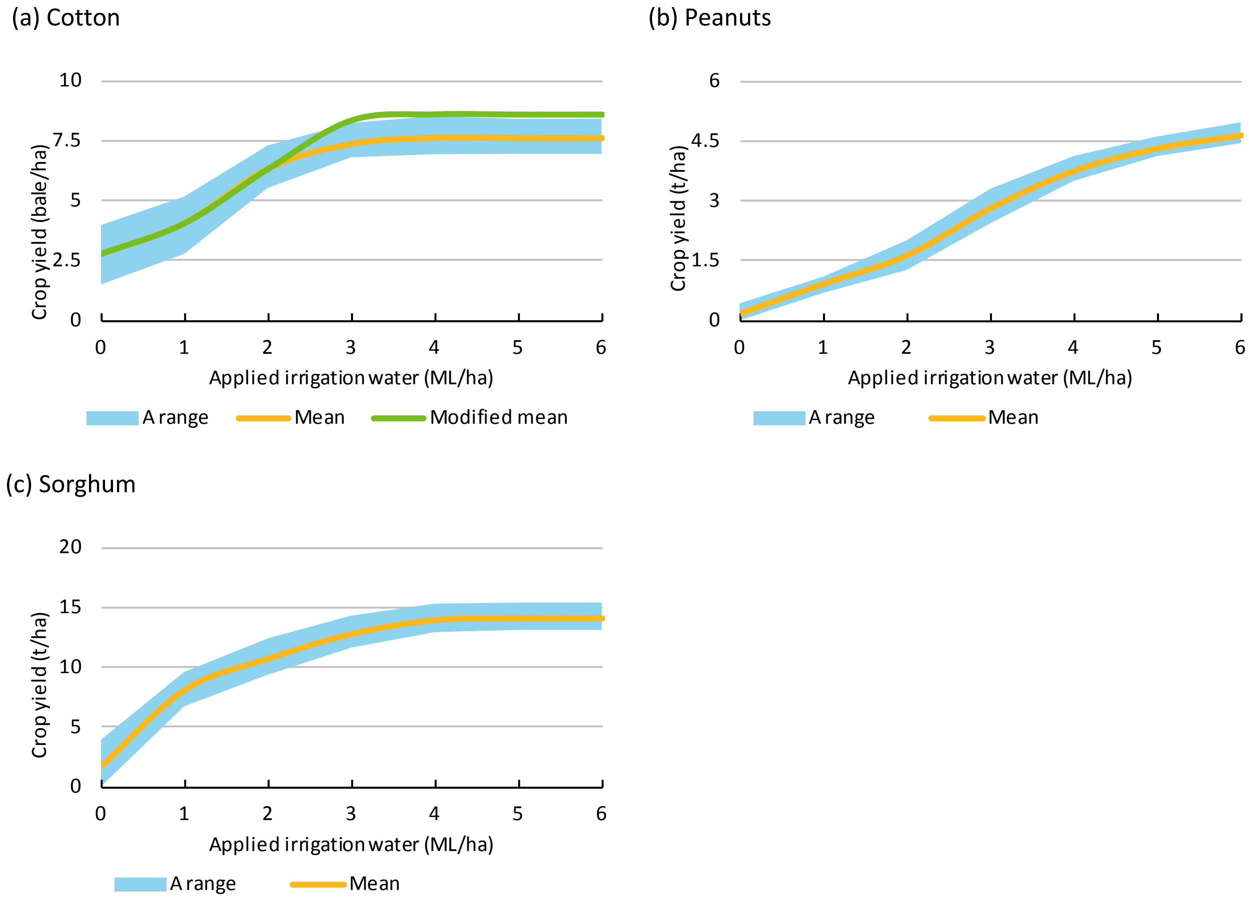


Figure 5.52 APSIM Yield Results

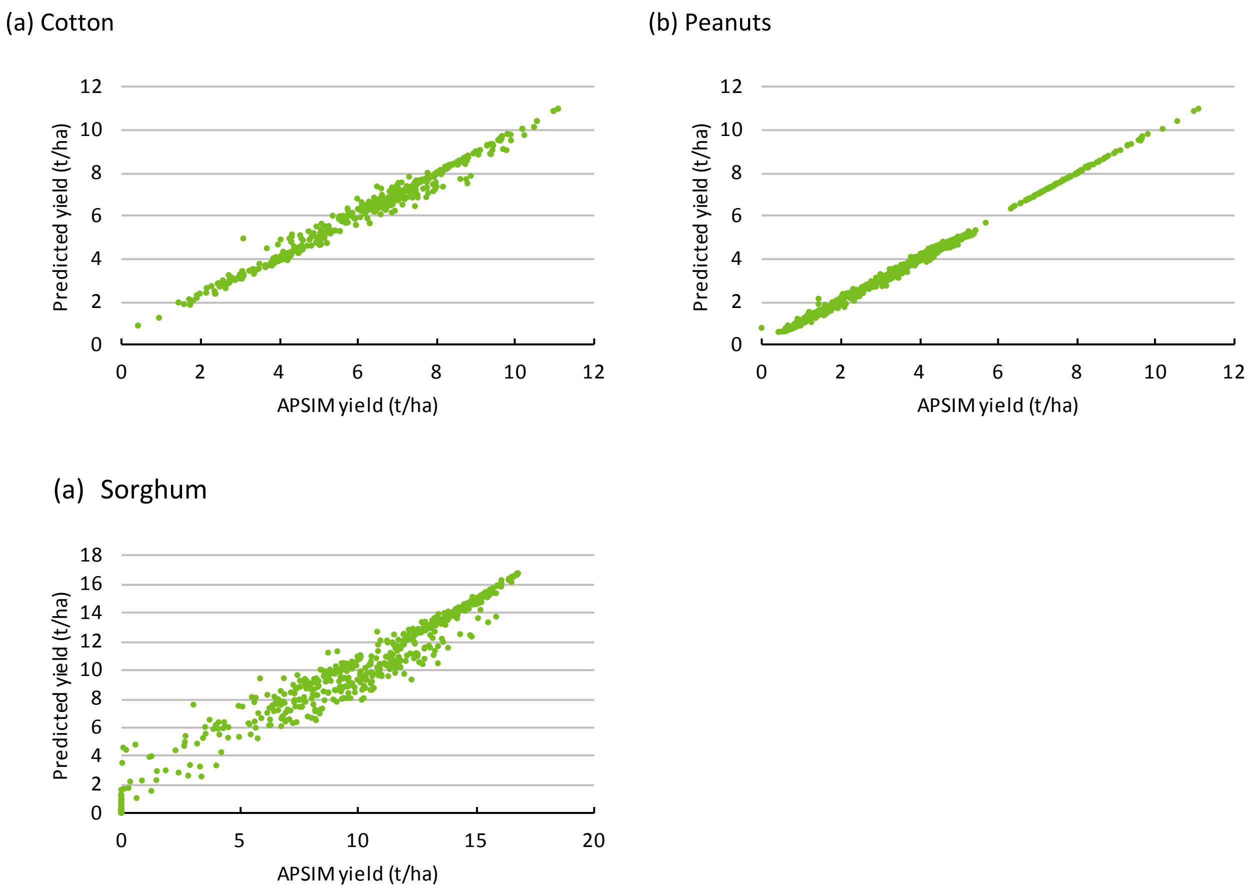


Figure 5.53 Comparison of APSIM and regression predicted specific yield

5.5.3 RESOURCE ASSESSMENT SYSTEM

An annual allocation and accounting system has been defined in Source. This system has been configured differently for the Impact and No Impact scenarios.

For the Impact scenario, downstream existing entitlements are ignored and Green Hills is allocated 100% to the new irrigation area.

The ‘No Impact’ scenario has been evaluated assuming that impacted users are supplied with water from Green Hills dam. A time series of extractions was generated for existing water harvesters using the baseline model. This time series was used to reserve water in the storage prior to allocating to the new irrigation area.

5.5.4 AREA AND PLANTING DECISION OPTIMISATION RESULTS (LH + MK AND SP GRAPHS)

Note: Please note that the planting decision reported in the following graphs relates to the available volume in storage at the time of planting multiplied by the efficiency factor of 0.68. Hence to convert into a relationship between volume in storage and area planted all crop area decisions should be divided by 0.68. Note also that the volume relates to the total for all three crops hence a crop area decision of 5ML/ha means that only 5ML/ha has been reserved for the entire scheme area.

Exploratory analysis

Larger scheme-scale crop yields are attained for larger scheme areas and higher levels of risk (i.e. smaller crop area decisions or less water allocated per ha of crop). This is because in the years the reservoir is full or nearly full, the planted area is less constrained by the scheme area. It also occurs because reducing water to the sorghum crop for example by 50% (from the 4 ML/ha full median requirement to 2 ML/ha) reduces the crop yield by 25% (Figure 5.52). In Figure 5.54 b and d, it can be seen that cotton and peanuts are rarely water stressed for scheme areas of about 12,000 ha and 10,000 ha respectively. Sorghum, however, is water stressed for most scheme areas and crop area decision combinations as yields per hectare are approximately half of the maximum possible (Figure 5.54f).

The larger the scheme area and the lower the crop area decision, the larger the total volume of water supplied to and used by the irrigation development (Figure 5.55a), but the smaller the amount of water applied per hectare of planted area (Figure 5.55b). Figure 5.55 shows that considerably more water is supplied to the cotton and peanut crops and that the sorghum (forage) receives the water that remains.

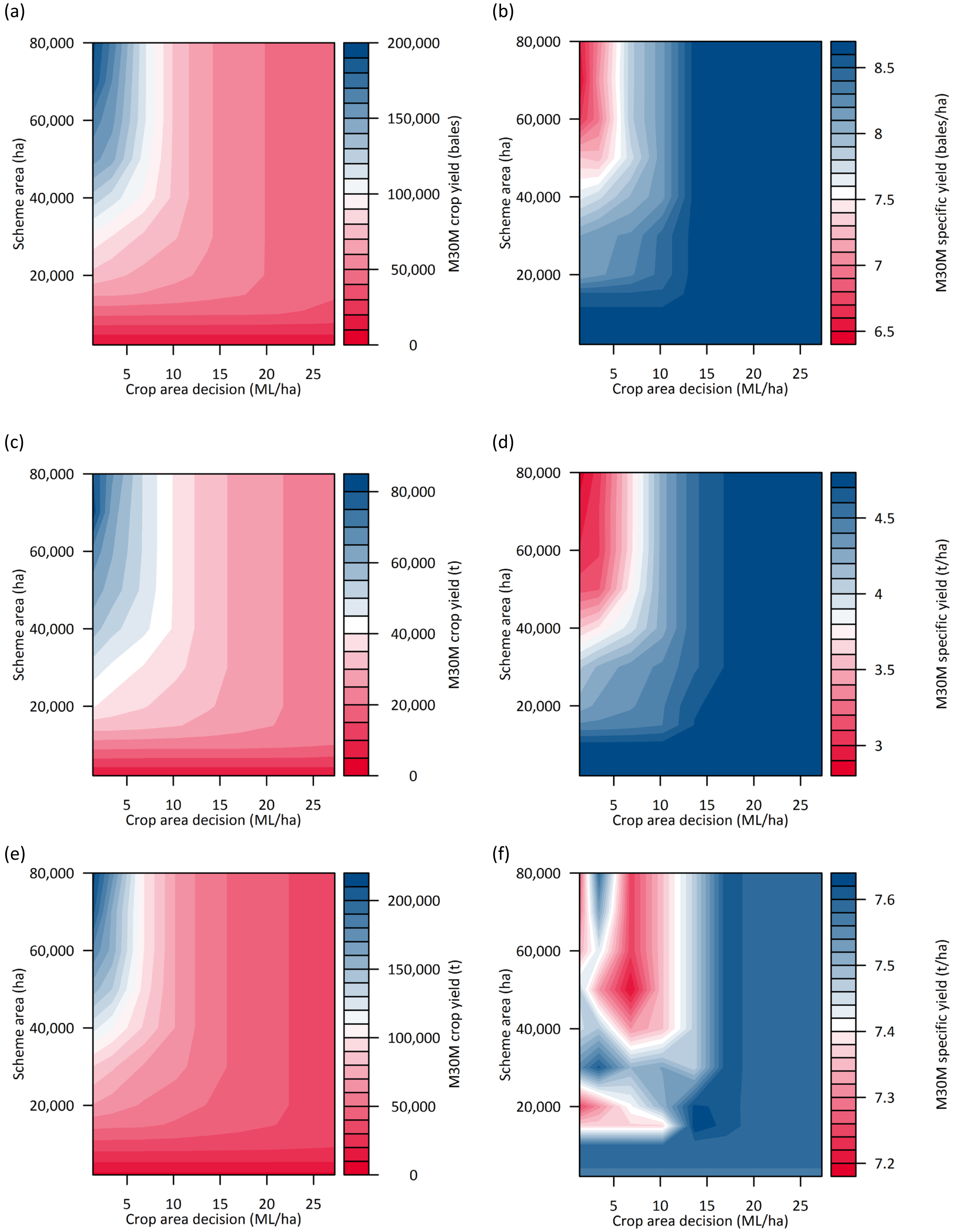
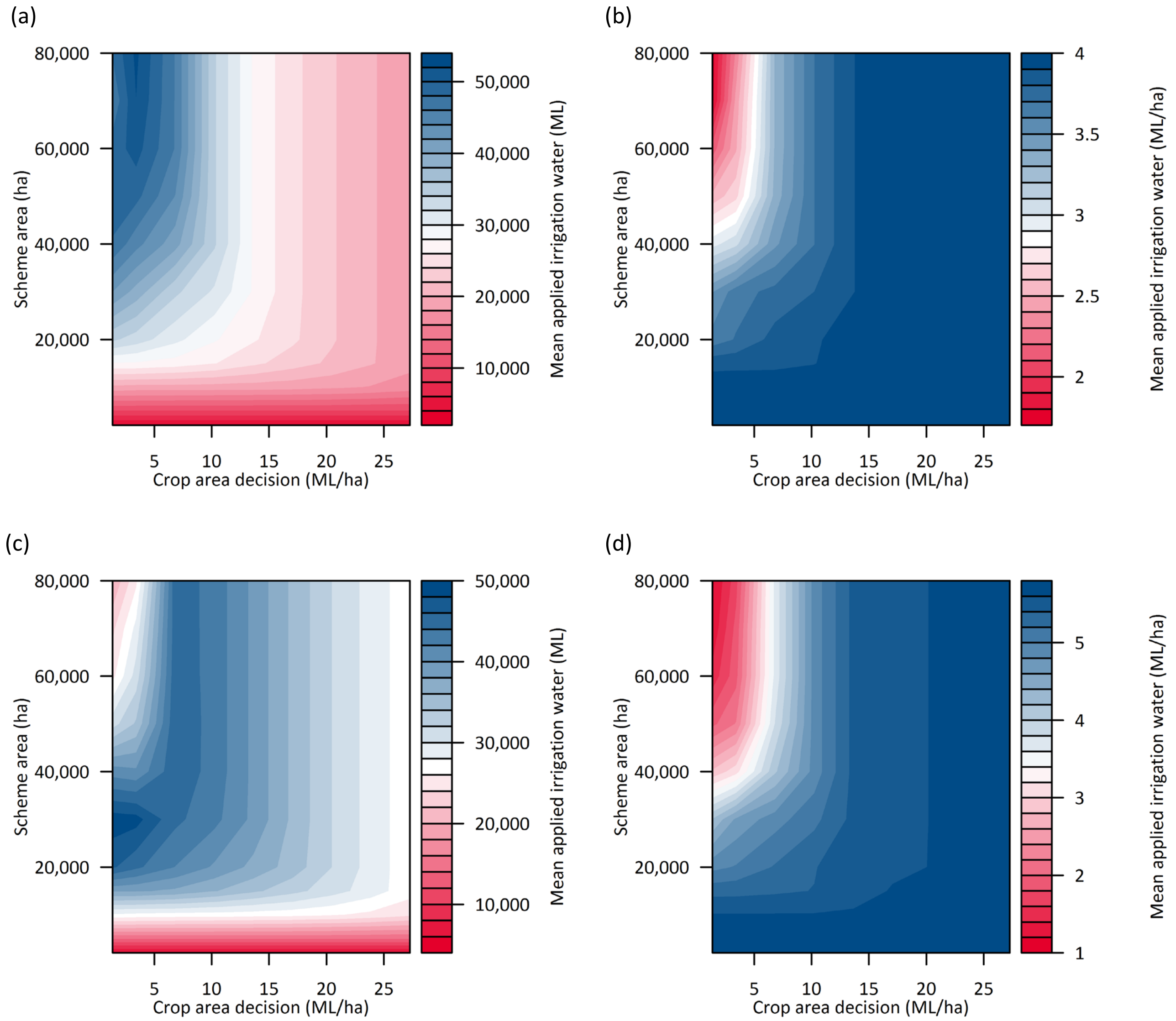


Figure 5.54 (a) Cotton, (c) peanuts and (e) sorghum (forage) median of the 30-year mean values (M30M) for crop yield and (b) cotton, (d) peanuts and (f) sorghum (forage) median of the 30-year mean values (M30M) for specific yield, under Scenario B for the irrigation development associated with the Green Hills dam

Results are presented as a function of scheme area and annual crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows within the period from 1890 to 2011. Both the median and the standard deviation of the mean values for each of the 92 windows are presented.



(a)
80,000
60,000
40,000
20,000
Scheme area (ha)
5
10
15
20
25
Crop area decision (ML/ha)
50,000
40,000
30,000
20,000
10,000
Mean applied irrigation water (ML)
(b)
80,000
60,000
40,000
20,000
Scheme area (ha)
5
10
15
20
25
Crop area decision (ML/ha)
4
3.5
3
2.5
2
Mean applied irrigation water (ML/ha)
(c)
80,000
60,000
40,000
20,000
Scheme area (ha)
5
10
15
20
25
Crop area decision (ML/ha)
50,000
40,000
30,000
20,000
10,000
Mean applied irrigation water (ML)
(d)
80,000
60,000
40,000
20,000
Scheme area (ha)
5
10
15
20
25
Crop area decision (ML/ha)
5
4
3
2
1
Mean applied irrigation water (ML/ha)

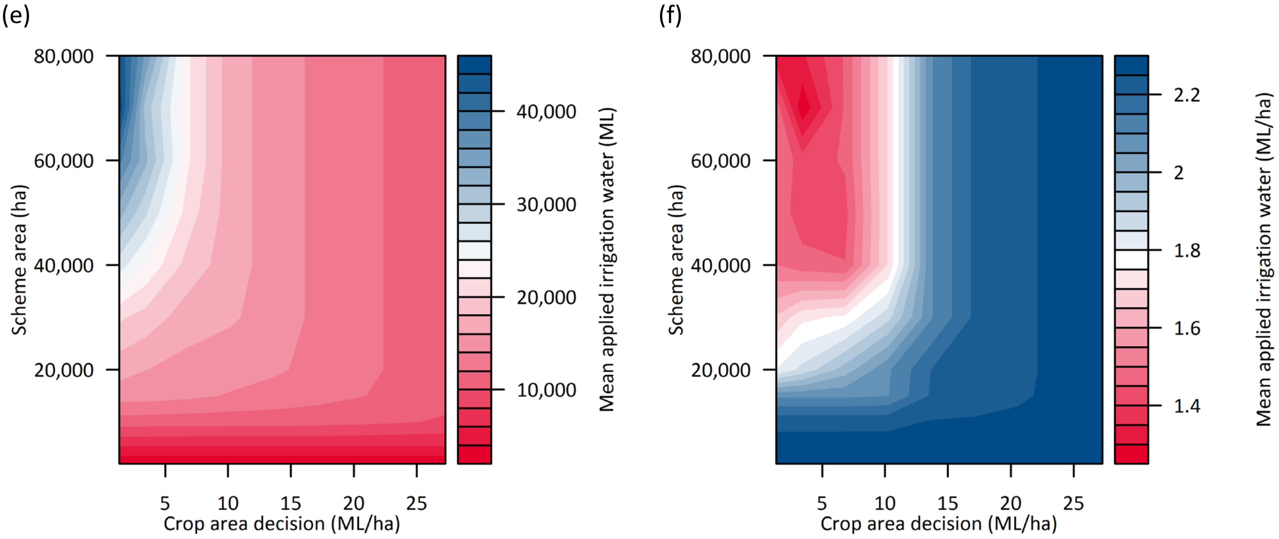


Figure 5.55Mean annual applied irrigation water supplied to the field in (a) cotton, (c) peanuts and (e) sorghum (forage) in ML/ha and (b) cotton, (d) peanuts and (f) sorghum (forage) mm depth equivalent, under Scenario B for the irrigation development associated with the Green Hills dam

Results are presented as a function of scheme area and crop area decision. Applied irrigation water is the water supplied from the dam, with the losses from river conveyance, channel distribution and field application removed. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Figure 5.56 illustrates the percentage of years that the entire scheme area is planted for different scheme area and crop area decision combinations. Lower crop area decisions result in the irrigation development being more fully planted in more years.

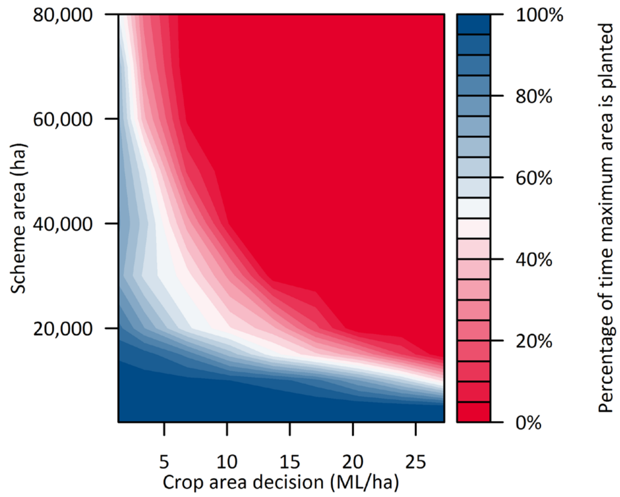


Figure 5.56 Percentage of years that the maximum area is planted, under Scenario B for the irrigation development associated with the Green Hills dam

Results are presented as a function of scheme area and crop area decision. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Conclusion regarding the option selected for further investigation

Based on the economic analysis of all options (Petheram et al., 2013 b) a scheme area of 12,000 ha and a risk factor of 0.25 has been chosen. This means that 0.25 has been multiplied by the sum of all crop requirements:

- $mlperhasorghum=3.98 *0.5 ML/ha (note previously mentioned 50% reduction factor)
- $mlperhapeanut=6.33 ML/ha
- $mlperhacotton=3.33 ML/ha

Hence the total base requirement is 11.65ML/ha. Applying the risk factor, this means that a total crop requirement of 2.9ML has been selected. By dividing by the efficiency factor of 0.68, this means that for every 4.2ML available in the resource assessment account a total of 1 hectare is planted. Half of this hectare is planted each to cotton and peanuts and, later in the season, half to sorghum.

Further results relating to the 32,000ha option are presented in the following sections.

5.5.5 RELIABILITY OF SUPPLY

The reliability of water available from Green Hills is illustrated in Figure 5.57 for both the time of planting cotton (1^{st} Jan) and for maximum available during the water year. Note that there is a significant increase in reliability between the planting date and maximum for the water year.

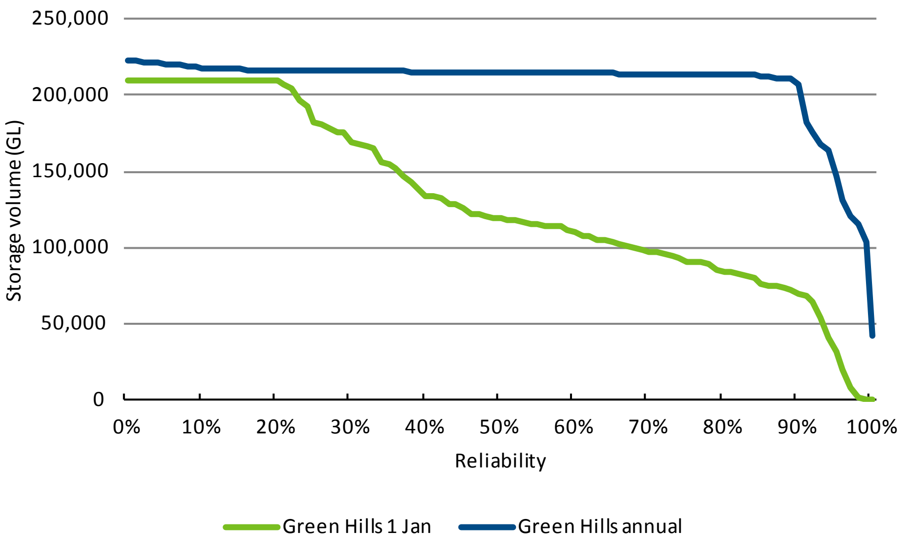


Figure 5.57 Available volume in storage at time of planting (1^{st} Jan) versus maximum annual (No Impact model - 12,000ha option). Available volume refers to the volume in storage above dead storage and above reserves required for other users. It does not account for storage operation and delivery losses however so the results are an overestimate.

5.5.6 IMPACTS ON EXISTING ENTITLEMENTS

The 12,000ha option resulted in some impacts for existing entitlements in comparison to the baseline model. Average annual diversions were reduced by approximately 3% downstream of Green Hills. Note that the impacts that would occur during any one season may be greater than the long term average.

5.5.7 STREAMFLOW IMPACTS

Figure 5.58 illustrates the median annual streamflow quotient at a streamflow gauging station downstream from the Green Hills dam irrigation development (917001D), and downstream of the confluence of the

Gilbert and Einasleigh rivers (917009A). This provides an indication of the extent to which the median annual streamflow may change under irrigation development for different combinations of scheme area and crop area decision. The smaller the number the larger the change in median annual streamflow. For all combinations of scheme area and crop area decision, the median annual streamflow quotient shows that the change in median annual streamflow will be small near the mouth of the Gilbert River. However, the change in median annual streamflow at gauge 917001D ranges from 0.6 to 1, depending on the scheme area and crop area decision. Higher scheme areas and low crop area decisions cause the greatest reduction in median annual streamflow.

For the 12,000ha development option, monthly average flows are reduced, primarily at the start of the wet season in December and January (Figure 5.59). Additional stream flow metrics for this option are illustrated in Appendix D.

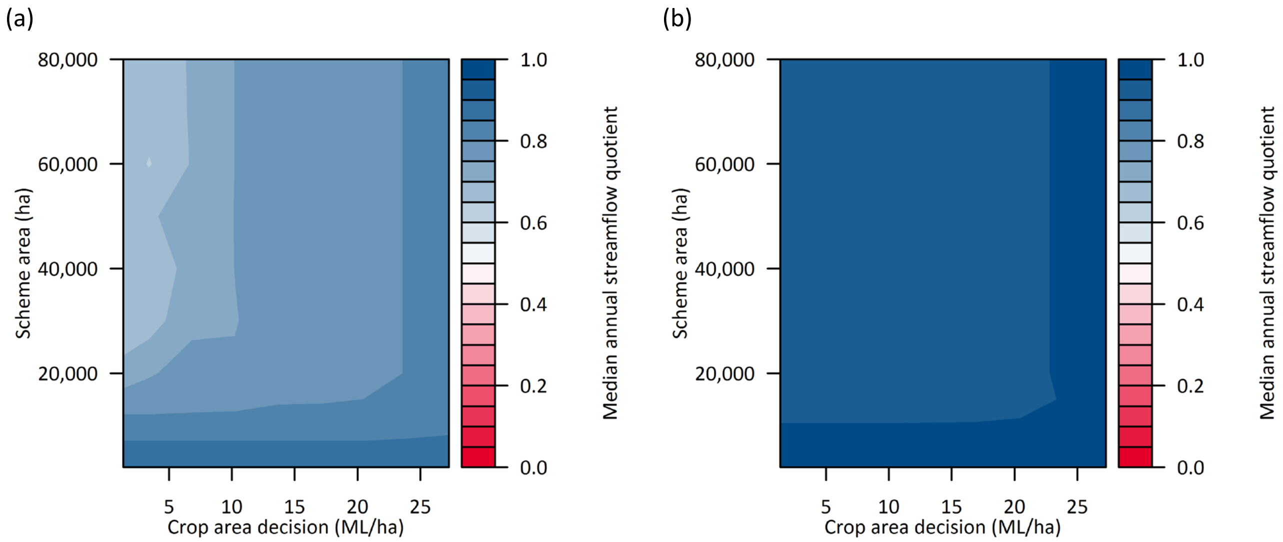
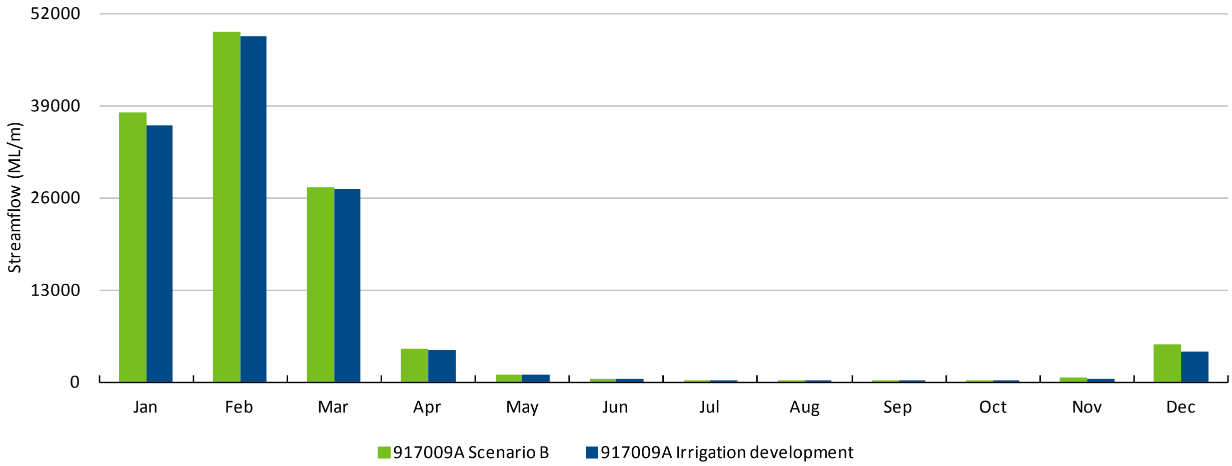


Figure 5.58 Median annual streamflow quotient at (a) gauge 917001D and (b) gauge 917009A for the irrigation development associated with the Green Hills dam

Median annual streamflow quotient is the median annual streamflow under Scenario B divided by the median annual streamflow under Scenario A. Scenario A is the historical climate (1890 to 2011) and current development. Scenario B is the historical climate (1890 to 2011) with irrigation development.



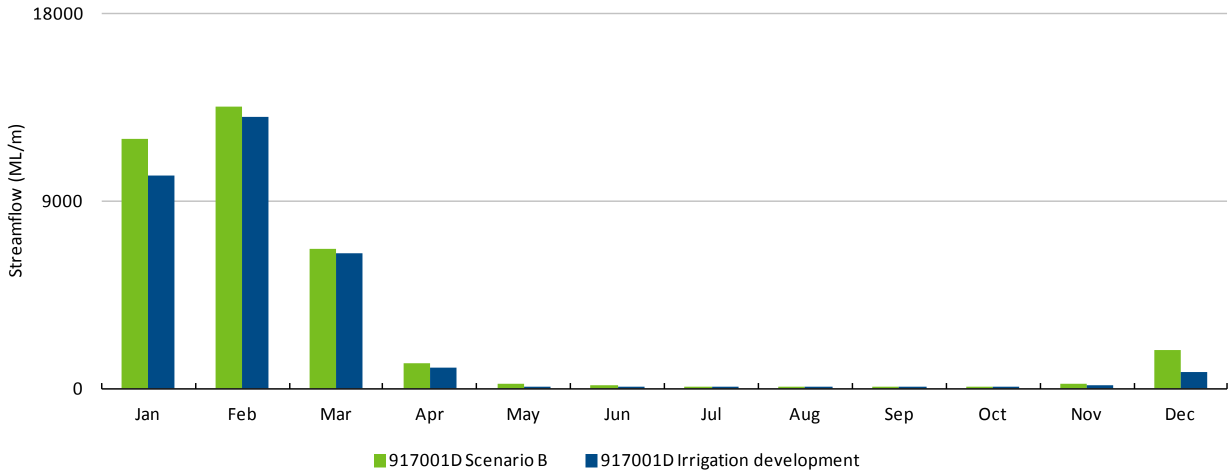


Figure 5.59 Change in monthly average flow for 12,000ha development option

5.6 Dagworth and Green Hills - Sugarcane

5.6.1 SCHEME CHARACTERISTICS

The potential Green Hills and Dagworth dams are 20 and 30 m high roller compacted concrete dams respectively. The Green Hills dam is located on the Gilbert River and the Dagworth dam is located on the Einasleigh River. Green Hills and Dagworth are the two of the most promising dam sites in the Gilbert catchment. Their key parameters are summarised in Table 5.27 and the relationship between water depth, volume and area is presented in Figure 5.60. For more detail see Petheram et al. 2013.

Table 5.27 Green Hills and Dagworth dam parameters

DAM NAME	CATCHMENT AREA (km^2)	HEIGHT (m)	CAPACITY (GL)	FULL SUPPLY LEVEL (m)	DEAD STORAGE (ML)	SEEPAGE (MM/DAY)
Green Hills	8310	20	227	254	4,544	0
Dagworth	15,351	30	498	227	9,964	0

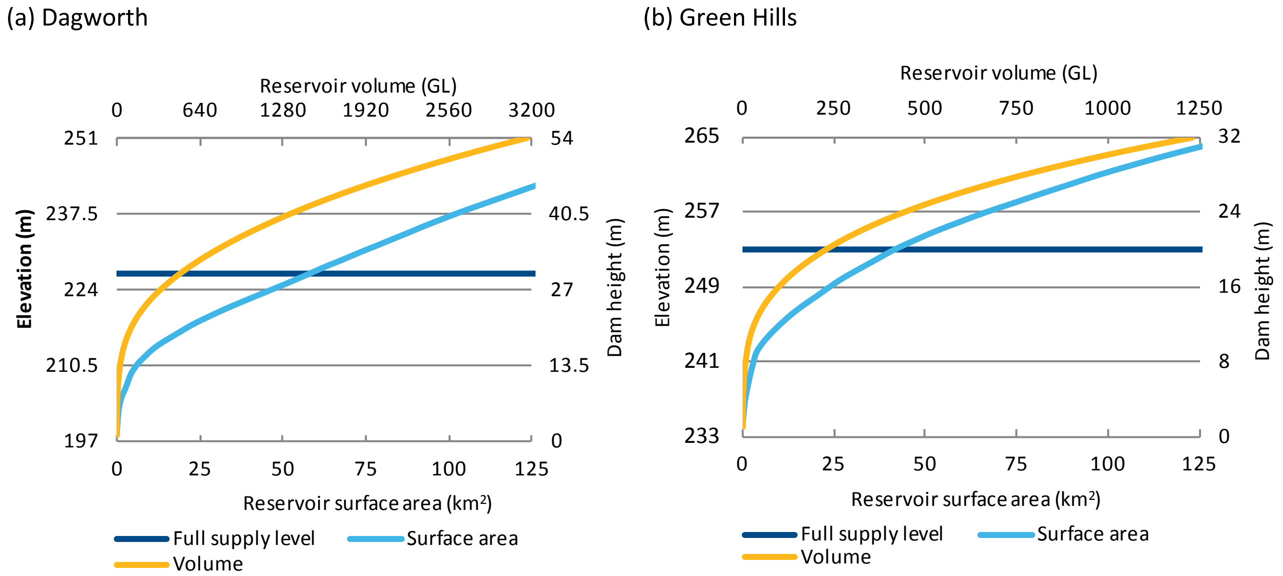


Figure 5.60 Storage volume area relationship – Dagworth and Green Hills

Configuration for water supply and irrigation development for Green Hills irrigation development

Under this nominal configuration, water would be released from the Green Hills dam to a re-regulating structure (sheet piling weir) at Prestwood, approximately 20 km downstream of the dam. Note that Source did not explicitly model the weir due to its small capacity.

Water would be pumped from behind the weir in the river (assuming a 10 m head requirement) into a main distribution channel on the right bank. This channel would need to be lined due to the sandy nature of the soils. The potential irrigation scheme is situated 2 km from the river due to the presence of marginally suitable land in the vicinity of the river. This enables a 2 km wide riparian zone to be maintained between the irrigation development and the river.

It is assumed that irrigation water is distributed within farm (i.e. from the farm gate to the field) using open lined channels. No on farm storage has been simulated.

Once at the field, water is applied using modern spray irrigation systems capable of delivering peak water requirements to the cane crop at periods of high evaporative demand. Overhead sprinklers are used to optimise irrigation productivity on the limited water supply and minimise accessions to groundwater, which have the potential to cause watertables to rise and increase salinity risk. Well managed spray irrigation generates very little tailwater runoff (i.e. water leaving the field following an irrigation event), except during large rainfall events that may occur immediately after irrigation on full soil profiles.

Storage evaporation and seepage losses are modelled explicitly in Source. Table 5.28 lists the conveyance efficiency assumptions used in this analysis. In total, the conveyance and application efficiency from the storage to the crop is about 68%. Note that on an optimistic farm distribution efficiency has been evaluated as it has been assumed that there is no on farm storage.

Table 5.28 Conveyance efficiency assumptions for the irrigation scheme associated with the Green Hills dam

COMPONENT	EFFICENCY	COMMENT
River conveyance efficiency	85%	Distance between dam and sheet piling re-regulating structure is about 15 km.
Channel distribution efficiency	95%	Representative of evaporation loss from re-regulation structure and channel loss between river and farm gate. Channel is lined due to sandy soils[1].
Evaporation and seepage estimate from on farm storage	100%	Case study does not include on farm storages
On-farm distribution efficiency	99%	Representative of on-farm evaporation and seepage loss from farm gate to edge of field. Assumed lined channel[1].
Field application efficiency (spray)	85%	Assumed majority of loss goes to deep drainage.
Overall efficiency	68%	

1 Poorly constructed channels will have lower conveyance efficiency than those values listed in this table.

Configuration for water supply and irrigation development for Dagworth irrigation development

The width of the Einasleigh River downstream of Dagworth dam varies between 500 m and over 1 km. The width of the river is such that the construction of a weir adjacent to the irrigation development would be very challenging. Under this nominal configuration water would be released from the potential Dagworth dam to a series of sand dams approximately 70 km downstream of the potential dam. These sand dams are low embankments comprised of river bed sands that partially span the lower Einasleigh River. They are constructed downstream of a natural waterhole to form a pool sufficiently deep from which to pump water. Although sand dams are cheap to construct relative to a concrete or sheet piling weir they have much larger seepage losses beneath and through the dam wall and need to be rebuilt every year.

Water is pumped from behind the sand dams into one of two 4000 ML ring tanks. These ring tanks act as balancing storages and serve to improve the efficiency with which water can be supplied from the Dagworth dam to the irrigation development. The potential irrigation development is situated 2 km from the river enabling a riparian zone to be maintained between the irrigation development and the river. Water is supplied from the ring tanks to the irrigation farms by an open channel. Once at the field, water is applied using spray irrigation.

Making this water supply scheme configuration operational is likely to be challenging and losses are likely to be high (Table 5.29). Overall the efficiency is estimated to be 48%.

Note that Source did not explicitly model the sand dam due to their small capacity. However seepage through the weir was represented. Additionally, the ring tanks were not represented in Source.

Table 5.29 Assumed conveyance efficiency assumptions for the irrigation scheme associated with the Dagworth dam

COMPONENT	EFFICENCY	COMMENT
River conveyance efficiency	70%	Distance between dam and sand dam re-regulating structure is about 70 km. Supplemented by flows from Etheridge. When Etheridge is flowing would in effect reduce transmission losses of water released from dam.
Sand dam – re-regulation infrastructure[1]	80%	Loss from sand dams (seepage) and balancing storages (seepage and evaporation).
Channel distribution efficiency	90%	Loss from balancing storage to farm gate[2]
Evaporation and seepage estimate from on farm storage	100%	Case study does not include on farm storages
On-farm distribution efficiency	95%	Loss from farm gate to field due to-on-farm evaporation and seepage loss[1]
Field application efficiency (spray)	85%	
Overall efficiency	48%	

[1] This was represented in Source through an over order factor at the supply point.
[2] Poorly constructed channels will have lower conveyance efficiency than those values listed in this table.

5.6.2 CROPPING SYSTEMS

This case study included an assessment of sugarcane as detailed in Table 5.30 and Table 5.31. See Section 3.4.2 for parameter definitions. A daily pattern has been defined for the crop factor (see Appendix C). There is no planting decision as the crop is a perennial.

Table 5.30 Characteristics of crops used in Dagworth and Green Hills Case Study

Crop	Planting date	Maximum planted area sensitivity testing (Ha)	Planting decision sensitivity testing (ML/ha)	Depth of roots (mm)	Target soil depletion (mm)
Sugarcane	Perennial	1,000 – 20,000	N/A	1800, 1500	77, 52

Table 5.31 Other crop model parameters used for the Dagworth and Green Hills Case Study

PARAMETER	VALUE
Soil moisture Capacity (%)	9.6, 8.3
Fallow depth (mm)	300, 400
Fallow Depletion factor (%)	100
Crop Depletion factor (%)	50
Soil description	Richmond Brown Dermosol, Tonks Camp

APSIM was run for a number of different water supply scenarios using historical environmental data to generate a relationship with crop yield (Figure 5.61). These results are modelled production potential under optimum management hence represent an upper limit.

Applied irrigation water and crop yield data for sugarcane were simulated using the sugarcane module of the Agricultural Production Systems Simulator (APSIM) crop model, and soils representative of the Green Hills dam and Dagworth dam irrigation developments. Figure 5.61 illustrates the relationship between applied irrigation water and crop yield assuming perfect irrigation timing (i.e. no losses). Mean sugarcane yields of about 110 to 120 (t/ha) occur at the mean water application rate of 12.5 ML/ha. At applications of less than 12.5 ML/ha, the crop becomes increasingly water stressed and reductions in yield occur as the allocation has insufficient water to meet the crop demand. Reducing water application by 50% from fully irrigated reduces crop yield by about 40%.

For this case study all yields reported are based on APSIM derivation rather than from a regression model. A regression model was developed however it was not sufficiently reliable for use. Regression models for perennial systems were unreliable as they did not take into account the effect of climate in previous years on the current year's biomass.

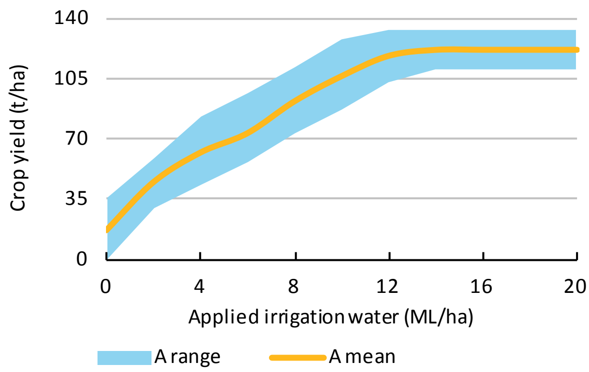


Figure 5.61 APSIM Yield Results used for both Dagworth and Green Hills, Scenario A for sugarcane for a sand or loam over relatively friable clay subsoil
Assumes perfect timing of irrigation. Results are an average of the plant crop and four ratoons. Representative of the production potential (i.e. assumes no nutrient limitations or pest damage). Scenario A is the historical climate (1890 to 2011). The range is the 20th to 80th percentile exceedance.

5.6.3 RESOURCE ASSESSMENT SYSTEM

An annual allocation and accounting system has been defined in Source. Separate systems were defined for Dagworth and Green Hills dams.

The 'No Impact' scenario has been evaluated assuming that impacted users are supplied primarily with water from the new storages. Source has a mechanism to enable forecasted inflows below a storage to be used to meet downstream orders, rather than releasing water from the storage. This forecast capacity was only configured for the major tributary inflow below Dagworth. Hence for Dagworth, the downstream demands were at times also met from tributary inflows. For Greenhills however, the impacted downstream users were supplied entirely from the storage.

For the impacted downstream users, a time series of extractions was generated using the baseline model. This time series was used to reserve water in the storage prior to allocating to the new irrigation area.

The 'Impact' scenario was configured such that the existing entitlements retained their water harvesting entitlement and the volume in the Dagworth and Green Hills storages was allocated entirely to the new irrigation areas.

It may be desirable to enable existing impacted users to maintain some water harvesting entitlement in addition to a share of the new storages; however this has not been evaluated. A combination scenario would mean that the cost effectiveness of the schemes would be somewhere between the 'Impact' and ''No Impact' scenarios.

5.6.4 AREA AND PLANTING DECISION OPTIMISATION RESULTS

Sensitivity analysis results

Larger scheme-scale median 30-year crop yields are attained for larger scheme areas (Figure 5.62a). This occurs because sugarcane yield declines by only 40% with a 50% reduction in irrigation volume from that required for maximum yield (Figure 5.61). Hence, larger scheme-scale median 30-year yields are attained at high scheme areas even if there is insufficient water to meet full irrigation needs. However, the variability in 30-year crop yields is high and increases for larger scheme areas (Figure 5.62b).

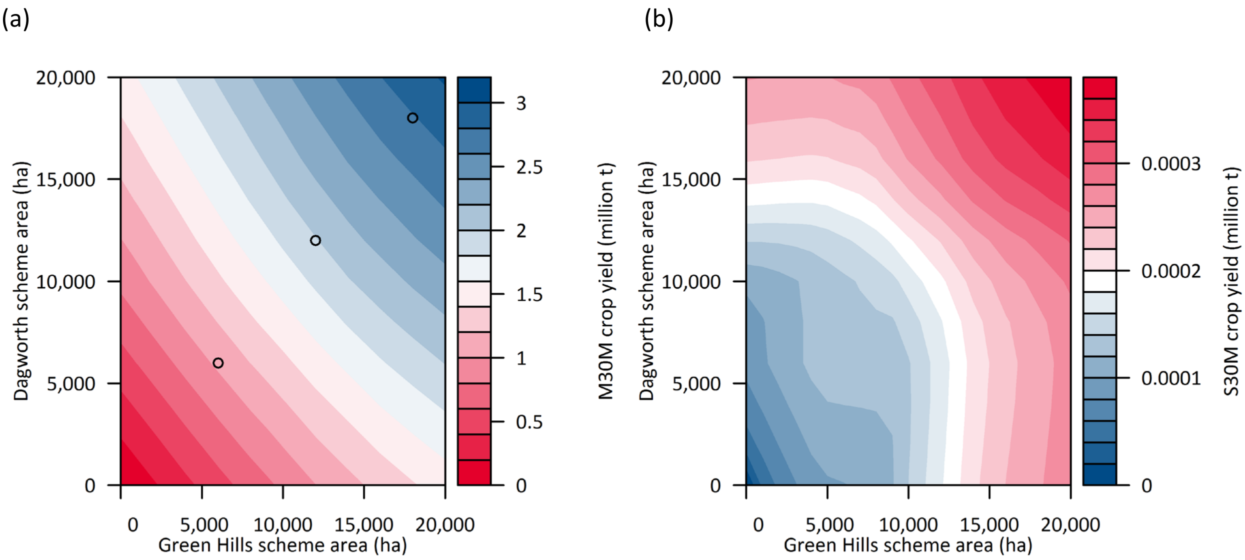


Figure 5.62 (a) Median of the 30-year mean values (M30M) for crop yield and (b) standard deviation of the 30-year mean values (S30M) for crop yield, under Scenario B for the irrigation development associated with the Green Hills and Dagworth dams

Scenario B is the historical climate (1890 to 2011) with irrigation development. Mean values are calculated for 30-year windows within the period from 1890 to 2011. Both the median and the standard deviation of the mean values for each of the 92 windows are presented.

The higher crop yields and higher variability for larger scheme areas is illustrated in Figure 5.63. Although the 6000 ha scheme area has the lowest total crop yield, there is always sufficient water in the dam to ensure there is not a crop failure. An irrigation development with a 18,000 ha scheme area, while able to exploit high rainfall years, results in higher variability in yields as there is not always sufficient water to avoid crop stress.

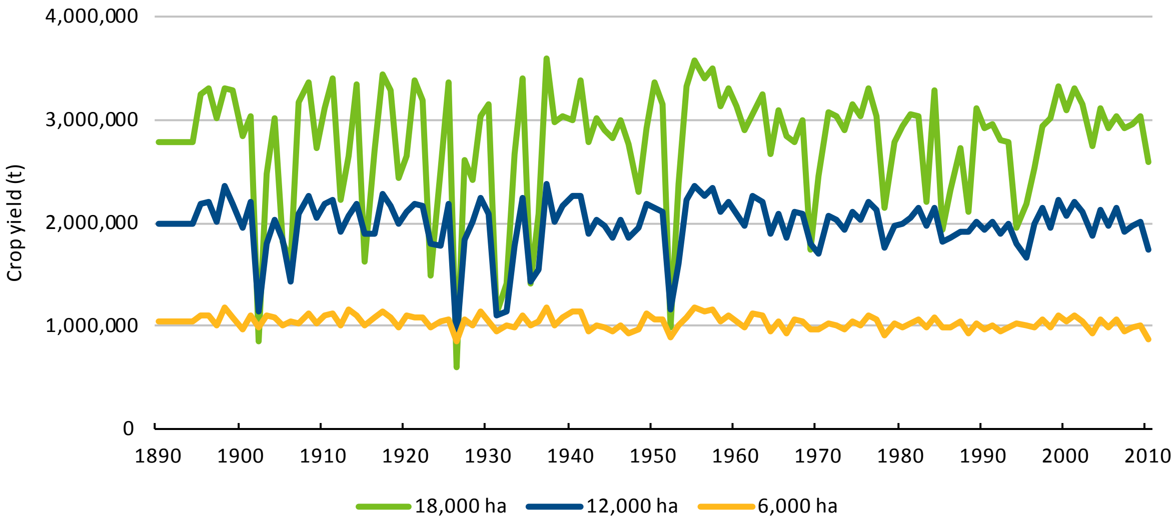


Figure 5.63 Crop yield from the total scheme area under Scenario B for three different scheme areas marked in Figure 5.62a).

Median 30-year average 'specific yield' (i.e. crop yield per hectare planted) decreases with higher planted areas as the crop is more often under water stress and this results in lower yields (Figure 5.64a).

Figure 5.64b illustrates the percentage of years that 2 million t of sugar cane is exceeded in the two irrigation developments. For example if both irrigation developments had a scheme area of 5000 ha, in no years would their combined production exceed 2 million t of sugarcane. If both irrigation developments had a scheme area of 12,000 ha their combined production would exceed 2 million t of sugarcane in more than 95% of years. When the Dagworth irrigation development has a scheme area of 17,000 t it produces more than 2 million t of sugarcane in 50% of years.

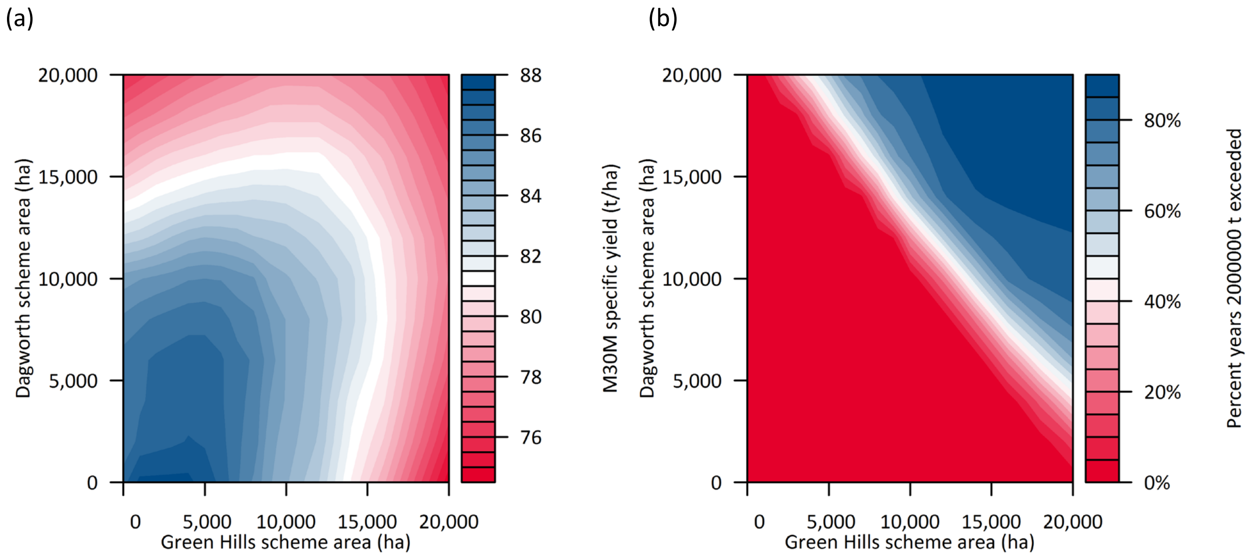


Figure 5.64 (a) Median of the 30-year mean values (M30M) for specific yield and (b) Percentage of time two million t of sugarcane is exceeded under Scenario B for the irrigation developments associated with the Green Hills and Dagworth dams

Scenario B is the historical climate (1890 to 2011) with irrigation development.

The larger the scheme area, the larger the total volume of water supplied to and used by the irrigation development (Figure 5.65a), but the lower the amount of water supplied to each hectare of the crop (Figure 5.65b).

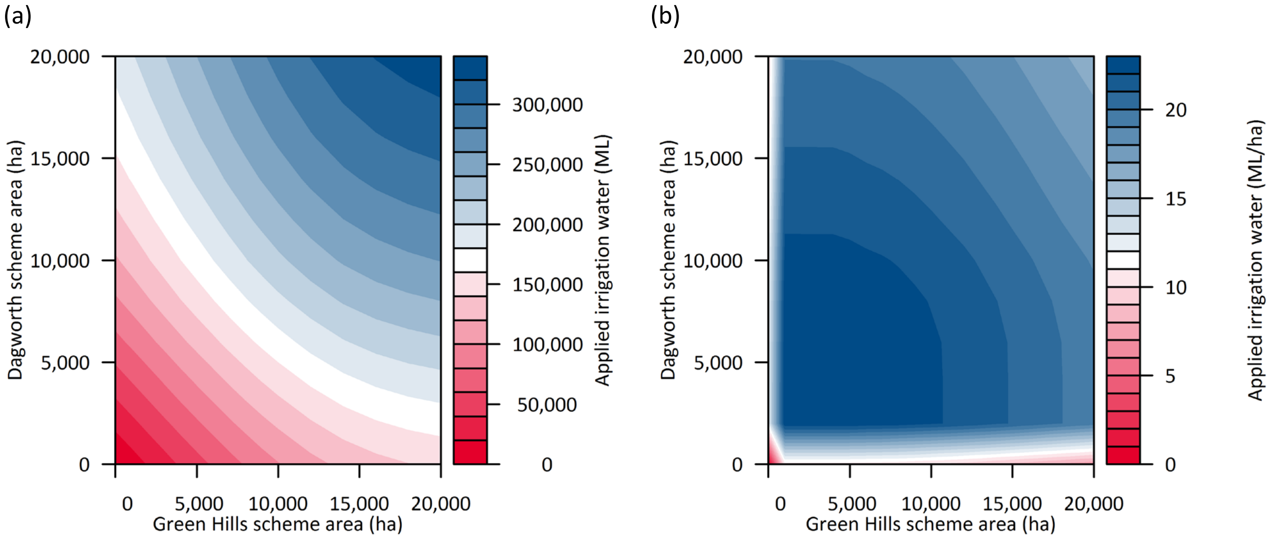


Figure 5.65 (a) Mean annual total applied irrigation water supplied to the field (ML) and (b) ML applied per hectare, under Scenario B for the irrigation development associated with Green Hills and Dagworth dams
Applied irrigation water is the water supplied from the dam, with the losses from river conveyance, channel distribution and field application removed. Scenario B is the historical climate (1890 to 2011) with irrigation development.

Figure 5.66 a, b presents the ratio of water lost to evaporation to water supplied at the dam wall for Green Hills and Dagworth dams respectively. At low scheme areas, water is not fully used and, in carrying water over into the following year, a large amount of water is lost to evaporation. At high scheme areas the ratio of evaporation to supply is low because all available water is used every year (i.e. reservoir is treated as within-year storage).

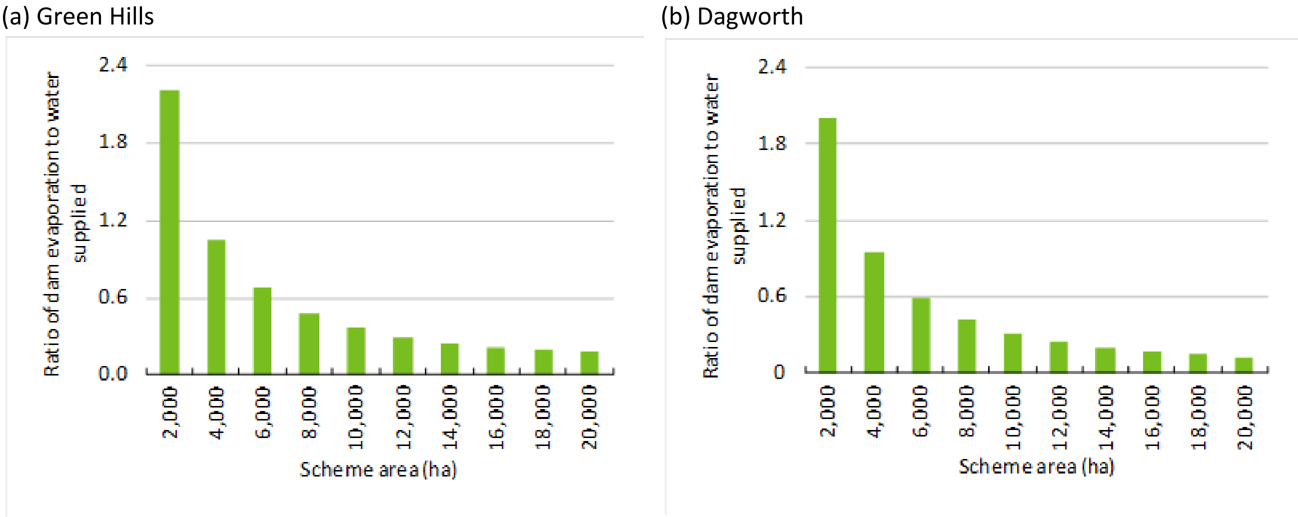


Figure 5.66 Ratio of evaporation from the reservoir to the applied irrigation water under Scenario B for (a) Green Hills dam and (b) Dagworth dam
Applied irrigation water is the water supplied from the dam, with the losses from river conveyance, channel distribution and field application removed. Scenario B is the historical climate (1890 to 2011) with irrigation development.

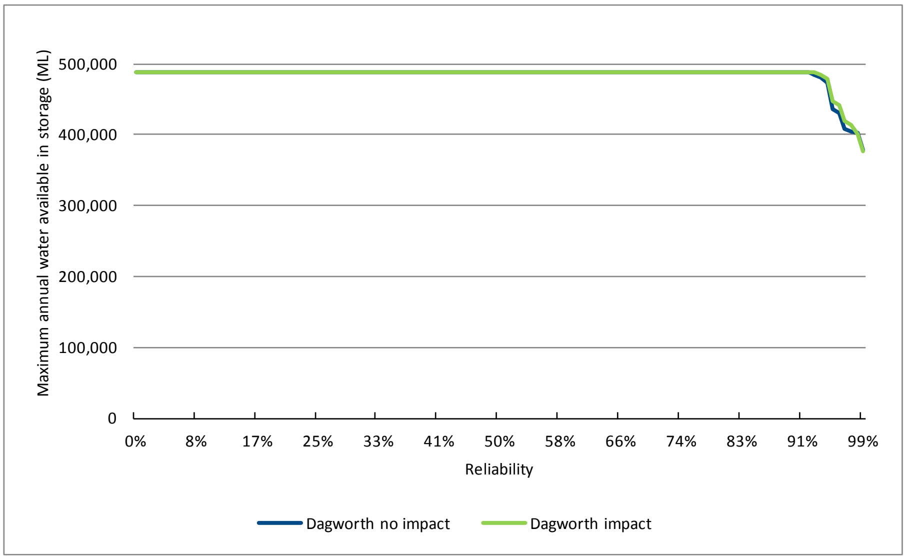
Conclusion regarding the option selected for further investigation

Based on the economic analysis of all options (Petheram et al., 2013 b) a scheme area of 16,000 ha was selected for both the Green Hills and Dagworth dam irrigation developments (i.e. total of 32,000ha). However, the following sections relate to an option of 12,000ha each for Green Hills and Dagworth (i.e. total of 24,000ha).

5.6.5 RELIABILITY OF SUPPLY

The reliability of water available from Green Hills and Dagworth is illustrated in Figure 5.67. Note that the maximum allocation is more reliably supplied from Dagworth than it is from Green Hills under 'No Impact' assumptions. However, Green Hills has a significant improvement in reliability under 'Impact' assumptions hence the reliability of the two storages may be comparable depending on the requirements for meeting existing user demands. Note also that it has been assumed that the Green Hills system is much more efficient as conveying water to the irrigation development (Section 5.6.1).

(a) Dagworth



(b) Green Hills

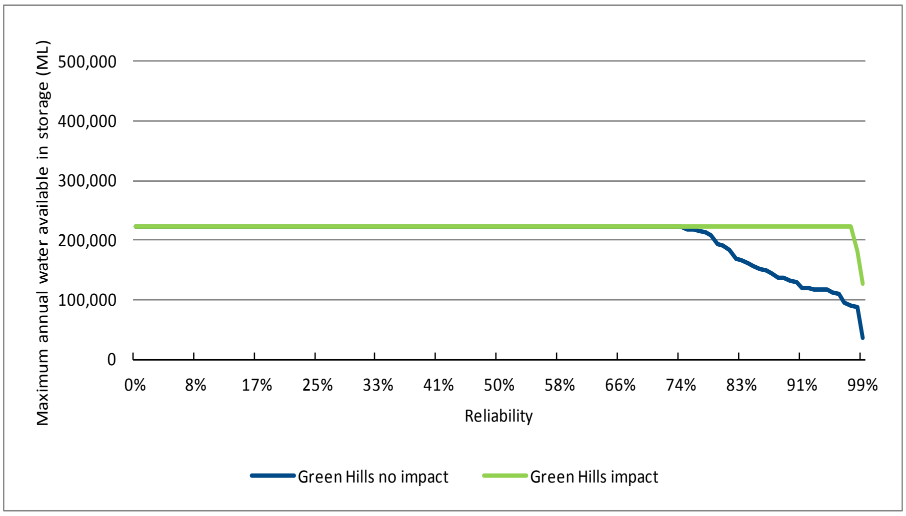


Figure 5.67 Maximum Annual Available Volume –Green Hills and Dagworth (No Impact 24,000ha option) Available volume refers volume allocated to the new scheme in the resource assessment system hence accounts for dead storage and reserves required for other users. It does not account for storage operation and delivery losses however so the results are an overestimate.

5.6.6 IRRIGATION SUPPLY RELIABILITY ASSESSMENT

An irrigation supply reliability assessment has been undertaken for this case study as detailed in Table 3.3 and introduced in Section 3.3.5. Each of the assessments was undertaken using the 'no impact' model for the option of 12,000ha each for Green Hills and Dagworth (i.e. total of 24,000ha).

Table 5.32 Irrigation supply reliability assessment criteria for Dagworth and Green Hills sugarcane scenario

Assessment criteria	Description
1. Streamflow uncertainty	Assessing the impact of streamflow uncertainty due to the inherent uncertainty in rating curves, based on 50 model ensembles.
2. Future climate	Assessing the impact of climate change including an upper (C_{dry}), median (C_{mid}) and lower (C_{wet}) impact case

3.	Scheme supply efficiency	Assessing the impact of scheme efficiency (storage, distribution and application efficiencies) including a high and low loss case impact

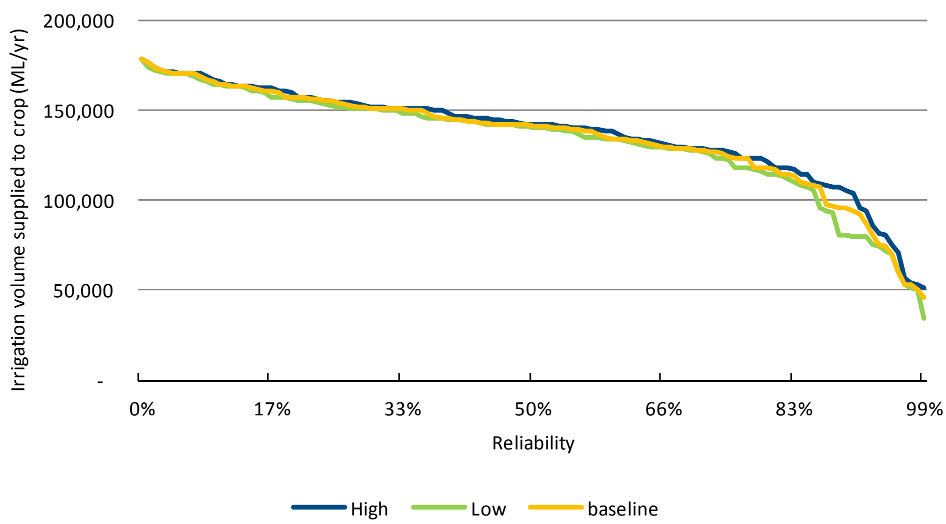
Impact on reliability of irrigation supply due to uncertainty in gauge flows

Model uncertainty due to flow gauging data has a relatively small impact on average annual volumes of irrigation water supplied to the crop (see Table 5.1) however the impacts are more significant in the driest years, particularly for Dagworth (see Figure 5.68).

Table 5.33 Average irrigation water supplied to crop – Model uncertainty % change from baseline.

Scheme	Baseline (ML/yr)	High % change	Low % change
Dagworth	134,944	2%	-1%
Green Hills	113,303	3%	-2%

(a) Dagworth



(b) Green Hills

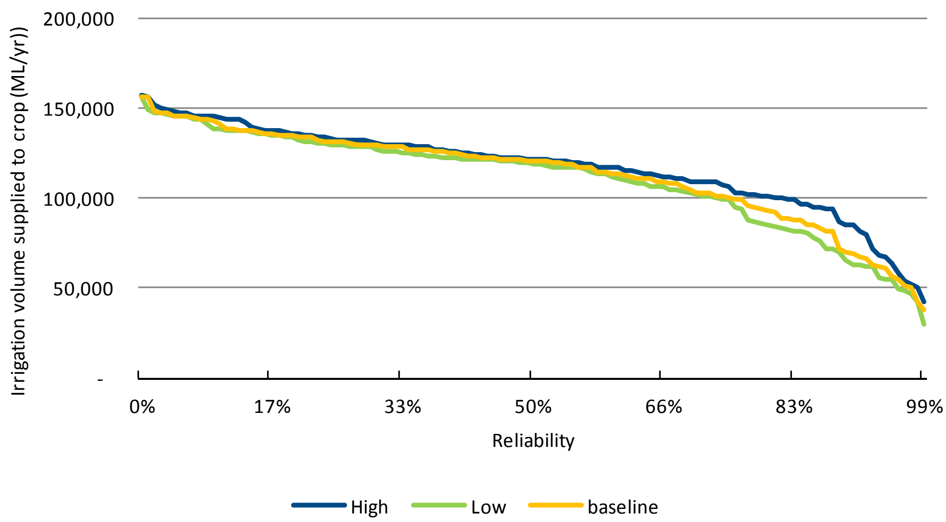


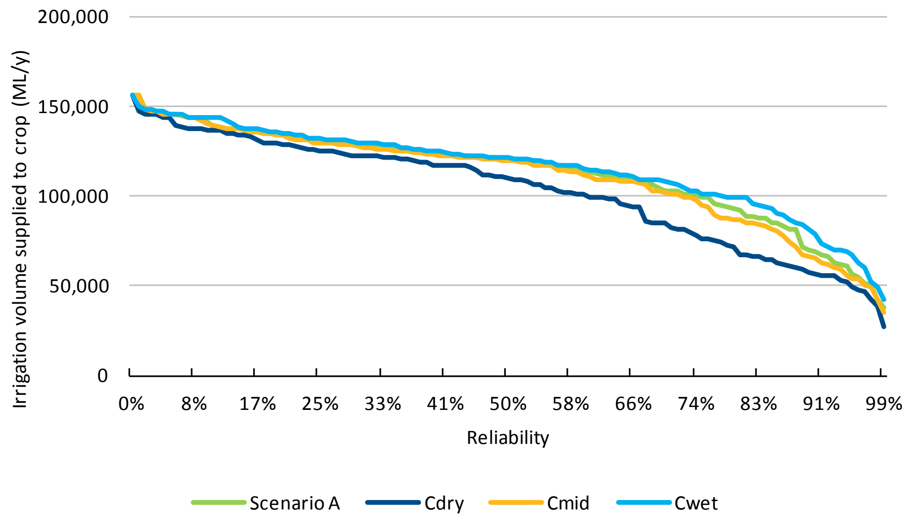
Figure 5.68 Impact of model uncertainty on irrigation water supplied to the crop (a) Dagworth and (b) Green Hills.

Impact on reliability of irrigation supply due to future climate

The selected climate change models have some impact on irrigation water supplied to the crop as detailed in Table 5.36 and illustrated in Figure 5.69. The Cdry model has the largest impact with reductions occurring across most years but the most significant impacts occurring in the driest 30% of years.

Table 5.34 Average irrigation water supplied to crop – climate models percentage change from baseline

Scheme	Scenario A (baseline) ML/yr	Scenario Cdry	Scenario Cmid	Scenario Cwet
Dagworth	134,944	-8%	-1%	5%
Green Hills	113,303	-9%	-2%	2%



(b) Green Hills

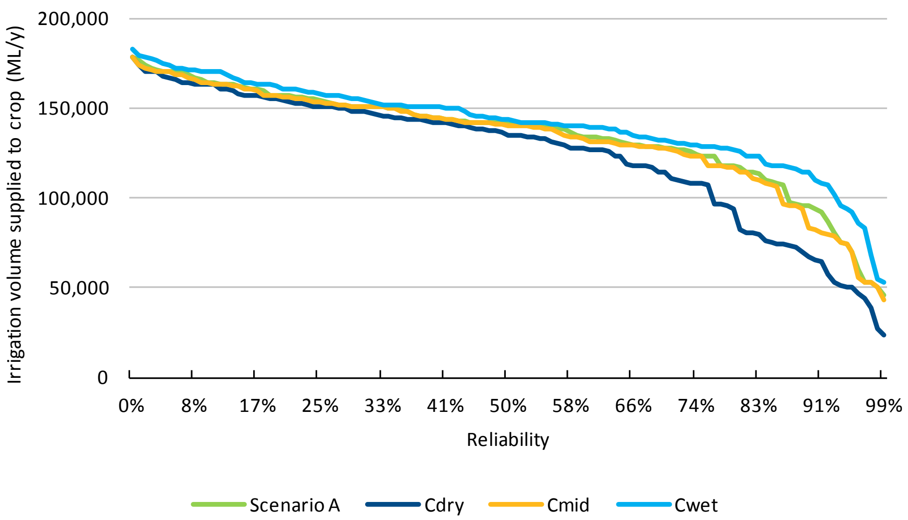


Figure 5.69 Impact of climate change on irrigation water supplied to crop (a) Dagworth and (b) Green Hills.

Impact on reliability of irrigation supply due to scheme efficiency

Table 5.35 and Table 5.36 summarise the range of efficiencies assumed for each component. Rather than combining each of these components using a multiplicative approach, as per the baseline assessment, a monte-carlo assessment was undertaken to determine the 10th and 90th percentile total efficiency values. These represent the total efficiency values for the low and high efficiency scenarios as reported in the tables below. The Source loss parameter values were subsequently derived to match the monte carlo total efficiency values. The monte carlo assessment assumed a normal distribution with the standard deviation estimated as the range divided by four.

Table 5.35 Assumptions used for high and low efficiency scenarios - Dagworth

Component	Baseline efficiency	Low efficiency	High efficiency
River conveyance	70%	55%	85%
Sand dams - re-regulation infrastructure	80%	70%	90%
Distribution infrastructure	90%	80%	95%
On-farm distribution	95%	90%	99%
Field application (spray)	85%	75%	90%
Total efficiency (monte carlo)	**41%**	**26%**	**56%**

Table 5.36 Assumptions used for high and low efficiency scenarios – Green Hills.

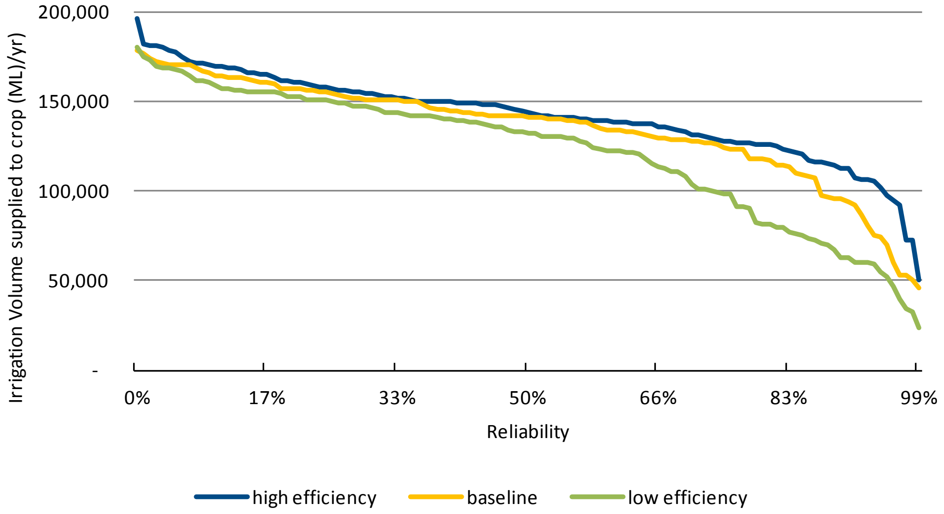
Component	Baseline efficiency	Low efficiency	High efficiency
River conveyance	85%	75%	90%
Re-regulating and distribution infrastructure	95%	92%	98%
On-farm distribution	99%	95%	99%
Field application (spray)	85%	75%	90%
Total efficiency (monte carlo)	**68%**	**55%**	**78%**

The efficiency of the scheme has some impact on irrigation water supplied to the crop as detailed in Table 5.37 and illustrated in Figure 5.70. The low efficiency scenario has the biggest impact on Dagworth with reductions particularly noticeable in the driest 50% of years.

Table 5.37 Average irrigation water supplied to crop – Percentage change of efficiency scenarios from baseline.

Scheme	Baseline (ML/yr)	High efficiency	Low efficiency
Dagworth	134,944	+5%	-10%
Green Hills	113,303	+2%	-6%

(a) Dagworth



(b) Green Hills

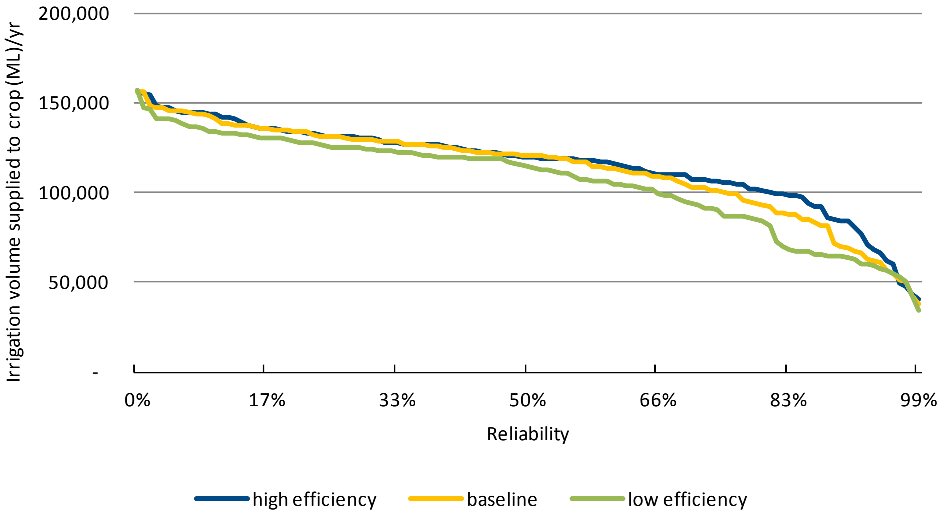


Figure 5.70 Impact of scheme efficiency on irrigation water supplied to crop (a) Dagworth and (b) Green Hills.

5.6.7 IMPACTS ON EXISTING ENTITLEMENTS

The option of 12,000ha each for Green Hills and Dagworth (i.e. total of 24,000ha) results in some impacts for existing entitlements in comparison to the baseline model. Average annual diversions were reduced by approximately 3% and 7% respectively downstream of Green Hills and Dagworth.

These impacts were determined to be partly an artefact of the model. The model simulates the release of the water required to meet downstream demands, however attenuation in the model means that the flow pattern simulated is slightly different to the baseline time series of extractions. Hence, some of the released water does not arrive on the exact same day at which the baseline model simulated a required extraction. This mismatch means that not all of the released water is extracted.

5.6.8 STREAMFLOW IMPACTS

Figure 5.71 shows the median annual flow quotient at locations just below the irrigation areas for both the Green Hills dam and Dagworth dam. This provides an indication of the extent to which the median annual

streamflow may change under different size irrigation developments. The smaller the number the larger than change in median annual streamflow. The median annual streamflow quotient is between 0.62 and 0.88 below the Green Hills irrigation development at 917001D and between 0.7 and 0.9 below the Dagworth irrigation development (virtual gauge 355).

The streamflow impacts arising from the selected scheme area (16,000 ha for each area i.e. total of 32,000ha) have been further evaluated (Figure 5.70). Monthly average flows are reduced at the start of the wet season however winter flows are slightly increased. Increased winter flows occur below the Dagworth irrigation development due to seepage from the sand dams. Additional stream flow metrics are illustrated in Appendix D for the option of 10,000ha for each scheme area.

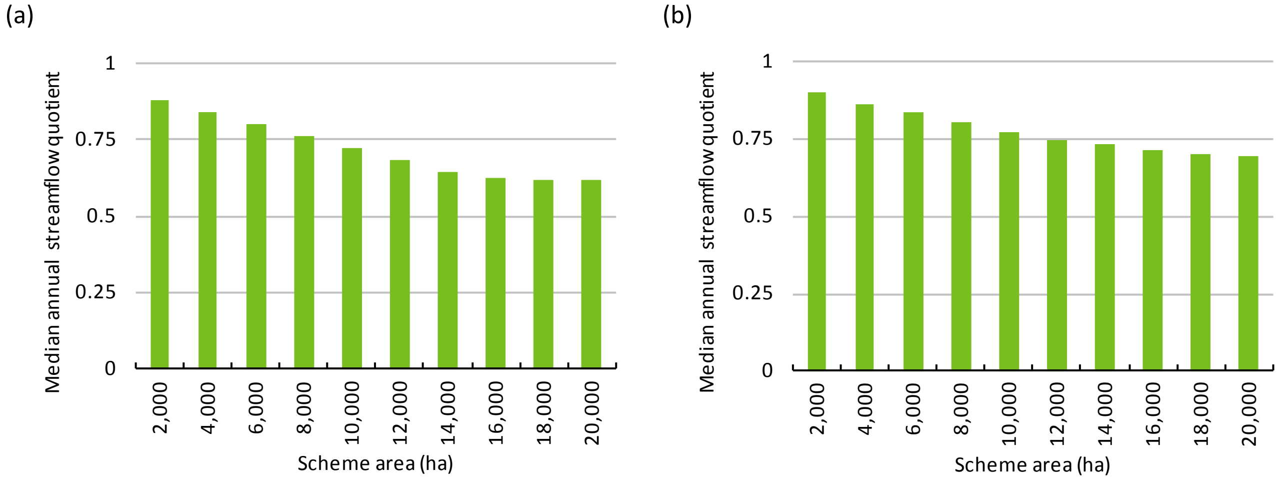


Figure 5.71 Median streamflow quotient at (a) Green Hills dam (gauge 917001D) and (b) Dagworth dam (virtual gauge 355)
Median streamflow quotient is the median annual streamflow under Scenario B divided by the median annual streamflow under Scenario A. Scenario A is the historical climate (1890 to 2011) and current development. Scenario B is the historical climate (1890 to 2011) with irrigation development.

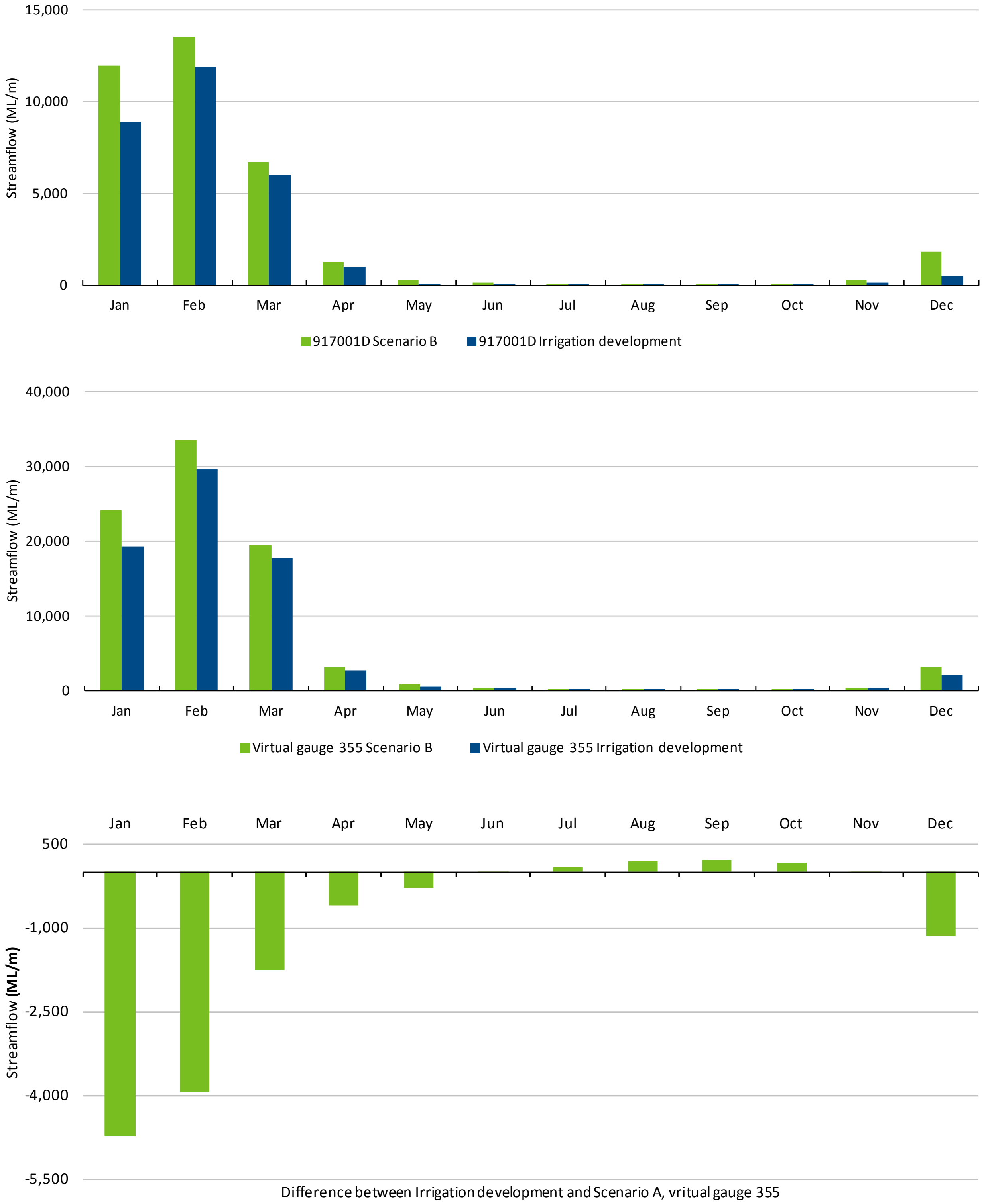


Figure 5.72 Change in monthly average flow for 32,000ha development option

6 Conclusions

The calibration river models outlined by Lerat et al., (2013) were modified to incorporate the 2013 water allocations. Unallocated entitlements were removed from the model. The modelling assumed full use of existing entitlements.

A combined river system modelling and crop modelling approach was used to evaluate six case studies. Two approaches for simulating crop yield were used, a regression based approach and the APSIM model. The regression based approach was fast and computationally efficient. For annual crops it satisfactorily reproduced APSIM crop yield output. For perennial crops (i.e. sugarcane and Rhodes grass) the regression modelling approach did a poor job and was discarded in favour of using APSIM directly.

For each of the case studies, the highest median crop yields were obtained based on the highest risk behaviour i.e. maximum scheme areas and smallest planting decision variable. These options, not surprisingly, incur the highest variability in yield and on this basis were not the most viable options.

For each case study a scheme area was selected for further analysis (Petheram et al., 2013a and b), with the exception of the Flinders water harvesting case study, where a generic financial analysis was undertaken. The selected options were as follows:

- Cave Hill: chosen on the basis of the minimum area required to maintain a feedlot supplying an abattoir. This was a scheme area of 12,000 ha with a planting decision which means that for every 3.9ML available in the resource assessment account 1 hectare of sorghum is planted.
- O'Connell Creek: a low scheme area was adopted so as to achieve a high degree of reliability. This was a scheme area of 5,300 ha and a planting decision which means that for every 6.25ML available in storage 1 hectare of rice is planted.
- Kidston: a scheme area of 1,000 ha supplemented with water harvesting (with 100 ML of on farm storage) was selected. This case study evaluated a perennial crop (Bambatsi) so no planting decision was required.
- Dagworth – Green Hills: a scheme area of 16,000 ha was selected for both the Green Hills and Dagworth dam irrigation developments. This case study evaluated a perennial crop (sugarcane) so no planting decision was required.
- Green Hills: a scheme area of 12,000 ha and a planting decision which means that for every 4.2ML available in the resource assessment account a total of 1 hectare is planted. The planted area was a rotation of cotton, peanuts and sorghum.

For each of these selected options, the reliability of the scheme was evaluated. The selected development options evaluated for Green Hills and Dagworth resulted in the most reliable systems. O'Connell creek off-stream storage and Cave Hill dam result in the least reliable systems.

The case study assessments included a configuration to try and avoid impacts on the reliability of existing entitlement holders. The exception is the O'Connell Creek off-stream storage and irrigation development, where no allowance was made for downstream existing entitlement holders. The impacts on existing entitlements were evaluated in terms of change in long term average extractions. All case studies, except O'Connell creek, reported an impact of less than 10%. Note that the impacts that would occur during any one season for any one existing user may be greater than the long term average. In order to assess the potential impacts of O'Connell creek off stream storage it would be necessary to use a model that accounts for the hydraulic constraint on diversions from the Flinders River. In the event that more stringent rules apply to any of the schemes to avoid impacts on existing entitlements or to avoid streamflow impacts, the viability of the schemes would be further eroded.

For the Flinders water harvesting case study, water availability is poor by 1st January but significantly improves by the 1st February. For most sites the full entitlement assigned to the site can be extracted in a high percentage of years (e.g. between 70 to 90% of years) for the smallest new entitlement release examined (80 GL). For this scenario, well informed risk taking may be a reasonable strategy when planting early season crops as the required resource is likely to eventuate. For example, cotton should be planted before the end of January hence unless it is planted at the end of the month it is likely that on farm

storages will have low water levels. However, risk taking on the basis of reasonably reliable flows later in the season may be a reasonable strategy, provided there was some soil and/or stored water during and after planting. For higher new entitlements scenarios, the reliability of extractions is decreased and hence a more conservative approach would be required.

Across the five regulated case studies total conveyance and application efficiency ranged from 0.48 to 0.68 with an average of about 0.53. That is 53% of water released from the dam is used by the crop. It is likely that the conveyance efficiencies adopted in the Assessment are more likely to be generous than conservative (i.e. the actual conveyance efficiencies are more likely to be lower than higher). Nevertheless the magnitude of the conveyance and application losses highlight the importance of giving due consideration to the conveyance efficiencies (i.e. loss assumptions) in the analysis of irrigation developments.

The impact of scheme efficiency on irrigation water supplied to the crop was evaluated for the Dagworth – Green Hills sugarcane case study. This was compared to the impact of both future climate and observed flow data uncertainty. The largest impact was a 10% reduction in average annual volumes supplied to the crop as a result of low scheme efficiency. Note however that impacts during dry periods are more significant. The impacts due to climate change were of similar magnitude to the impacts of scheme efficiency. The largest increase in average annual volumes supplied was 5%. Potential increases may be more significant in other case studies where water availability is less reliable. The report did not assess impacts on crop yield modelling and this would be an informative area of future work.

The impact on median flows downstream of the case study irrigation developments varied but generally the impact on median flow increased with scheme area and decreased with distance below the irrigation development. Detailed hydrological metrics for each case study are presented in Appendix D. River reaches immediately downstream of the irrigation development would experience a moderate impact to median flow (i.e. median streamflow quotient typically between 0.6 and 0.8). None of the case studies resulted in a large change in the median flow at the end of system. River reaches downstream of water storages but upstream of irrigation developments did not experience a notable change in their mean annual flow but did experience a change in seasonality of flows with increased dry season flows. There was no shift in seasonality of streamflow downstream of the irrigation developments because the case studies assumed best practise with no tail water return to the rivers (i.e. most case studies were based on the use of spray irrigation). The exception was below the Dagworth irrigation development, where there was an increase in dry season flows as a result of seepage through the sand dams. Across the six case studies the impact on median flow varied. Results for the selected option from each case study are summarised below:

- Flinders water harvesting: the EOS impact is relatively small but localised impacts are greater. For example gauge 915203A results in considerable change (0.72 for the 240GL scenario).
- Cave Hill: A small change at the 915203A (upstream of the irrigation area) and very little change at the mouth of the Flinders River because the catchment of the Cave Hill dam is small relative to the entire Flinders catchment.
- O’Connell Creek off stream storage: considerable changes in median flows were modelled downstream of the diversion weir on the Flinders River, however, the model overestimates the impacts due to lack of consideration of hydraulic constraints. There was very little change EOS flows.
- Kidston and water harvesting: a small change in the flow regime occurs at gauge 917106A (downstream of the irrigation area) and no distinguishable change occurs at the end of system.
- Dagworth – Green Hills: considerable changes occur downstream of both irrigation developments with the impact varying across development options. For the selected option of 16,000 ha for each area the impacts were approximately 0.7 for Dagworth and 0.6 for Green Hills.
- Green Hills: The impacts vary for different scheme areas and crop area decisions, however, the selected option of 12,000ha has an impact of approximately 0.8 downstream of the irrigation area. There was a small change for the end of system.

7 References

ANCID (Australian National Commission for Irrigation and Drainage) (2000) Australian Irrigation Water Provider: Benchmarking Report, Tatura: ANCID.

Barrett, Hugh & Irrigation Australia 2007, Guidelines for ring tank storages, 2nd ed, Irrigation Australia, Hornsby, N.S.W

Bethune, M and G Podger (2013) 'Irrigator Demand Model', in Kelley, P. & O'Brien, A. (eds) 2012, Source Scientific Reference Guide, eWater Cooperative Research Centre, Canberra, Australia, https://ewater.atlassian.net/wiki/display/SD35/Irrigator+Demand+Model+-+SRG

Bos, M.G. and J. Nugteren (1990) On irrigatio efficiencies, 4th edition. Wageningen: International Institute for Land Reclamation and Improvements/LRI publication 19.

Carr, R, Podger, G. eWater Source — Australia's Next Generation IWRM Modelling Platform 34th Hydrology and Water Resources Symposium (December 2012), ISBN 978-1-922107-62-6

CSIRO (2009a) Water in the Flinders-Leichhardt region, pp 187-274 in CSIRO (2009) Water in the Gulf of Carpentaria Drainage Division. A report to the Australian Government from the CSIRO Northern Australia Sustainable Yields Project. CSIRO Water for a Healthy Country Flagship, Australia. xl + 479pp

CSIRO (2009b) Water in the South-East Gulf region, pp 275-345 in CSIRO (2009) Water in the Gulf of Carpentaria Drainage Division. A report to the Australian Government from the CSIRO Northern Australia Sustainable Yields Project. CSIRO Water for a Healthy Country Flagship, Australia. xl + 479pp

Jeffrey SJ, Carter JO, Moodie KM and Beswick AR (2001) Using spatial interpolation to construct a comprehensive archive of Australian climate data. Environmental Modelling and Software 16/4, 309-330.

Keating, BA, Carberry, PS, Hammer, GL, Probert, ME, Robertson, MJ, Holzworth, D, Huth, NI, Hargreaves, JNG, Meinke, H, Hochman, Z, McLean, G, Verburg, K, Snow, V, Dimes, JP, Silburn, M, Wang, E, Brown, S, Bristow, KL, Asseng, S, Chapman, S et al. (2003) An overview of APSIM, a model designed for farming systems simulation. *European Journal of Agronomy*, *18* 3-4: 267-288.

Lerat J, Egan C, Kim S, Gooda M, Loy A, Shao Q, and Petheram C (2013) Calibration of river models for the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Marsden Jacobs Associates, 2003, improving water-use efficiency in irrigation conveyance systems: a study of investment strategies. Pub: Land and Water Australia, 45 p. http://lwa.gov.au/files/products/river-landscapes/pr030493/pr030493.pdf

MDBA 2010 MD1015 Estimating Land Surface Diversions: Stage 2

Meyer , W (2005) The Irrigation Industry in the Murray and Murrumbidgee Basins, CRC for Irrigation Futures, Adelaide, Australia

Petheram C, Hughes D, Rustomji P, Smith K, Van Neil TG and Yang A (2009) Information supporting river modelling undertaken for the Northern Australia Sustainable Yields project. A report to the Australian Government from the CSIRO Northern Australia Sustainable Yields Project. CSIRO Water for a Healthy Country flagship, Australia.

Petheram, Cuan; Rustomji, Paul; McVicar, Tim; Cai, Wenju; Chiew, Francis; Vleeshouwer, Jamie; et al. Estimating impact of climate change on runoff across the tropical savannas and semi-arid rangelands of northern Australia. Journal of Hydrometeorology. 2012; 13(2):483-503.

Petheram C and Yang A (2013) Climatic data and their characterisation for hydrological and agricultural scenario modelling across the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North

Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia

Petheram C, Watson I and Stone P (eds.) (2013a) Agricultural resource assessment for the Flinders catchment. A report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Petheram C, Watson I and Stone P (eds.) (2013b) Agricultural resource assessment for the Gilbert catchment. A report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Pratt Water 2004, *The business of saving water: the report of the Murrumbidgee Valley Water Efficiency Project: appendices*, Pratt Water, Campbellfield, Victoria, viewed 18 December 2013, <http://nrmonline.nrm.gov.au/catalog/mql:217>.

Webster T and Poulton P (2013) Agricultural production in the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Welsh WD, Vaze J, Dutta D, Rassam D, Rahman JM, Jolly ID, Wallbrink P, Podger GM, Bethune M, Hardy M, Teng J, Lerat J. An integrated modelling framework for regulated river systems. Environmental Modelling and Software (2012), DOI 10.1016/j.envsoft.2012.02.022.

Wigginton, David (2012) *Measuring to improve water storage efficiency,* in Australian Cotton Research Institute & Cotton Catchment Communities Cooperative Research Centre (Australia) 2012, *The Australian cotton water story : a decade of research & development 2002-2012*, Cotton Catchment Communities CRC Limited : Australian Cotton Research Institute, Narrabri, N.S.W

Appendix A Assessment products

More information about the Flinders and Gilbert Agricultural Resource Assessment can be found at <http://www.csiro.au/FGARA>. The website provides readers with a communications suite including factsheets, multimedia content, FAQs, reports and links to other related sites, particularly about other research in northern Australia.

In order to meet the requirements specified in the contracted Timetable for the Services, the Assessment provided the following key deliverables:

- Technical reports present scientific work at a level of detail sufficient for technical and scientific experts to reproduce the work. Each of the activities of the Assessment has a corresponding technical report.
- Each of the two catchment reports (one for each of the Flinders and Gilbert catchments) synthesises key material from the technical reports, providing well-informed but non-scientific readers with the information required to make decisions about the opportunities, costs and benefits associated with irrigated agriculture.
- Three summary reports – one for each catchment and another for northern Australia – are provided for a general public audience.

This appendix lists all such deliverables.

Please cite as they appear.

A.1.1 METHODS REPORTS

CSIRO (2012) Proposed project methods. A report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

A.1.2 TECHNICAL REPORTS

Barber M (2013) Indigenous water values, rights and interests in the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Bartley R, Thomas MF, Clifford D, Phillip S, Brough D, Harms D, Willis R, Gregory L, Glover M, Moodie K, Sugars M, Eyre L, Smith DJ, Hicks W and Petheram C (2013) Land suitability: technical methods. A technical report to the Australian Government from the Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Brennan McKellar L, Monjardino M, Bark R, Wittwer G, Banerjee O, Higgins A, MacLeod N, Crossman N, Prestwidge D and Laredo L (2013) Irrigation costs and benefits. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Crossman N and Bark R (2013) Socio-economics: triple-bottom-line accounting. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Dutta D, Karim F, Ticehurst C, Marvanek S and Petheram C (2013) Floodplain inundation mapping and modelling in the Flinders and Gilbert Catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland

Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Holz L, Kim S, Petheram C, Podger G, Hughes J, Kehoe M, Aramini D, Podger S, Lerat J, Poulton P, Hornbuckle J and Perraud J-M (2013) River system modelling for the Flinders and Gilbert Agricultural Resource Assessment case study analysis. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Jolly I, Taylor A, Rassam D, Knight J, Davies P and Harrington G (2013) Surface water – groundwater connectivity. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Lee A, Voogt S, Harding P and Loy A (2013) Design flood hydrology for selected dam sites in the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Lerat J, Egan C, Kim S, Gooda M, Loy A, Shao Q and Petheram C (2013) Calibration river models for the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

McJannet D, Marvanek S, Kinsey-Henderson A, Petheram C and Wallace J (2013) Instream waterholes. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Munday T, Davis A, Cahill K and Abdat T (2013) Geophysics. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Petheram C and Yang A (2013) Climate data and their characterisation for hydrological and agricultural scenario modelling across the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Petheram C, Rogers L, Eades G, Marvanek S, Gallant J, Read A, Sherman B, Yang A, Waltham N, McIntyre-Tamwoy S, Burrows D, Kim S, Podger S, Tomkins K, Poulton P, Holz L, Bird M, Atkinson F, Gallant S and Kehoe M (2013) Assessment of surface water storage options in the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Tomkins K (2013) Estimated sediment infilling rates for dams in Northern Australia based on a review of previous literature. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Waltham N, Burrows D, Butler B, Brodie J, Thomas C and Wallace J (2013) Waterhole ecology in the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Webster T, Poulton P, Yeates S, Cocks B, Hornbuckle J, Gentle J, Brennan McKellar L, Mayberry D, Jones D and Wixon A (2013) Agricultural productivity in the Flinders and Gilbert catchments. A technical report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

A.1.3 CATCHMENT REPORTS

Petheram C, Watson I and Stone P (eds.) (2013) Agricultural resource assessment for the Flinders catchment. A report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

Petheram C, Watson I and Stone P (eds.) (2013) Agricultural resource assessment for the Gilbert catchment. A report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

A.1.4 OVERVIEW REPORTS

CSIRO (2013) Agricultural resource assessment for the Flinders catchment. An overview report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

CSIRO (2013) Agricultural resource assessment for the Gilbert catchment. An overview report to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

CSIRO (2013) Flinders and Gilbert Agricultural Resource Assessment. Key findings of reports to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

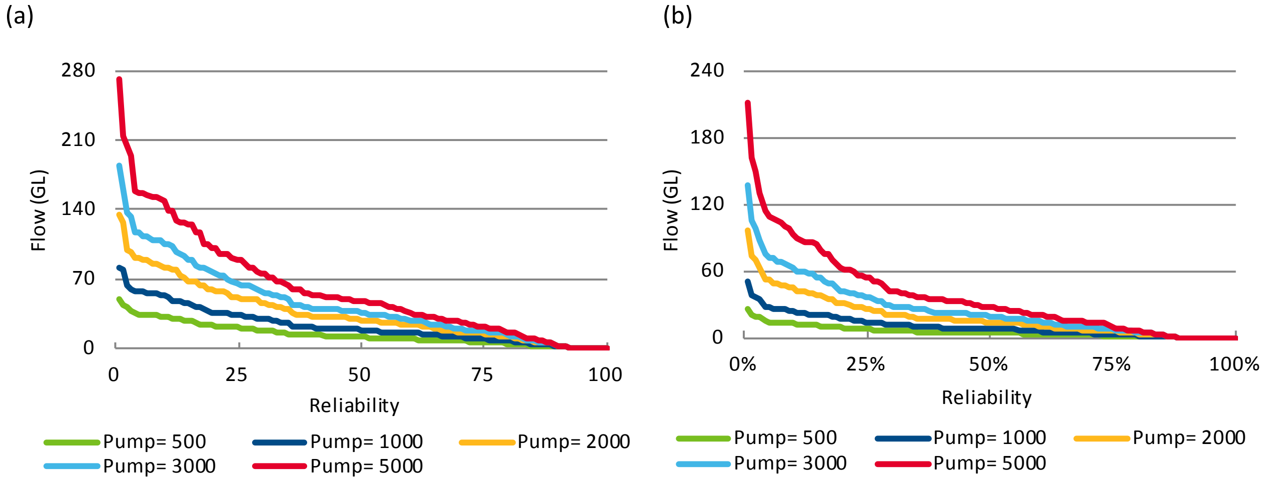
A.1.5 FACTSHEET ON KEY FINDINGS

CSIRO (2013) Flinders and Gilbert Agricultural Resource Assessment. Key findings of reports to the Australian Government from the CSIRO Flinders and Gilbert Agricultural Resource Assessment, part of the North Queensland Irrigated Agriculture Strategy. CSIRO Water for a Healthy Country and Sustainable Agriculture flagships, Australia.

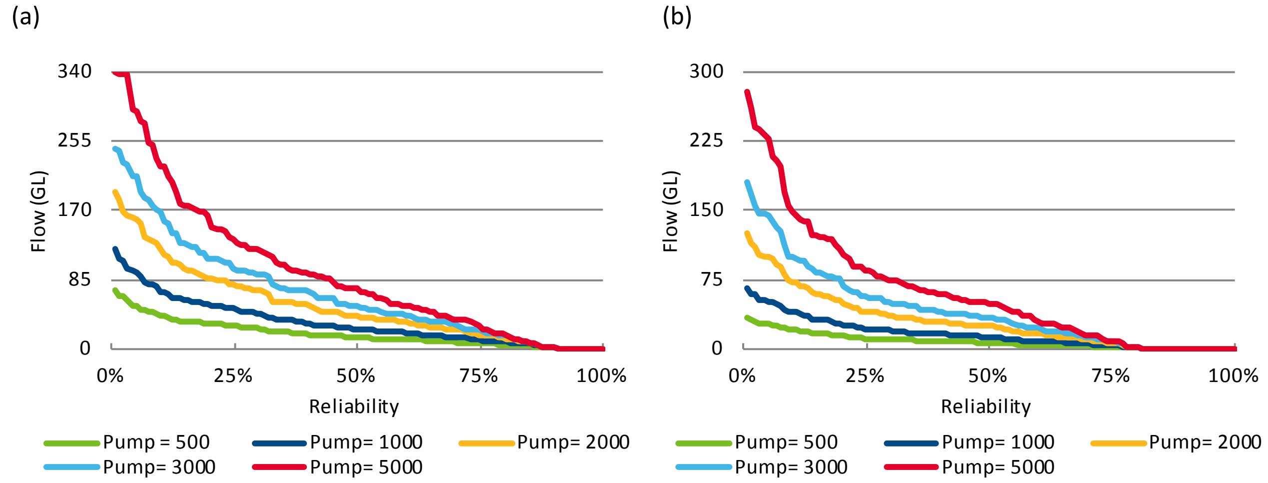
Appendix B Spreadsheet flow analysis

A spreadsheet analysis of flow data was undertaken for Flinders gauges to support the development of the Flinders Water Harvesting case study. This section presents some results which illustrate the sensitivity of the volume that can be harvested to the assumed pump capacity and commence to pump flow threshold. Results presented here are restricted to three gauges (915204A, 915008A and 915003A), four commence to pump thresholds (i.e. the streamflow value above which pumping or extraction can commence) and five pump capacities (i.e. the maximum volume of water that can be extracted by a pump in a day).

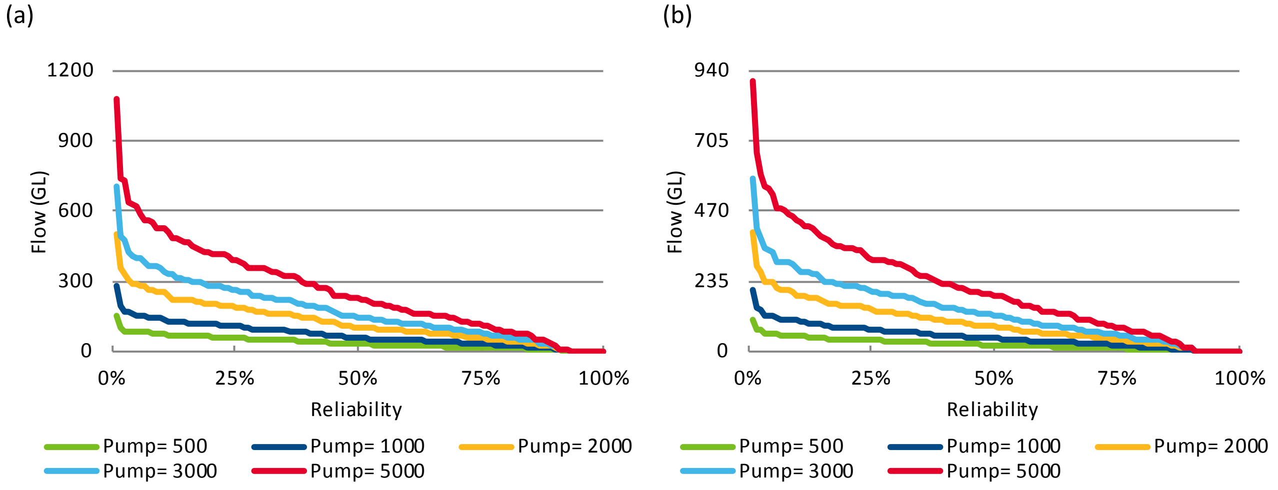
Apx Figure B.2 presents the results from a headwater catchment (9152034A), Apx Figure B.1 presents results from the middle reaches of the Flinders River (915008A) and Apx Figure B.3 presents results from the most downstream gauging station on the Flinders River (915003A).



Apx Figure B.1 Volume of streamflow extracted versus annual time reliability for streamflow gauge 915204A
(a) Commence to pump threshold of 100 ML/day. (b) Commence to pump threshold of 2000 ML/day. Pump capacities are in ML/day



Apx Figure B.2 Volume of streamflow extracted versus annual time reliability for streamflow gauge 915008A
(a) Commence to pump threshold of 100 ML/day. (b) Commence to pump threshold of 2000 ML/day. Pump capacities are in ML/day



Apx Figure B.3 Volume of streamflow extracted versus annual time reliability for streamflow gauge 915003A
(a) Commence to pump threshold of 100 ML/day. (b) Commence to pump threshold of 2000 ML/day. Pump capacities are in ML/day

The water harvesting figures show the reliability of extracting water at two thresholds for a range of pump capacities. The reliability curve is derived by choosing an annual water extraction on the y axis and following that line across to the desired pump capacity and then following that pump curve to the x axis. The reliability of annual extraction occurs at the percentage where the annual extraction intersects with the desired pump capacity. For example in Apx Figure B.3a a 5000 ML/day pump can extract 300 GL of water in about 40% of years.

Collectively these water harvesting curves show some interesting behaviours:

1. The pump curves converge on the x-axis. This represents the years when there is no flow to extract. For example in Apx Figure B.3 in 10% of years there is no water to extract.

2. The years where water cannot be extracted are not strongly dependent on the commence to pump threshold. Comparing Apx Figure B.2a and Apx Figure B.2b shows that increasing the commence to pump from 100 ML/day to 2000 ML/day only makes a small change in the number of years where no water can be extracted.

3. The relationship between the commence to pump threshold and pump capacity is reasonably planar i.e. for a higher commence to pump threshold the same reliability can be achieved by using a larger pump. However, the larger the pump the larger the capital cost of the pump.

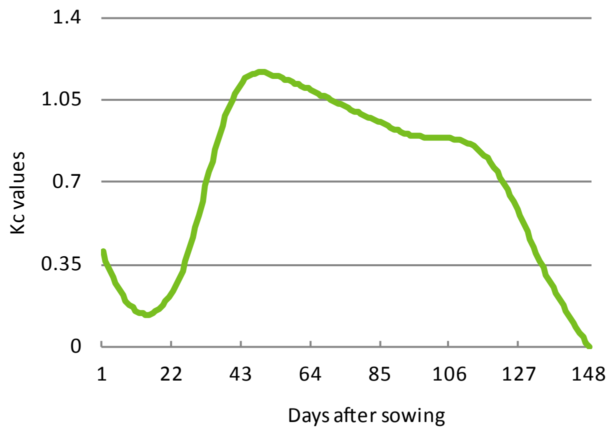
5. At lower percentage exceedance the volume of water extracted is directly related to pump capacity. At the lower percentage exceedance the streamflow events are extremely large and consequently the volume that can be taken is only limited by the size of the pump. At these low percentage exceedance the streamflow events are large and water levels rise and fall quickly i.e. the duration of the streamflow events is short.

6. The reliability increases with catchment area i.e. more downstream gauges are more reliable.

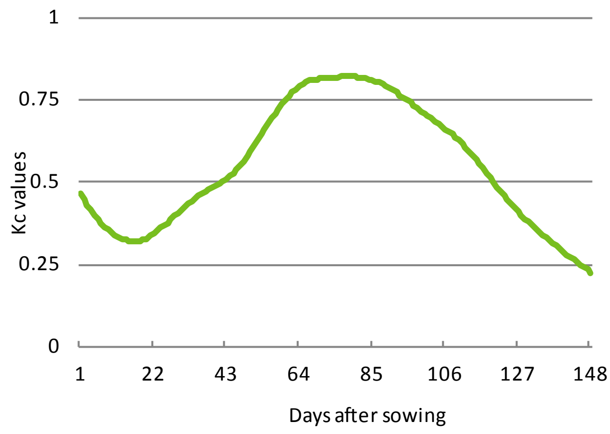
In using the water reliability curves presented in Apx Figure B.1 toApx Figure B.3, the reader needs to recognise that these curves do not provide any indication of the sequencing of dry spells or events. Successive years without any water extraction will have a considerable impact on the viability of a water user. The curves do not indicate when or how often water is extracted in a year. For example the volume of extraction does not distinguish between taking all of the water from a single event or from several events across a year. This may have implications on the cost of infrastructure required to store the water to obtain a sufficiently reliable supply.

Appendix C Crop k-c parameters

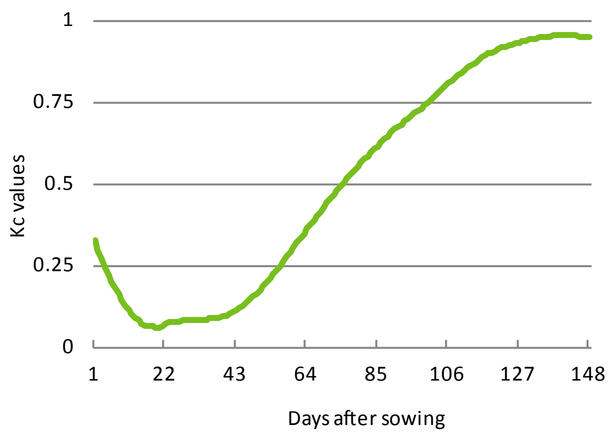
(a) Cave Hill - Sorghum



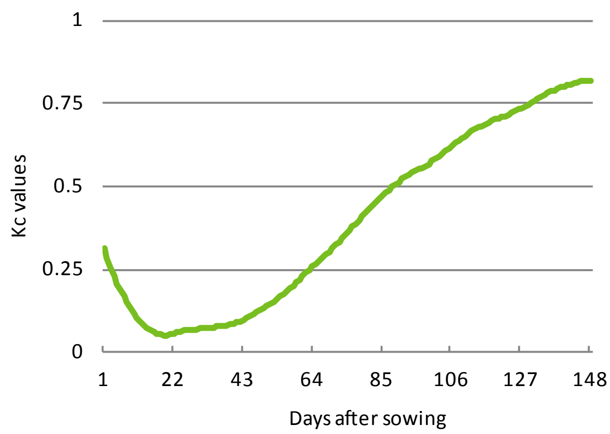
(b) Flinders water harvesting- Cotton



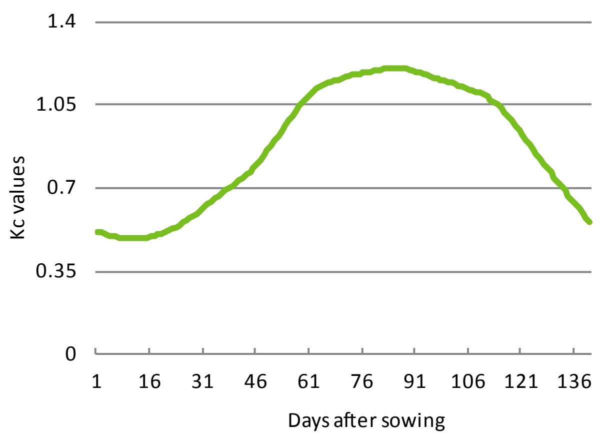
(e) Dagworth- Dagworth Sugar cane



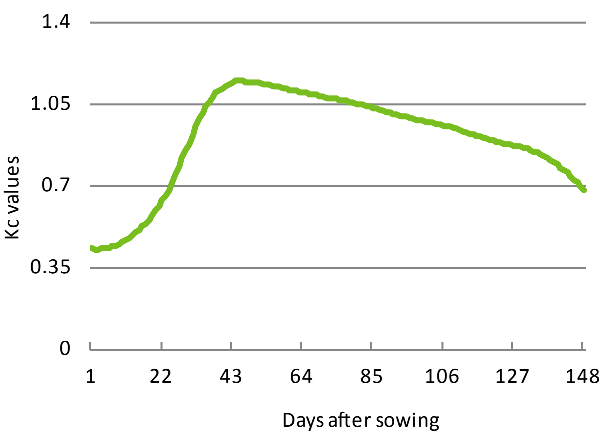
(f) Dagworth- Green Hills Sugar cane



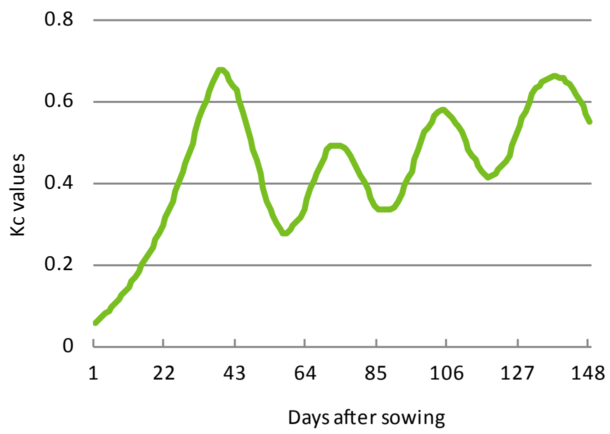
(g) Green Hills- Cotton



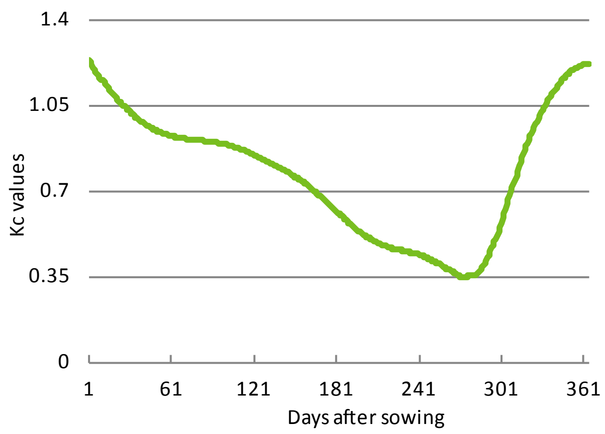
(h) Green Hills- Peanuts



(i) Green Hills- Sorghum



(j) Kidston- Bambatsi



Appendix D Hydrological metrics

This appendix provides detailed hydrological metrics for each case study for the selected irrigation development size.

FGARA Hydrological Metrics - Dry run on Cavehill ensemble runs

About this document

Purpose is to have a dry run on 50 runs ensembles for Dagworth vs Gilbert baseline

This document was generated on 2013-11-21 14:57:57 using among other things the packages 'knitr' and 'garaHydroMetrics' (https://stash.csiro.au/projects/~per202/repos/hydrometrics/browse)

Calculate statistics

Load the package the usual. It includes a fair level of documentation, that should be accessible using the '?' command, shortcut for help(garaHydroMetrics).

```
library(garaHydroMetrics)
```

```
## Warning: package 'garaHydroMetrics' was built under R version 3.0.2
```

```
## Loading required package: plyr
```

```
## Warning: package 'plyr' was built under R version 3.0.2
```

```
## Loading required package: xts
```

```
## Warning: package 'xts' was built under R version 3.0.2
```

```
## Loading required package: zoo
##
## Attaching package: 'zoo'
##
## The following object is masked from 'package:base':
##
##     as.Date, as.Date.numeric
##
## Loading required package: ggplot2
```

```
## Warning: package 'ggplot2' was built under R version 3.0.2
```

```
## Loading required package: stringr
```

```
## Warning: package 'stringr' was built under R version 3.0.2
```

```
## Loading required package: lubridate
```

```
## Warning: package 'lubridate' was built under R version 3.0.2
```

```
##
## Attaching package: 'lubridate'
##
## The following object is masked from 'package:plyr':
##
##     here
##
## Loading required package: reshape2
```

```
## Warning: package 'reshape2' was built under R version 3.0.2
```

```
## Loading required package: scales
```

```
## Warning: package 'scales' was built under R version 3.0.2
## Warning: replacing previous import 'here' when loading 'plyr'
```

```
library(plyr)
```

Mapping \wron\Project\GARA\2_Rivers\3_All\8_Case_Studies to a W: drive to preempt issues to do with too long paths.

```
baselineDir <- "X:/ScenarioB/"
# develDir <-
# 'X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns'
develDir <-
"X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates/"
# develDir <-
# 'X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles/'

findGaugeFiles <- function(topFolder) {
    pattern <- ".*_Gauge_daily.csv.gz"
    csvfiles <- list.files(path = topFolder, pattern = pattern, all.files = TRUE,
        full.names = TRUE, recursive = TRUE, ignore.case = TRUE)
}
baseFiles <- findGaugeFiles(baselineDir)
develFiles <- findGaugeFiles(develDir)

timeSeries <- lapply(c(baseFiles[c(1, 51)], develFiles[1]), loadXts)
gaugeNames <- lapply(timeSeries, names)
gaugeNames
```

```
## [[1]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[2]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[3]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
```

```
selectedGauges = gaugeNames[[1]][1:5]
subsetGauges <- function(ts, selectedGauges) {
    ts[, selectedGauges]
}
timeSeriesSubset <- lapply(timeSeries, subsetGauges, selectedGauges)
```

It looks like the second and third are matches, i.e.:

```
c(baseFiles[c(51)], develFiles[1])
```

```
## [1]
"X:/ScenarioB//Flinders_runfolders/run_rep_0047_scenarioA_wrpnores_v143_20131811_220632_2934/postpro
## [2]
"X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_baseline_noen
```

So let's roll the stats (circa 15 sec per file, expect around 25 minutes runtime). Given the considerable runtime, this is important to have a caching mechanism i.e. saving the result to an RData file. The file is only 2MB so it is worth caching.

```
scenarioFolders <- c("Flinders_runfolders", "CaveHill_v3NoImpact_12000_4_Replicates")
scenarioTags <- c("base", "dev")

statFile <- "Z:/GARA/2_Rivers/4_Working/per202/Cavehill/EnsFiles.RData"
stopifnot(file.exists(dirname(statFile)))

if (!file.exists(statFile)) {
    statList <- univStatsMultiScenario(c(baseFiles, develFiles), scenarioFolders,
        scenarioTags)
    save(statList, file = statFile)
} else {
    load(statFile)
}
```

```
## [1] "2013-11-21 14:58:36
X:/ScenarioB//Flinders_runfolders/run_baseline_noensemble_0000_scenarioA_wrpnores_v143_20131809_1610

## [1] "2013-11-21 14:58:47
X:/ScenarioB//Flinders_runfolders/run_baseline_noensemble_0000_scenarioCdry_wrpnores_v143_20131809_1

## [1] "2013-11-21 14:58:57
X:/ScenarioB//Flinders_runfolders/run_baseline_noensemble_0000_scenarioCmid_wrpnores_v143_20131809_1

## [1] "2013-11-21 14:59:07
X:/ScenarioB//Flinders_runfolders/run_baseline_noensemble_0000_scenarioCwet_wrpnores_v143_20131809_1

## [1] "2013-11-21 14:59:18
X:/ScenarioB//Flinders_runfolders/run_rep_0001_scenarioA_wrpnores_v143_20131811_150355_18492/postpro

## [1] "2013-11-21 14:59:29
X:/ScenarioB//Flinders_runfolders/run_rep_0002_scenarioA_wrpnores_v143_20131811_150357_18498/postpro

## [1] "2013-11-21 14:59:40
X:/ScenarioB//Flinders_runfolders/run_rep_0003_scenarioA_wrpnores_v143_20131811_150400_18505/postpro

## [1] "2013-11-21 14:59:52
X:/ScenarioB//Flinders_runfolders/run_rep_0004_scenarioA_wrpnores_v143_20131811_150402_18511/postpro

## [1] "2013-11-21 15:00:04
X:/ScenarioB//Flinders_runfolders/run_rep_0005_scenarioA_wrpnores_v143_20131811_150404_18518/postpro

## [1] "2013-11-21 15:00:14
X:/ScenarioB//Flinders_runfolders/run_rep_0006_scenarioA_wrpnores_v143_20131811_150405_18524/postpro

## [1] "2013-11-21 15:00:25
X:/ScenarioB//Flinders_runfolders/run_rep_0007_scenarioA_wrpnores_v143_20131811_150407_18531/postpro

## [1] "2013-11-21 15:00:36
X:/ScenarioB//Flinders_runfolders/run_rep_0008_scenarioA_wrpnores_v143_20131811_150409_18538/postpro

## [1] "2013-11-21 15:00:46
X:/ScenarioB//Flinders_runfolders/run_rep_0009_scenarioA_wrpnores_v143_20131811_150411_18544/postpro

## [1] "2013-11-21 15:00:58
X:/ScenarioB//Flinders_runfolders/run_rep_0010_scenarioA_wrpnores_v143_20131811_150413_18551/postpro

## [1] "2013-11-21 15:01:08
X:/ScenarioB//Flinders_runfolders/run_rep_0011_scenarioA_wrpnores_v143_20131811_150415_18557/postpro

## [1] "2013-11-21 15:01:19
X:/ScenarioB//Flinders_runfolders/run_rep_0012_scenarioA_wrpnores_v143_20131811_150417_18564/postpro

## [1] "2013-11-21 15:01:30
X:/ScenarioB//Flinders_runfolders/run_rep_0013_scenarioA_wrpnores_v143_20131811_150420_18570/postpro

## [1] "2013-11-21 15:01:41
X:/ScenarioB//Flinders_runfolders/run_rep_0014_scenarioA_wrpnores_v143_20131811_150421_18577/postpro

## [1] "2013-11-21 15:01:51
X:/ScenarioB//Flinders_runfolders/run_rep_0015_scenarioA_wrpnores_v143_20131811_150423_18583/postpro

## [1] "2013-11-21 15:02:01
X:/ScenarioB//Flinders_runfolders/run_rep_0016_scenarioA_wrpnores_v143_20131811_150425_18590/postpro

## [1] "2013-11-21 15:02:12
X:/ScenarioB//Flinders_runfolders/run_rep_0017_scenarioA_wrpnores_v143_20131811_150427_18596/postpro

## [1] "2013-11-21 15:02:23
X:/ScenarioB//Flinders_runfolders/run_rep_0018_scenarioA_wrpnores_v143_20131811_150429_18603/postpro

## [1] "2013-11-21 15:02:33
X:/ScenarioB//Flinders_runfolders/run_rep_0019_scenarioA_wrpnores_v143_20131811_150431_18609/postpro

## [1] "2013-11-21 15:02:45
X:/ScenarioB//Flinders_runfolders/run_rep_0020_scenarioA_wrpnores_v143_20131811_150433_18616/postpro

## [1] "2013-11-21 15:02:55
X:/ScenarioB//Flinders_runfolders/run_rep_0021_scenarioA_wrpnores_v143_20131811_150435_18622/postpro

## [1] "2013-11-21 15:03:06
X:/ScenarioB//Flinders_runfolders/run_rep_0022_scenarioA_wrpnores_v143_20131811_150437_18629/postpro
```

```
## [1] "2013-11-21 15:03:19
X:/ScenarioB//Flinders_runfolders/run_rep_0023_scenarioA_wrpnores_v143_20131811_150439_18636/postpro

## [1] "2013-11-21 15:03:30
X:/ScenarioB//Flinders_runfolders/run_rep_0024_scenarioA_wrpnores_v143_20131811_150442_18645/postpro

## [1] "2013-11-21 15:03:40
X:/ScenarioB//Flinders_runfolders/run_rep_0025_scenarioA_wrpnores_v143_20131811_150443_18649/postpro

## [1] "2013-11-21 15:03:51
X:/ScenarioB//Flinders_runfolders/run_rep_0026_scenarioA_wrpnores_v143_20131811_220456_2680/postproc

## [1] "2013-11-21 15:04:01
X:/ScenarioB//Flinders_runfolders/run_rep_0027_scenarioA_wrpnores_v143_20131811_220458_2686/postproc

## [1] "2013-11-21 15:04:12
X:/ScenarioB//Flinders_runfolders/run_rep_0028_scenarioA_wrpnores_v143_20131811_220500_2693/postproc

## [1] "2013-11-21 15:04:23
X:/ScenarioB//Flinders_runfolders/run_rep_0029_scenarioA_wrpnores_v143_20131811_220503_2699/postproc

## [1] "2013-11-21 15:04:33
X:/ScenarioB//Flinders_runfolders/run_rep_0030_scenarioA_wrpnores_v143_20131811_220504_2706/postproc

## [1] "2013-11-21 15:04:43
X:/ScenarioB//Flinders_runfolders/run_rep_0031_scenarioA_wrpnores_v143_20131811_220506_2712/postproc

## [1] "2013-11-21 15:04:54
X:/ScenarioB//Flinders_runfolders/run_rep_0032_scenarioA_wrpnores_v143_20131811_220508_2719/postproc

## [1] "2013-11-21 15:05:05
X:/ScenarioB//Flinders_runfolders/run_rep_0033_scenarioA_wrpnores_v143_20131811_220510_2725/postproc

## [1] "2013-11-21 15:05:16
X:/ScenarioB//Flinders_runfolders/run_rep_0034_scenarioA_wrpnores_v143_20131811_220520_2732/postproc

## [1] "2013-11-21 15:05:26
X:/ScenarioB//Flinders_runfolders/run_rep_0035_scenarioA_wrpnores_v143_20131811_220526_2738/postproc

## [1] "2013-11-21 15:05:36
X:/ScenarioB//Flinders_runfolders/run_rep_0036_scenarioA_wrpnores_v143_20131811_220526_2748/postproc

## [1] "2013-11-21 15:05:46
X:/ScenarioB//Flinders_runfolders/run_rep_0037_scenarioA_wrpnores_v143_20131811_220526_2755/postproc

## [1] "2013-11-21 15:05:56
X:/ScenarioB//Flinders_runfolders/run_rep_0038_scenarioA_wrpnores_v143_20131811_220526_2761/postproc

## [1] "2013-11-21 15:06:07
X:/ScenarioB//Flinders_runfolders/run_rep_0039_scenarioA_wrpnores_v143_20131811_220526_2774/postproc

## [1] "2013-11-21 15:06:16
X:/ScenarioB//Flinders_runfolders/run_rep_0040_scenarioA_wrpnores_v143_20131811_220548_2781/postproc

## [1] "2013-11-21 15:06:28
X:/ScenarioB//Flinders_runfolders/run_rep_0041_scenarioA_wrpnores_v143_20131811_220548_2791/postproc

## [1] "2013-11-21 15:06:38
X:/ScenarioB//Flinders_runfolders/run_rep_0042_scenarioA_wrpnores_v143_20131811_220548_2807/postproc

## [1] "2013-11-21 15:06:49
X:/ScenarioB//Flinders_runfolders/run_rep_0043_scenarioA_wrpnores_v143_20131811_220548_2814/postproc

## [1] "2013-11-21 15:07:00
X:/ScenarioB//Flinders_runfolders/run_rep_0044_scenarioA_wrpnores_v143_20131811_220548_2833/postproc

## [1] "2013-11-21 15:07:11
X:/ScenarioB//Flinders_runfolders/run_rep_0045_scenarioA_wrpnores_v143_20131811_220550_2853/postproc

## [1] "2013-11-21 15:07:21
X:/ScenarioB//Flinders_runfolders/run_rep_0046_scenarioA_wrpnores_v143_20131811_220613_2895/postproc

## [1] "2013-11-21 15:07:32
X:/ScenarioB//Flinders_runfolders/run_rep_0047_scenarioA_wrpnores_v143_20131811_220632_2934/postproc

## [1] "2013-11-21 15:07:42
X:/ScenarioB//Flinders_runfolders/run_rep_0048_scenarioA_wrpnores_v143_20131811_220633_2970/postproc

## [1] "2013-11-21 15:07:52
X:/ScenarioB//Flinders_runfolders/run_rep_0049_scenarioA_wrpnores_v143_20131811_220632_2993/postproc

## [1] "2013-11-21 15:08:02
X:/ScenarioB//Flinders_runfolders/run_rep_0050_scenarioA_wrpnores_v143_20131811_220634_3000/postproc

## [1] "2013-11-21 15:08:12
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_baseline_noens

## [1] "2013-11-21 15:08:23
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0001_scena

## [1] "2013-11-21 15:08:34
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0002_scena

## [1] "2013-11-21 15:08:44
```

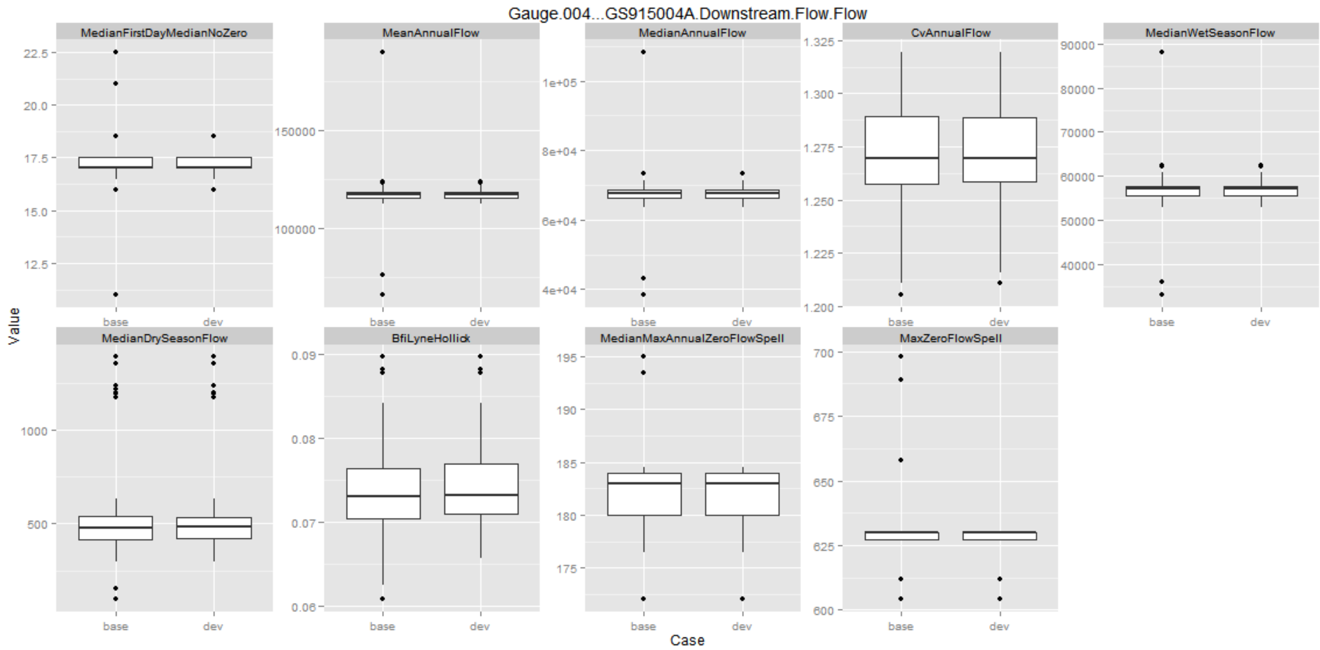
```
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0003_scenar

## [1] "2013-11-21 15:08:54
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0004_scenar

## [1] "2013-11-21 15:09:04
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0005_scenar

## [1] "2013-11-21 15:09:16
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0006_scenar

## [1] "2013-11-21 15:09:26
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0007_scenar

## [1] "2013-11-21 15:09:37
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0008_scenar

## [1] "2013-11-21 15:09:48
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0009_scenar

## [1] "2013-11-21 15:09:58
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0010_scenar

## [1] "2013-11-21 15:10:09
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0011_scenar

## [1] "2013-11-21 15:10:19
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0012_scenar

## [1] "2013-11-21 15:10:30
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0013_scenar

## [1] "2013-11-21 15:10:41
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0014_scenar

## [1] "2013-11-21 15:10:51
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0015_scenar

## [1] "2013-11-21 15:11:02
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0016_scenar

## [1] "2013-11-21 15:11:12
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0017_scenar

## [1] "2013-11-21 15:11:25
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0018_scenar

## [1] "2013-11-21 15:11:36
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0019_scenar

## [1] "2013-11-21 15:11:46
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0020_scenar

## [1] "2013-11-21 15:11:57
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0021_scenar

## [1] "2013-11-21 15:12:07
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0022_scenar

## [1] "2013-11-21 15:12:18
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0023_scenar

## [1] "2013-11-21 15:12:29
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0024_scenar

## [1] "2013-11-21 15:12:39
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0025_scenar

## [1] "2013-11-21 15:12:50
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0026_scenar

## [1] "2013-11-21 15:13:00
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0027_scenar

## [1] "2013-11-21 15:13:11
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0028_scenar

## [1] "2013-11-21 15:13:21
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0029_scenar

## [1] "2013-11-21 15:13:32
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0030_scenar

## [1] "2013-11-21 15:13:43
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0031_scenar

## [1] "2013-11-21 15:13:53
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0032_scenar

## [1] "2013-11-21 15:14:04
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0033_scenar

## [1] "2013-11-21 15:14:15
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0034_scenar
```

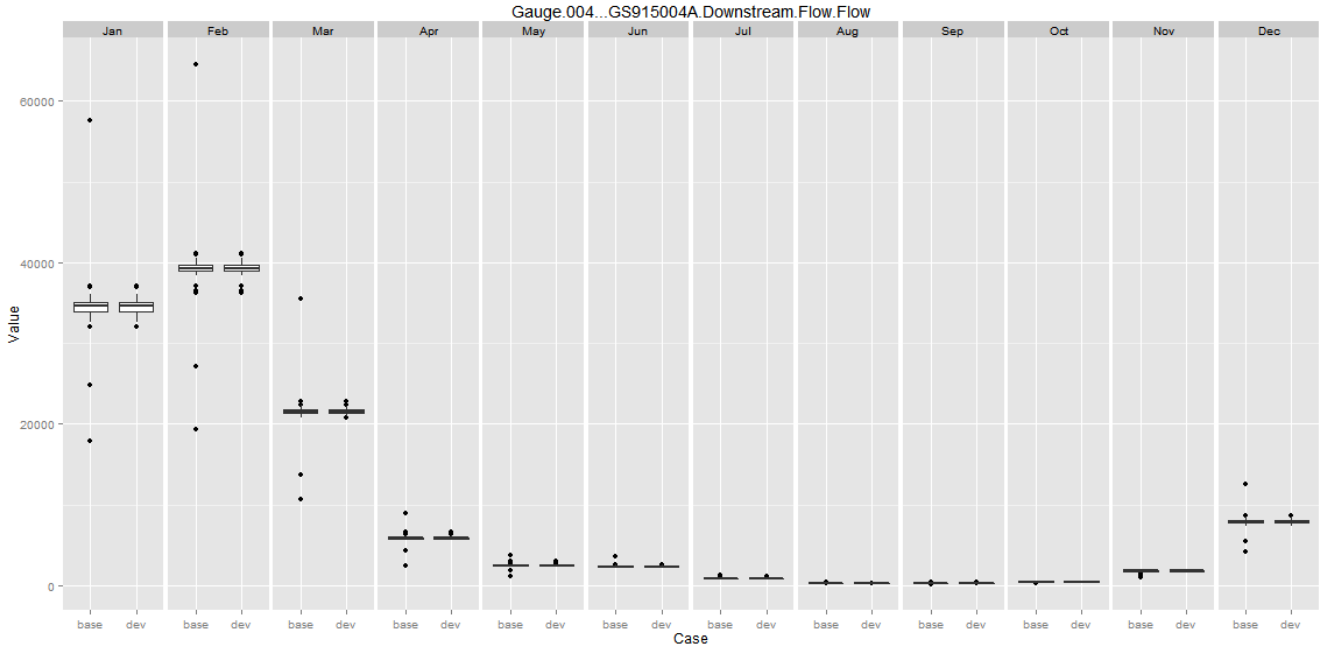
```
## [1] "2013-11-21 15:14:26
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0035_scena

## [1] "2013-11-21 15:14:36
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0036_scena

## [1] "2013-11-21 15:14:47
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0037_scena

## [1] "2013-11-21 15:14:57
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0038_scena

## [1] "2013-11-21 15:15:07
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0039_scena

## [1] "2013-11-21 15:15:17
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0040_scena

## [1] "2013-11-21 15:15:27
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0041_scena

## [1] "2013-11-21 15:15:37
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0042_scena

## [1] "2013-11-21 15:15:48
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0043_scena

## [1] "2013-11-21 15:15:58
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0044_scena

## [1] "2013-11-21 15:16:09
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0045_scena

## [1] "2013-11-21 15:16:19
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0046_scena

## [1] "2013-11-21 15:16:29
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0047_scena

## [1] "2013-11-21 15:16:39
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0048_scena

## [1] "2013-11-21 15:16:49
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0049_scena

## [1] "2013-11-21 15:16:59
X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates//run_rep_0050_scena
```

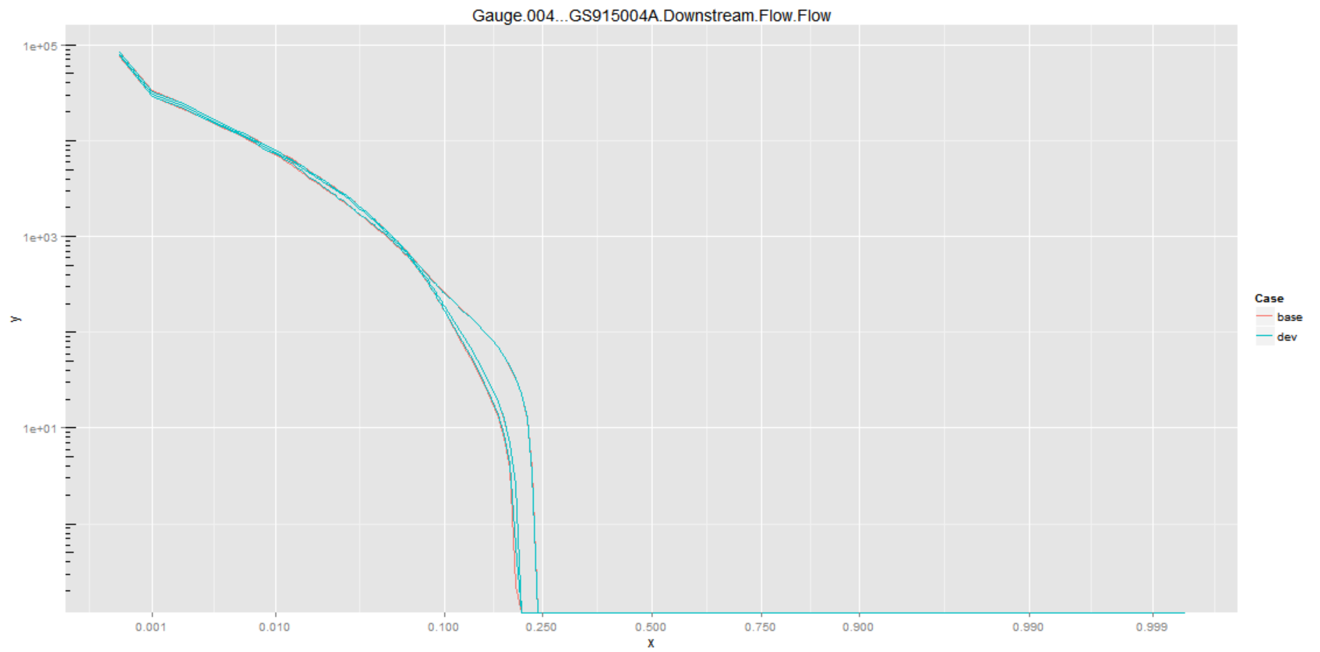
Visualization

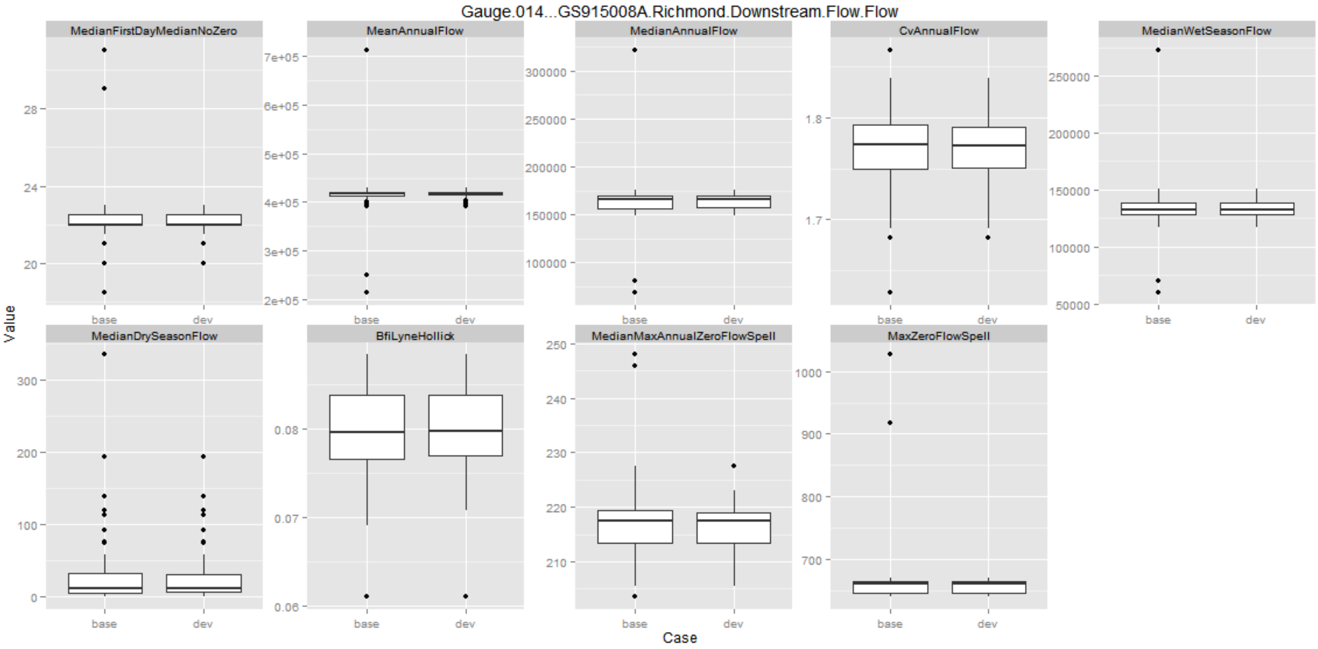
The visualization itself is not all that time comsuming.

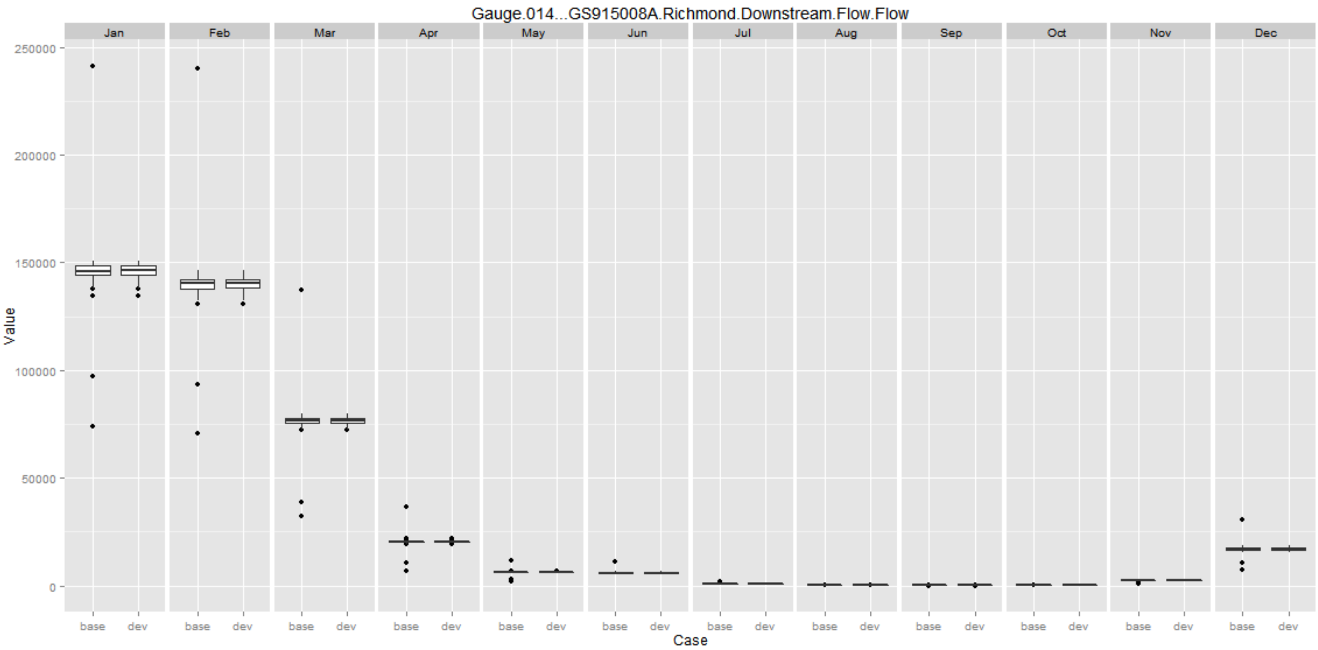
```
d <- listByGauge(rbind(statList[[c(1, 1)]], statList[[c(2, 1)]]))
mthFlows <- listByGauge(rbind(statList[[c(1, 2)]], statList[[c(2, 2)]]))
fdcData <- listByGauge(rbind(statList[[c(1, 3)]], statList[[c(2, 3)]]))
for (gaugename in names(d)) {
    print(getBoxplotsUniv(d[[gaugename]]) + ggtitle(gaugename))
    print(getBoxplotsMthly(mthFlows[[gaugename]], gaugename))
    print(getPlotFdc(fdcData[[gaugename]], gaugename))
}
```

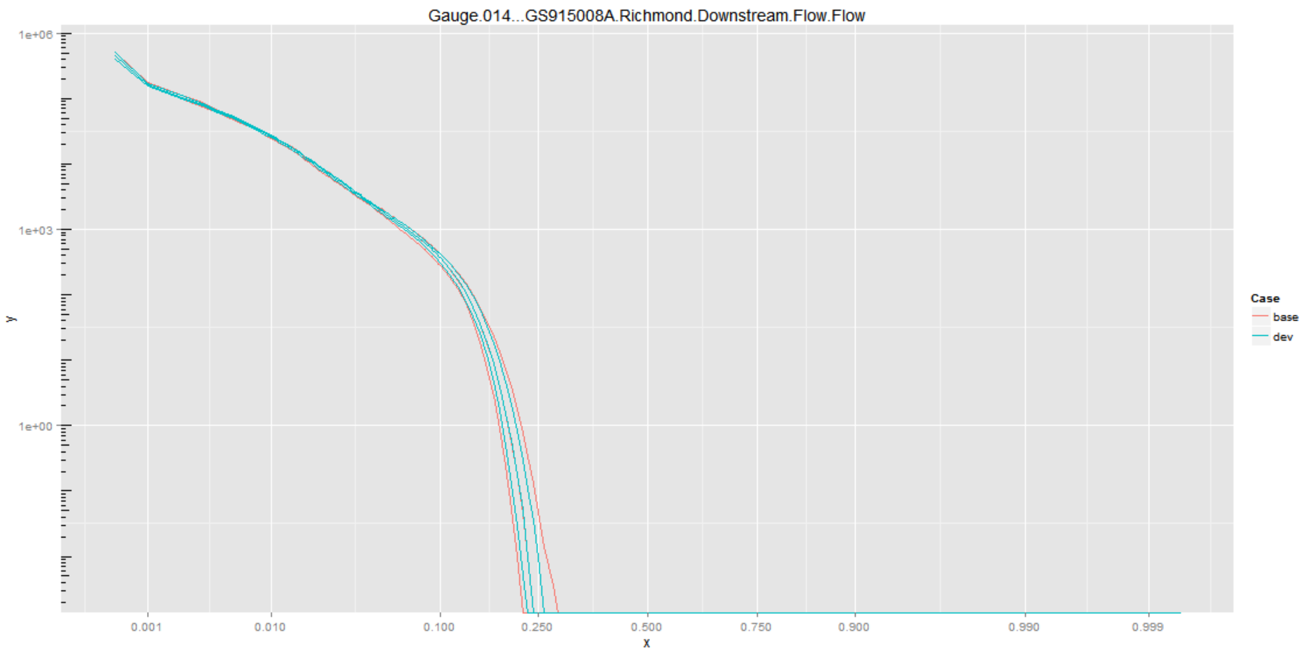

Gauge.004...GS915004A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

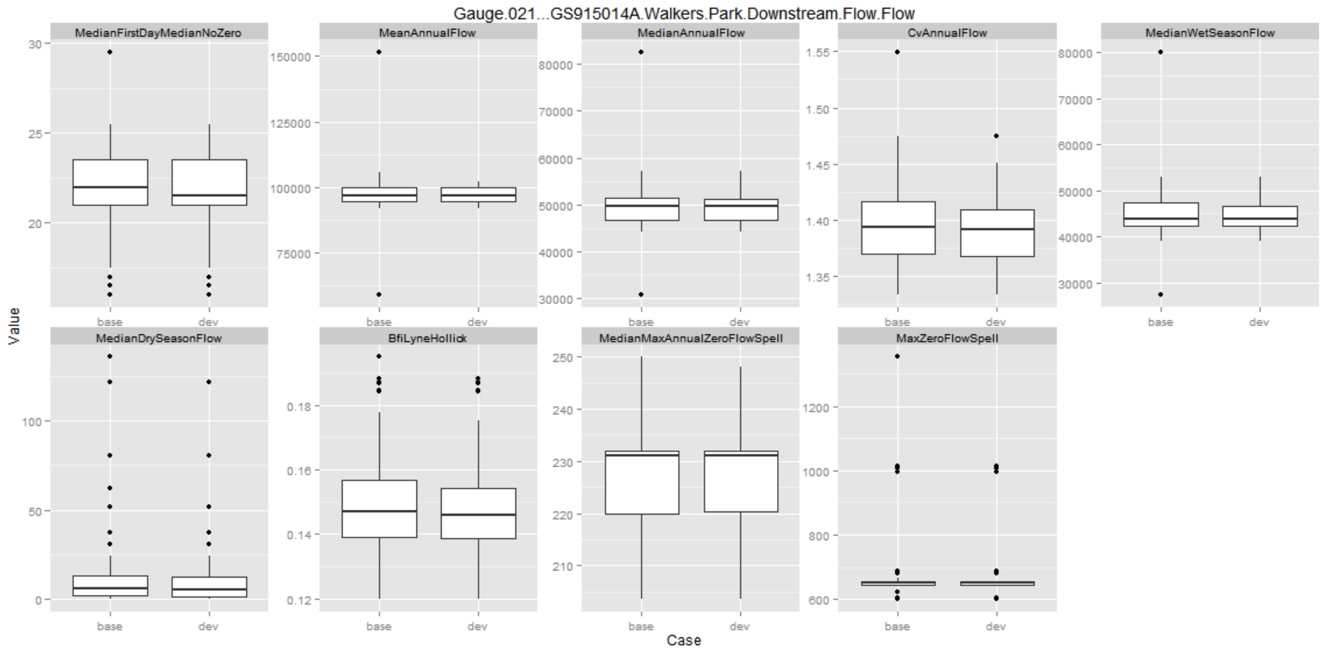

Gauge.004...GS915004A.Downstream.Flow.Flow
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Value
Case
base
dev

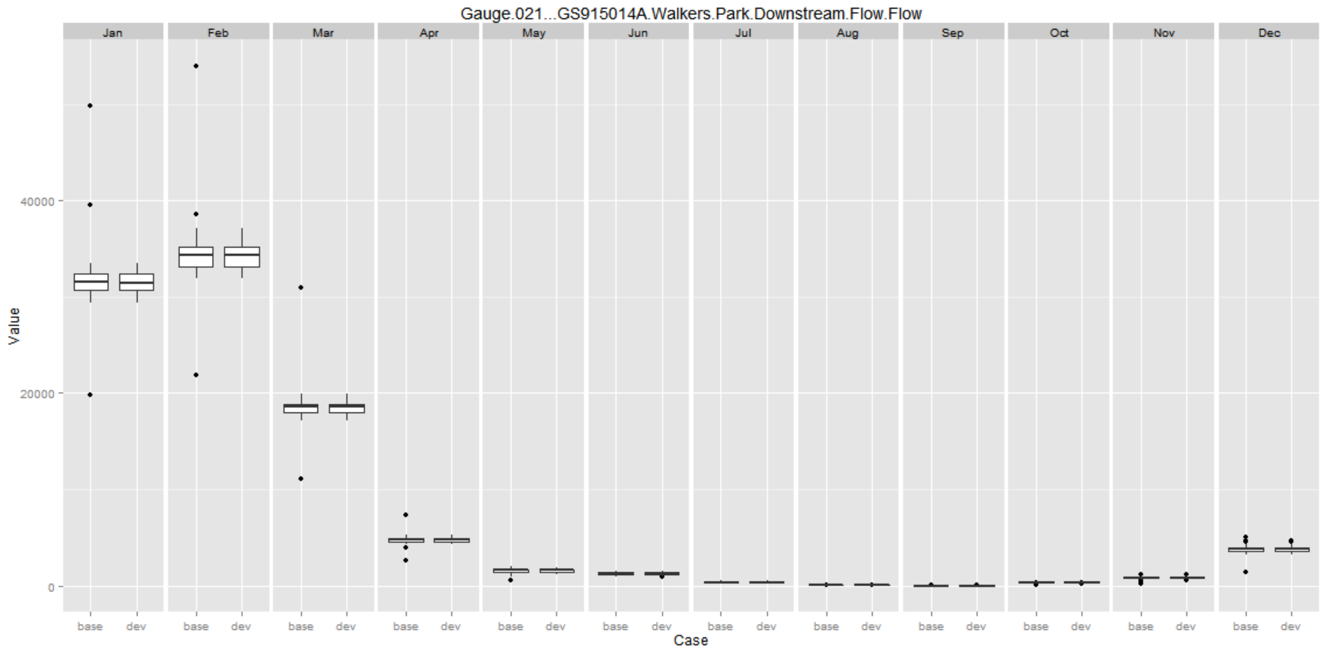

Gauge.004...GS915004A.Downstream.Flow.Flow
y
x
Case
base
dev

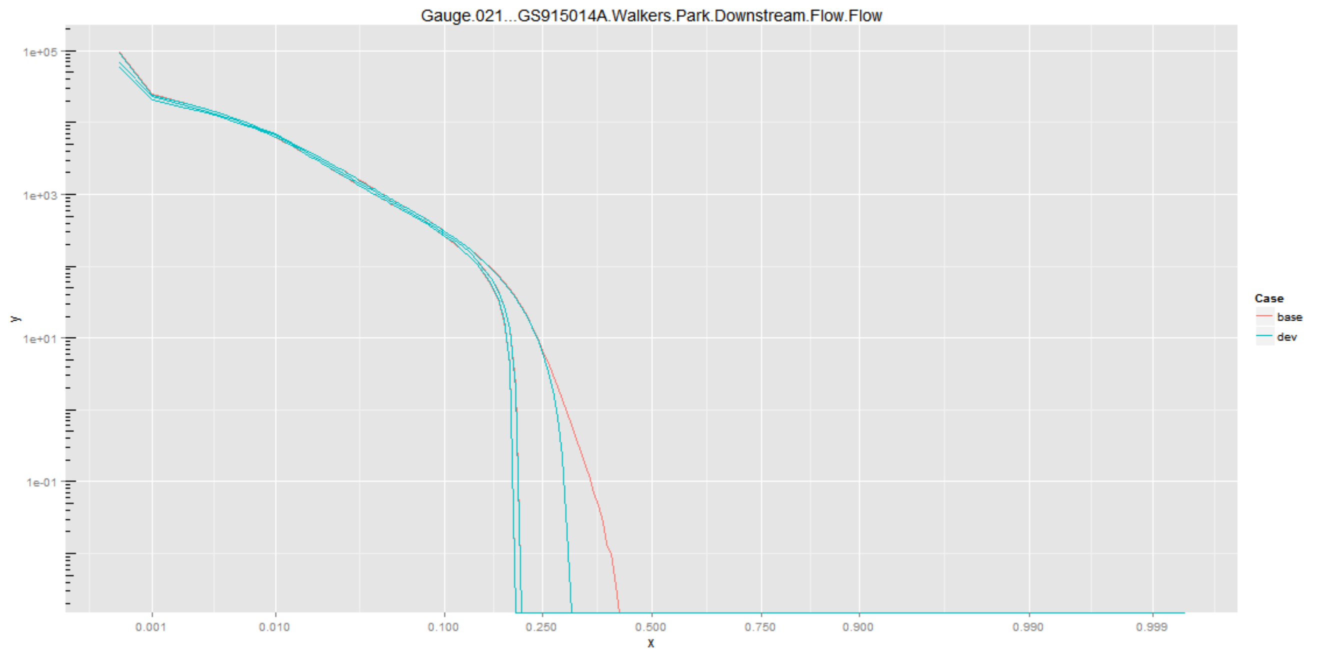

Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

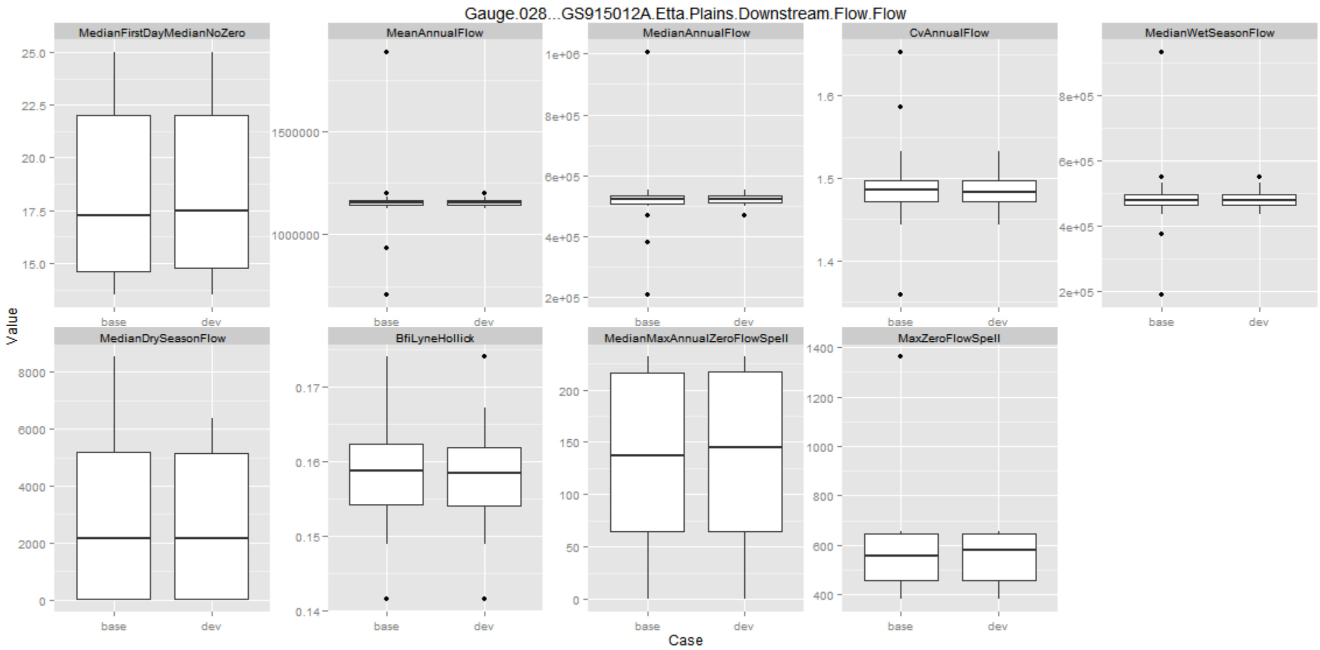

Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

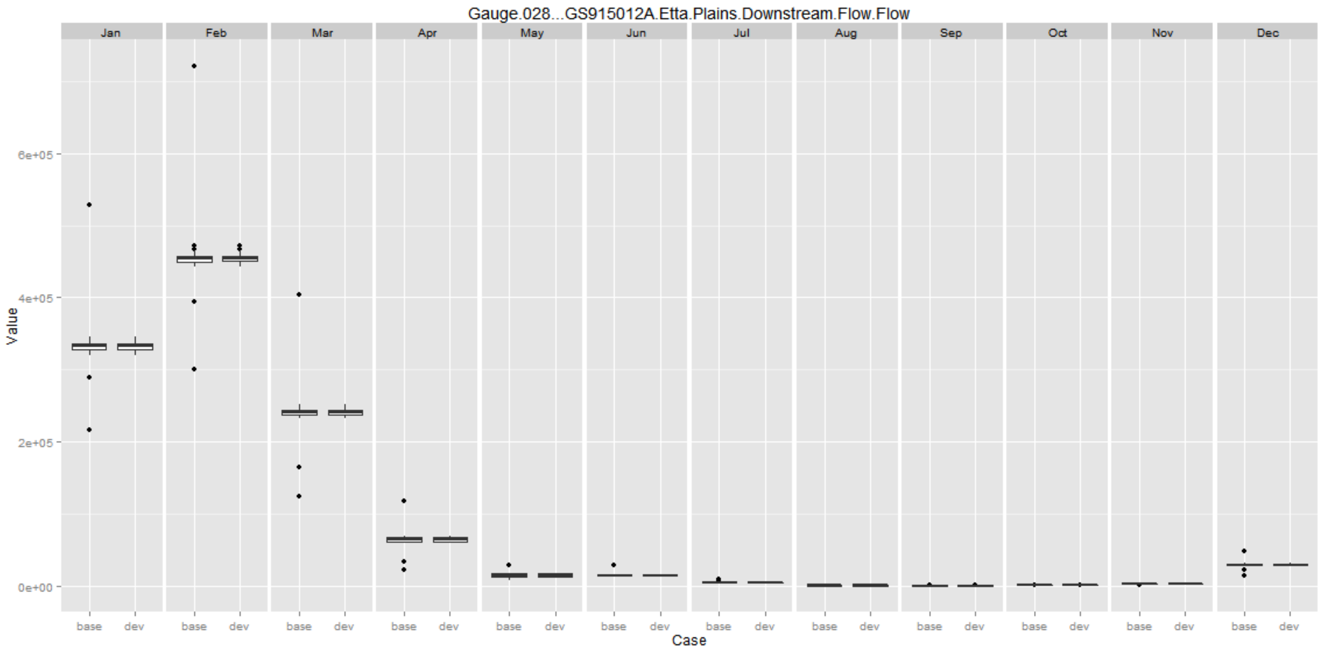

Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow
y
x
Case
base
dev

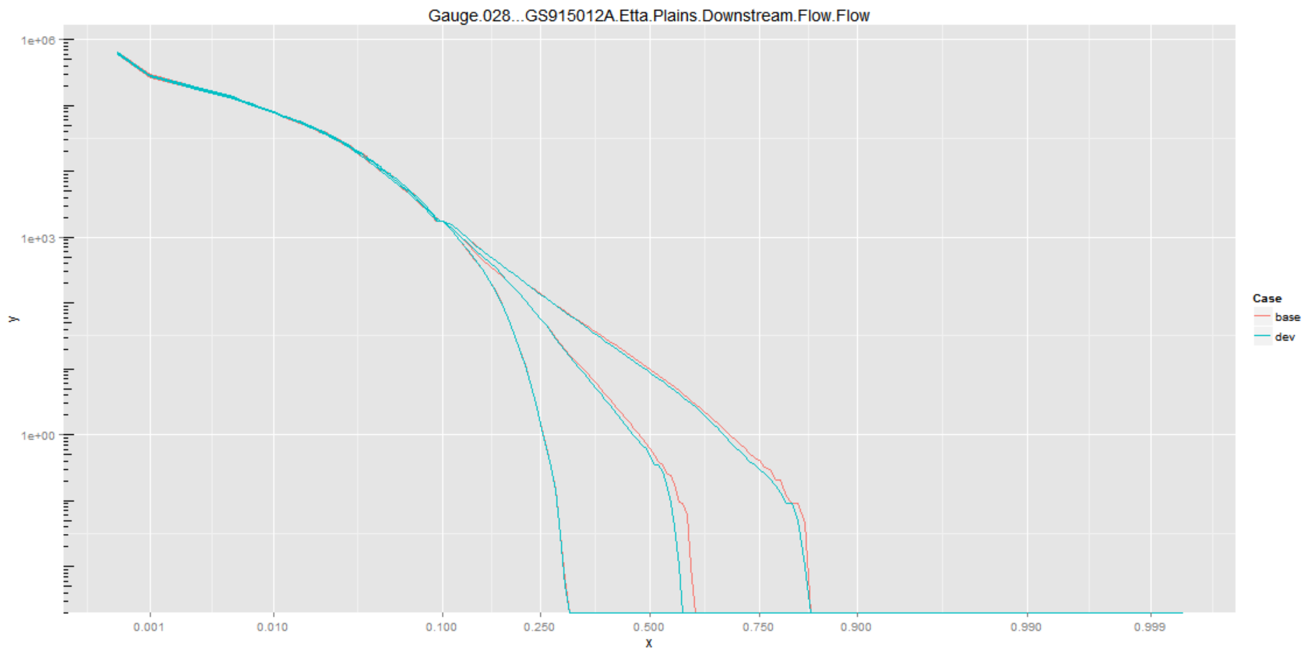

Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

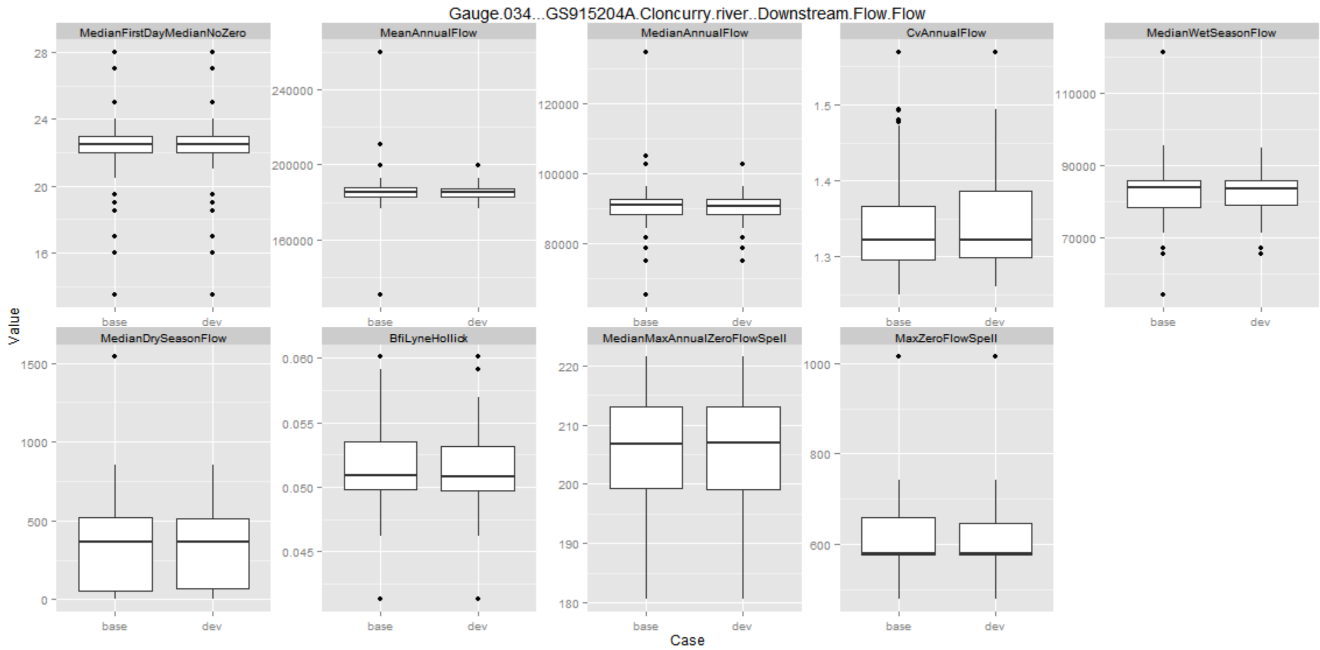

Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

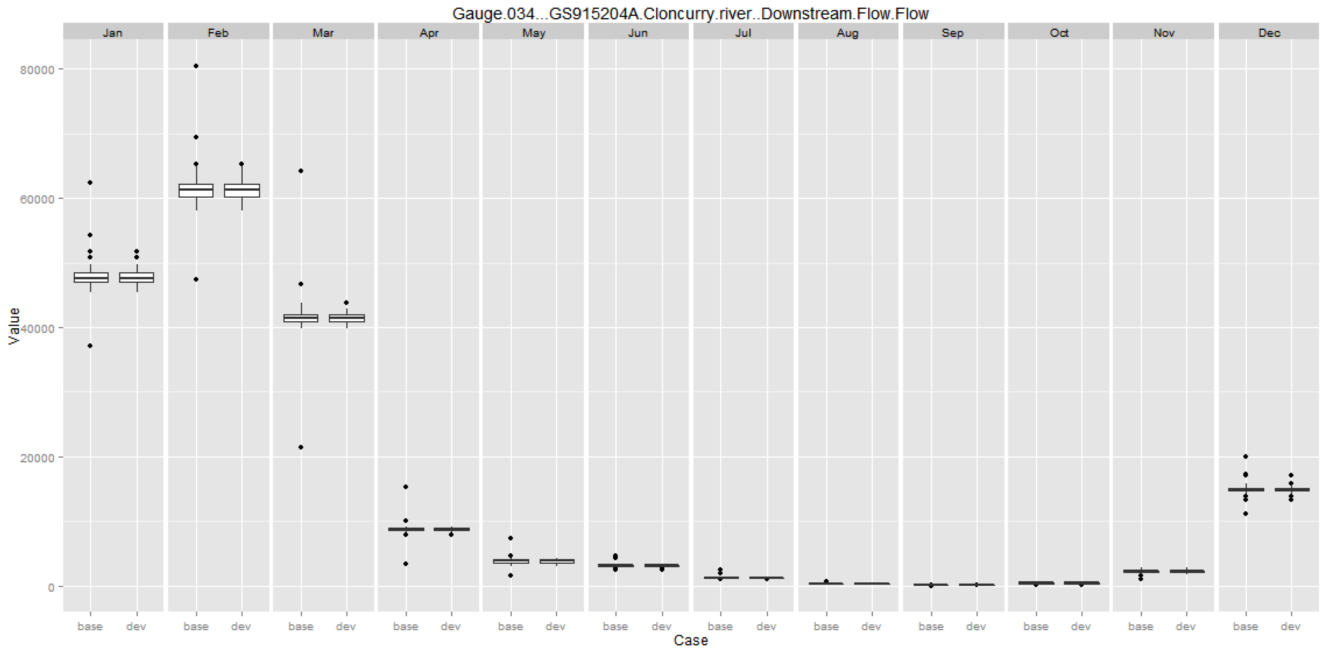

Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow
y
x
Case
base
dev

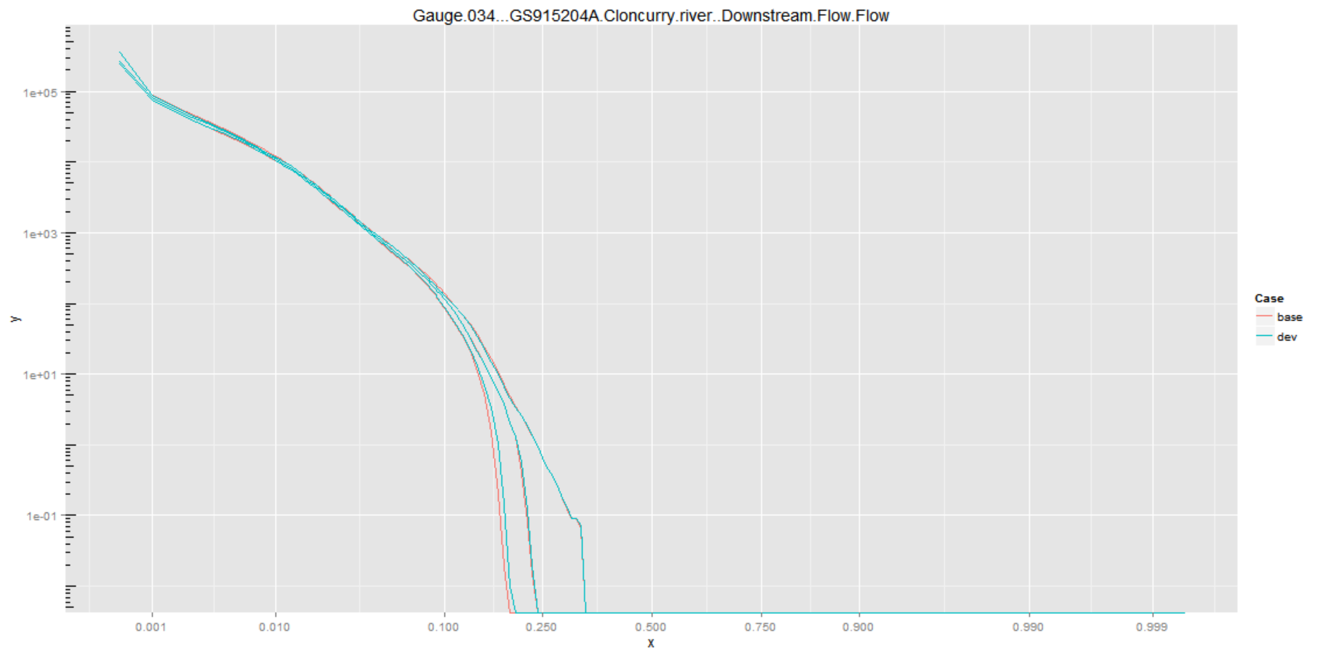

Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

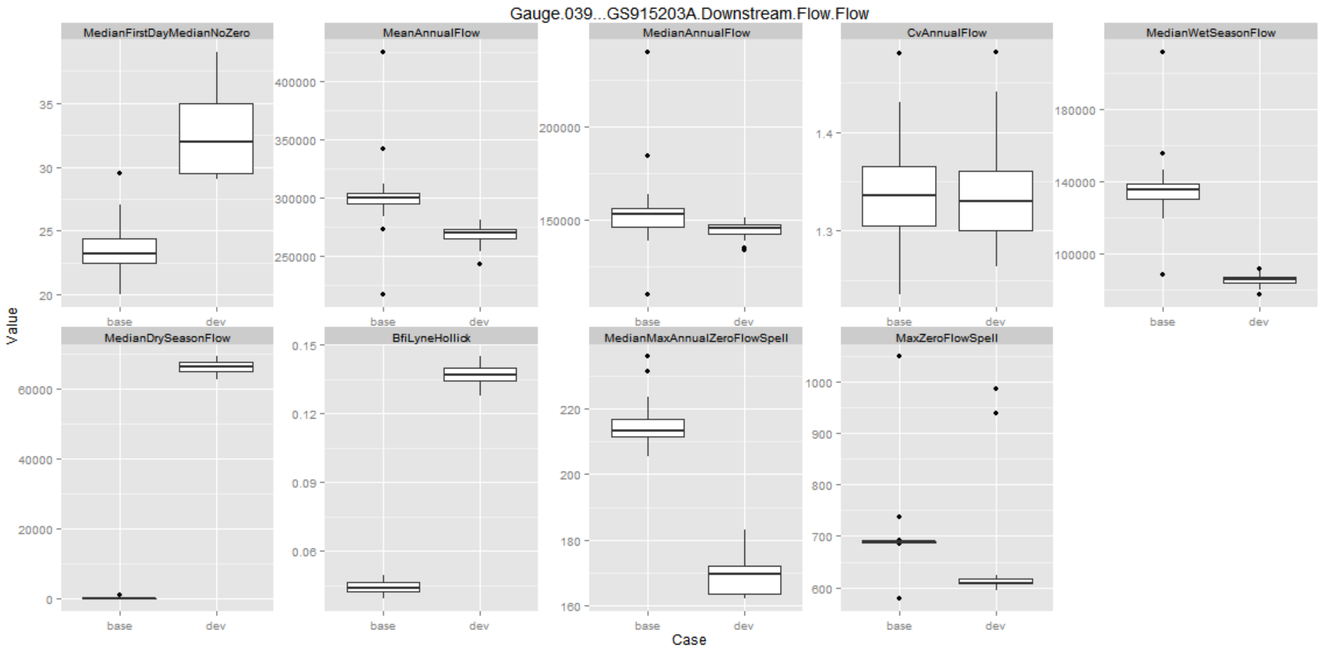

Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

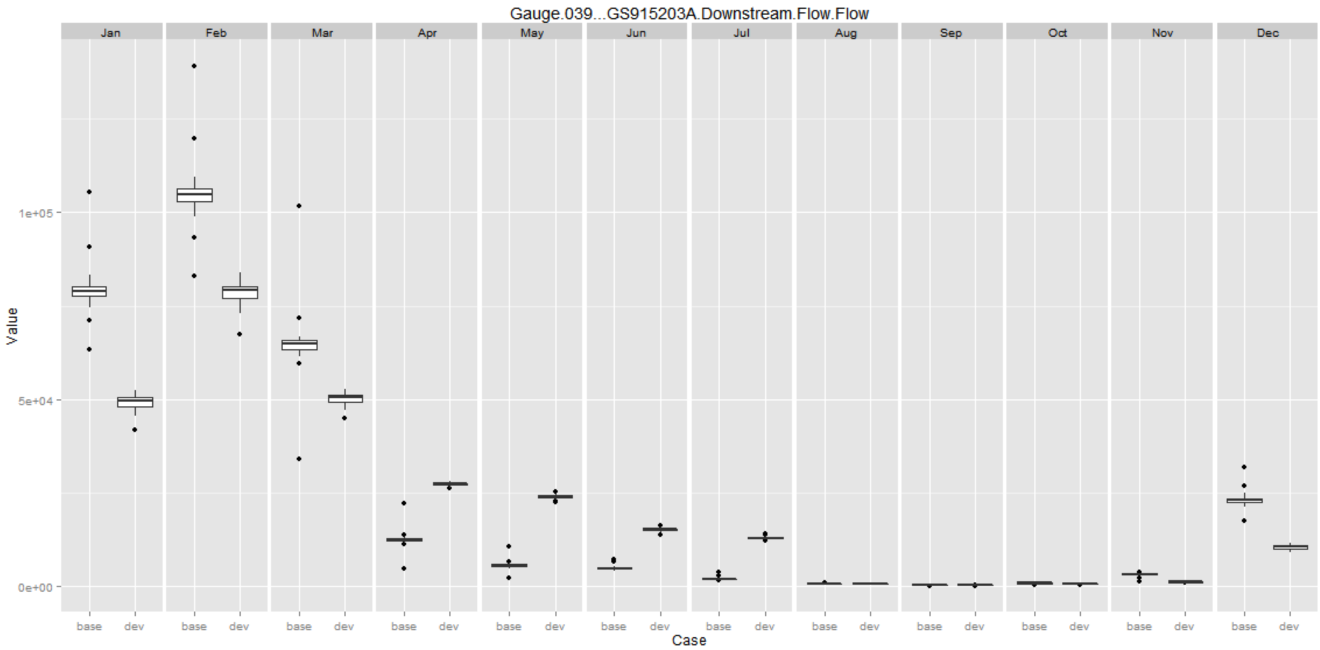

Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow
y
x
Case
base
dev

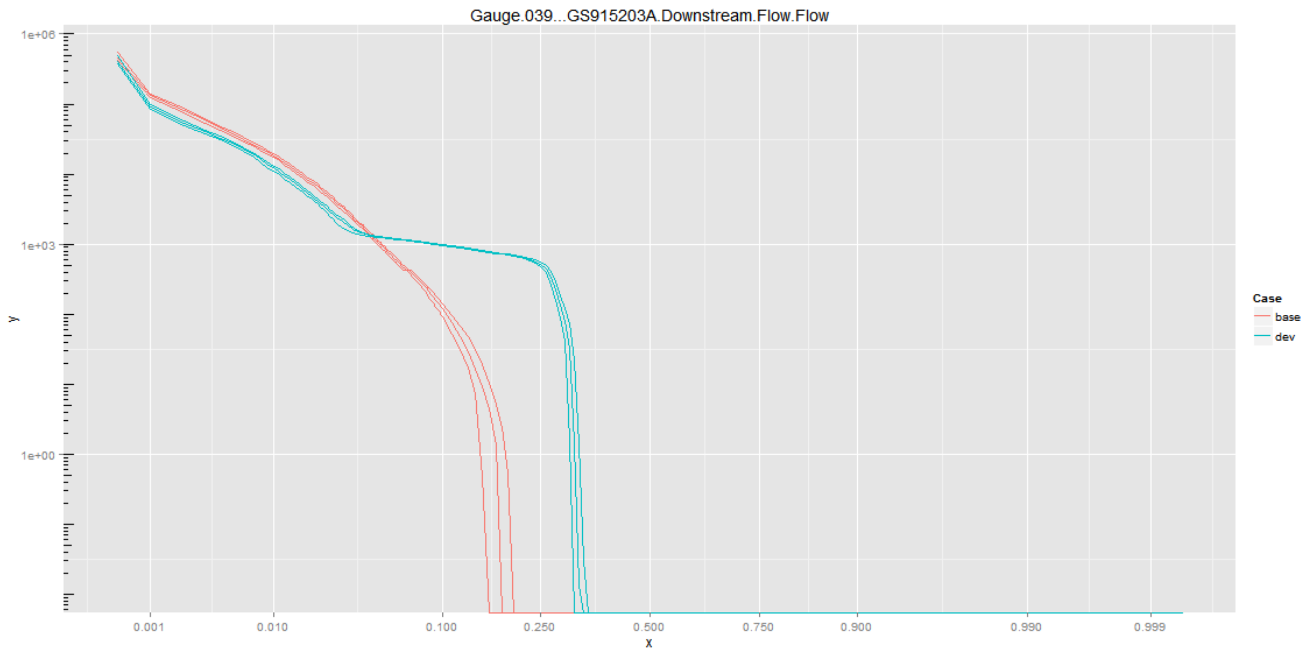

Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

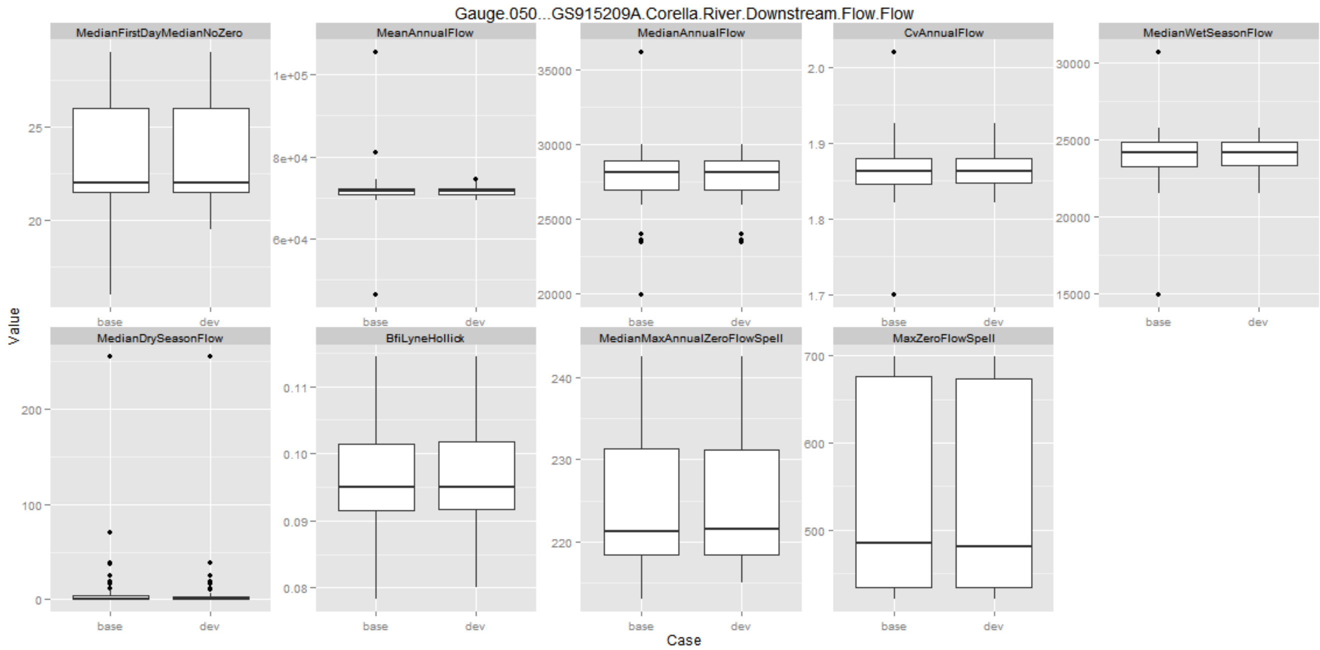

Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

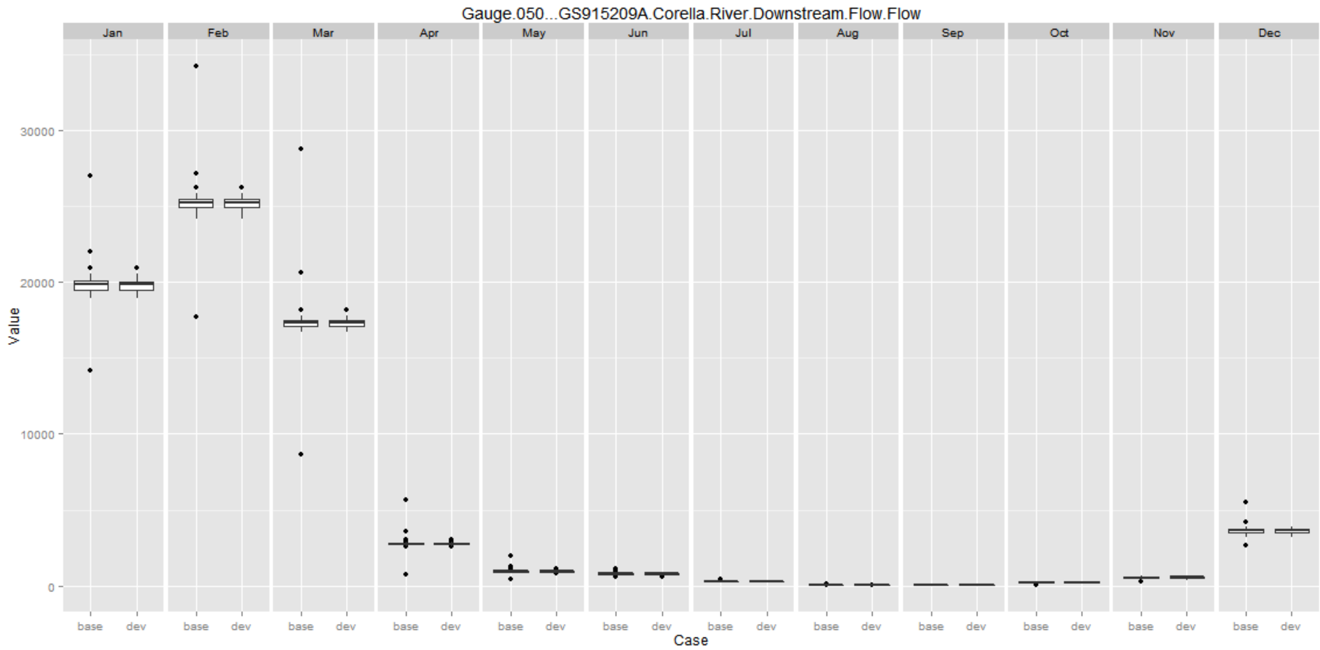

Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow
y
x
Case
base
dev

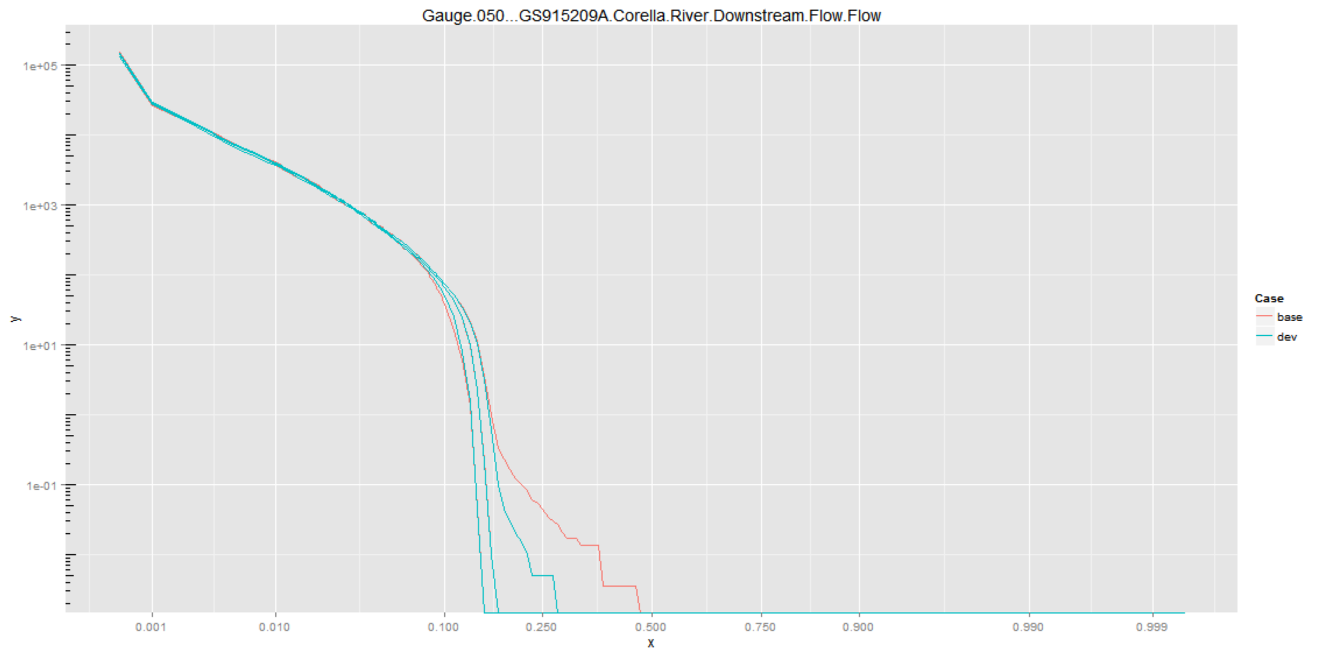

Gauge.039...GS915203A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

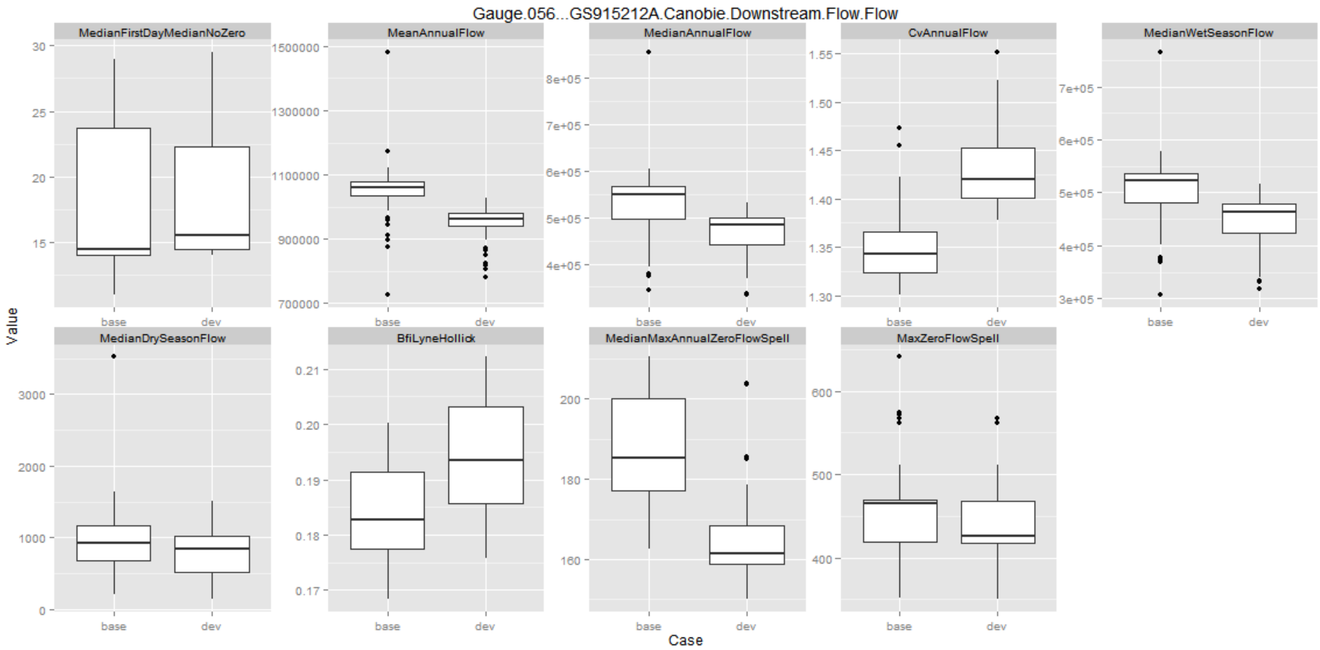

Gauge.039...GS915203A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

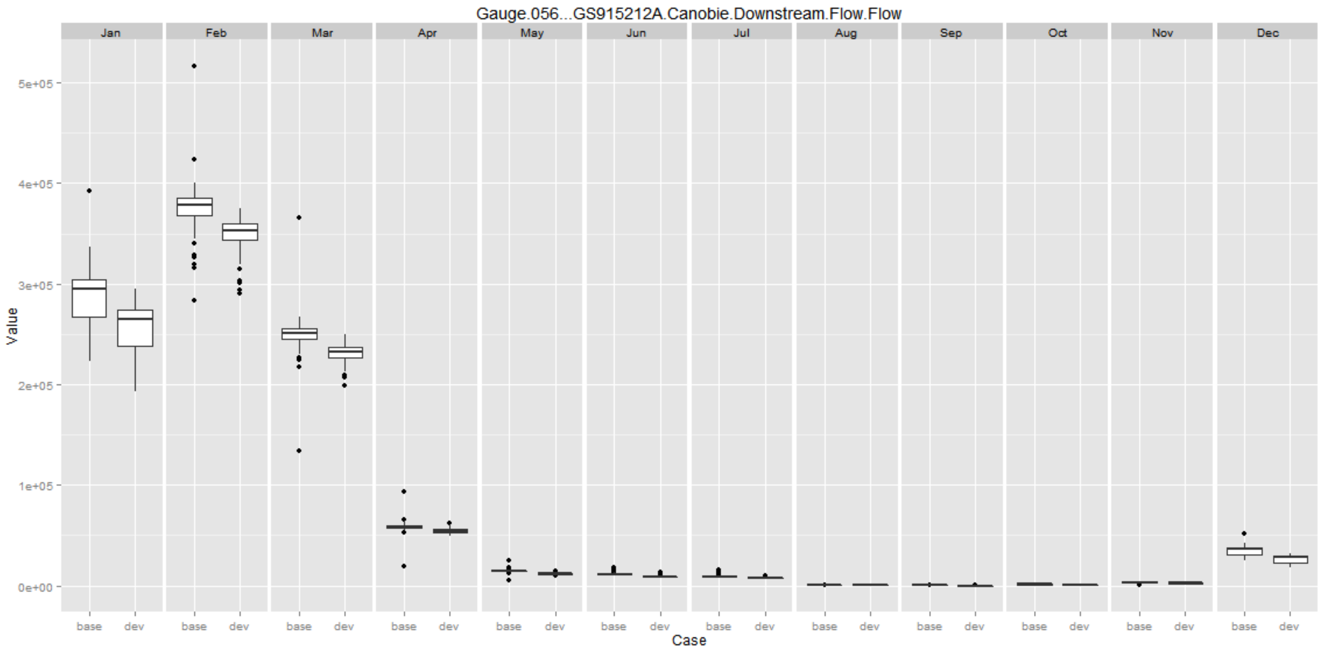

Gauge.039...GS915203A.Downstream.Flow.Flow
y
x
Case
base
dev

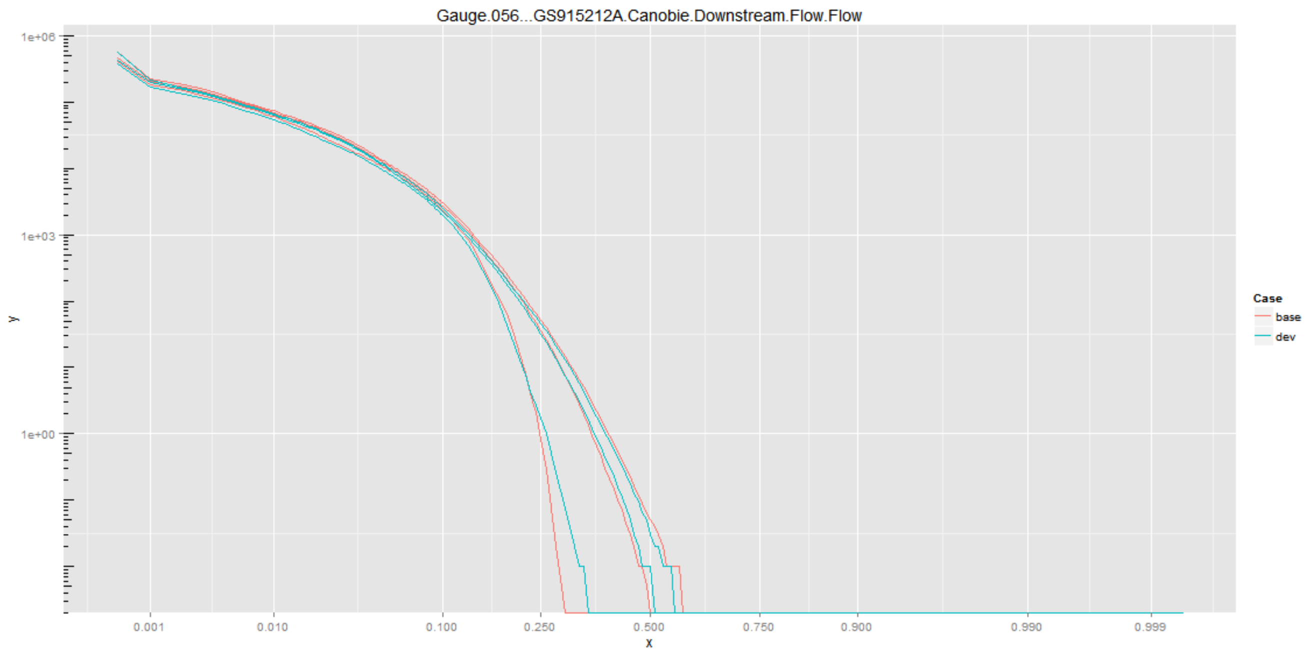

Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

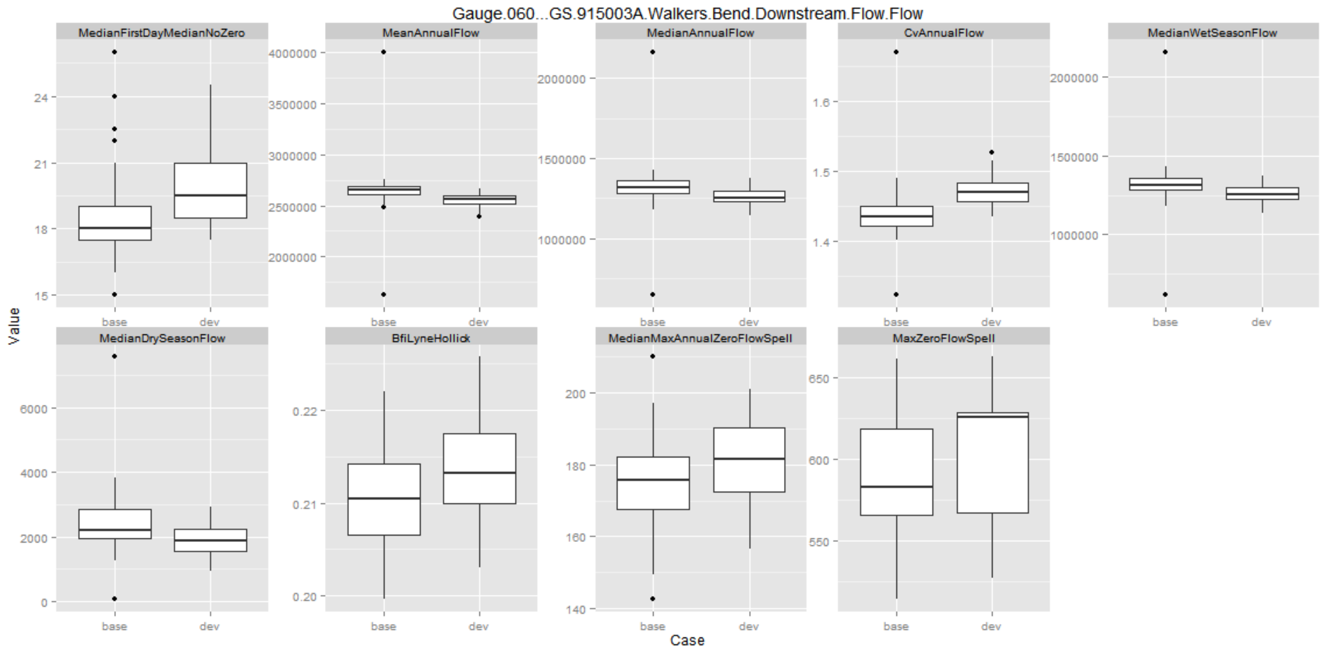

Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

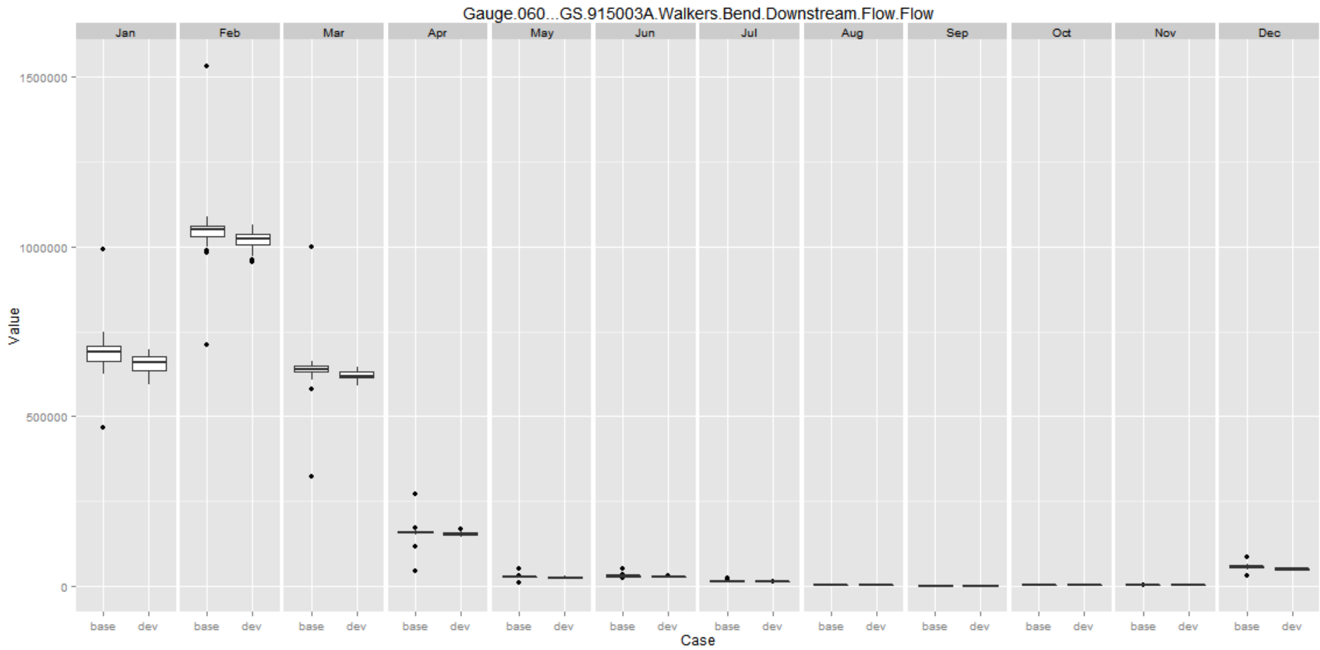

Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow
y
x
Case
base
dev

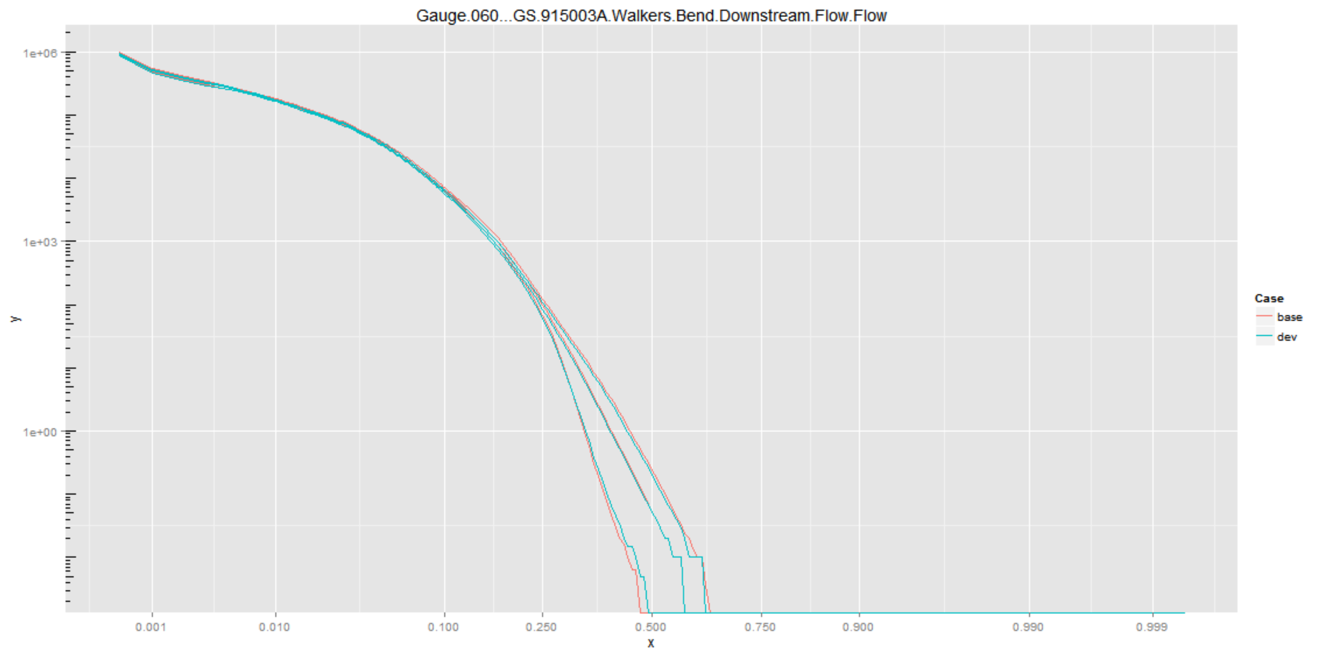

Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

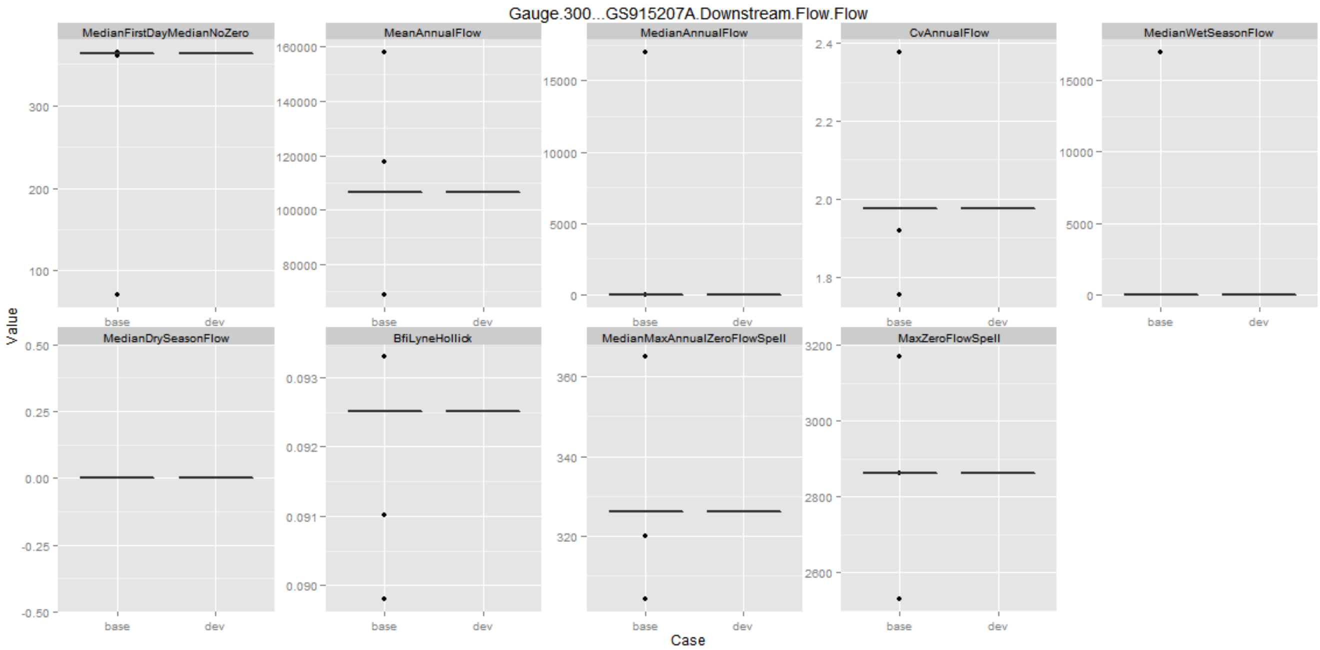

Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

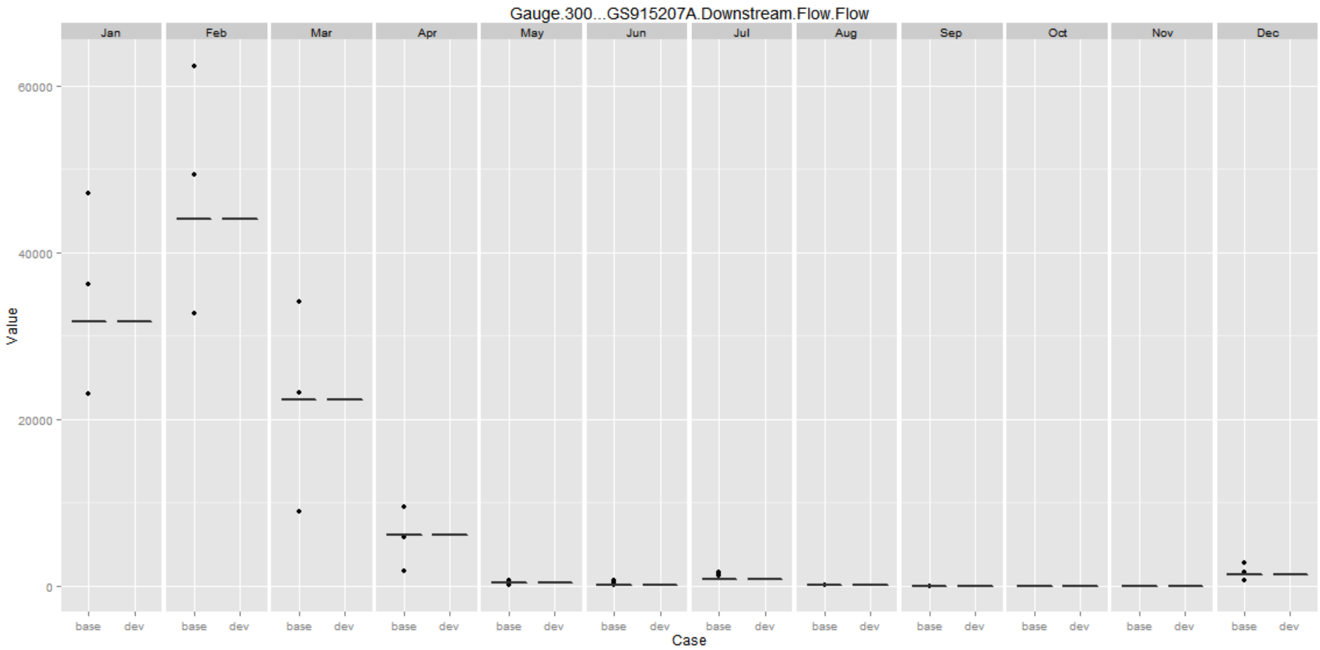

Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow
y
x
Case
base
dev

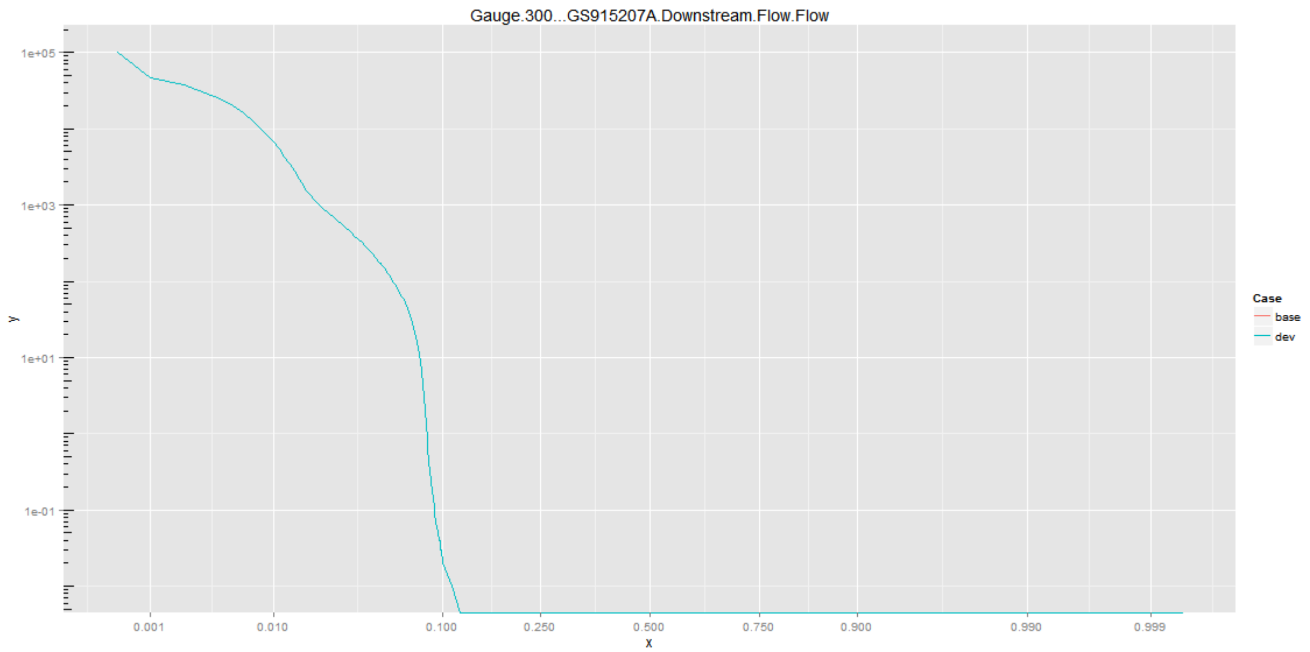

Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev


Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow
y
x
Case
base
dev


Gauge.300...GS915207A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.300...GS915207A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev


Gauge.300...GS915207A.Downstream.Flow.Flow
y
x
Case
base
dev

Appendix

R session information for the generation of this document:

```
sessionInfo()
```

```
## R version 3.0.1 (2013-05-16)
## Platform: i386-w64-mingw32/i386 (32-bit)
##
## locale:
## [1] LC_COLLATE=English_Australia.1252  LC_CTYPE=English_Australia.1252
## [3] LC_MONETARY=English_Australia.1252 LC_NUMERIC=C
## [5] LC_TIME=English_Australia.1252
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] garaHydroMetrics_0.1-4 scales_0.2.3           reshape2_1.2.2
##  [4] lubridate_1.3.1        stringr_0.6.2          ggplot2_0.9.3.1
##  [7] xts_0.9-7              zoo_1.7-10             plyr_1.8
## [10] knitr_1.5
##
## loaded via a namespace (and not attached):
##  [1] colorspace_1.2-4   dichromat_2.0-0    digest_0.6.3
##  [4] evaluate_0.5.1     formatR_0.10       grid_3.0.1
##  [7] gtable_0.1.2       labeling_0.2       lattice_0.20-15
## [10] MASS_7.3-26        munsell_0.4.2      proto_0.3-10
## [13] RColorBrewer_1.0-5 tools_3.0.1
```

FGARA Hydrological Metrics - Dry run on Dagworth ensemble runs

About this document

Purpose is to have a dry run on 50 runs ensembles for Dagworth vs Gilbert baseline

This document was generated on 2013-11-21 14:57:37 using among other things the packages 'knitr' and 'garaHydroMetrics' (https://stash.csiro.au/projects/~per202/repos/hydrometrics/browse)

Calculate statistics

Load the package the usual. It includes a fair level of documentation, that should be accessible using the '?' command, shortcut for help(garaHydroMetrics).

```
library(garaHydroMetrics)
```

```
## Warning: package 'garaHydroMetrics' was built under R version 3.0.2
```

```
## Loading required package: plyr
```

```
## Warning: package 'plyr' was built under R version 3.0.2
```

```
## Loading required package: xts
```

```
## Warning: package 'xts' was built under R version 3.0.2
```

```
## Loading required package: zoo
##
## Attaching package: 'zoo'
##
## The following object is masked from 'package:base':
##
##     as.Date, as.Date.numeric
##
## Loading required package: ggplot2
```

```
## Warning: package 'ggplot2' was built under R version 3.0.2
```

```
## Loading required package: stringr
```

```
## Warning: package 'stringr' was built under R version 3.0.2
```

```
## Loading required package: lubridate
```

```
## Warning: package 'lubridate' was built under R version 3.0.2
```

```
##
## Attaching package: 'lubridate'
##
## The following object is masked from 'package:plyr':
##
##     here
##
## Loading required package: reshape2
```

```
## Warning: package 'reshape2' was built under R version 3.0.2
```

```
## Loading required package: scales
```

```
## Warning: package 'scales' was built under R version 3.0.2
## Warning: replacing previous import 'here' when loading 'plyr'
```

```
library(plyr)
```

Mapping \wron\Project\GARA\2_Rivers\3_All\8_Case_Studies to a W: drive to preempt issues to do with too long paths.

```
baselineDir <- "X:/ScenarioB/"
develDir <- "X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns"
# develDir <-
# 'X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates/'
# develDir <-
# 'X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles/'

findGaugeFiles <- function(topFolder) {
    pattern <- ".*_Gauge_daily.csv.gz"
    csvfiles <- list.files(path = topFolder, pattern = pattern, all.files = TRUE,
        full.names = TRUE, recursive = TRUE, ignore.case = TRUE)
}
baseFiles <- findGaugeFiles(baselineDir)
develFiles <- findGaugeFiles(develDir)

timeSeries <- lapply(c(baseFiles[c(1, 51)], develFiles[1]), loadXts)
gaugeNames <- lapply(timeSeries, names)
gaugeNames
```

```
## [[1]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[2]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[3]]
##  [1] "Gauge.026...GS.917006A.Downstream.Flow.Flow"
##  [2] "Gauge.034...GS.917013A.Downstream.Flow.Flow"
##  [3] "Gauge.003...GS.917108A.Downstream.Flow.Flow"
##  [4] "Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow"
##  [5] "Gauge.006...GS.917106A.Downstream.Flow.Flow"
##  [6] "Gauge.009...GS.917109A.Downstream.Flow.Flow"
##  [7] "Gauge.018...GS.917113A.Downstream.Flow.Flow"
##  [8] "Gauge.013....GS917112A.Downstream.Flow.Flow"
##  [9] "Gauge.022...GS.917111A.Downstream.Flow.Flow"
## [10] "Gauge.038...GS.917001D.Downstream.Flow.Flow"
## [11] "Gauge.138...GS.917009A.Downstream.Flow.Flow"
## [12] "Gauge.823...GS.917107A.Downstream.Flow.Flow"
## [13] "Gauge.824...GS.917115A.Downstream.Flow.Flow"
```

```
selectedGauges = gaugeNames[[1]][1:5]
subsetGauges <- function(ts, selectedGauges) {
    ts[, selectedGauges]
}
timeSeriesSubset <- lapply(timeSeries, subsetGauges, selectedGauges)
```

It looks like the second and third are matches, i.e.:

```
c(baseFiles[c(51)], develFiles[1])
```

```
## [1]
"X:/ScenarioB//Flinders_runfolders/run_rep_0047_scenarioA_wrpnores_v143_20131811_220632_2934/postpro
## [2]
"X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_1_
```

So let's roll the stats (circa 15 sec per file, expect around 25 minutes runtime). Given the considerable runtime, this is important to have a caching mechanism i.e. saving the result to an RData file. The file is only 2MB so it is worth caching.

```
scenarioFolders <- c("Gilbert_runfolders", "Dagworthv3_Noimpact_EnsembleRuns")
scenarioTags <- c("base", "dev")

statFile <- "Z:/GARA/2_Rivers/4_Working/per202/Dagworth/EnsFiles.RData"
stopifnot(file.exists(dirname(statFile)))

if (!file.exists(statFile)) {
    statList <- univStatsMultiScenario(c(baseFiles, develFiles), scenarioFolders,
        scenarioTags)
    save(statList, file = statFile)
} else {
    load(statFile)
}
```

```
## [1] "2013-11-21 14:58:12
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioA_wrpnores_v27_20132409_130052_20138/postpro

## [1] "2013-11-21 14:58:21
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioCdry_wrpnores_v27_20132409_130054_20144/post

## [1] "2013-11-21 14:58:30
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioCmid_wrpnores_v27_20132409_130056_20151/post

## [1] "2013-11-21 14:58:39
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioCwet_wrpnores_v27_20132409_130058_20157/post

## [1] "2013-11-21 14:58:48
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_1_scenarioA_wrpnores_v27_20131911_72013_13175/

## [1] "2013-11-21 14:58:57
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_10_scenarioA_wrpnores_v27_20131911_72031_1323

## [1] "2013-11-21 14:59:06
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_11_scenarioA_wrpnores_v27_20131911_72033_1324

## [1] "2013-11-21 14:59:14
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_12_scenarioA_wrpnores_v27_20131911_72035_1324

## [1] "2013-11-21 14:59:23
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_13_scenarioA_wrpnores_v27_20131911_72037_1325

## [1] "2013-11-21 14:59:32
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_14_scenarioA_wrpnores_v27_20131911_72039_1326

## [1] "2013-11-21 14:59:42
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_15_scenarioA_wrpnores_v27_20131911_72041_1326

## [1] "2013-11-21 14:59:52
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_16_scenarioA_wrpnores_v27_20131911_72043_1327

## [1] "2013-11-21 15:00:01
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_17_scenarioA_wrpnores_v27_20131911_72045_1327

## [1] "2013-11-21 15:00:10
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_18_scenarioA_wrpnores_v27_20131911_72047_1328

## [1] "2013-11-21 15:00:19
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_19_scenarioA_wrpnores_v27_20131911_72049_1329

## [1] "2013-11-21 15:00:28
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_2_scenarioA_wrpnores_v27_20131911_72015_13181/

## [1] "2013-11-21 15:00:37
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_20_scenarioA_wrpnores_v27_20131911_72051_1329

## [1] "2013-11-21 15:00:46
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_21_scenarioA_wrpnores_v27_20131911_72053_1330

## [1] "2013-11-21 15:00:55
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_22_scenarioA_wrpnores_v27_20131911_72055_1331

## [1] "2013-11-21 15:01:05
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_23_scenarioA_wrpnores_v27_20131911_72057_1331

## [1] "2013-11-21 15:01:14
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_24_scenarioA_wrpnores_v27_20131911_72059_1332

## [1] "2013-11-21 15:01:23
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_25_scenarioA_wrpnores_v27_20131911_72101_1333

## [1] "2013-11-21 15:01:32
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_26_scenarioA_wrpnores_v27_20131911_115310_111

## [1] "2013-11-21 15:01:42
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_27_scenarioA_wrpnores_v27_20131911_115312_112

## [1] "2013-11-21 15:01:51
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_28_scenarioA_wrpnores_v27_20131911_115314_113

## [1] "2013-11-21 15:02:00
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_29_scenarioA_wrpnores_v27_20131911_115316_113
```

```
## [1] "2013-11-21 15:02:09
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_3_scenarioA_wrpnores_v27_20131911_72017_13188,

## [1] "2013-11-21 15:02:18
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_30_scenarioA_wrpnores_v27_20131911_115318_114!

## [1] "2013-11-21 15:02:29
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_31_scenarioA_wrpnores_v27_20131911_115320_115:

## [1] "2013-11-21 15:02:38
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_32_scenarioA_wrpnores_v27_20131911_115322_115!

## [1] "2013-11-21 15:02:47
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_33_scenarioA_wrpnores_v27_20131911_115324_116!

## [1] "2013-11-21 15:02:55
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_34_scenarioA_wrpnores_v27_20131911_115326_117:

## [1] "2013-11-21 15:03:05
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_35_scenarioA_wrpnores_v27_20131911_115328_117!

## [1] "2013-11-21 15:03:13
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_36_scenarioA_wrpnores_v27_20131911_115330_118!

## [1] "2013-11-21 15:03:22
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_37_scenarioA_wrpnores_v27_20131911_115332_119:

## [1] "2013-11-21 15:03:31
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_38_scenarioA_wrpnores_v27_20131911_115334_119!

## [1] "2013-11-21 15:03:40
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_39_scenarioA_wrpnores_v27_20131911_115336_120!

## [1] "2013-11-21 15:03:49
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_4_scenarioA_wrpnores_v27_20131911_72019_13195,

## [1] "2013-11-21 15:03:58
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_40_scenarioA_wrpnores_v27_20131911_115338_121:

## [1] "2013-11-21 15:04:07
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_41_scenarioA_wrpnores_v27_20131911_115340_121:

## [1] "2013-11-21 15:04:15
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_42_scenarioA_wrpnores_v27_20131911_115342_122!

## [1] "2013-11-21 15:04:24
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_43_scenarioA_wrpnores_v27_20131911_115344_123!

## [1] "2013-11-21 15:04:33
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_44_scenarioA_wrpnores_v27_20131911_115346_123:

## [1] "2013-11-21 15:04:42
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_45_scenarioA_wrpnores_v27_20131911_115348_124:

## [1] "2013-11-21 15:04:50
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_46_scenarioA_wrpnores_v27_20131911_115350_125!

## [1] "2013-11-21 15:04:59
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_47_scenarioA_wrpnores_v27_20131911_115352_125!

## [1] "2013-11-21 15:05:08
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_48_scenarioA_wrpnores_v27_20131911_115354_126:

## [1] "2013-11-21 15:05:17
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_49_scenarioA_wrpnores_v27_20131911_115356_127!

## [1] "2013-11-21 15:05:25
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_5_scenarioA_wrpnores_v27_20131911_72021_13201,

## [1] "2013-11-21 15:05:34
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_50_scenarioA_wrpnores_v27_20131911_115358_127!

## [1] "2013-11-21 15:05:42
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_6_scenarioA_wrpnores_v27_20131911_72023_13208,

## [1] "2013-11-21 15:05:52
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_7_scenarioA_wrpnores_v27_20131911_72025_13214,

## [1] "2013-11-21 15:06:01
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_8_scenarioA_wrpnores_v27_20131911_72027_13221,

## [1] "2013-11-21 15:06:10
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_9_scenarioA_wrpnores_v27_20131911_72029_13227,

## [1] "2013-11-21 15:06:19
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_1_!

## [1] "2013-11-21 15:06:29
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_10_

## [1] "2013-11-21 15:06:38
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_11_

## [1] "2013-11-21 15:06:47
```

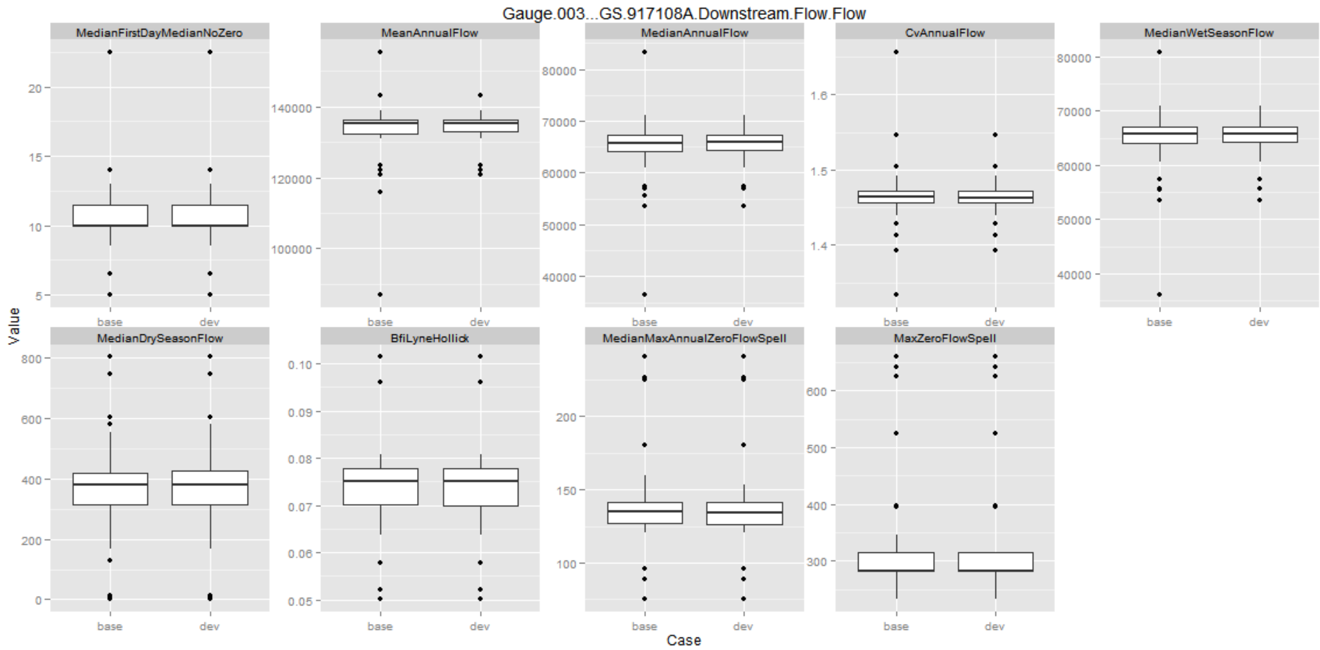
```
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_12_

## [1] "2013-11-21 15:06:55
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_13_

## [1] "2013-11-21 15:07:04
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_14_

## [1] "2013-11-21 15:07:14
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_15_

## [1] "2013-11-21 15:07:22
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_16_

## [1] "2013-11-21 15:07:31
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_17_

## [1] "2013-11-21 15:07:40
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_18_

## [1] "2013-11-21 15:07:49
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_19_

## [1] "2013-11-21 15:07:58
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_2_

## [1] "2013-11-21 15:08:06
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_20_

## [1] "2013-11-21 15:08:15
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_21_

## [1] "2013-11-21 15:08:24
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_22_

## [1] "2013-11-21 15:08:33
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_23_

## [1] "2013-11-21 15:08:42
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_24_

## [1] "2013-11-21 15:08:50
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_25_

## [1] "2013-11-21 15:08:59
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_26_

## [1] "2013-11-21 15:09:08
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_27_

## [1] "2013-11-21 15:09:18
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_28_

## [1] "2013-11-21 15:09:27
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_29_

## [1] "2013-11-21 15:09:36
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_3_

## [1] "2013-11-21 15:09:45
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_30_

## [1] "2013-11-21 15:09:54
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_31_

## [1] "2013-11-21 15:10:03
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_32_

## [1] "2013-11-21 15:10:12
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_33_

## [1] "2013-11-21 15:10:20
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_34_

## [1] "2013-11-21 15:10:30
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_35_

## [1] "2013-11-21 15:10:39
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_36_

## [1] "2013-11-21 15:10:47
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_37_

## [1] "2013-11-21 15:10:57
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_38_

## [1] "2013-11-21 15:11:06
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_39_

## [1] "2013-11-21 15:11:15
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_4_

## [1] "2013-11-21 15:11:25
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_40_
```

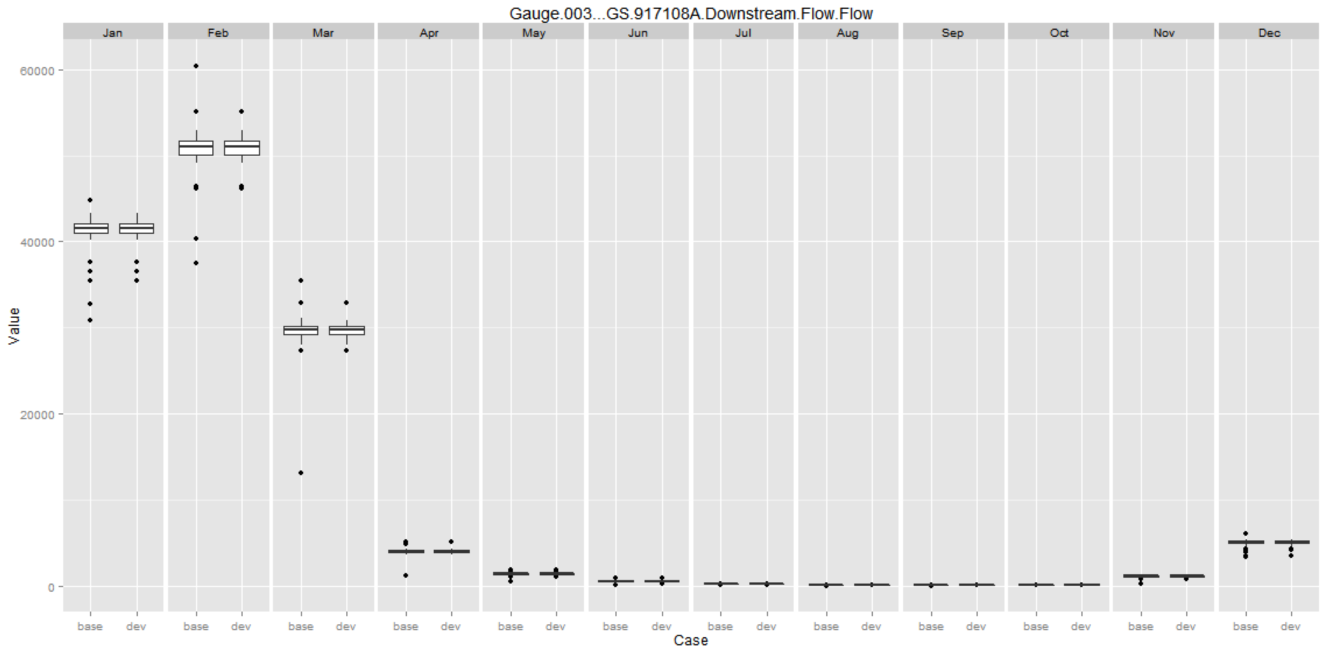
```
## [1] "2013-11-21 15:11:33
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_41_

## [1] "2013-11-21 15:11:43
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_42_

## [1] "2013-11-21 15:11:52
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_43_

## [1] "2013-11-21 15:12:01
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_44_

## [1] "2013-11-21 15:12:10
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_45_

## [1] "2013-11-21 15:12:19
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_46_

## [1] "2013-11-21 15:12:28
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_47_

## [1] "2013-11-21 15:12:37
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_48_

## [1] "2013-11-21 15:12:46
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_49_

## [1] "2013-11-21 15:12:54
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_5_

## [1] "2013-11-21 15:13:03
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_50_

## [1] "2013-11-21 15:13:12
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_6_

## [1] "2013-11-21 15:13:21
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_7_

## [1] "2013-11-21 15:13:30
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_8_

## [1] "2013-11-21 15:13:38
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_ensemble_9_

## [1] "2013-11-21 15:13:47
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_noensemble_

## [1] "2013-11-21 15:13:56
X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns/run_baseline_noensemble_
```

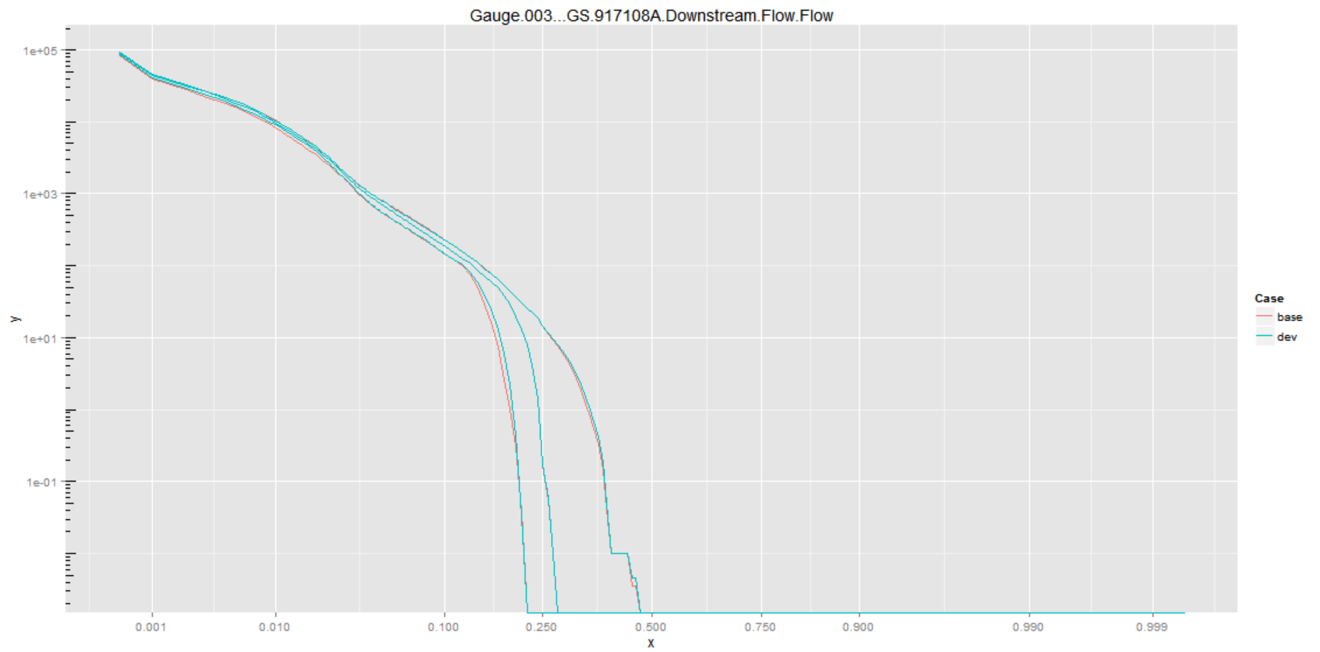
Visualization

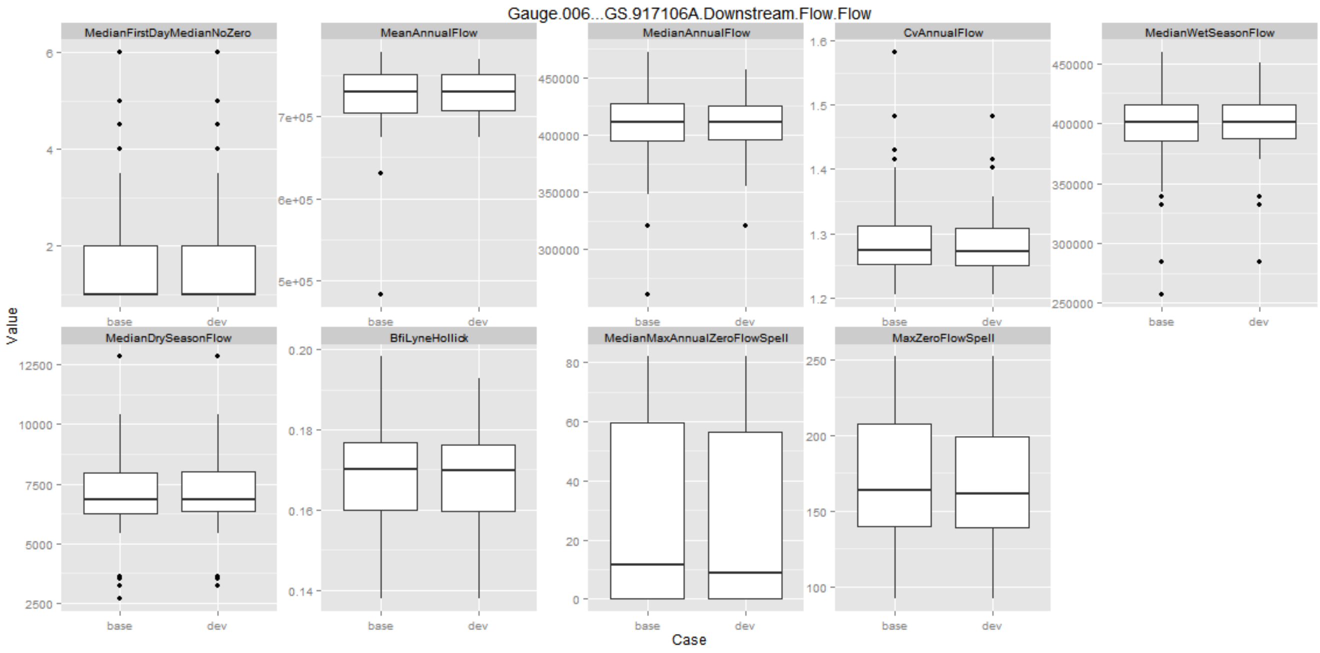
The visualization itself is not all that time comsuming.

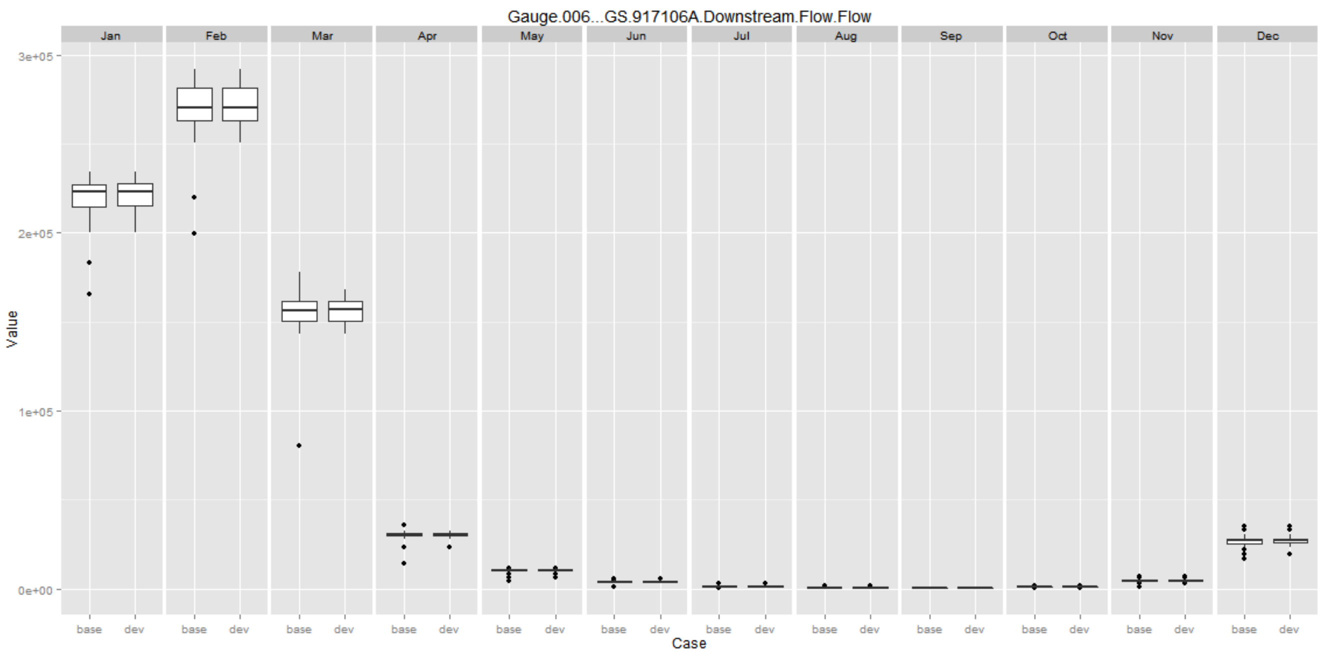
```
d <- listByGauge(rbind(statList[[c(1, 1)]], statList[[c(2, 1)]]))
mthFlows <- listByGauge(rbind(statList[[c(1, 2)]], statList[[c(2, 2)]]))
fdcData <- listByGauge(rbind(statList[[c(1, 3)]], statList[[c(2, 3)]]))
for (gaugename in names(d)) {
    print(getBoxplotsUniv(d[[gaugename]]) + ggtitle(gaugename))
    print(getBoxplotsMthly(mthFlows[[gaugename]], gaugename))
    print(getPlotFdc(fdcData[[gaugename]], gaugename))
}
```

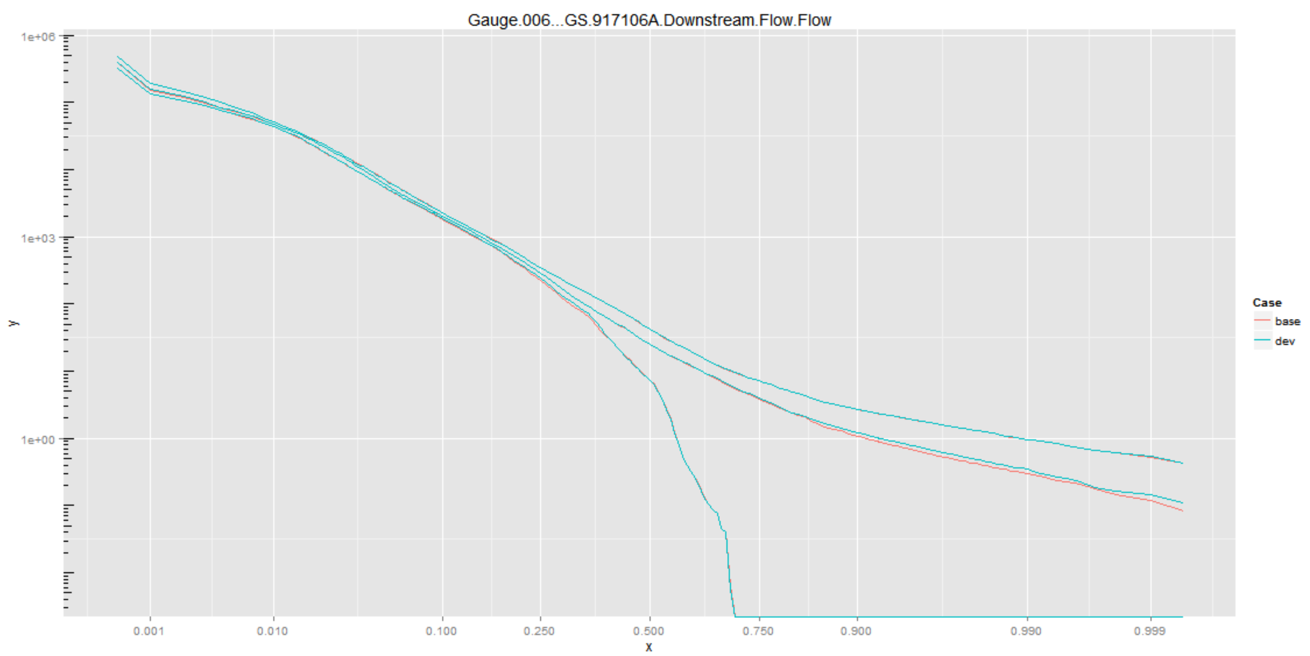

Gauge.003...GS.917108A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

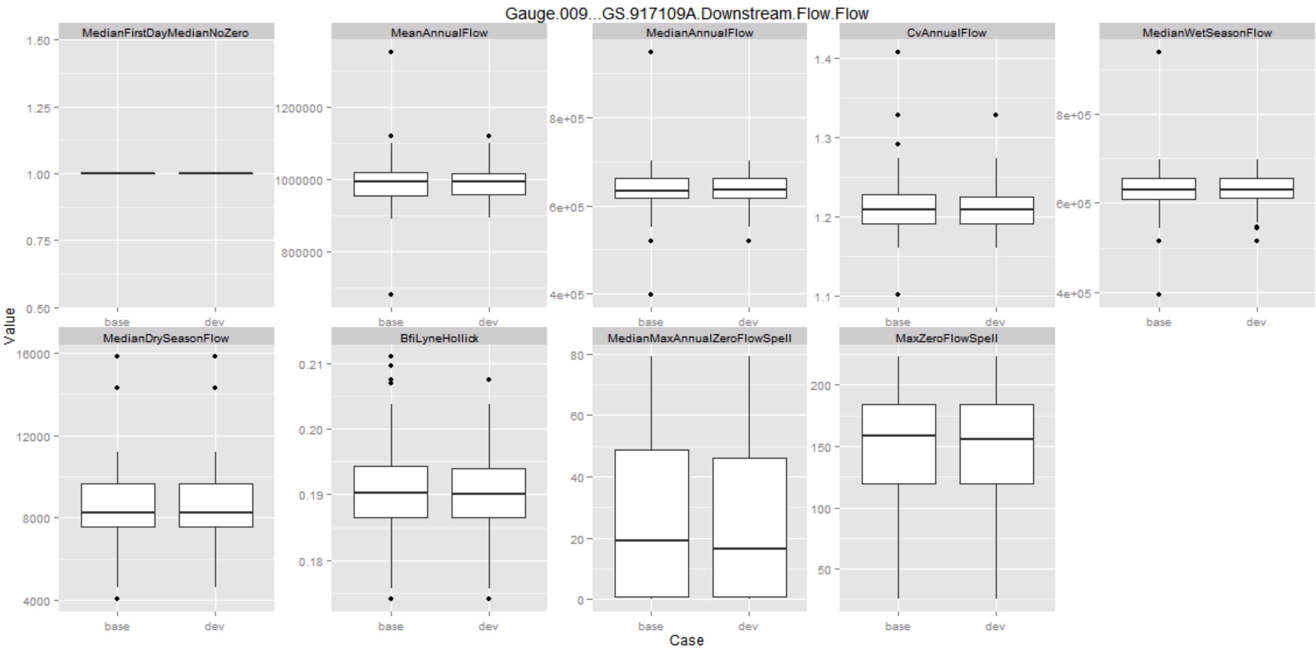

Gauge.003...GS.917108A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

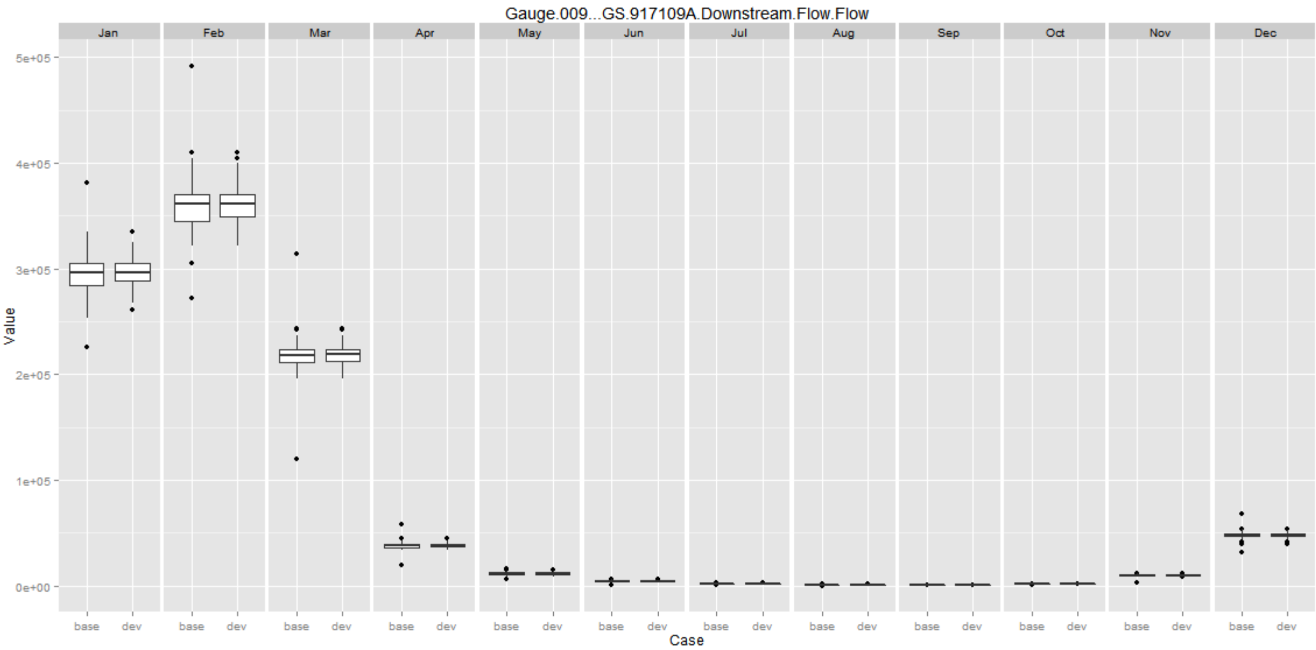

Gauge.003...GS.917108A.Downstream.Flow.Flow
y
x
Case
base
dev

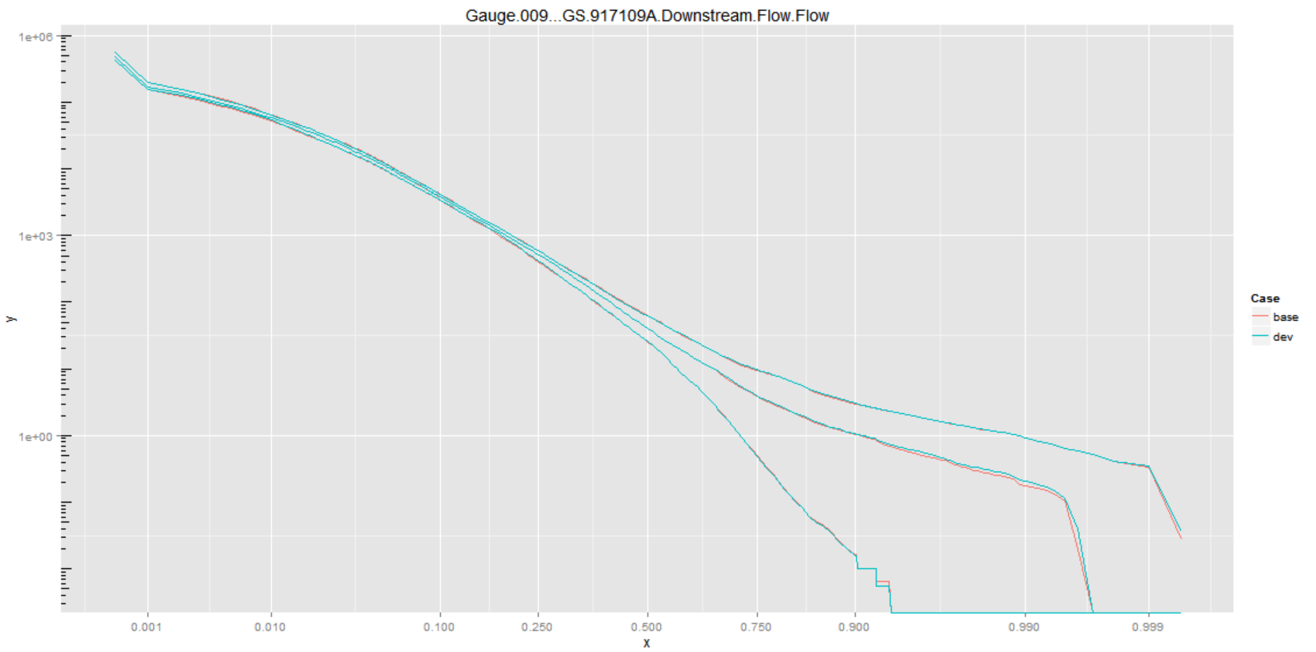

Gauge.006...GS.917106A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

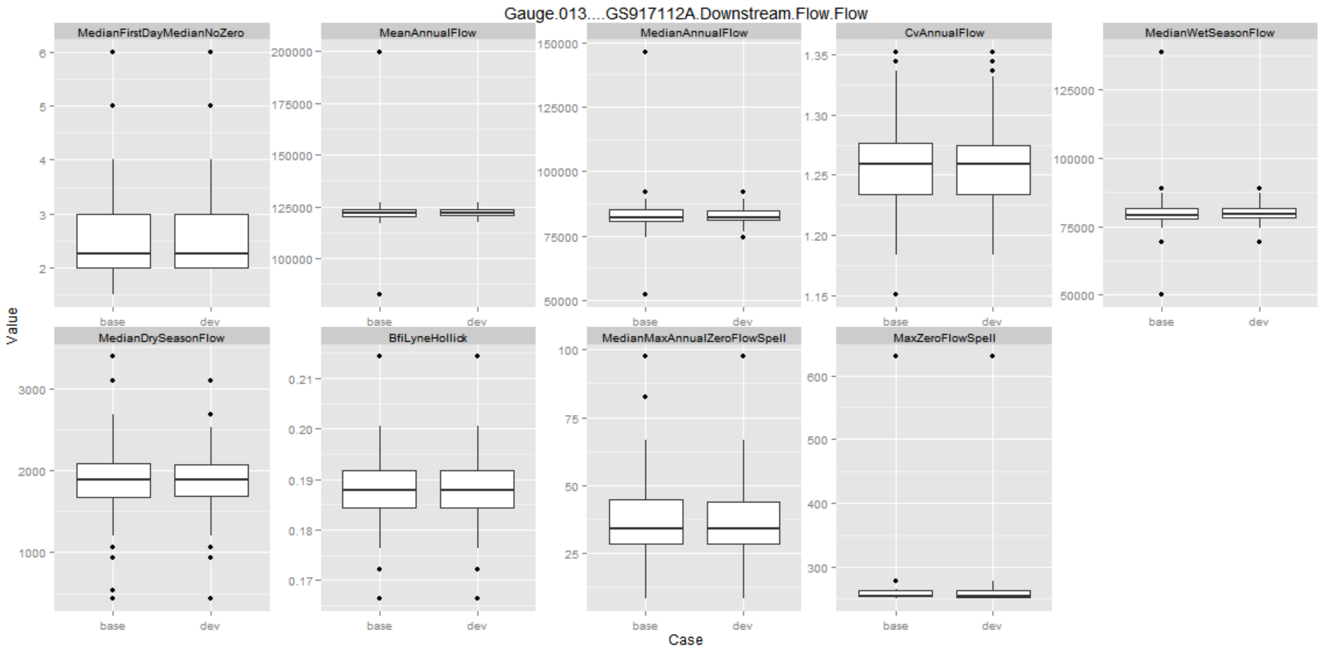

Gauge.006...GS.917106A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

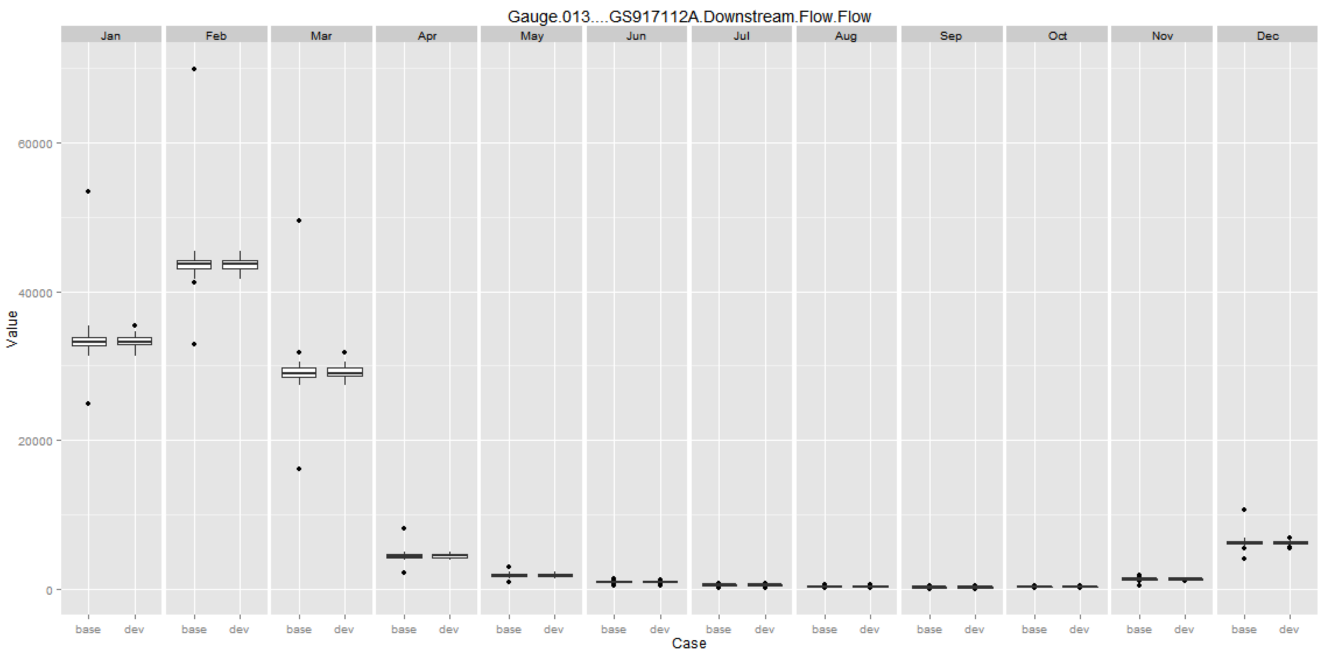

Gauge.006...GS.917106A.Downstream.Flow.Flow
y
x
Case
base
dev

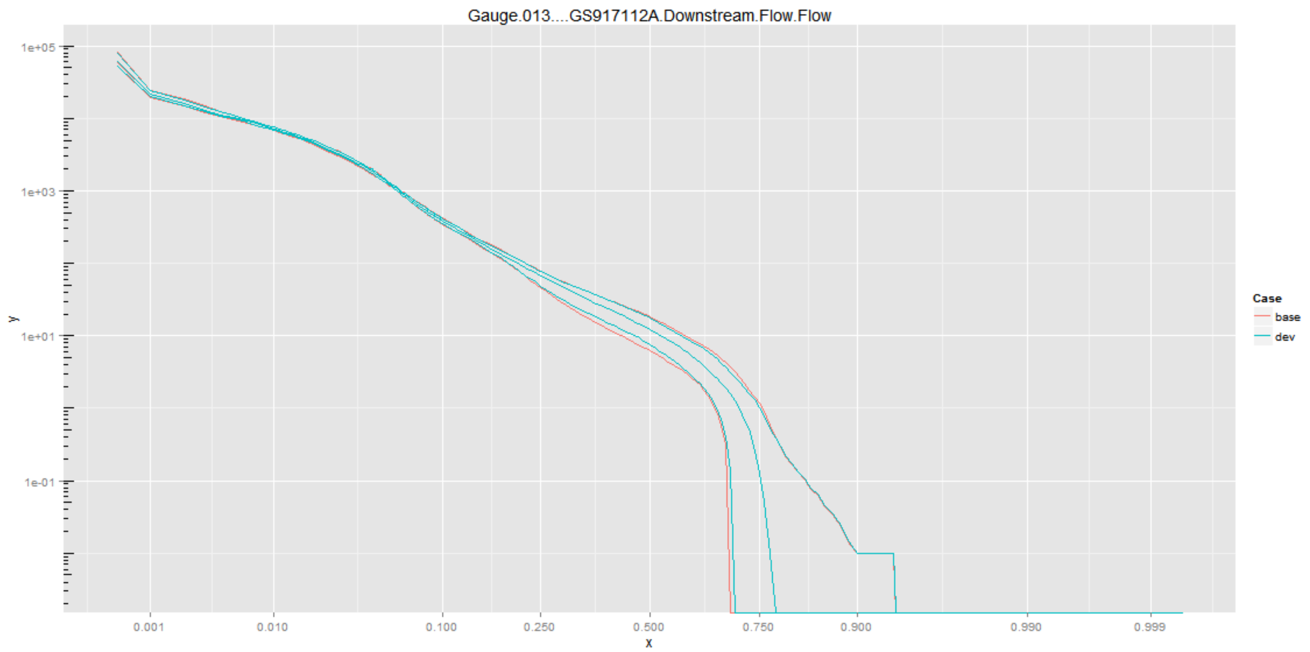

Gauge.009...GS.917109A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

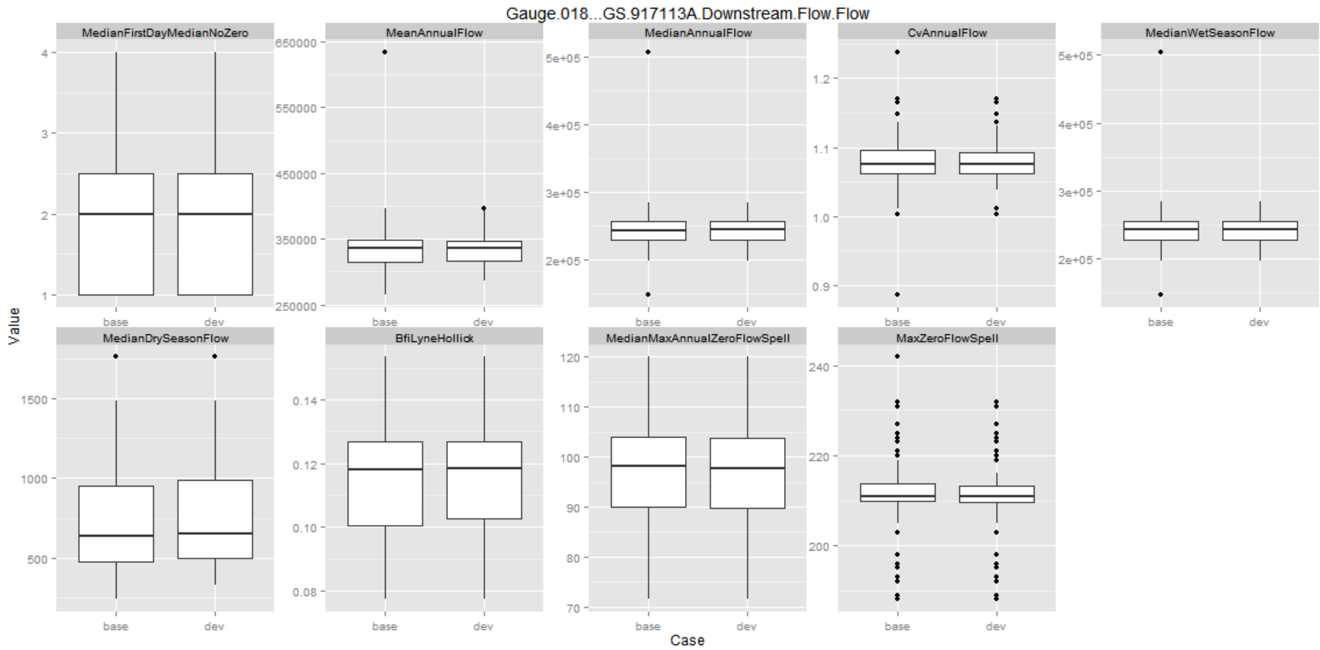

Gauge.009...GS.917109A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

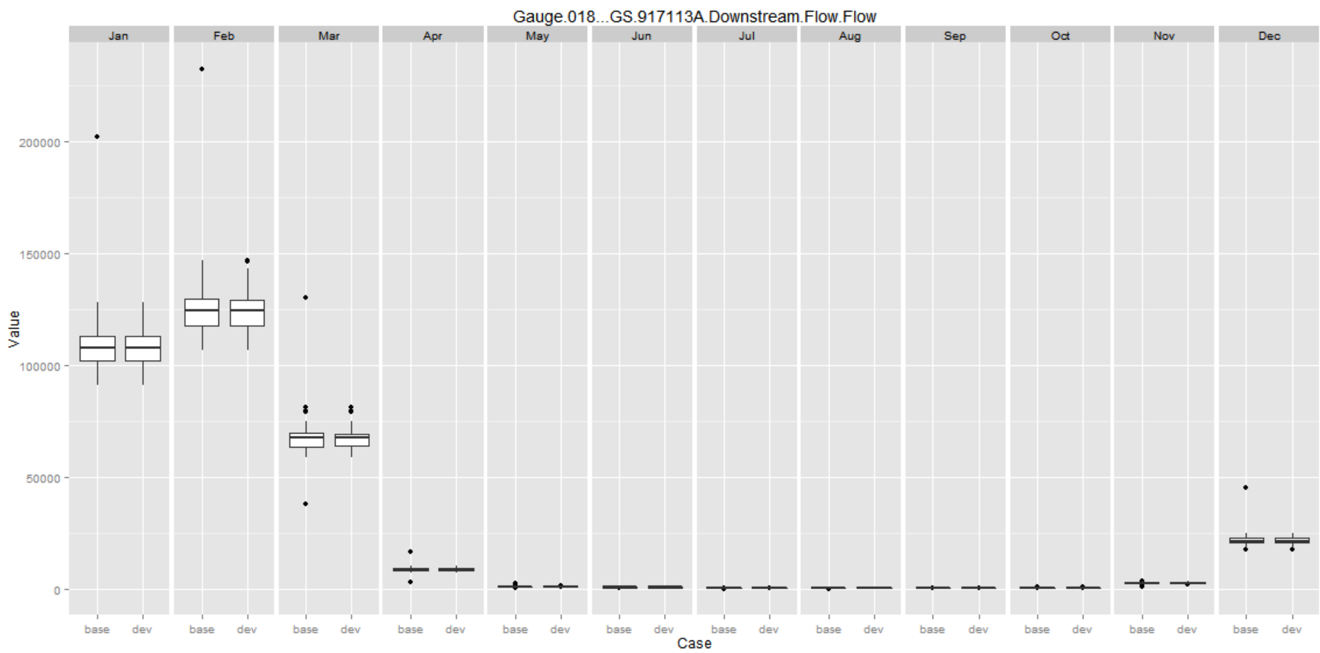

Gauge.009...GS.917109A.Downstream.Flow.Flow
y
x
Case
base
dev

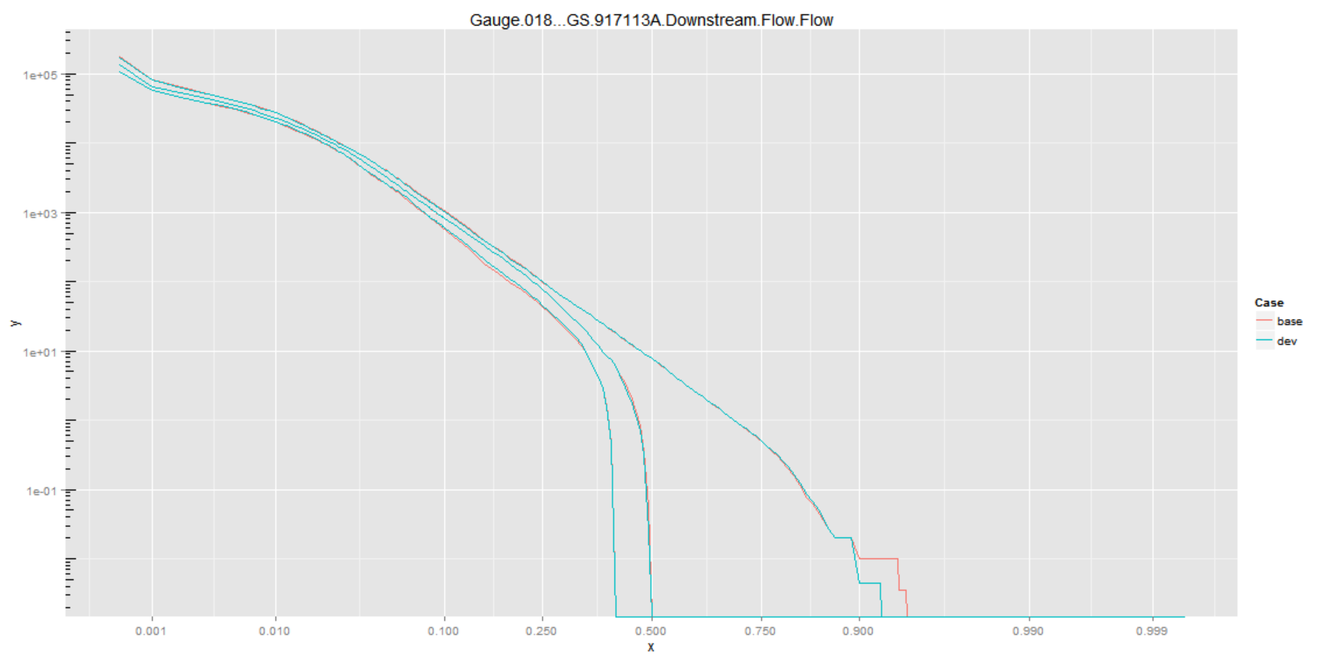

Gauge.013....GS917112A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

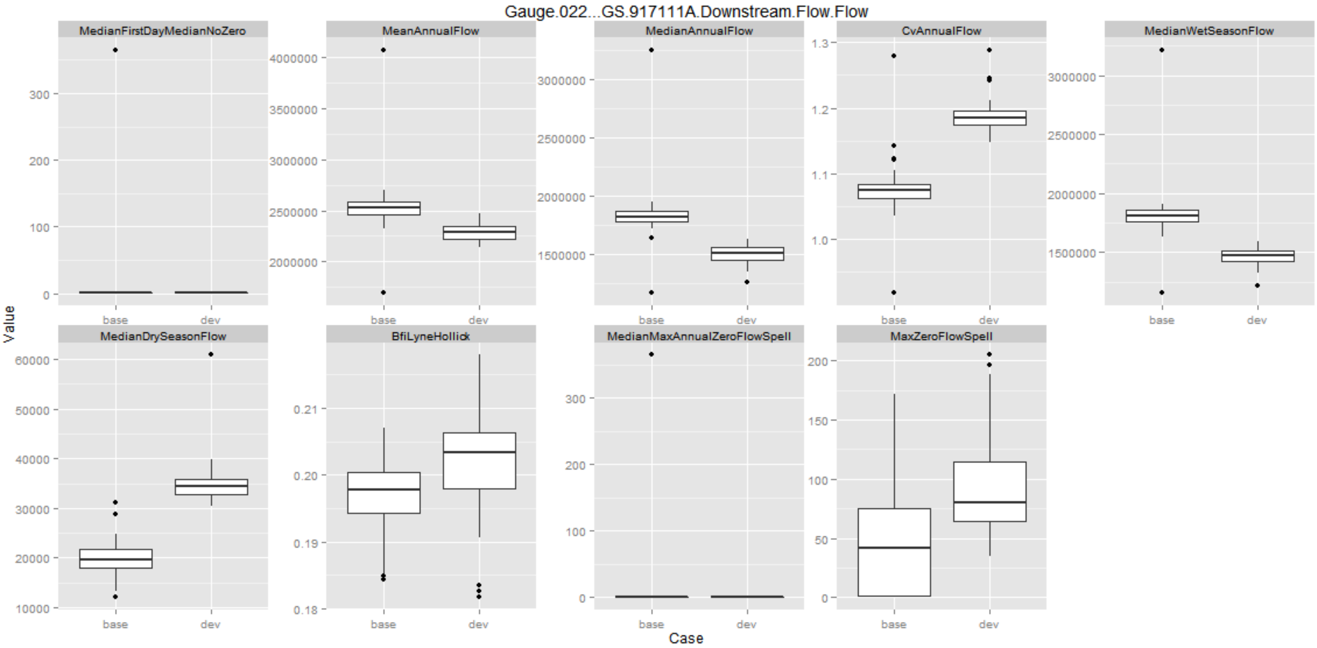

Gauge.013....GS917112A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

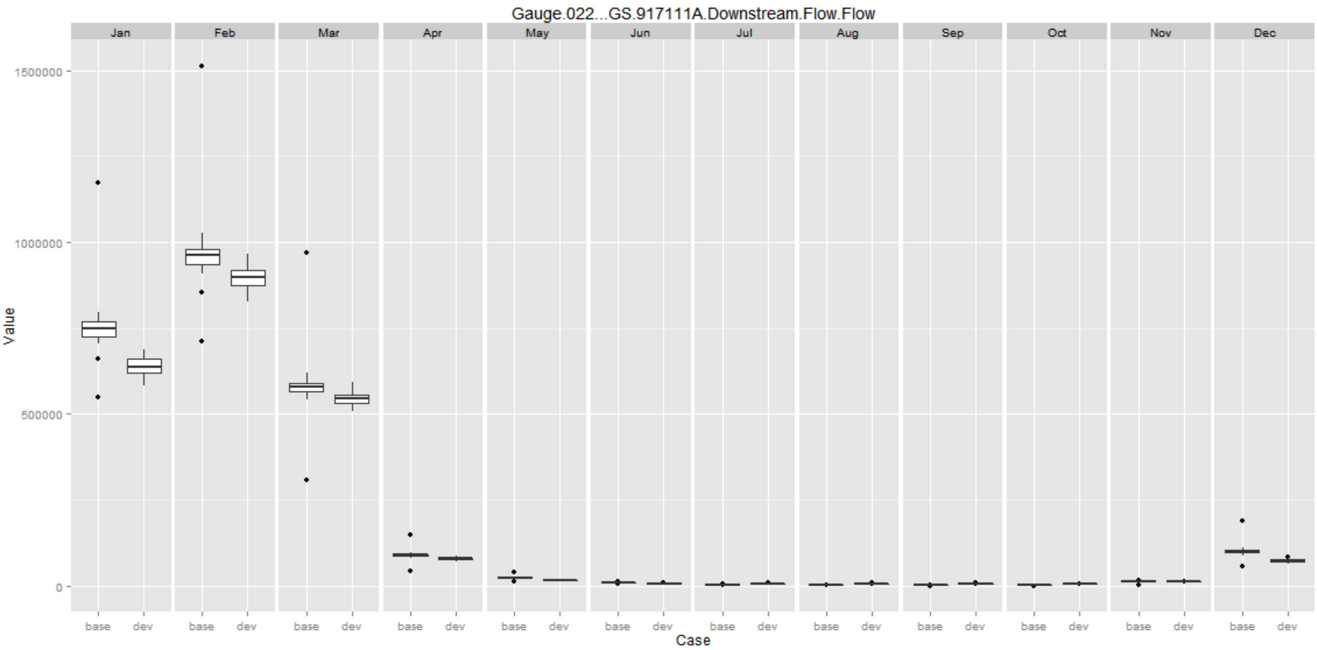

Gauge.013....GS917112A.Downstream.Flow.Flow
y
x
Case
base
dev

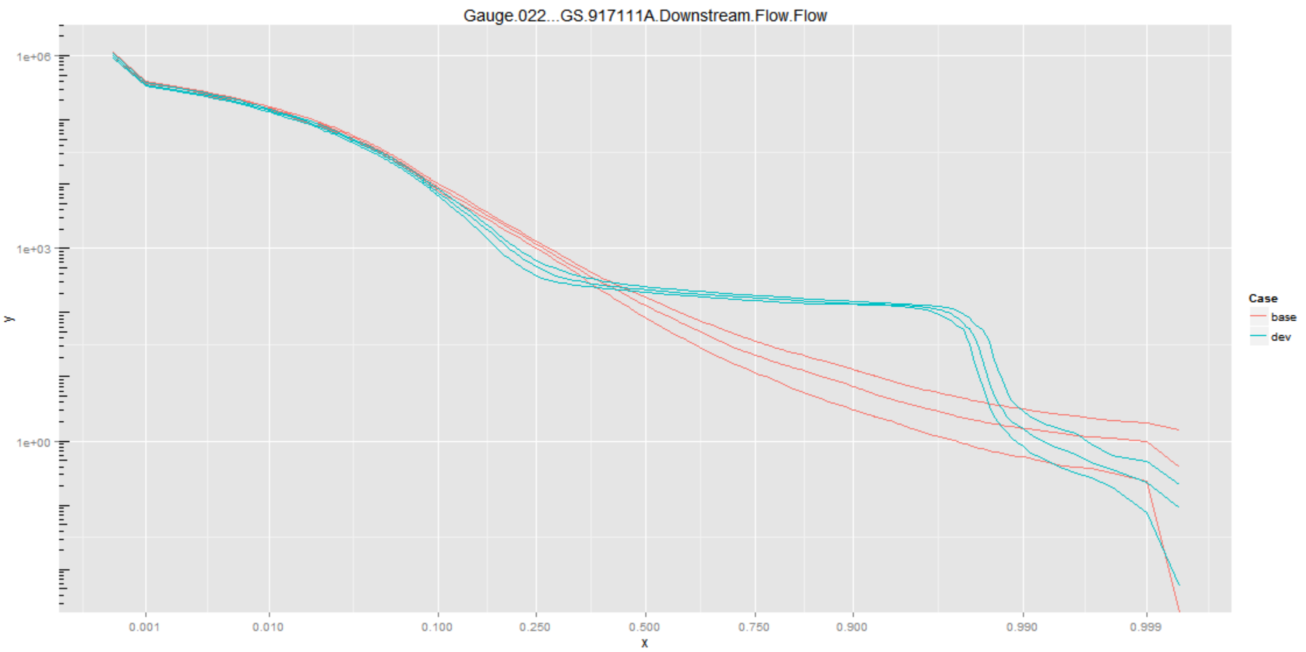

Gauge.018...GS.917113A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

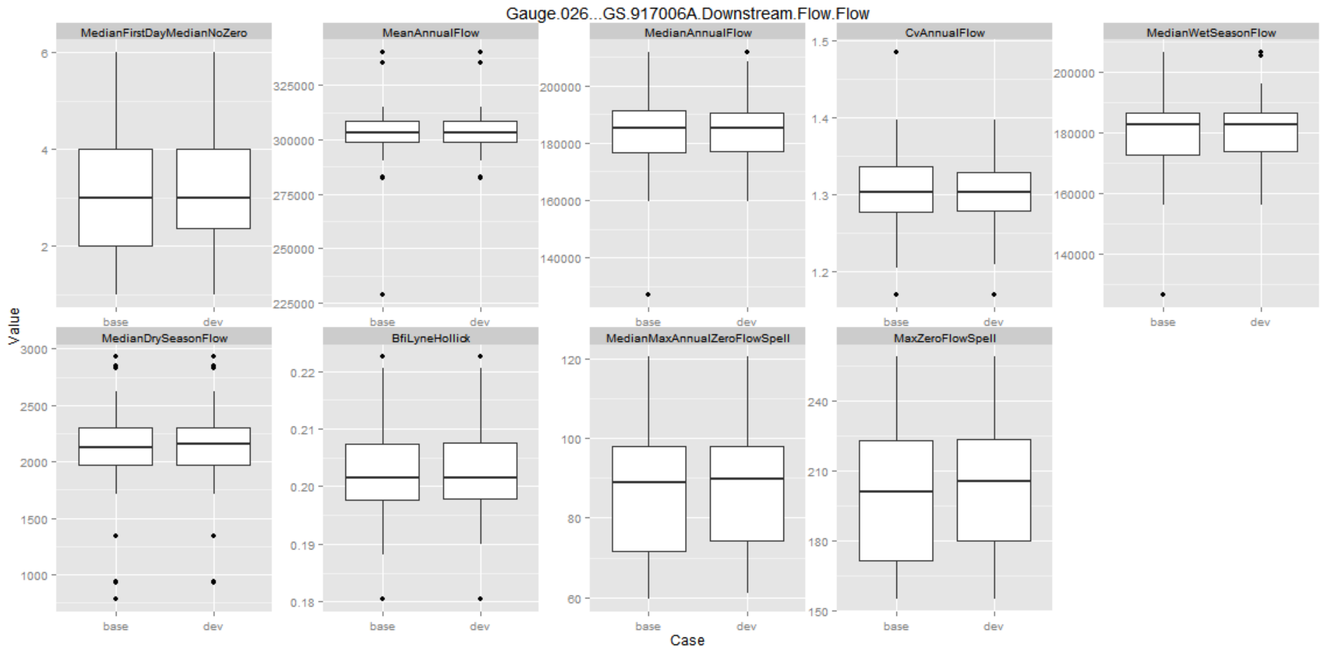

Gauge.018...GS.917113A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

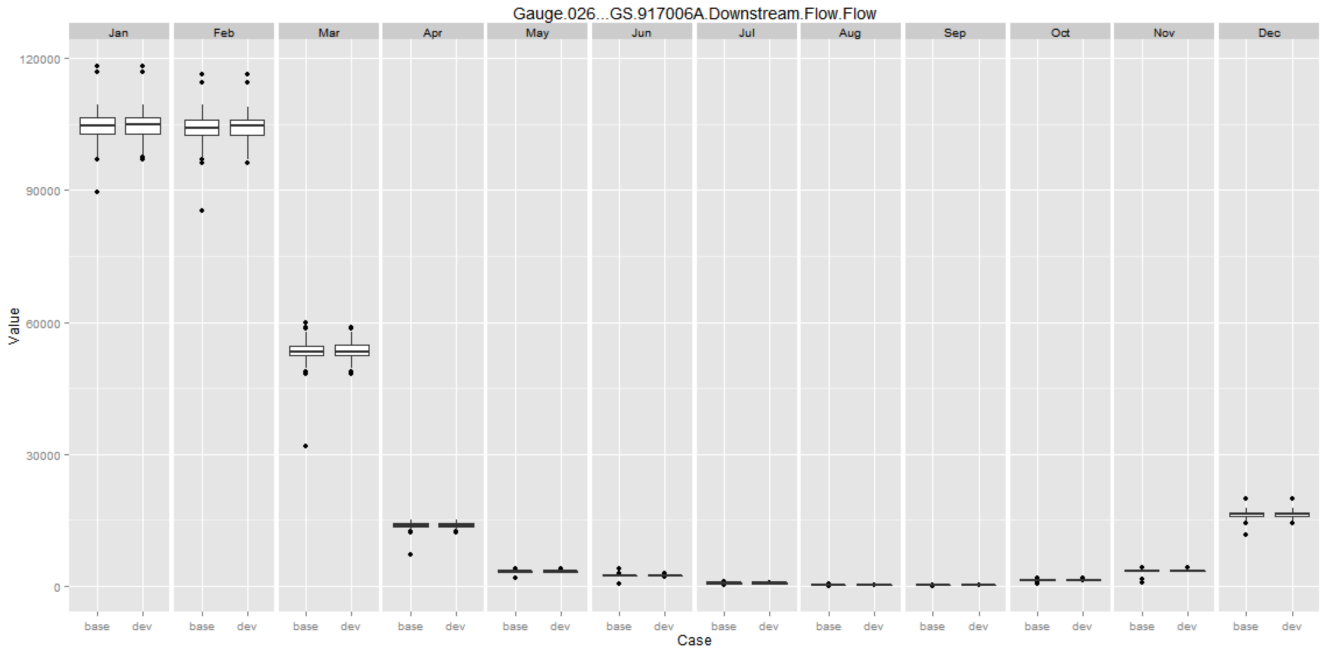

Gauge.018...GS.917113A.Downstream.Flow.Flow
y
x
Case
base
dev

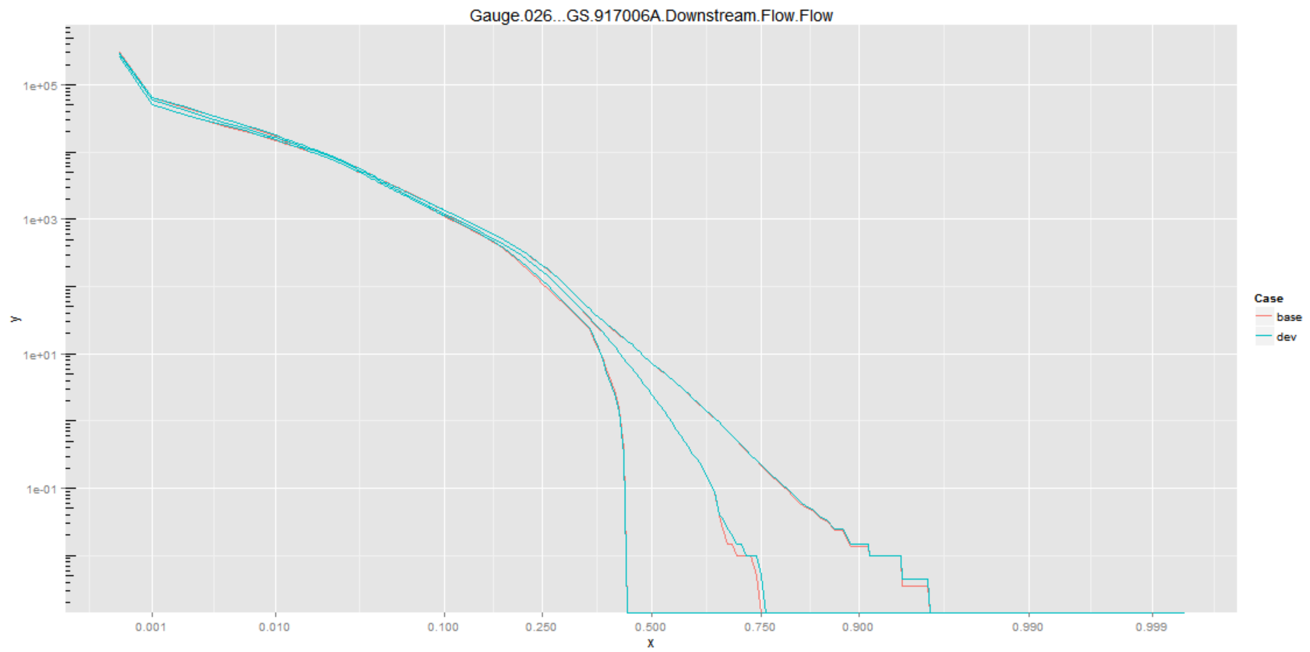

Gauge.022...GS.917111A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

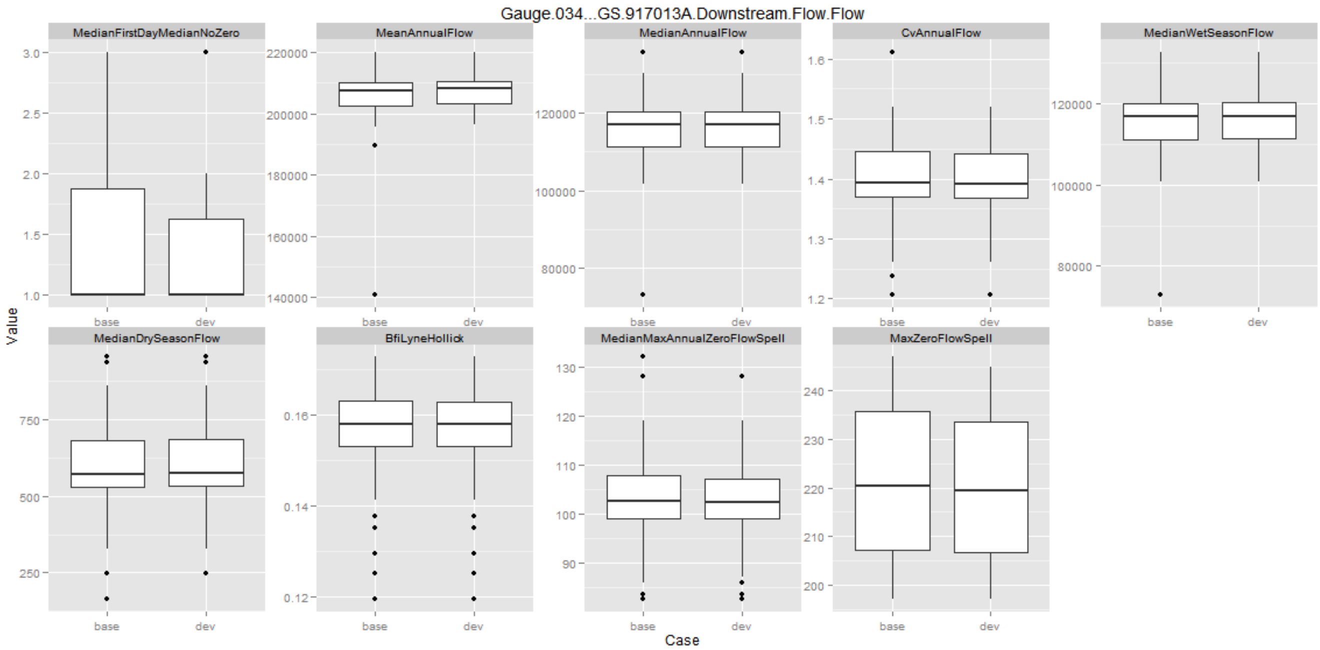

Gauge.022...GS.917111A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

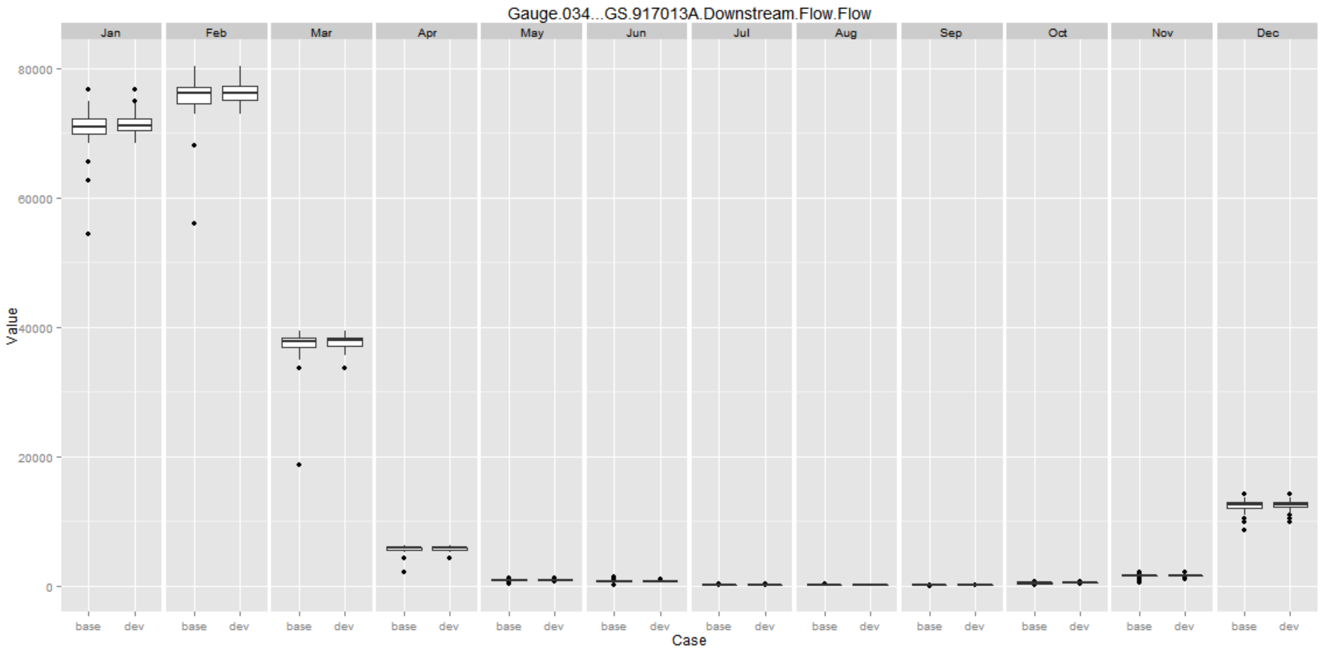

Gauge.022...GS.917111A.Downstream.Flow.Flow
y
x
Case
base
dev

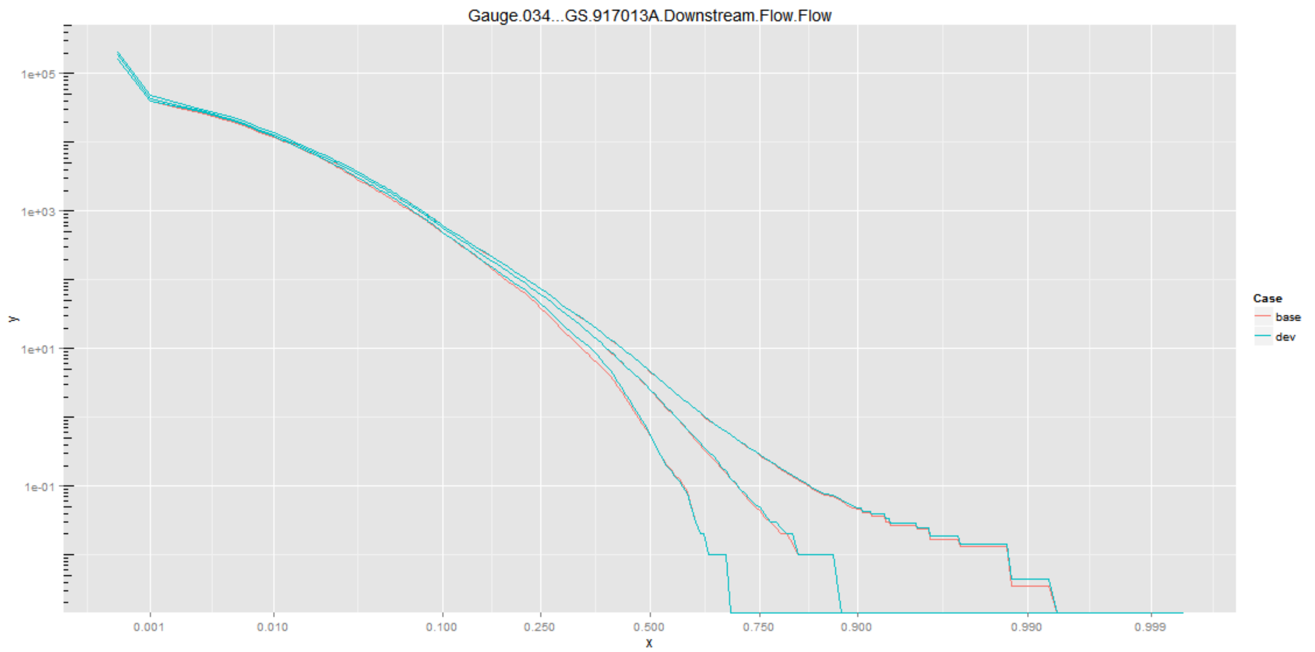

Gauge.026...GS.917006A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

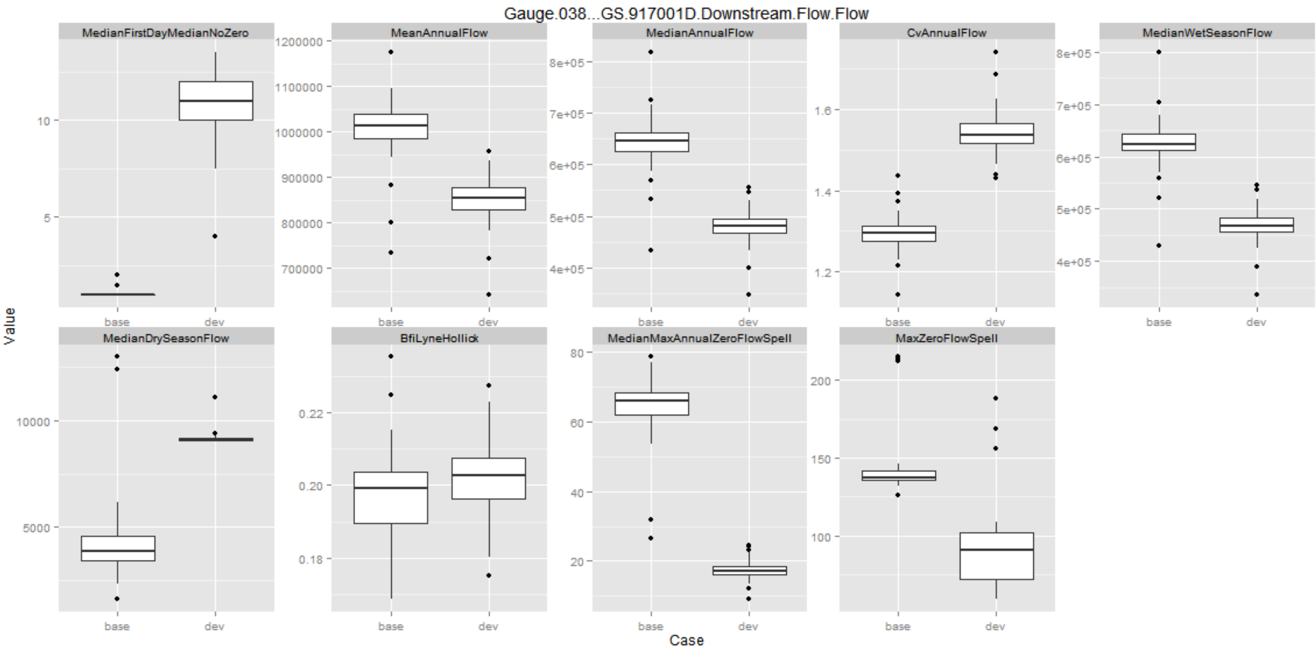

Gauge.026...GS.917006A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

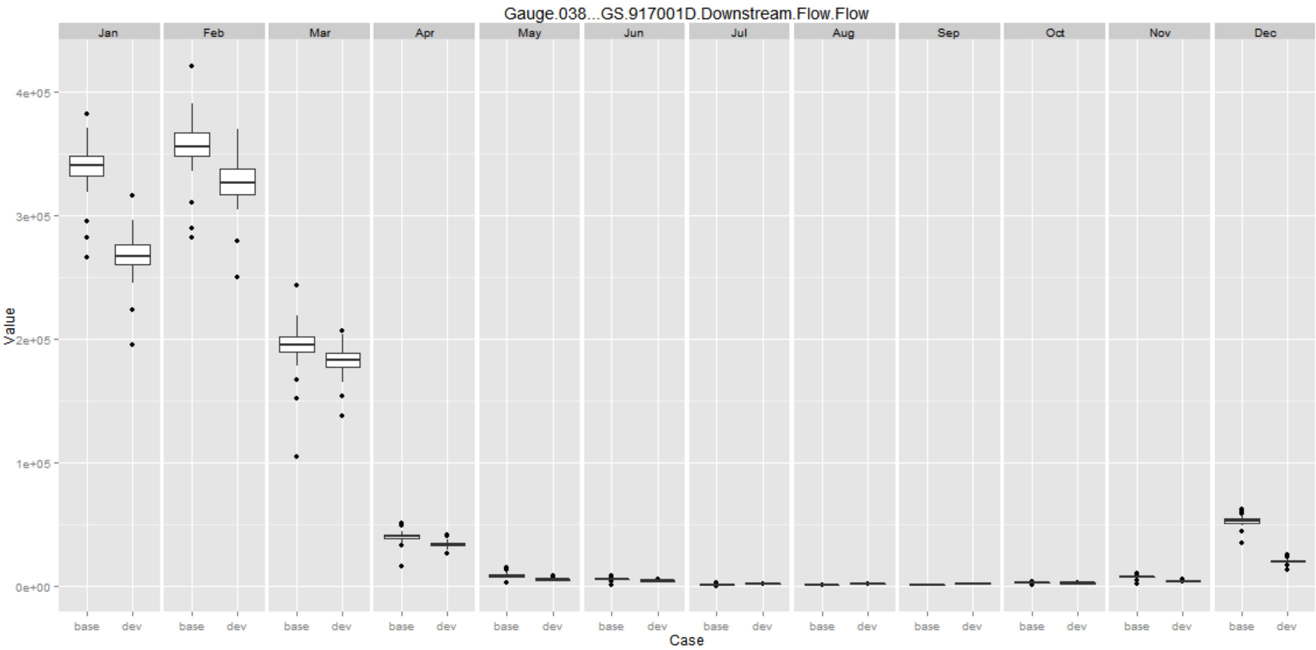

Gauge.026...GS.917006A.Downstream.Flow.Flow
y
x
Case
base
dev

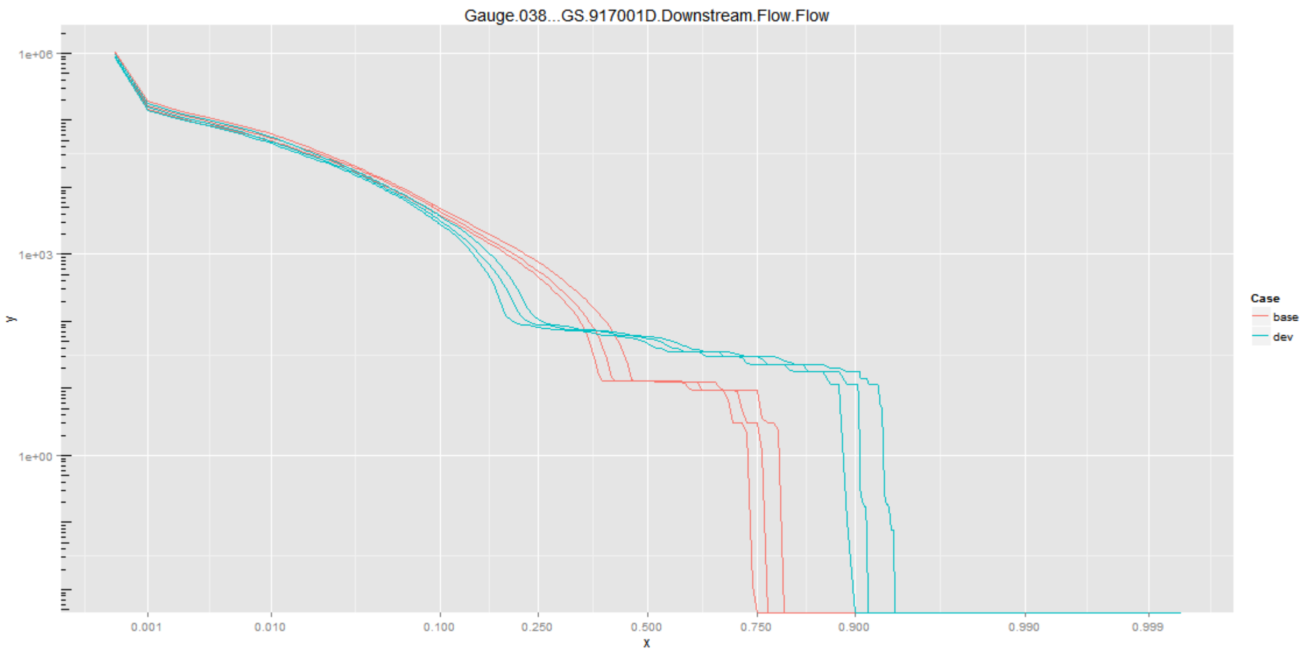

Gauge.034...GS.917013A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

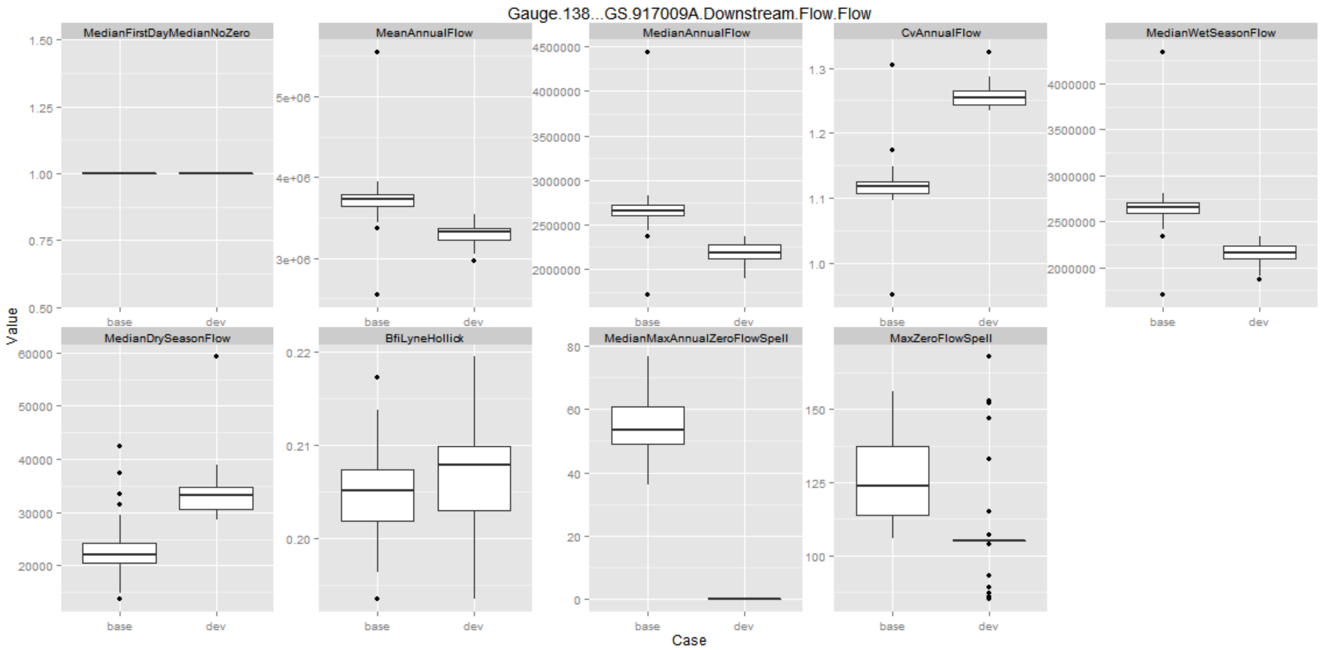

Gauge.034...GS.917013A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

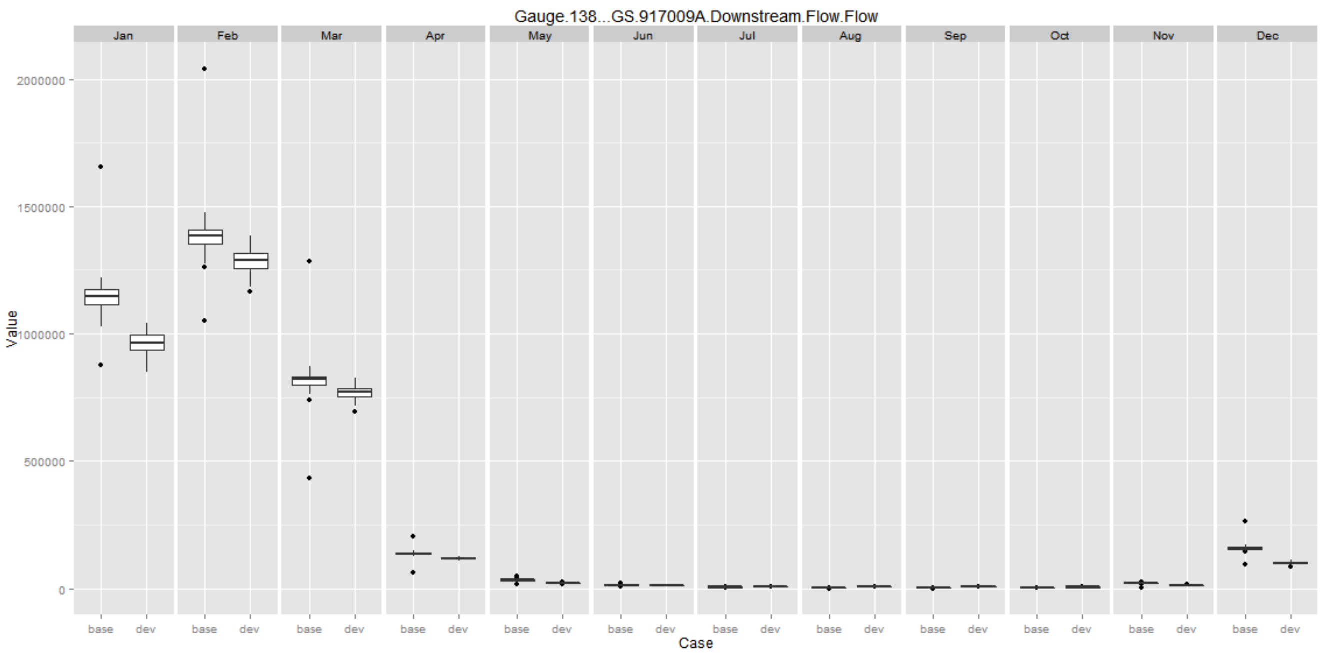

Gauge.034...GS.917013A.Downstream.Flow.Flow
y
x
Case
base
dev

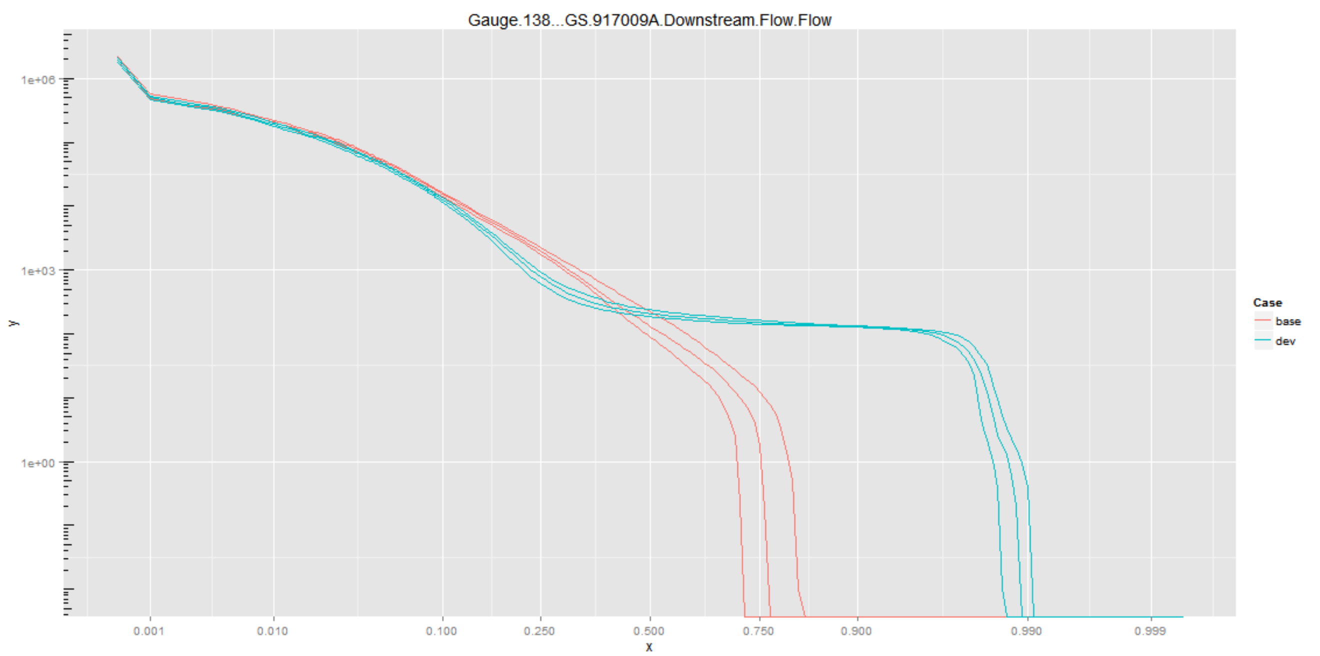

Gauge.038...GS.917001D.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

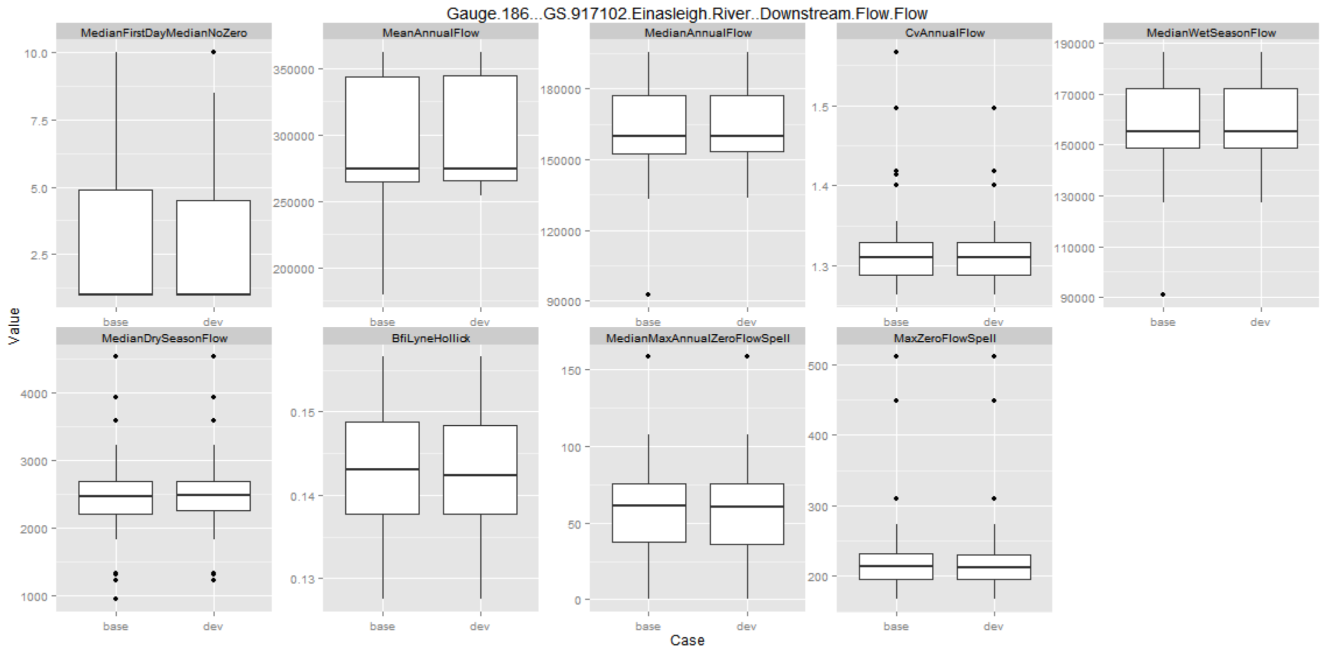

Gauge.038...GS.917001D.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

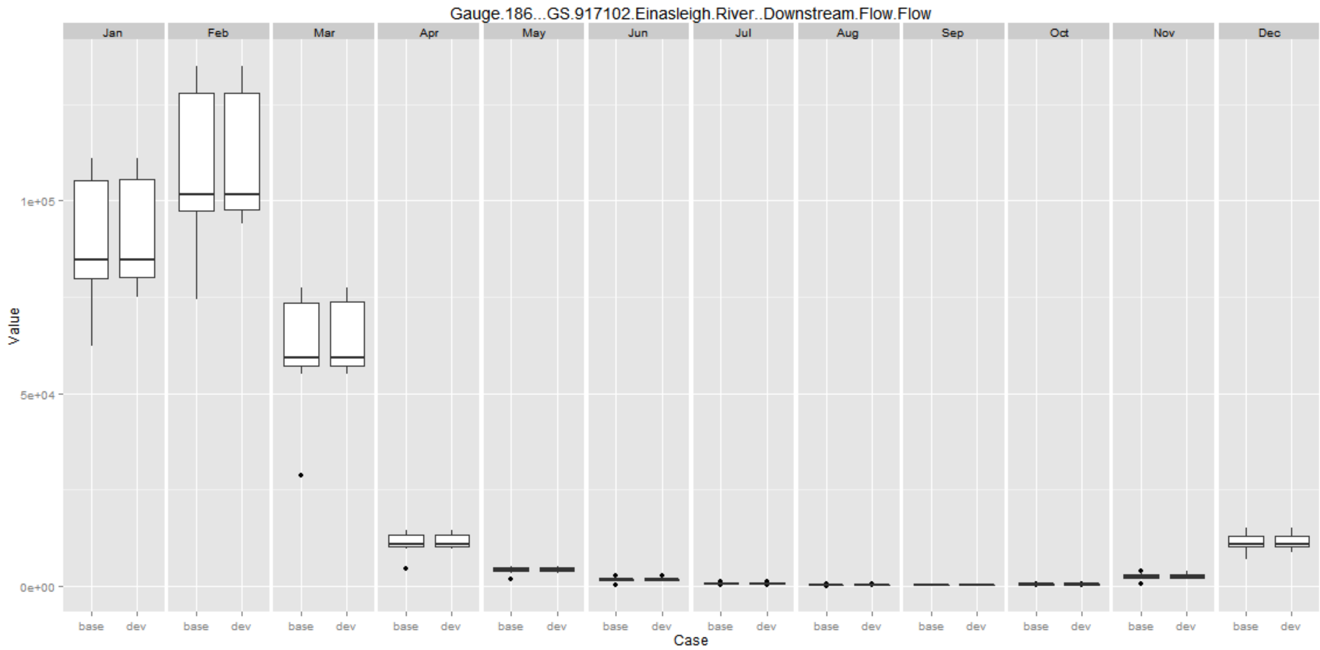

Gauge.038...GS.917001D.Downstream.Flow.Flow
y
x
Case
base
dev

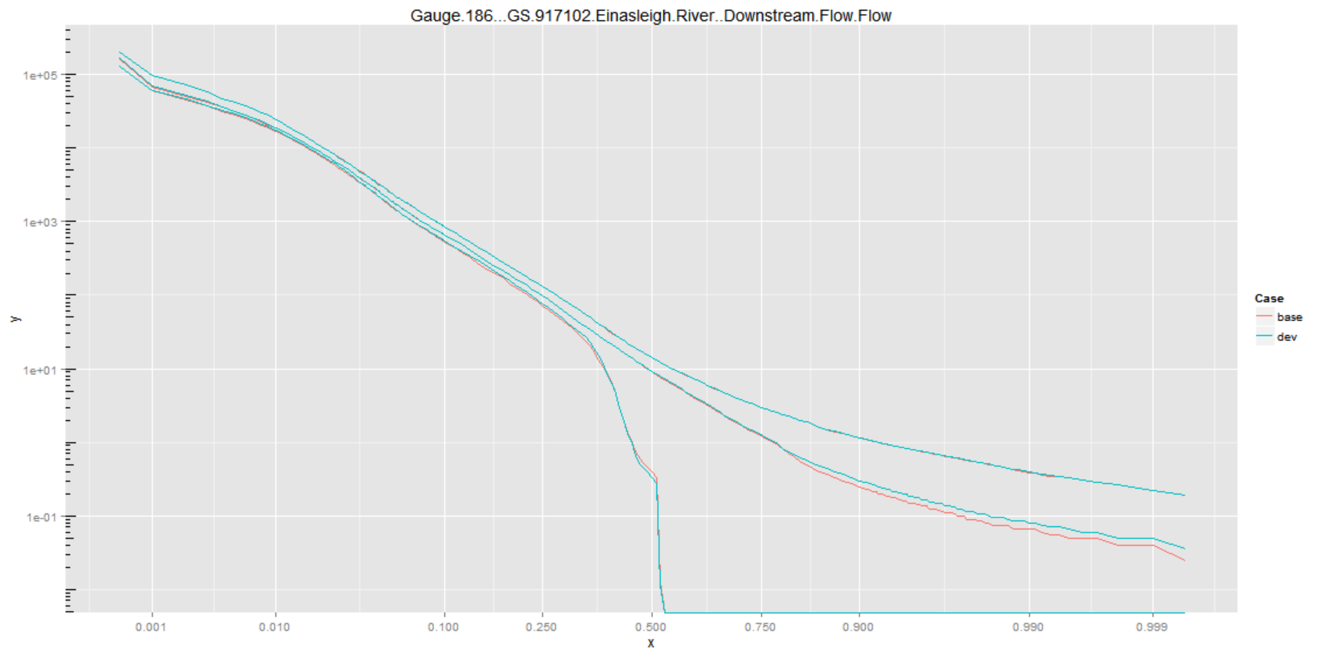

Gauge.138...GS.917009A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

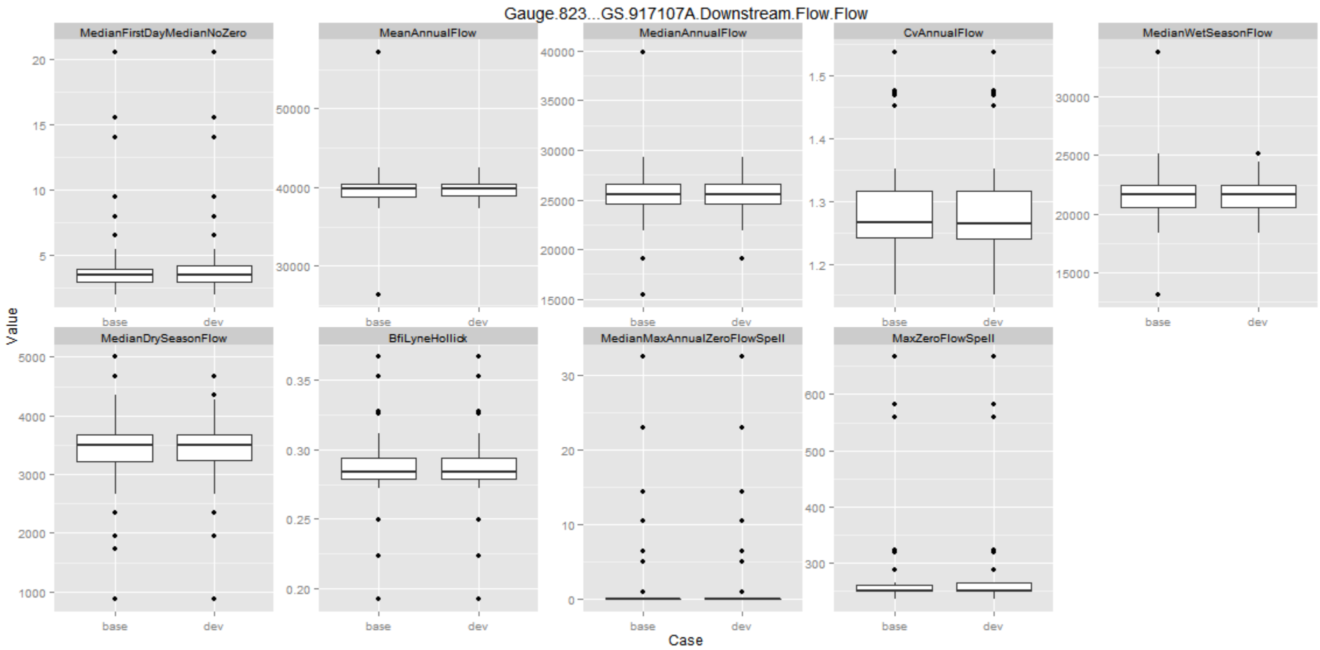

Gauge.138...GS.917009A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

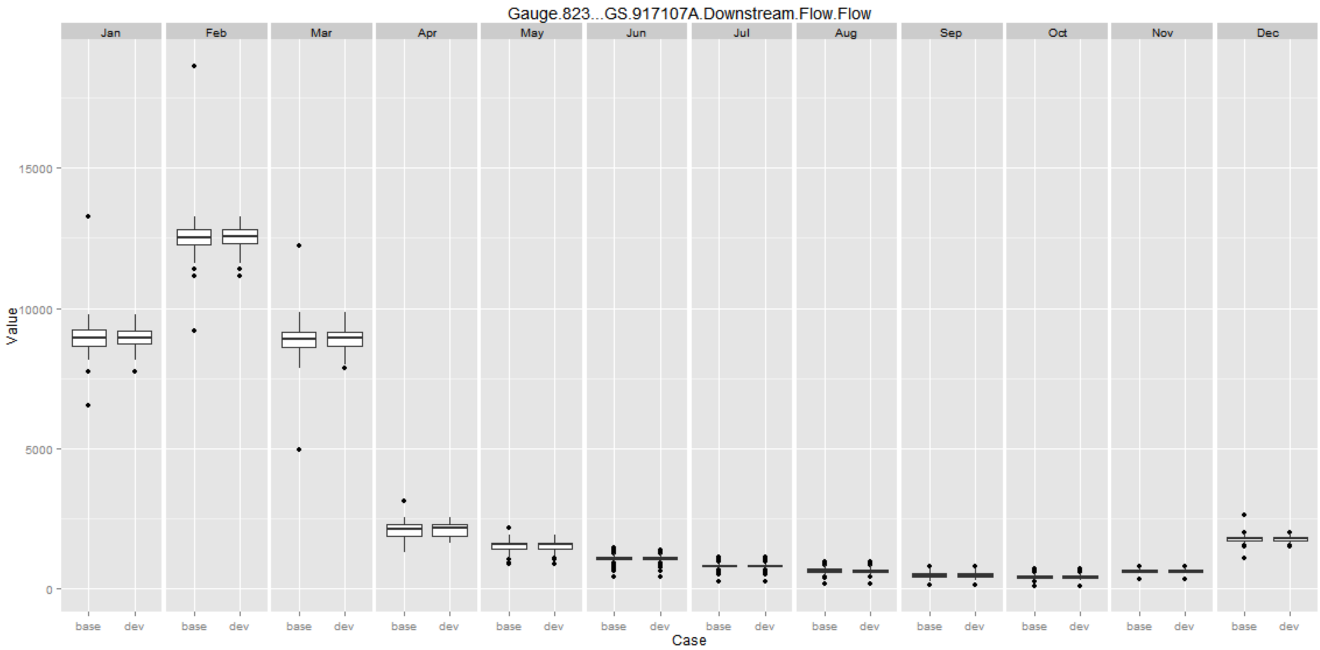

Gauge.138...GS.917009A.Downstream.Flow.Flow
y
x
Case
base
dev

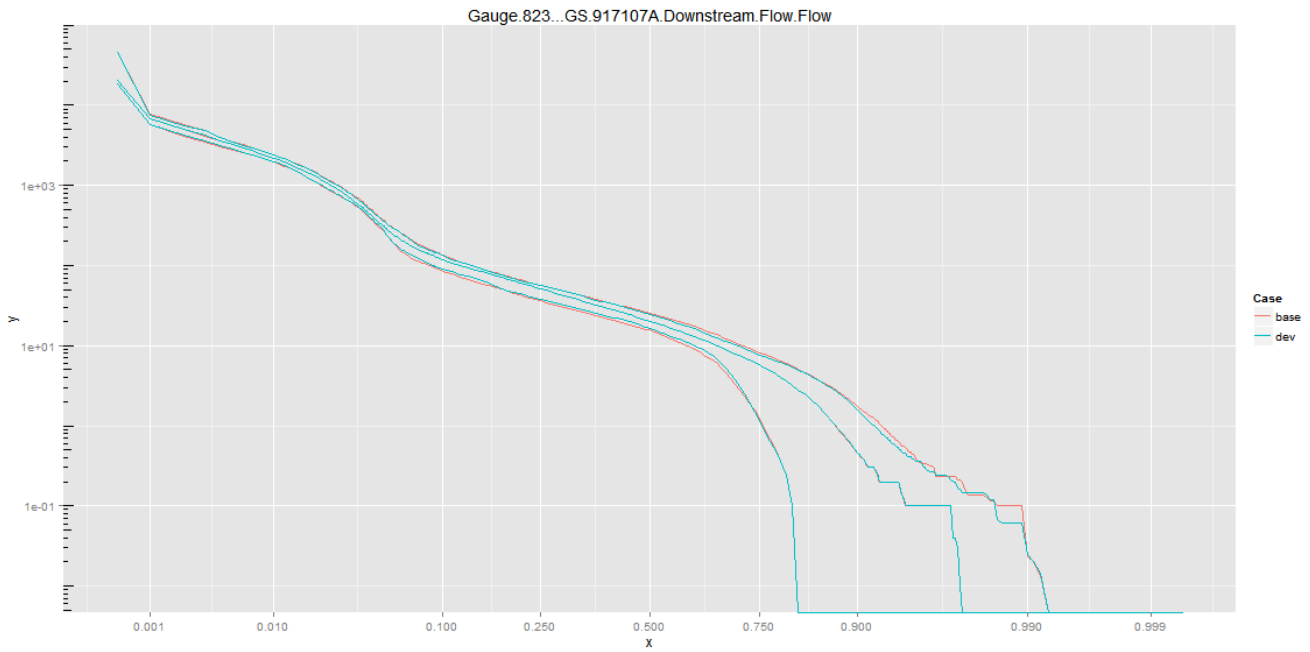

Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

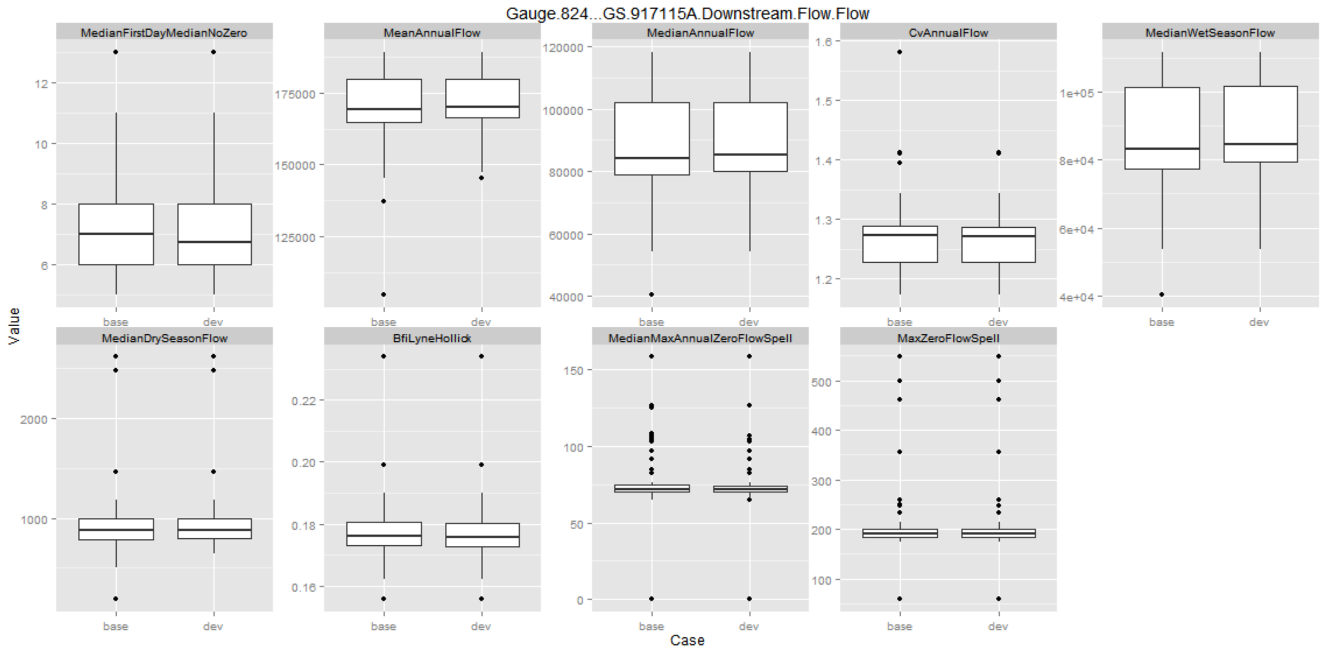

Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

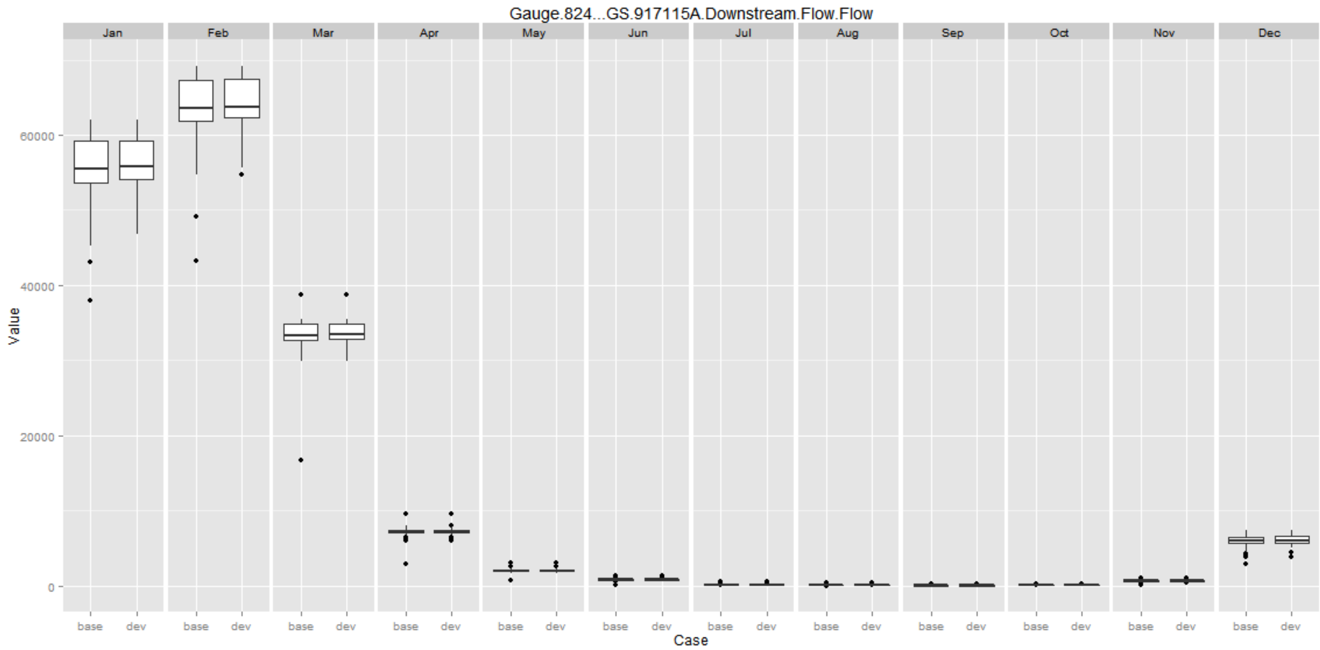

Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow
y
x
Case
base
dev

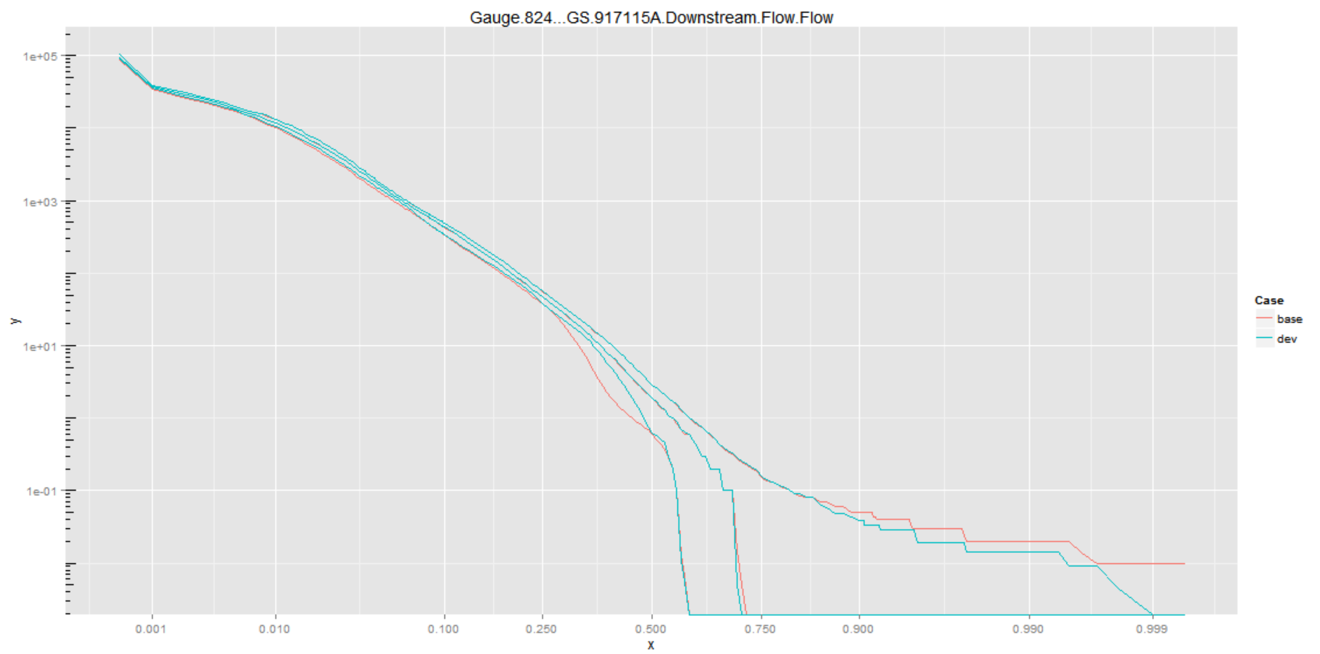

Gauge.823...GS.917107A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.823...GS.917107A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev


Gauge.823...GS.917107A.Downstream.Flow.Flow
y
x
Case
base
dev


Gauge.824...GS.917115A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.824...GS.917115A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev


Gauge.824...GS.917115A.Downstream.Flow.Flow
y
x
Case
base
dev

Appendix

R session information for the generation of this document:

```
sessionInfo()
```

```
## R version 3.0.1 (2013-05-16)
## Platform: i386-w64-mingw32/i386 (32-bit)
##
## locale:
## [1] LC_COLLATE=English_Australia.1252  LC_CTYPE=English_Australia.1252
## [3] LC_MONETARY=English_Australia.1252 LC_NUMERIC=C
## [5] LC_TIME=English_Australia.1252
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] garaHydroMetrics_0.1-4 scales_0.2.3           reshape2_1.2.2
##  [4] lubridate_1.3.1        stringr_0.6.2          ggplot2_0.9.3.1
##  [7] xts_0.9-7              zoo_1.7-10             plyr_1.8
## [10] knitr_1.5
##
## loaded via a namespace (and not attached):
##  [1] colorspace_1.2-4   dichromat_2.0-0    digest_0.6.3
##  [4] evaluate_0.5.1     formatR_0.10       grid_3.0.1
##  [7] gtable_0.1.2       labeling_0.2       lattice_0.20-15
## [10] MASS_7.3-26        munsell_0.4.2      proto_0.3-10
## [13] RColorBrewer_1.0-5 tools_3.0.1
```

FGARA Hydrological Metrics - Dry run on Greenhills ensemble runs

About this document

Purpose is to have a dry run on 50 runs ensembles for Dagworth vs Gilbert baseline

This document was generated on 2013-11-21 16:35:46 using among other things the packages 'knitr' and 'garaHydroMetrics' (https://stash.csiro.au/projects/~per202/repos/hydrometrics/browse)

Calculate statistics

Load the package the usual. It includes a fair level of documentation, that should be accessible using the '?' command, shortcut for help(garaHydroMetrics).

```
library(garaHydroMetrics)
```

```
## Warning: package 'garaHydroMetrics' was built under R version 3.0.2
```

```
## Loading required package: plyr
```

```
## Warning: package 'plyr' was built under R version 3.0.2
```

```
## Loading required package: xts
```

```
## Warning: package 'xts' was built under R version 3.0.2
```

```
## Loading required package: zoo
##
## Attaching package: 'zoo'
##
## The following object is masked from 'package:base':
##
##     as.Date, as.Date.numeric
##
## Loading required package: ggplot2
```

```
## Warning: package 'ggplot2' was built under R version 3.0.2
```

```
## Loading required package: stringr
```

```
## Warning: package 'stringr' was built under R version 3.0.2
```

```
## Loading required package: lubridate
```

```
## Warning: package 'lubridate' was built under R version 3.0.2
```

```
##
## Attaching package: 'lubridate'
##
## The following object is masked from 'package:plyr':
##
##     here
##
## Loading required package: reshape2
```

```
## Warning: package 'reshape2' was built under R version 3.0.2
```

```
## Loading required package: scales
```

```
## Warning: package 'scales' was built under R version 3.0.2
## Warning: replacing previous import 'here' when loading 'plyr'
```

```
library(plyr)
```

Mapping \wron\Project\GARA\2_Rivers\3_All\8_Case_Studies to a W: drive to preempt issues to do with too long paths.

```
baselineDir <- "X:/ScenarioB/"
develDir <- "X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles/"
# develDir <-
# 'X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates/'
# develDir <-
# 'X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles/'

findGaugeFiles <- function(topFolder) {
    pattern <- ".*_Gauge_daily.csv.gz"
    csvfiles <- list.files(path = topFolder, pattern = pattern, all.files = TRUE,
        full.names = TRUE, recursive = TRUE, ignore.case = TRUE)
}
baseFiles <- findGaugeFiles(baselineDir)
develFiles <- findGaugeFiles(develDir)

timeSeries <- lapply(c(baseFiles[c(1, 51)], develFiles[1]), loadXts)
gaugeNames <- lapply(timeSeries, names)
gaugeNames
```

```
## [[1]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[2]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[3]]
##  [1] "Gauge.026...GS.917006A.Downstream.Flow.Flow"
##  [2] "Gauge.034...GS.917013A.Downstream.Flow.Flow"
##  [3] "Gauge.003...GS.917108A.Downstream.Flow.Flow"
##  [4] "Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow"
##  [5] "Gauge.006...GS.917106A.Downstream.Flow.Flow"
##  [6] "Gauge.009...GS.917109A.Downstream.Flow.Flow"
##  [7] "Gauge.018...GS.917113A.Downstream.Flow.Flow"
##  [8] "Gauge.013....GS917112A.Downstream.Flow.Flow"
##  [9] "Gauge.022...GS.917111A.Downstream.Flow.Flow"
## [10] "Gauge.038...GS.917001D.Downstream.Flow.Flow"
## [11] "Gauge.138...GS.917009A.Downstream.Flow.Flow"
## [12] "Gauge.823...GS.917107A.Downstream.Flow.Flow"
## [13] "Gauge.824...GS.917115A.Downstream.Flow.Flow"
```

```
selectedGauges = gaugeNames[[1]][1:5]
subsetGauges <- function(ts, selectedGauges) {
    ts[, selectedGauges]
}
timeSeriesSubset <- lapply(timeSeries, subsetGauges, selectedGauges)
```

It looks like the second and third are matches, i.e.:

```
c(baseFiles[c(51)], develFiles[1])
```

```
## [1]
"X:/ScenarioB//Flinders_runfolders/run_rep_0047_scenarioA_wrpnores_v143_20131811_220632_2934/postpro

## [2]
"X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_0_scenarioA_wrpnores_v
```

So let's roll the stats (circa 15 sec per file, expect around 25 minutes runtime). Given the considerable runtime, this is important to have a caching mechanism i.e. saving the result to an RData file. The file is only 2MB so it is worth caching.

```
scenarioFolders <- c("Gilbert_runfolders", "no_impact_ensembles")
scenarioTags <- c("base", "dev")

statFile <- "Z:/GARA/2_Rivers/4_Working/per202/Greenhills/EnsFiles.RData"
stopifnot(file.exists(dirname(statFile)))

if (!file.exists(statFile)) {
    statList <- univStatsMultiScenario(c(baseFiles, develFiles), scenarioFolders,
        scenarioTags)
    save(statList, file = statFile)
} else {
    load(statFile)
}
```

```
## [1] "2013-11-21 16:37:10
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioA_wrpnores_v27_20132409_130052_20138/postpro

## [1] "2013-11-21 16:37:19
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioCdry_wrpnores_v27_20132409_130054_20144/post

## [1] "2013-11-21 16:37:29
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioCmid_wrpnores_v27_20132409_130056_20151/post

## [1] "2013-11-21 16:37:38
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioCwet_wrpnores_v27_20132409_130058_20157/post

## [1] "2013-11-21 16:37:47
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_1_scenarioA_wrpnores_v27_20131911_72013_13175/

## [1] "2013-11-21 16:37:57
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_10_scenarioA_wrpnores_v27_20131911_72031_1323

## [1] "2013-11-21 16:38:05
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_11_scenarioA_wrpnores_v27_20131911_72033_1324

## [1] "2013-11-21 16:38:14
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_12_scenarioA_wrpnores_v27_20131911_72035_1324

## [1] "2013-11-21 16:38:26
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_13_scenarioA_wrpnores_v27_20131911_72037_1325

## [1] "2013-11-21 16:38:35
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_14_scenarioA_wrpnores_v27_20131911_72039_1326

## [1] "2013-11-21 16:38:44
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_15_scenarioA_wrpnores_v27_20131911_72041_1326

## [1] "2013-11-21 16:38:54
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_16_scenarioA_wrpnores_v27_20131911_72043_1327

## [1] "2013-11-21 16:39:03
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_17_scenarioA_wrpnores_v27_20131911_72045_1327

## [1] "2013-11-21 16:39:11
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_18_scenarioA_wrpnores_v27_20131911_72047_1328

## [1] "2013-11-21 16:39:20
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_19_scenarioA_wrpnores_v27_20131911_72049_1329

## [1] "2013-11-21 16:39:28
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_2_scenarioA_wrpnores_v27_20131911_72015_13181/

## [1] "2013-11-21 16:39:38
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_20_scenarioA_wrpnores_v27_20131911_72051_1329

## [1] "2013-11-21 16:39:46
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_21_scenarioA_wrpnores_v27_20131911_72053_1330

## [1] "2013-11-21 16:39:56
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_22_scenarioA_wrpnores_v27_20131911_72055_1331

## [1] "2013-11-21 16:40:06
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_23_scenarioA_wrpnores_v27_20131911_72057_1331

## [1] "2013-11-21 16:40:15
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_24_scenarioA_wrpnores_v27_20131911_72059_1332

## [1] "2013-11-21 16:40:25
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_25_scenarioA_wrpnores_v27_20131911_72101_1333

## [1] "2013-11-21 16:40:34
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_26_scenarioA_wrpnores_v27_20131911_115310_111

## [1] "2013-11-21 16:40:43
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_27_scenarioA_wrpnores_v27_20131911_115312_112

## [1] "2013-11-21 16:40:52
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_28_scenarioA_wrpnores_v27_20131911_115314_113

## [1] "2013-11-21 16:41:03
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_29_scenarioA_wrpnores_v27_20131911_115316_113
```

```
## [1] "2013-11-21 16:41:12
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_3_scenarioA_wrpnores_v27_20131911_72017_13188,

## [1] "2013-11-21 16:41:23
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_30_scenarioA_wrpnores_v27_20131911_115318_114

## [1] "2013-11-21 16:41:32
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_31_scenarioA_wrpnores_v27_20131911_115320_115

## [1] "2013-11-21 16:41:41
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_32_scenarioA_wrpnores_v27_20131911_115322_115

## [1] "2013-11-21 16:41:50
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_33_scenarioA_wrpnores_v27_20131911_115324_116

## [1] "2013-11-21 16:42:00
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_34_scenarioA_wrpnores_v27_20131911_115326_117

## [1] "2013-11-21 16:42:10
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_35_scenarioA_wrpnores_v27_20131911_115328_117

## [1] "2013-11-21 16:42:18
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_36_scenarioA_wrpnores_v27_20131911_115330_118

## [1] "2013-11-21 16:42:28
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_37_scenarioA_wrpnores_v27_20131911_115332_119

## [1] "2013-11-21 16:42:37
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_38_scenarioA_wrpnores_v27_20131911_115334_119

## [1] "2013-11-21 16:42:45
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_39_scenarioA_wrpnores_v27_20131911_115336_120

## [1] "2013-11-21 16:42:57
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_4_scenarioA_wrpnores_v27_20131911_72019_13195,

## [1] "2013-11-21 16:43:05
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_40_scenarioA_wrpnores_v27_20131911_115338_121

## [1] "2013-11-21 16:43:14
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_41_scenarioA_wrpnores_v27_20131911_115340_121

## [1] "2013-11-21 16:43:23
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_42_scenarioA_wrpnores_v27_20131911_115342_122

## [1] "2013-11-21 16:43:31
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_43_scenarioA_wrpnores_v27_20131911_115344_123

## [1] "2013-11-21 16:43:39
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_44_scenarioA_wrpnores_v27_20131911_115346_123

## [1] "2013-11-21 16:43:48
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_45_scenarioA_wrpnores_v27_20131911_115348_124

## [1] "2013-11-21 16:43:57
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_46_scenarioA_wrpnores_v27_20131911_115350_125

## [1] "2013-11-21 16:44:06
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_47_scenarioA_wrpnores_v27_20131911_115352_125

## [1] "2013-11-21 16:44:15
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_48_scenarioA_wrpnores_v27_20131911_115354_126

## [1] "2013-11-21 16:44:23
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_49_scenarioA_wrpnores_v27_20131911_115356_127

## [1] "2013-11-21 16:44:31
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_5_scenarioA_wrpnores_v27_20131911_72021_13201,

## [1] "2013-11-21 16:44:41
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_50_scenarioA_wrpnores_v27_20131911_115358_127

## [1] "2013-11-21 16:44:49
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_6_scenarioA_wrpnores_v27_20131911_72023_13208,

## [1] "2013-11-21 16:44:58
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_7_scenarioA_wrpnores_v27_20131911_72025_13214,

## [1] "2013-11-21 16:45:06
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_8_scenarioA_wrpnores_v27_20131911_72027_13221,

## [1] "2013-11-21 16:45:18
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_9_scenarioA_wrpnores_v27_20131911_72029_13227,

## [1] "2013-11-21 16:45:27
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_0_scenarioA_wrpnores_v

## [1] "2013-11-21 16:45:35
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_1_scenarioA_w

## [1] "2013-11-21 16:45:46
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_10_scenarioA_

## [1] "2013-11-21 16:45:55
```

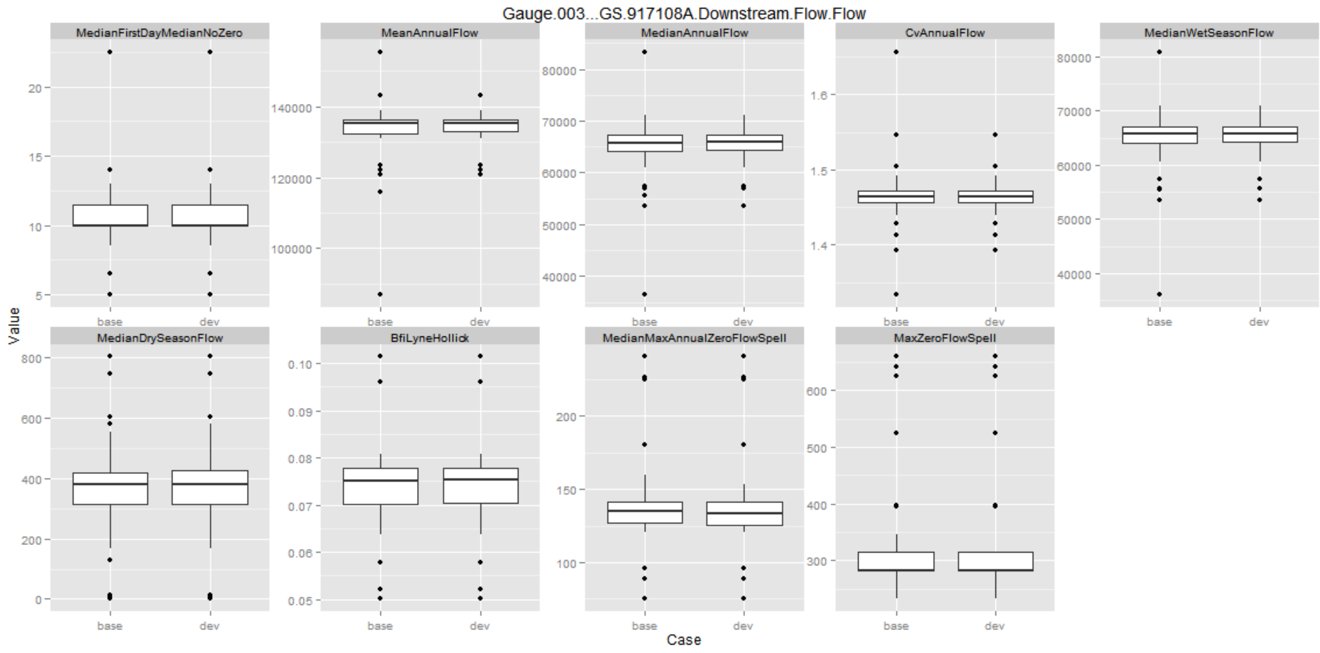
```
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_11_scenarioA_\

## [1] "2013-11-21 16:46:04
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_12_scenarioA_\

## [1] "2013-11-21 16:46:17
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_13_scenarioA_\

## [1] "2013-11-21 16:46:26
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_14_scenarioA_\

## [1] "2013-11-21 16:46:35
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_15_scenarioA_\

## [1] "2013-11-21 16:46:46
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_16_scenarioA_\

## [1] "2013-11-21 16:46:55
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_17_scenarioA_\

## [1] "2013-11-21 16:47:03
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_18_scenarioA_\

## [1] "2013-11-21 16:47:14
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_19_scenarioA_\

## [1] "2013-11-21 16:47:23
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_2_scenarioA_wi

## [1] "2013-11-21 16:47:32
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_20_scenarioA_\

## [1] "2013-11-21 16:47:42
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_21_scenarioA_\

## [1] "2013-11-21 16:47:53
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_22_scenarioA_\

## [1] "2013-11-21 16:48:01
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_23_scenarioA_\

## [1] "2013-11-21 16:48:13
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_24_scenarioA_\

## [1] "2013-11-21 16:48:24
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_25_scenarioA_\

## [1] "2013-11-21 16:48:32
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_26_scenarioA_\

## [1] "2013-11-21 16:48:45
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_27_scenarioA_\

## [1] "2013-11-21 16:48:54
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_28_scenarioA_\

## [1] "2013-11-21 16:49:03
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_29_scenarioA_\

## [1] "2013-11-21 16:49:14
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_3_scenarioA_wi

## [1] "2013-11-21 16:49:24
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_30_scenarioA_\

## [1] "2013-11-21 16:49:33
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_31_scenarioA_\

## [1] "2013-11-21 16:49:42
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_32_scenarioA_\

## [1] "2013-11-21 16:49:53
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_33_scenarioA_\

## [1] "2013-11-21 16:50:01
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_34_scenarioA_\

## [1] "2013-11-21 16:50:11
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_35_scenarioA_\

## [1] "2013-11-21 16:50:21
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_36_scenarioA_\

## [1] "2013-11-21 16:50:30
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_37_scenarioA_\

## [1] "2013-11-21 16:50:39
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_38_scenarioA_\

## [1] "2013-11-21 16:50:49
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_39_scenarioA_\

## [1] "2013-11-21 16:50:59
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_4_scenarioA_wi
```

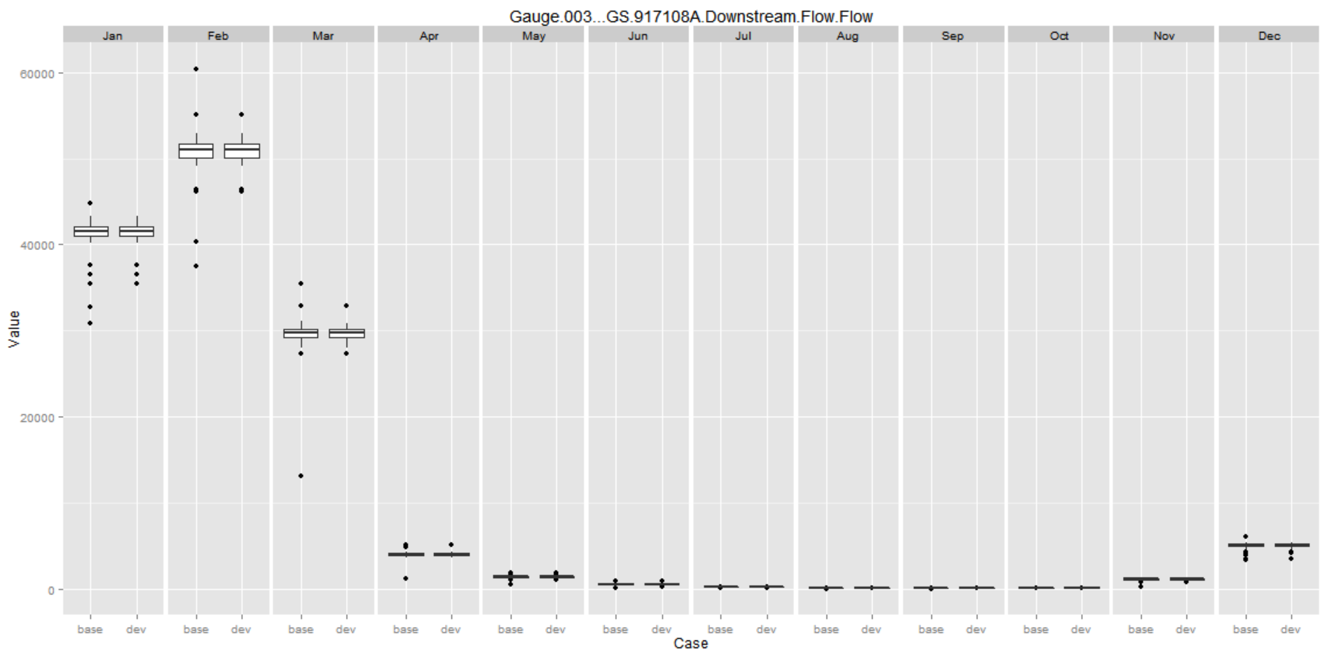
```
## [1] "2013-11-21 16:51:09
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_40_scenarioA_w

## [1] "2013-11-21 16:51:17
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_41_scenarioA_w

## [1] "2013-11-21 16:51:26
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_42_scenarioA_w

## [1] "2013-11-21 16:51:35
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_43_scenarioA_w

## [1] "2013-11-21 16:51:46
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_44_scenarioA_w

## [1] "2013-11-21 16:51:56
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_45_scenarioA_w

## [1] "2013-11-21 16:52:04
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_46_scenarioA_w

## [1] "2013-11-21 16:52:13
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_47_scenarioA_w

## [1] "2013-11-21 16:52:24
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_48_scenarioA_w

## [1] "2013-11-21 16:52:33
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_49_scenarioA_w

## [1] "2013-11-21 16:52:42
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_5_scenarioA_wi

## [1] "2013-11-21 16:52:54
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_50_scenarioA_w

## [1] "2013-11-21 16:53:03
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_6_scenarioA_wi

## [1] "2013-11-21 16:53:14
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_7_scenarioA_wi

## [1] "2013-11-21 16:53:23
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_8_scenarioA_wi

## [1] "2013-11-21 16:53:32
X:/4_GreenHillsUS/_Source_projects_packaged/no_impact_ensembles//run_baseline_ensemble_9_scenarioA_wi
```

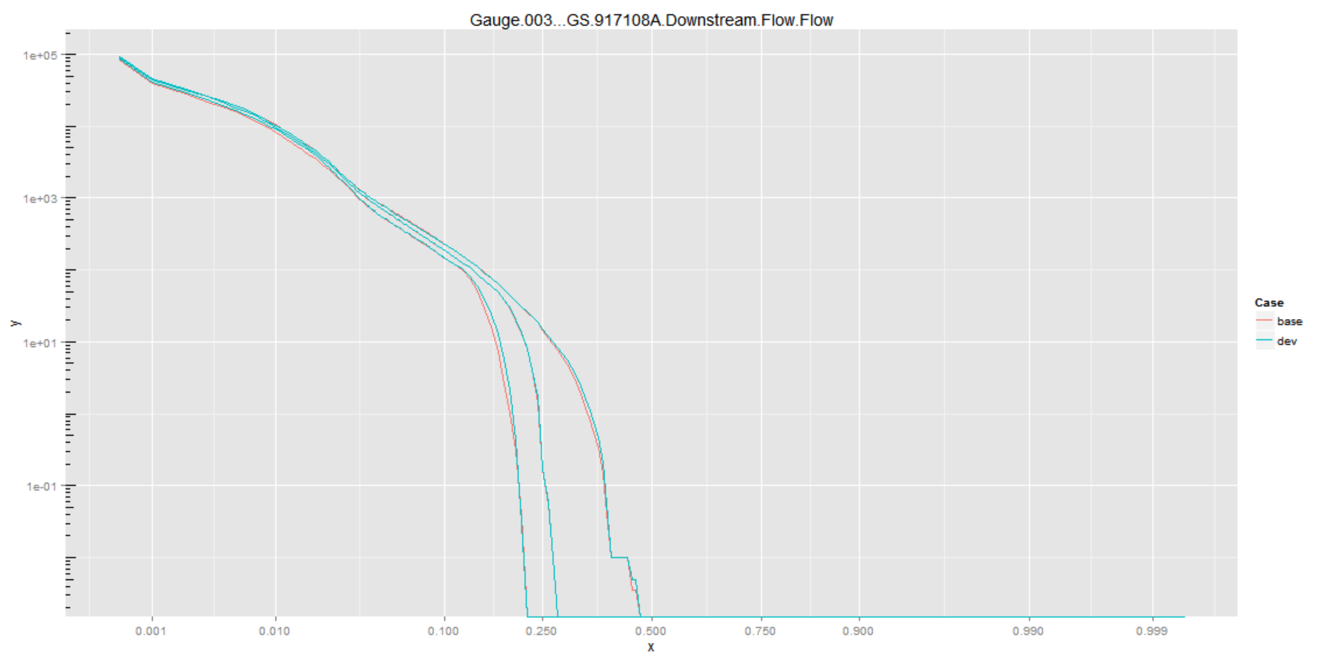
Visualization

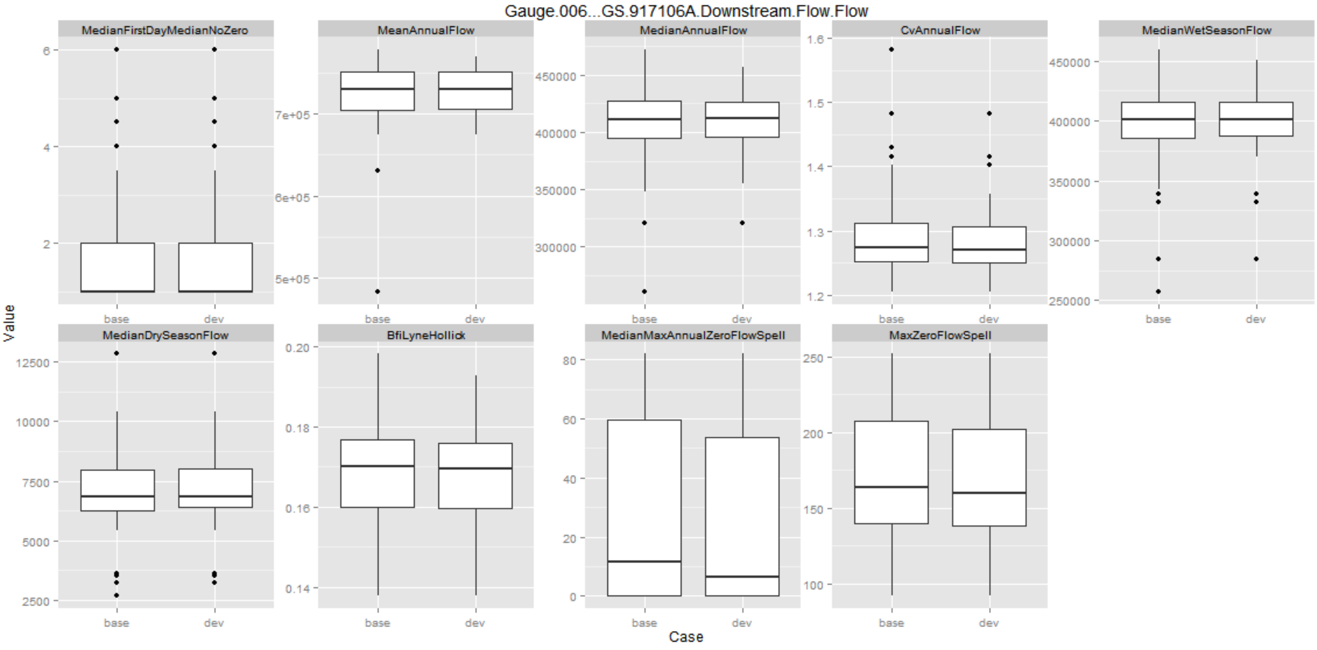
The visualization itself is not all that time comsuming.

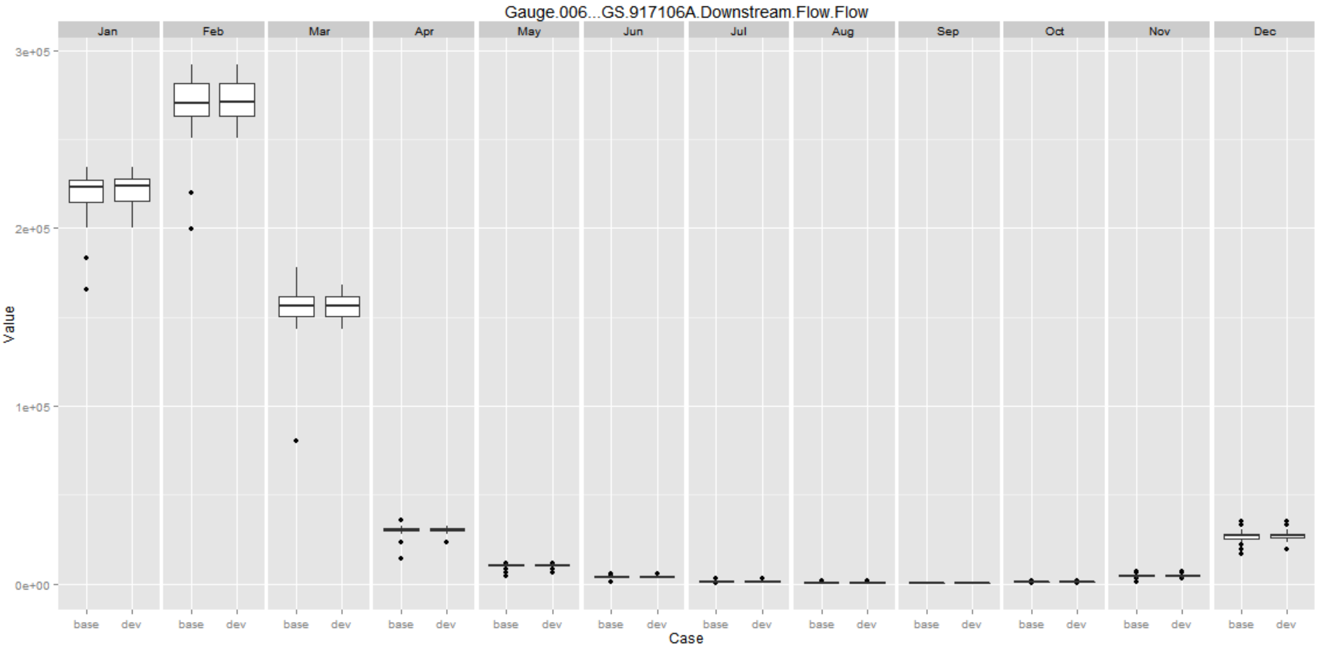
```
d <- listByGauge(rbind(statList[[c(1, 1)]], statList[[c(2, 1)]]))
mthFlows <- listByGauge(rbind(statList[[c(1, 2)]], statList[[c(2, 2)]]))
fdcData <- listByGauge(rbind(statList[[c(1, 3)]], statList[[c(2, 3)]]))
for (gaugename in names(d)) {
    print(getBoxplotsUniv(d[[gaugename]]) + ggtitle(gaugename))
    print(getBoxplotsMthly(mthFlows[[gaugename]], gaugename))
    print(getPlotFdc(fdcData[[gaugename]], gaugename))
}
```

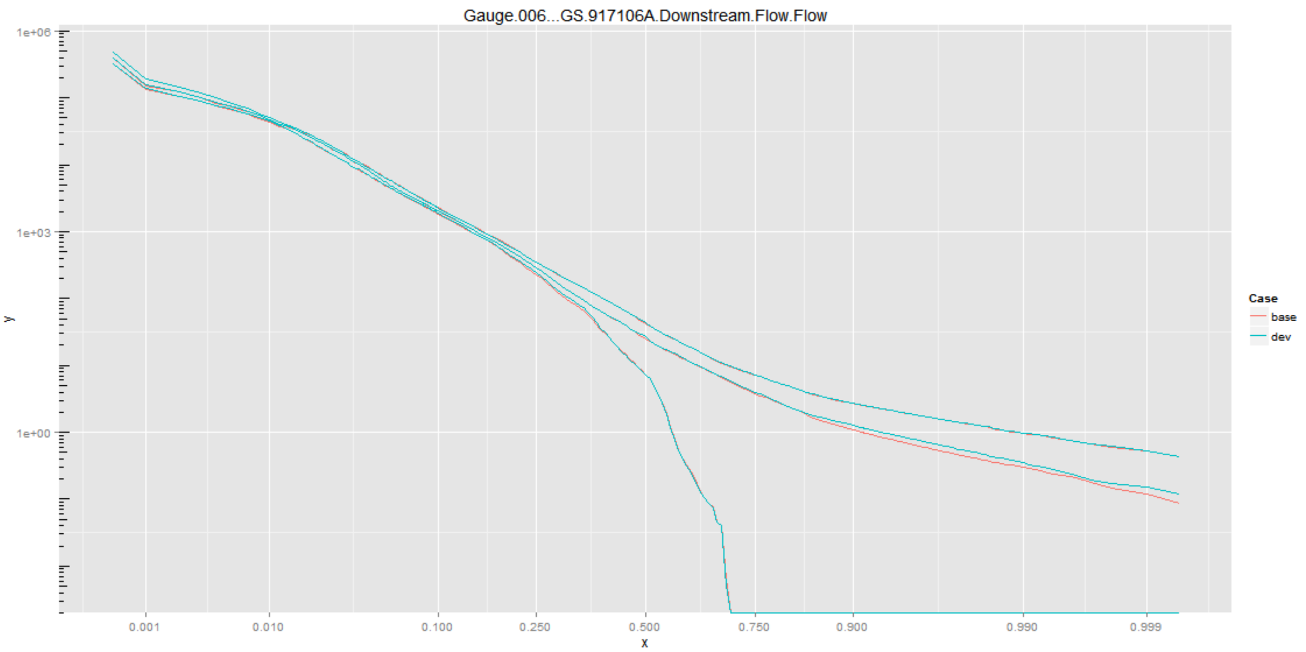

Gauge.003...GS.917108A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

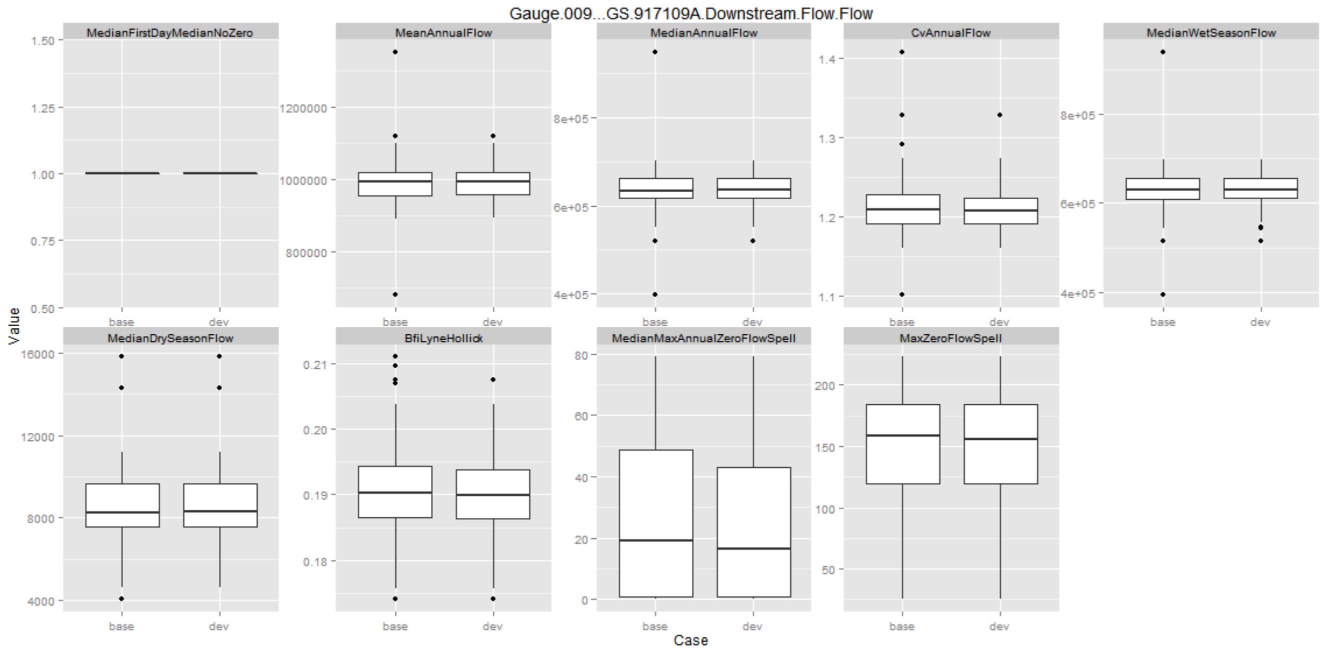

Gauge.003...GS.917108A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

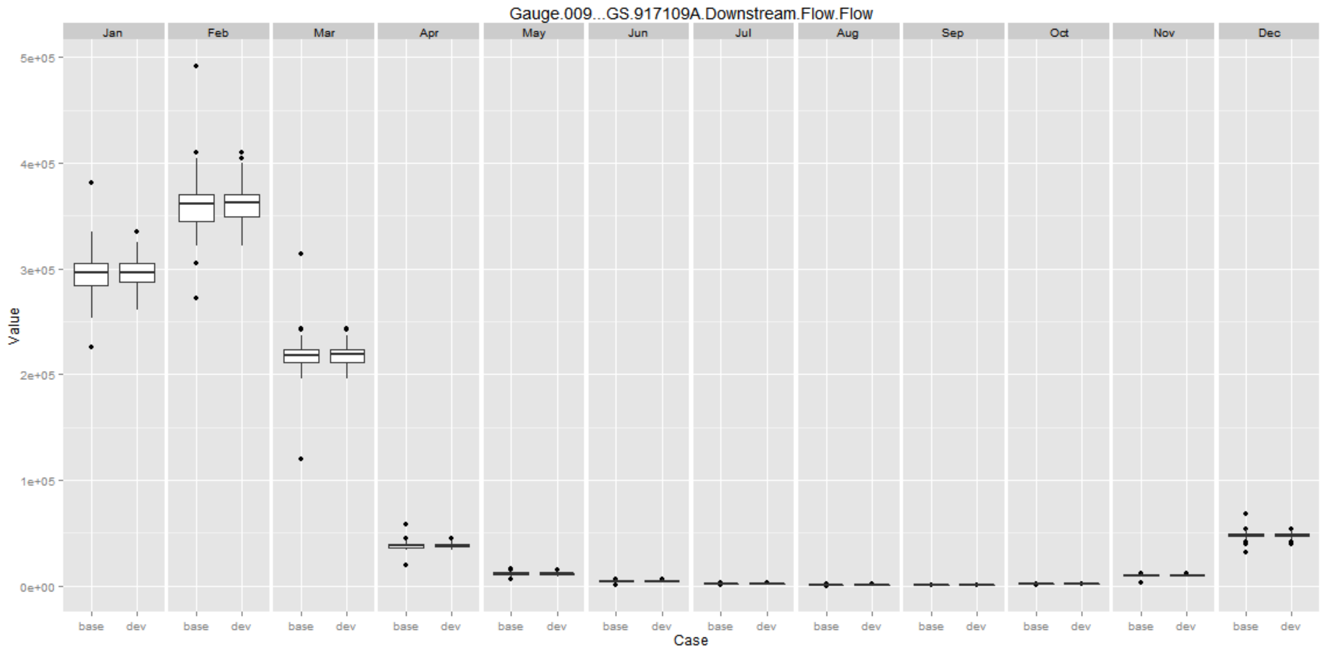

Gauge.003...GS.917108A.Downstream.Flow.Flow
y
x
Case
base
dev

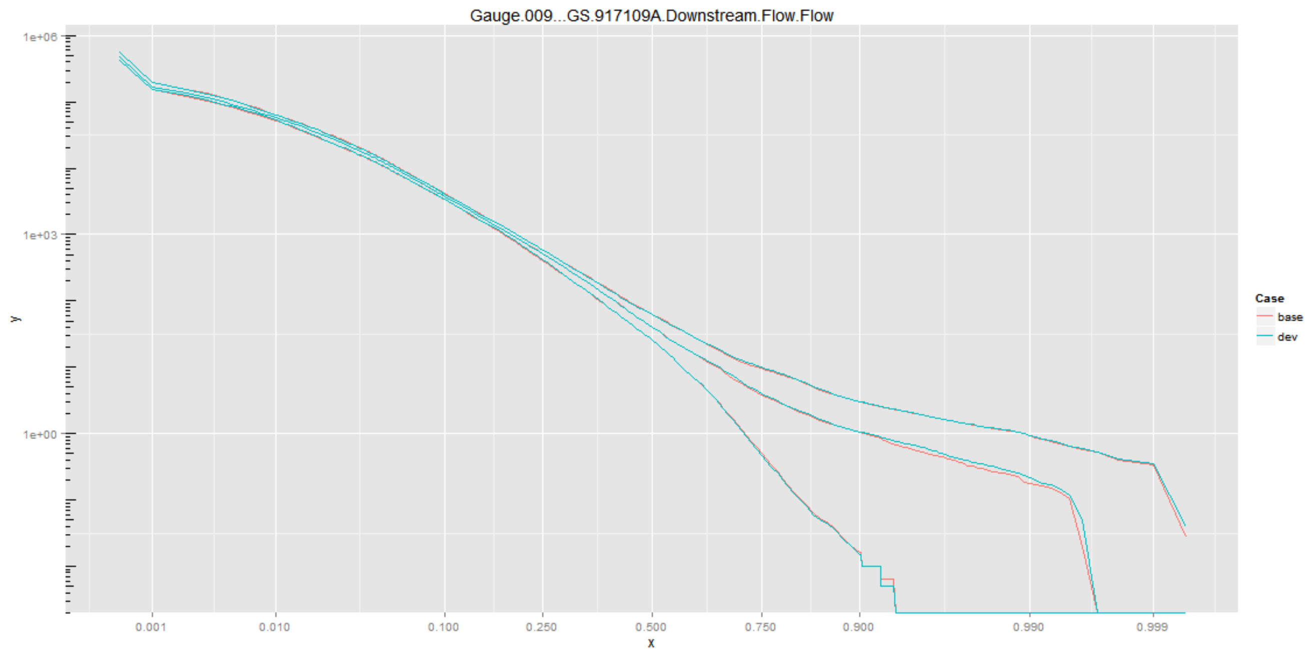

Gauge.006...GS.917106A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

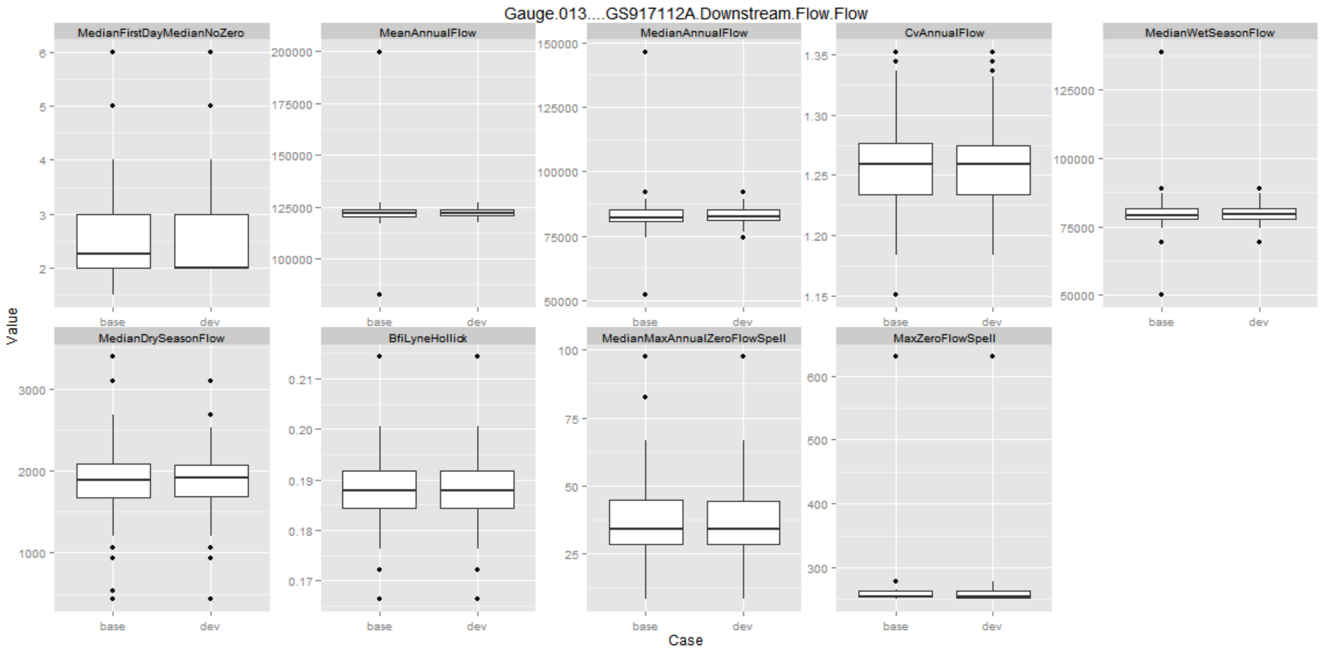

Gauge.006...GS.917106A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

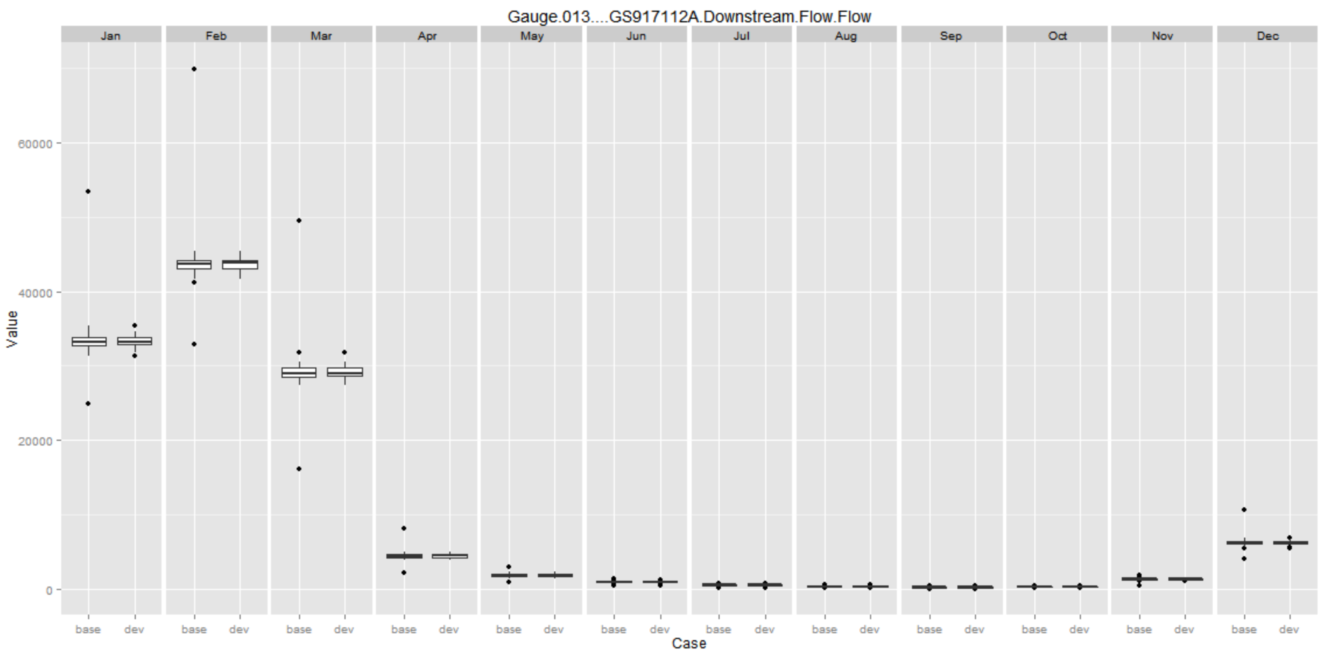

Gauge.006...GS.917106A.Downstream.Flow.Flow
y
x
Case
base
dev

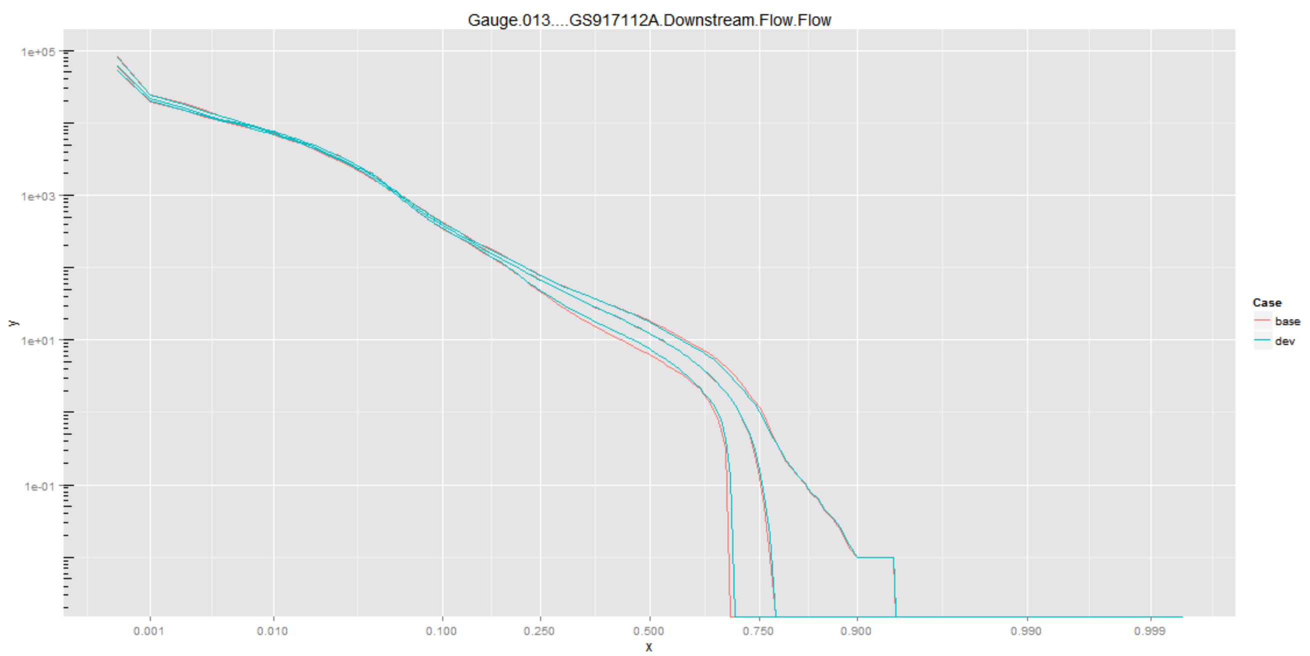

Gauge.009...GS.917109A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

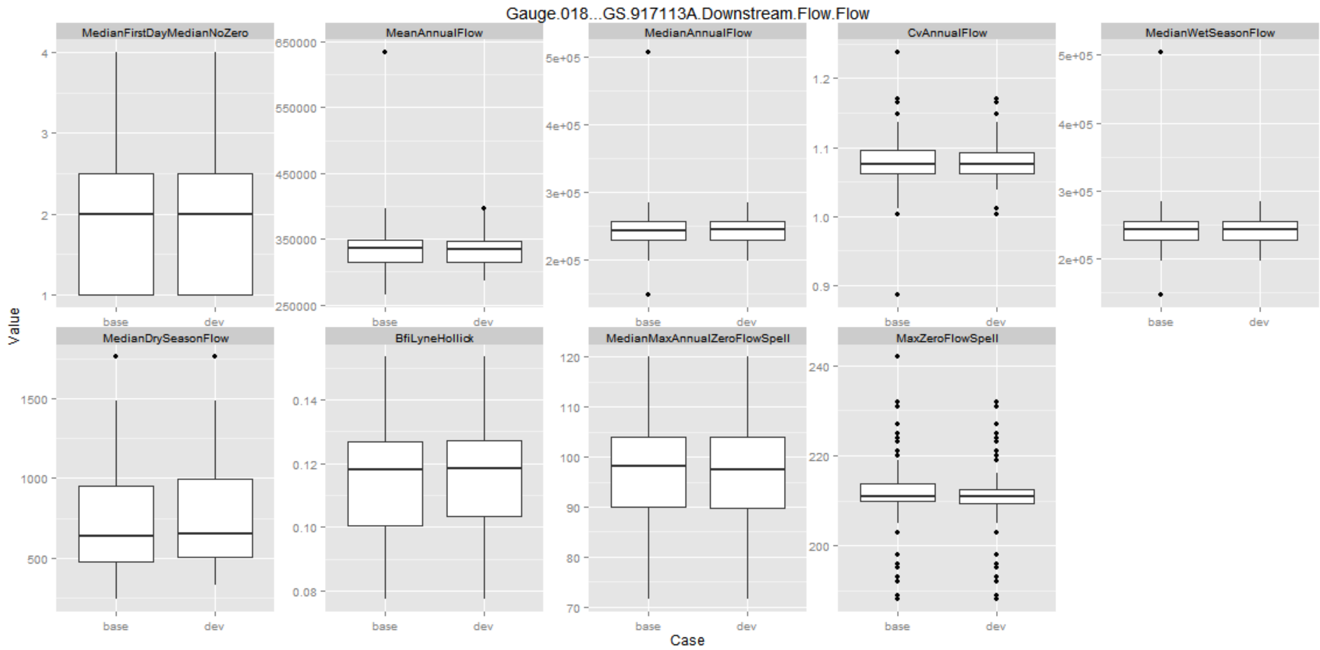

Gauge.009...GS.917109A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

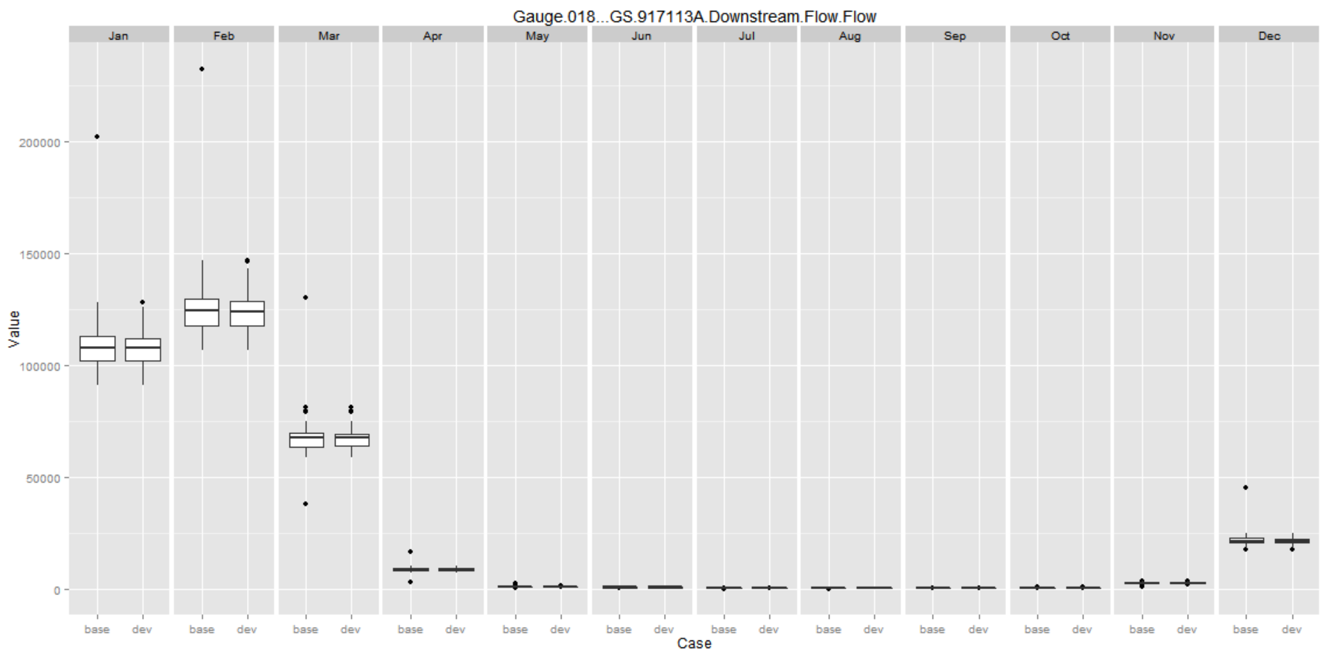

Gauge.009...GS.917109A.Downstream.Flow.Flow
y
x
Case
base
dev

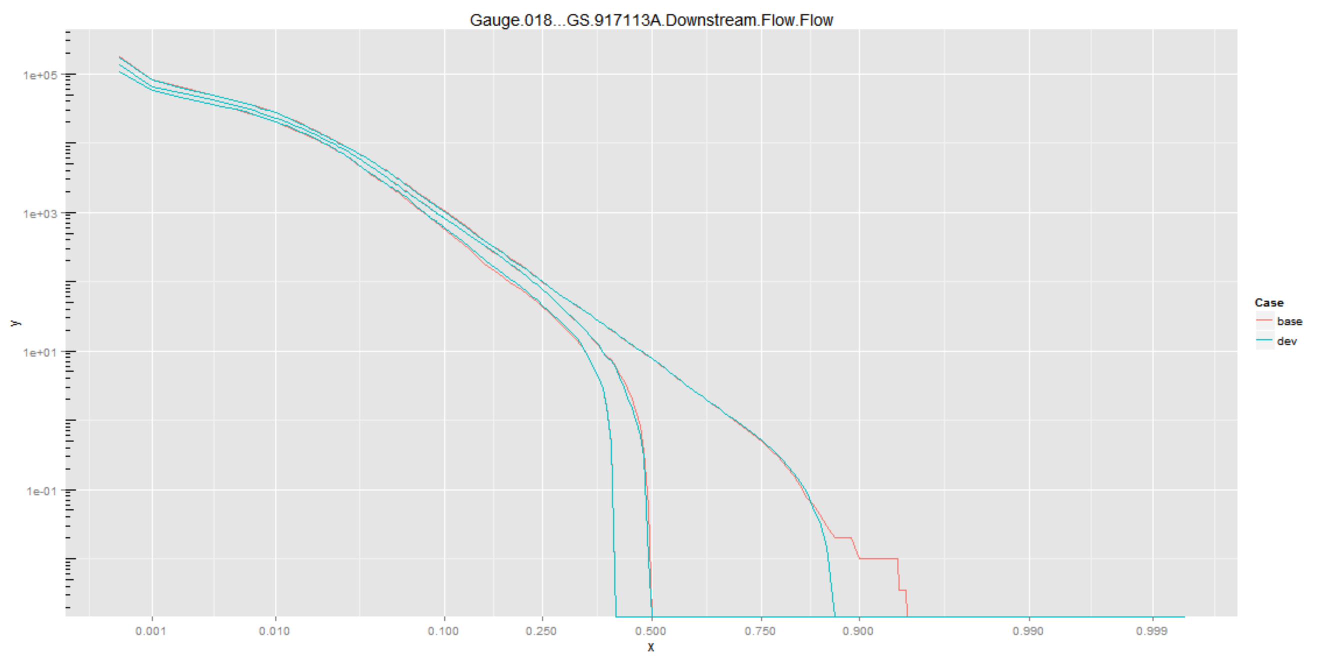

Gauge.013....GS917112A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

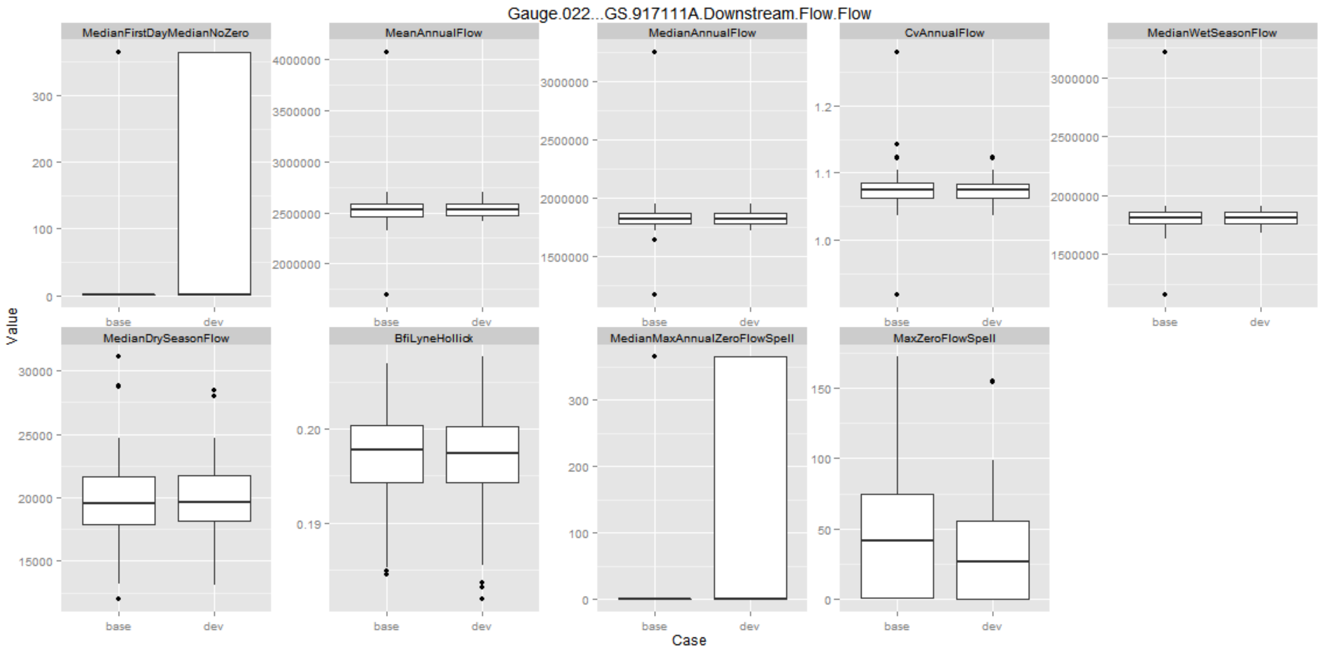

Gauge.013....GS917112A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

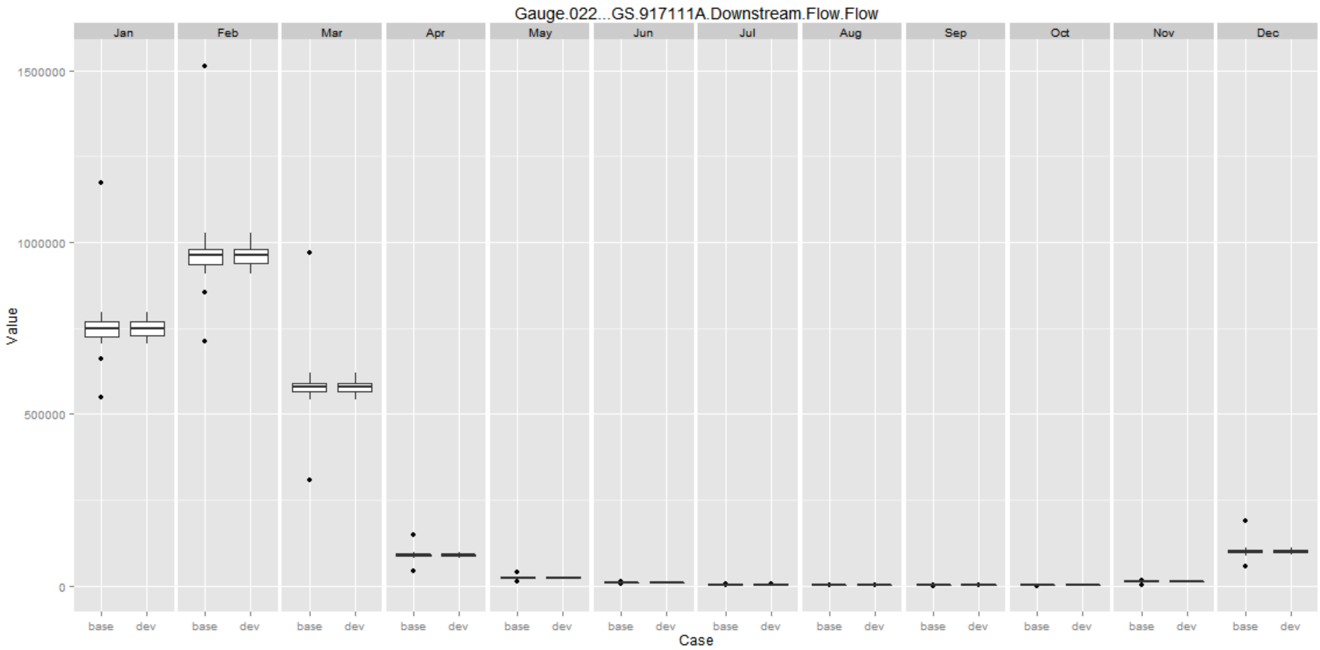

Gauge.013....GS917112A.Downstream.Flow.Flow
y
x
Case
base
dev

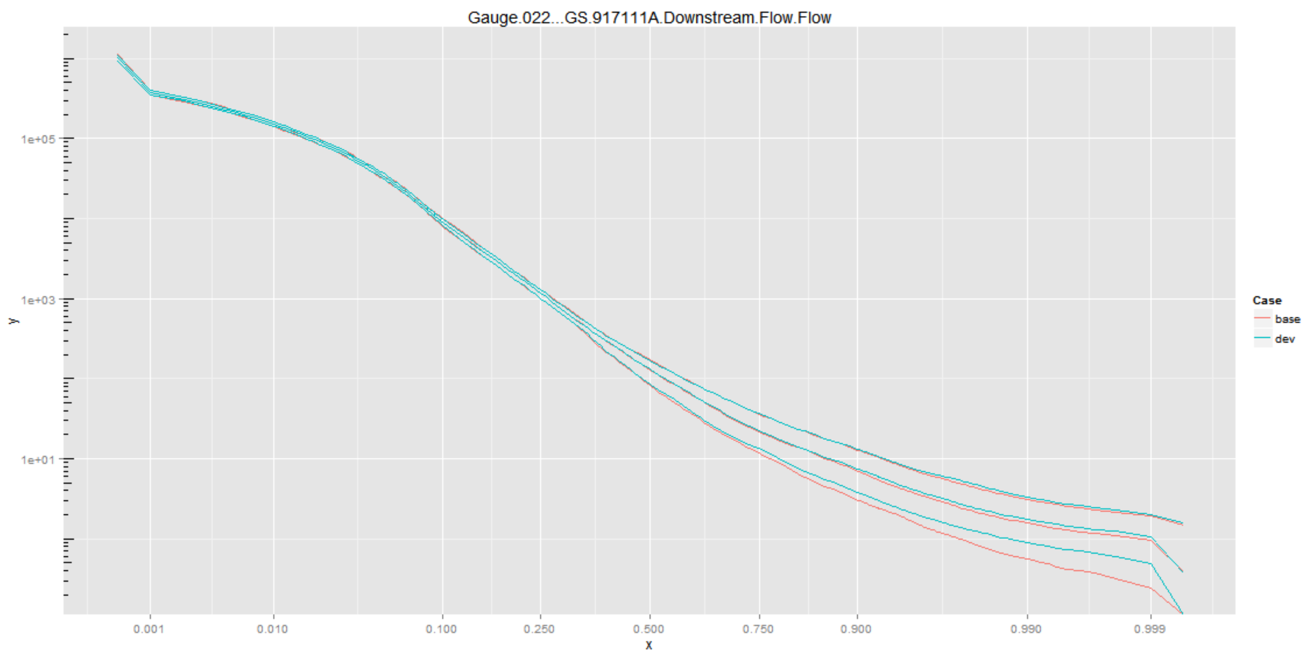

Gauge.018...GS.917113A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

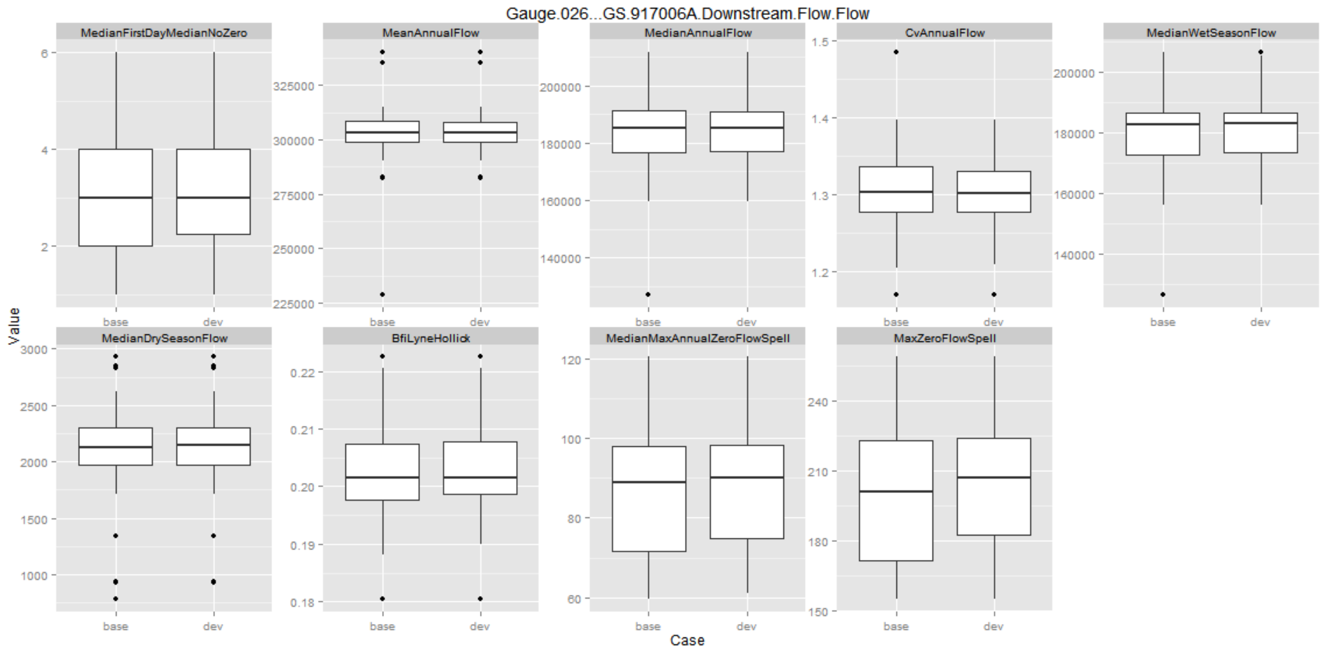

Gauge.018...GS.917113A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

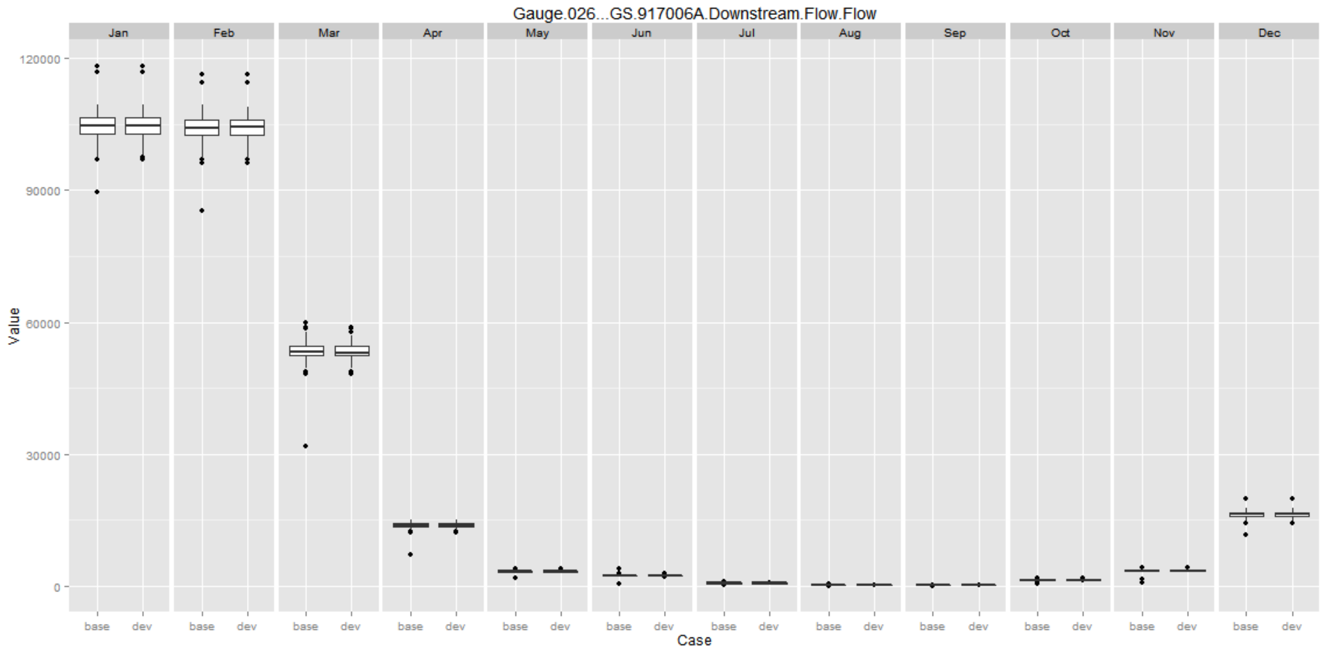

Gauge.018...GS.917113A.Downstream.Flow.Flow
y
x
Case
base
dev

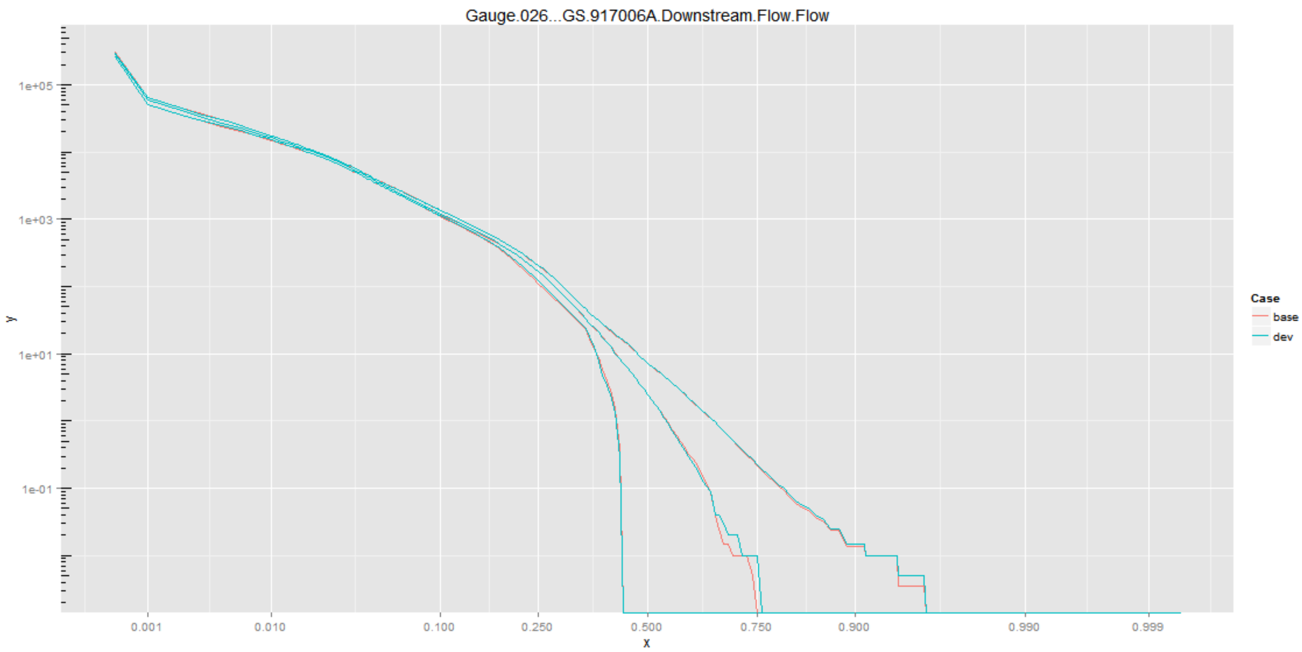

Gauge.022...GS.917111A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

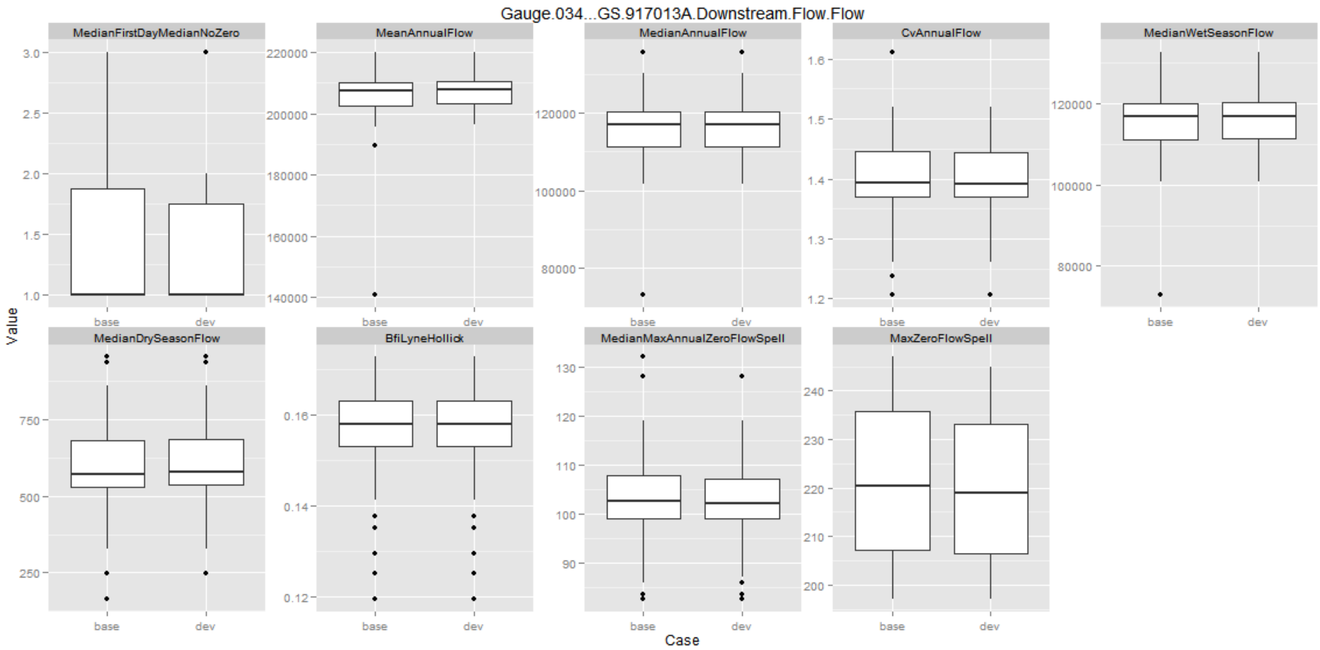

Gauge.022...GS.917111A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

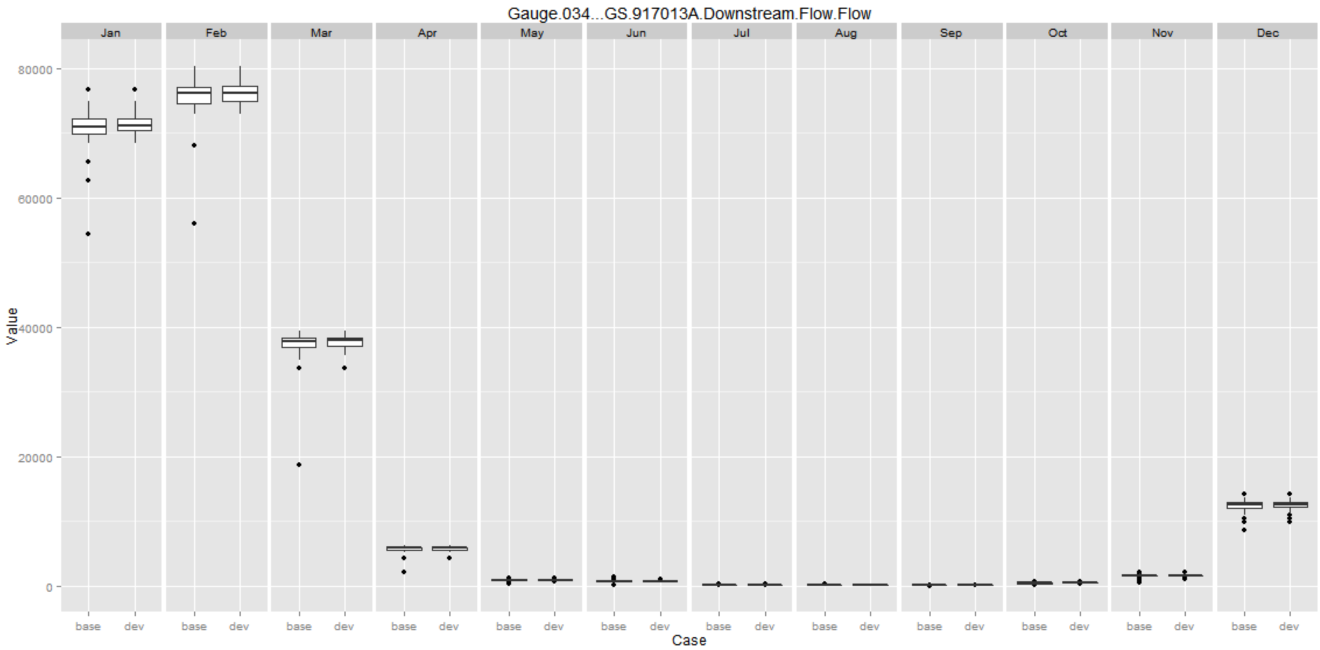

Gauge.022...GS.917111A.Downstream.Flow.Flow
y
x
Case
base
dev

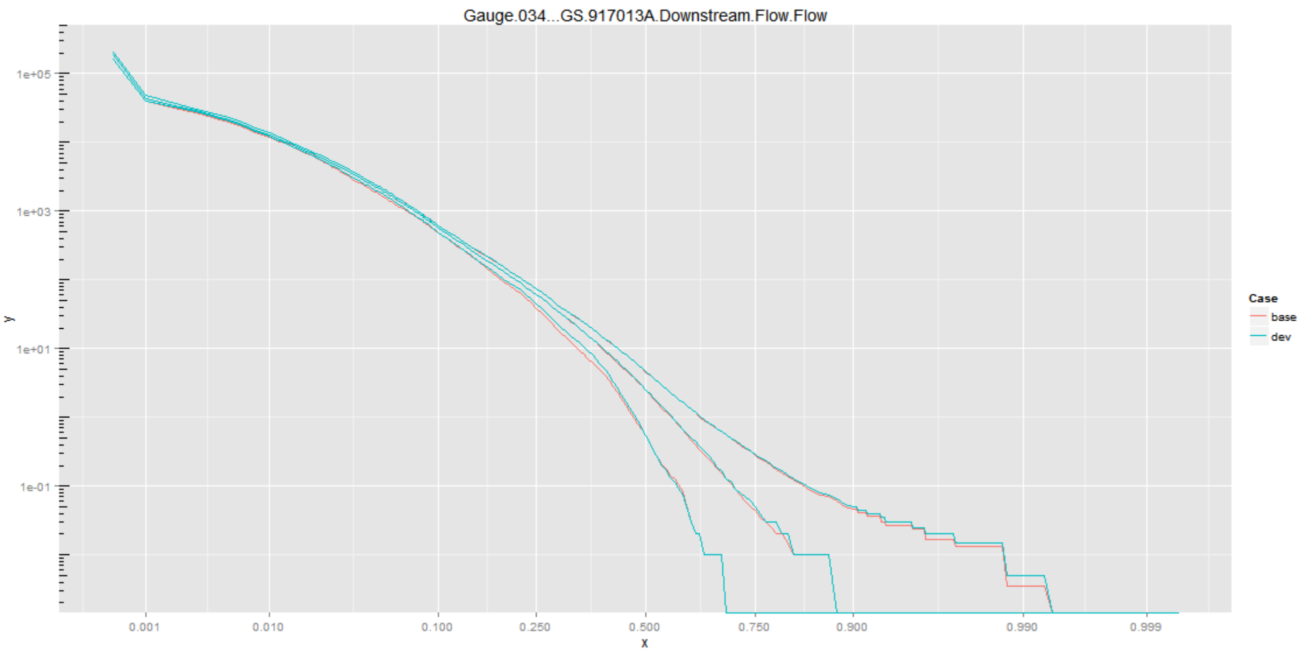

Gauge.026...GS.917006A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

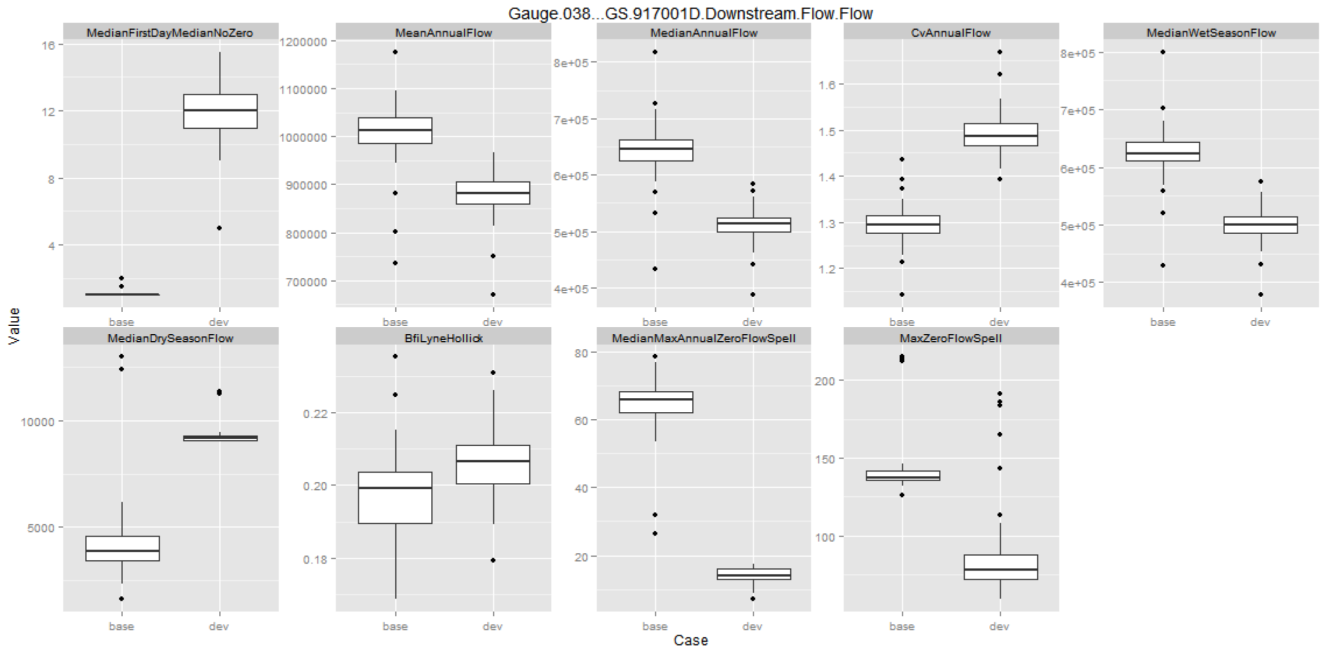

Gauge.026...GS.917006A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
120000
90000
60000
30000
0
Value
Case
base
dev

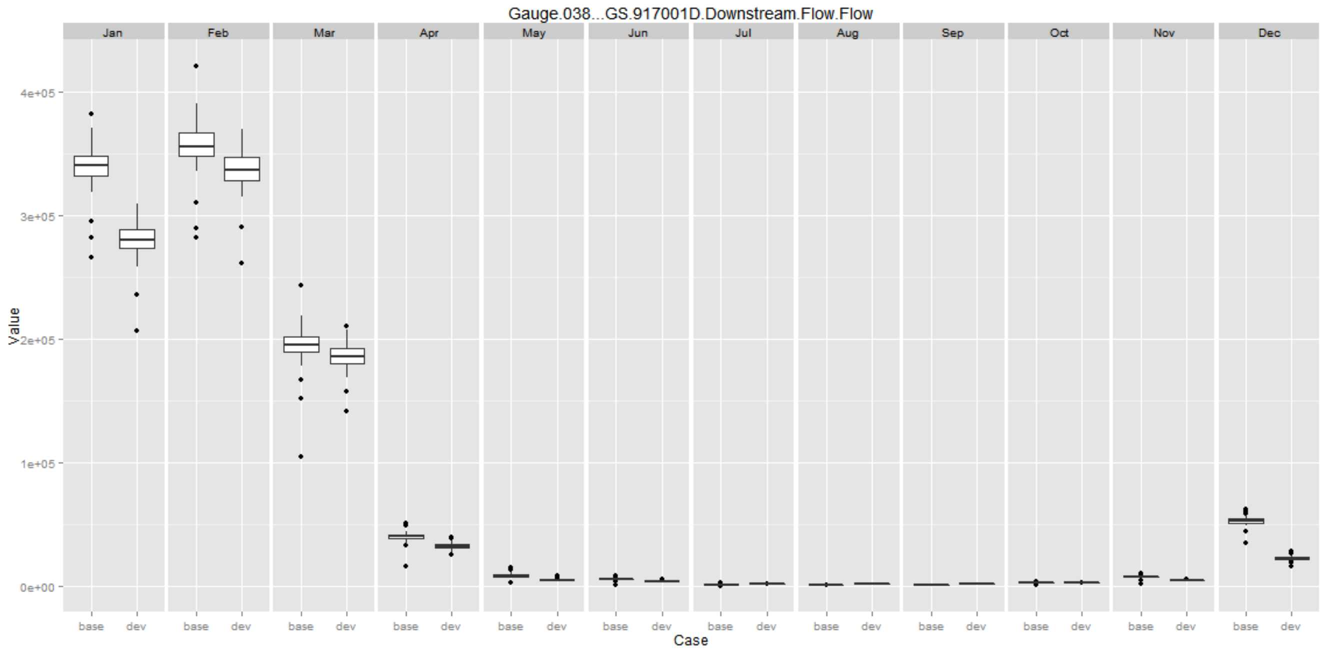

Gauge.026...GS.917006A.Downstream.Flow.Flow
1e+05
1e+03
1e+01
1e-01
y
0.001
0.010
0.100
0.250
0.500
0.750
0.900
0.990
0.999
x
Case
base
dev

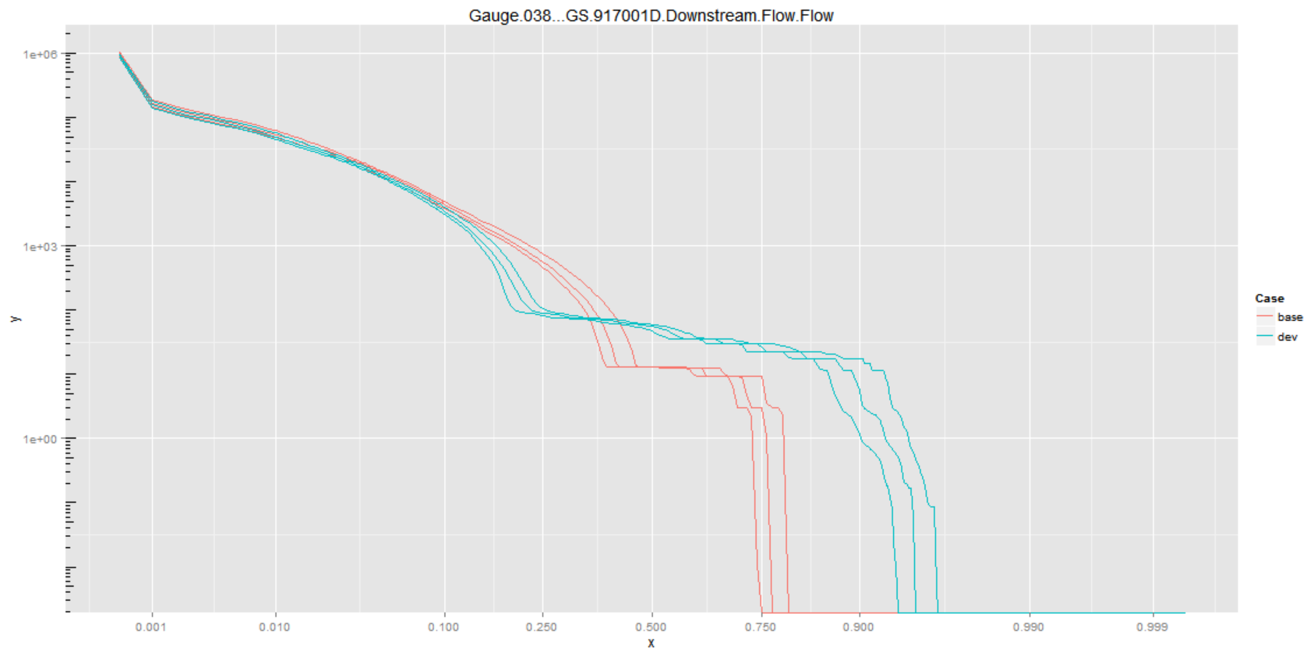

Gauge.034...GS.917013A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

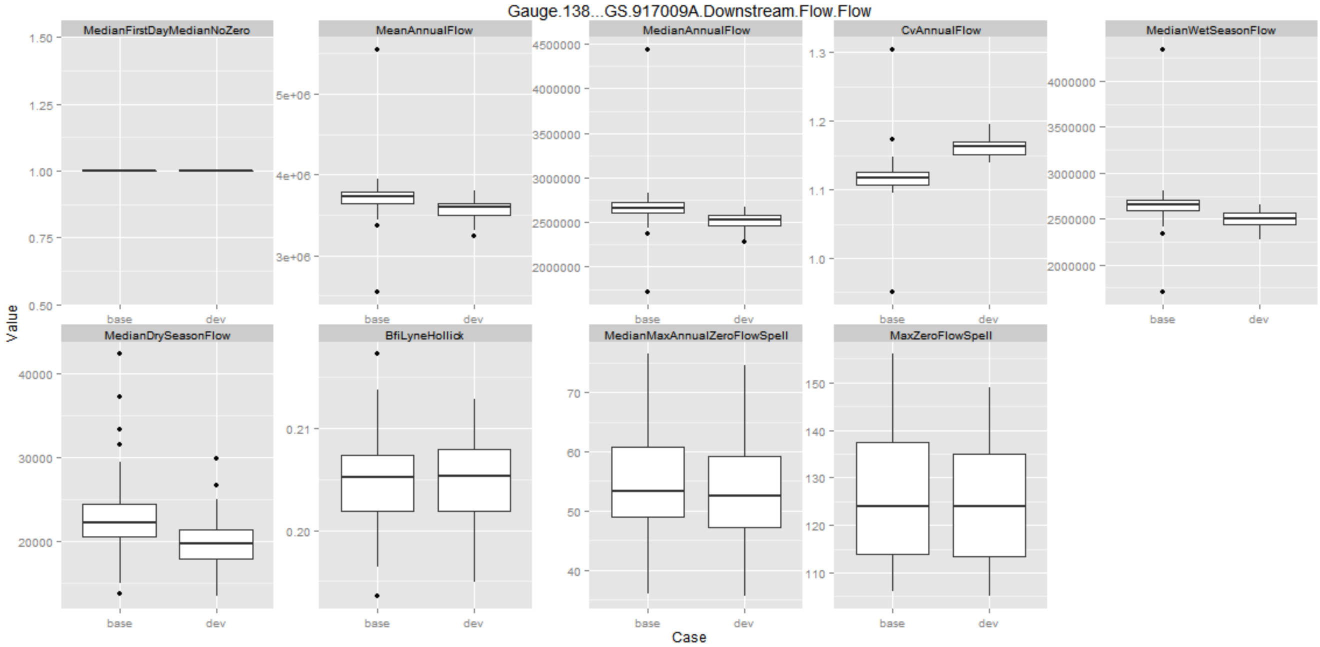

Gauge.034...GS.917013A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

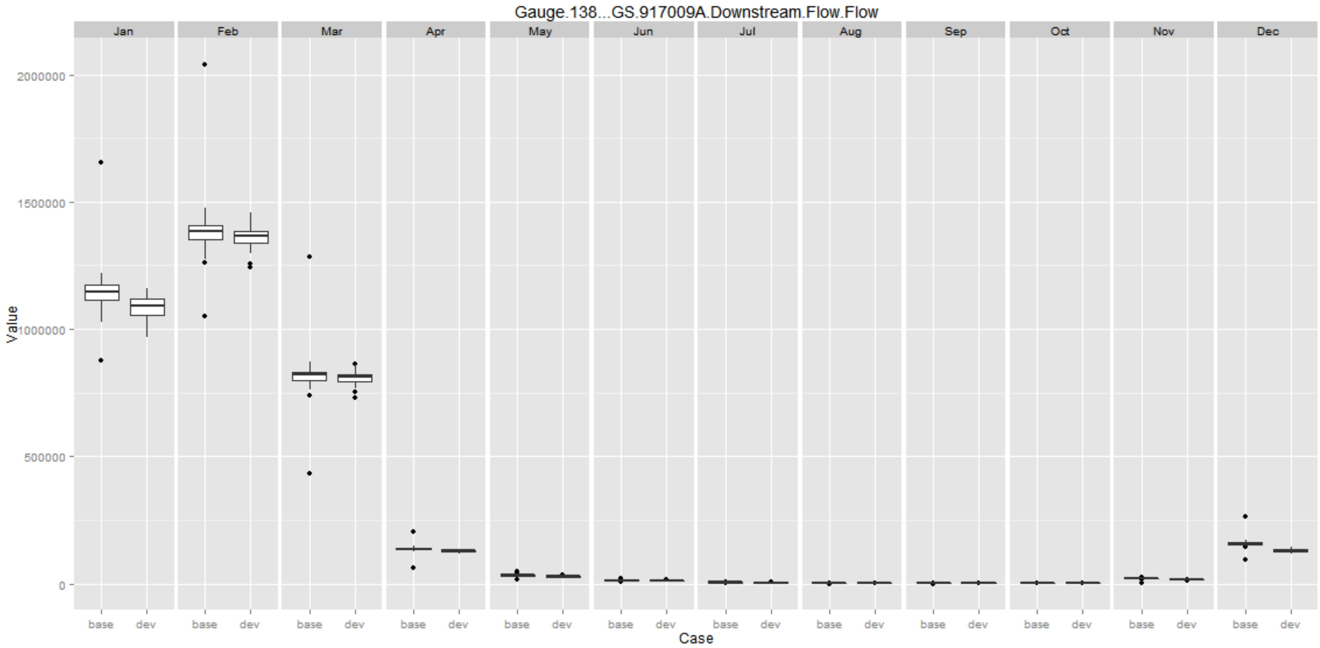

Gauge.034...GS.917013A.Downstream.Flow.Flow
y
x
Case
base
dev

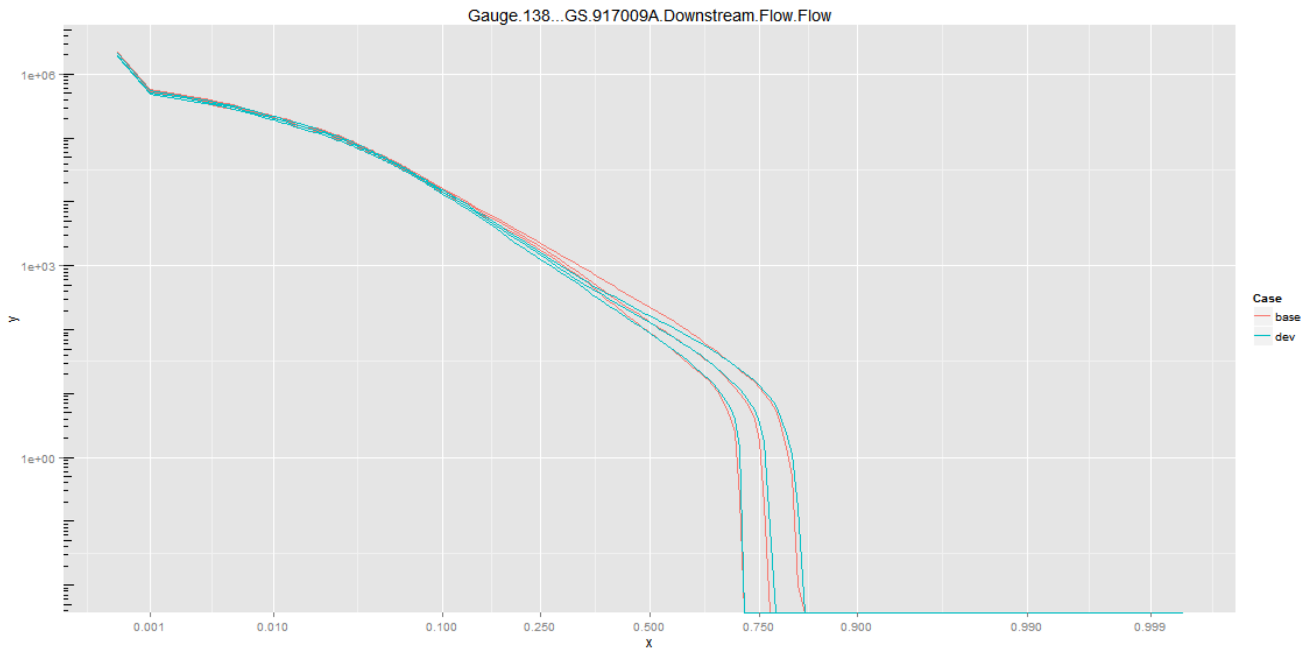

Gauge.038...GS.917001D.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

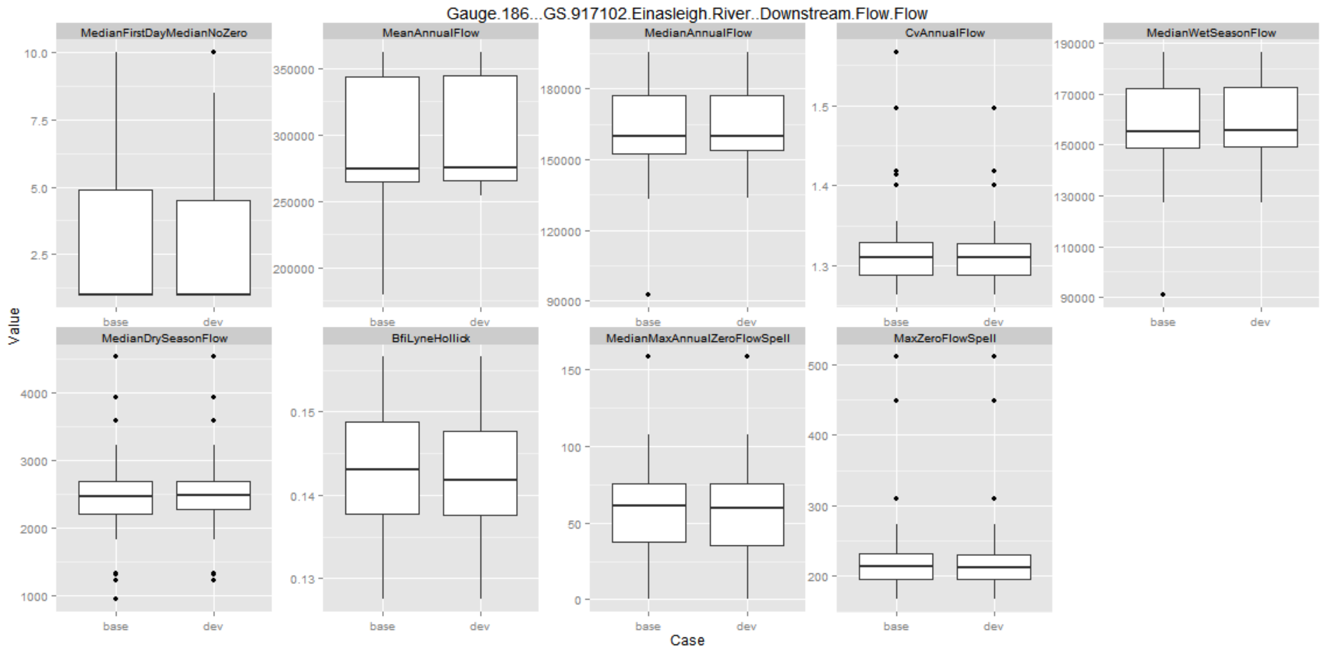

Gauge.038...GS.917001D.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

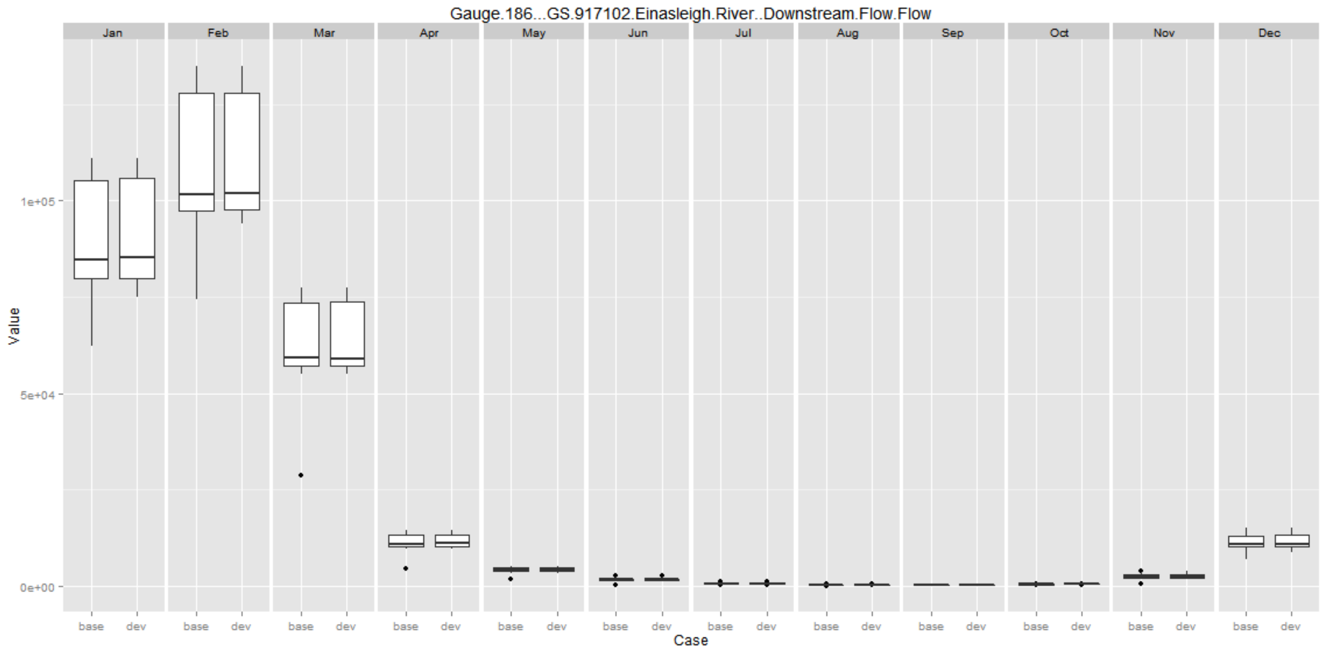

Gauge.038...GS.917001D.Downstream.Flow.Flow
y
x
Case
base
dev

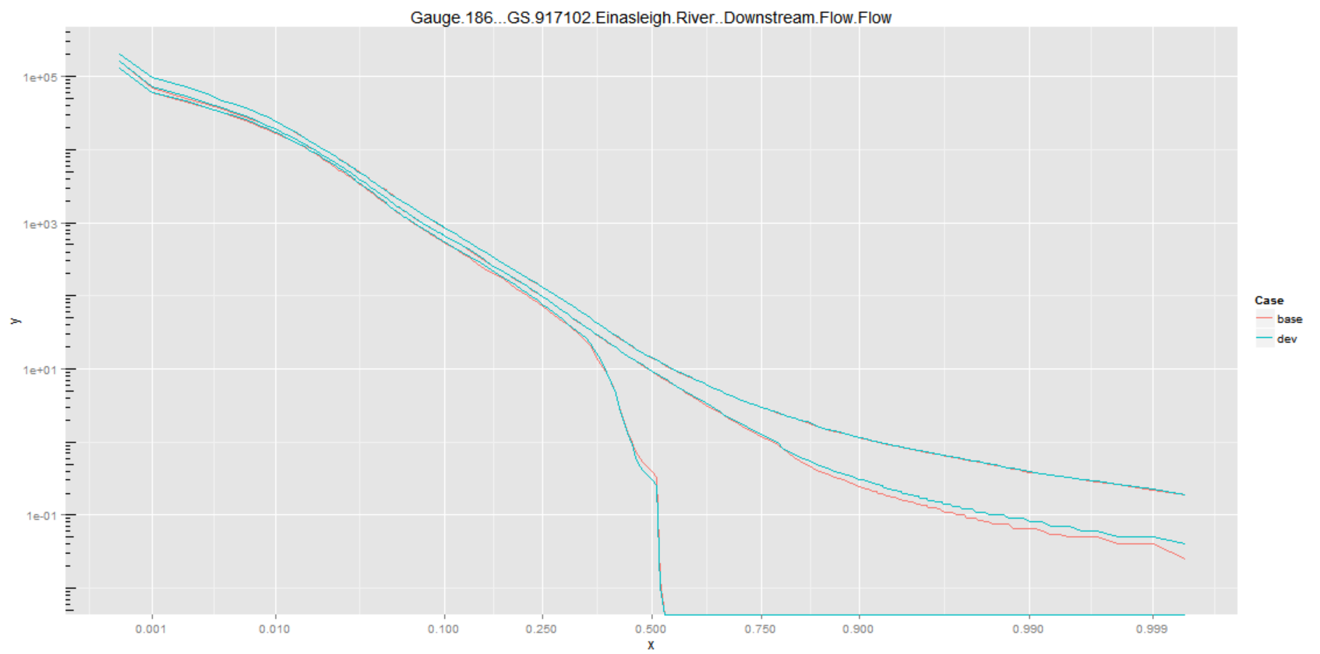

Gauge.138...GS.917009A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

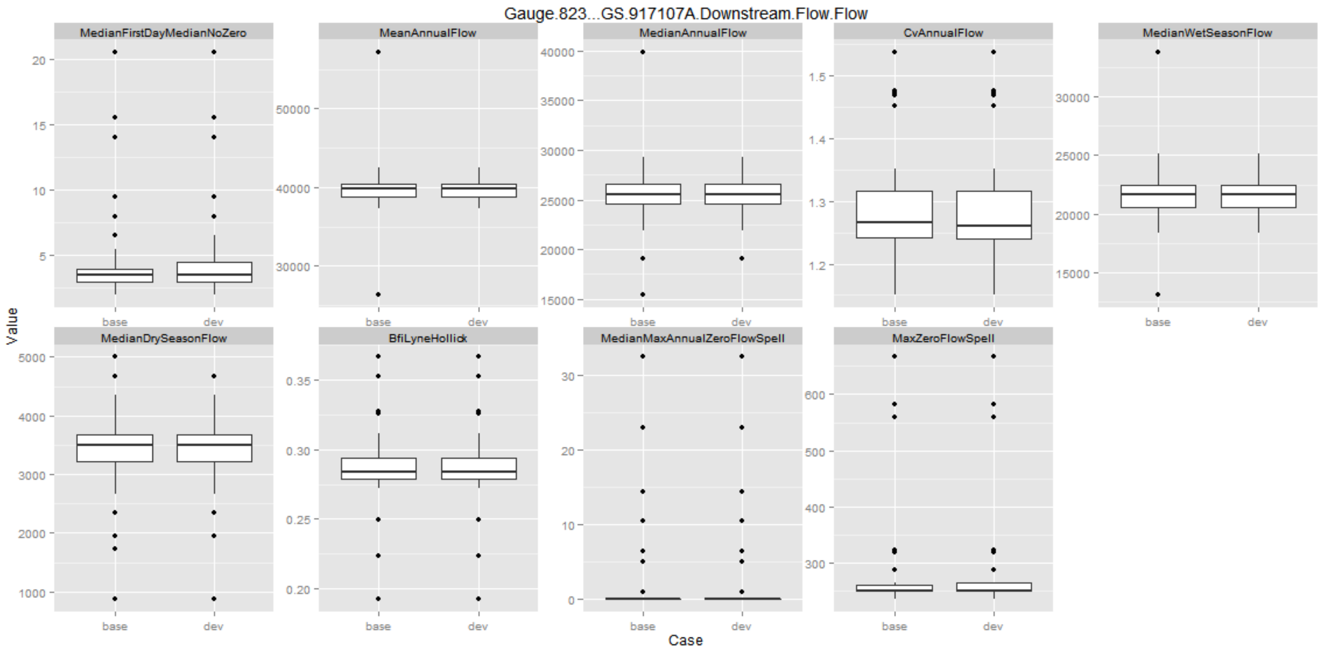

Gauge.138...GS.917009A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

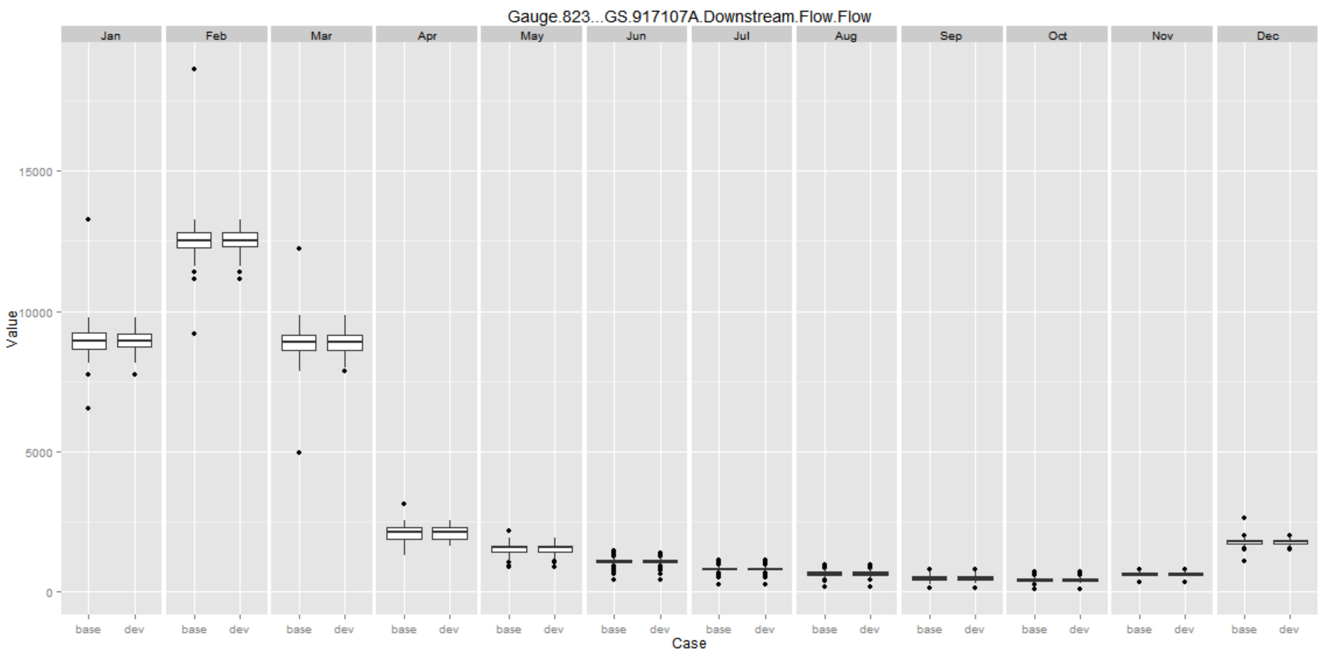

Gauge.138...GS.917009A.Downstream.Flow.Flow
y
x
Case
base
dev

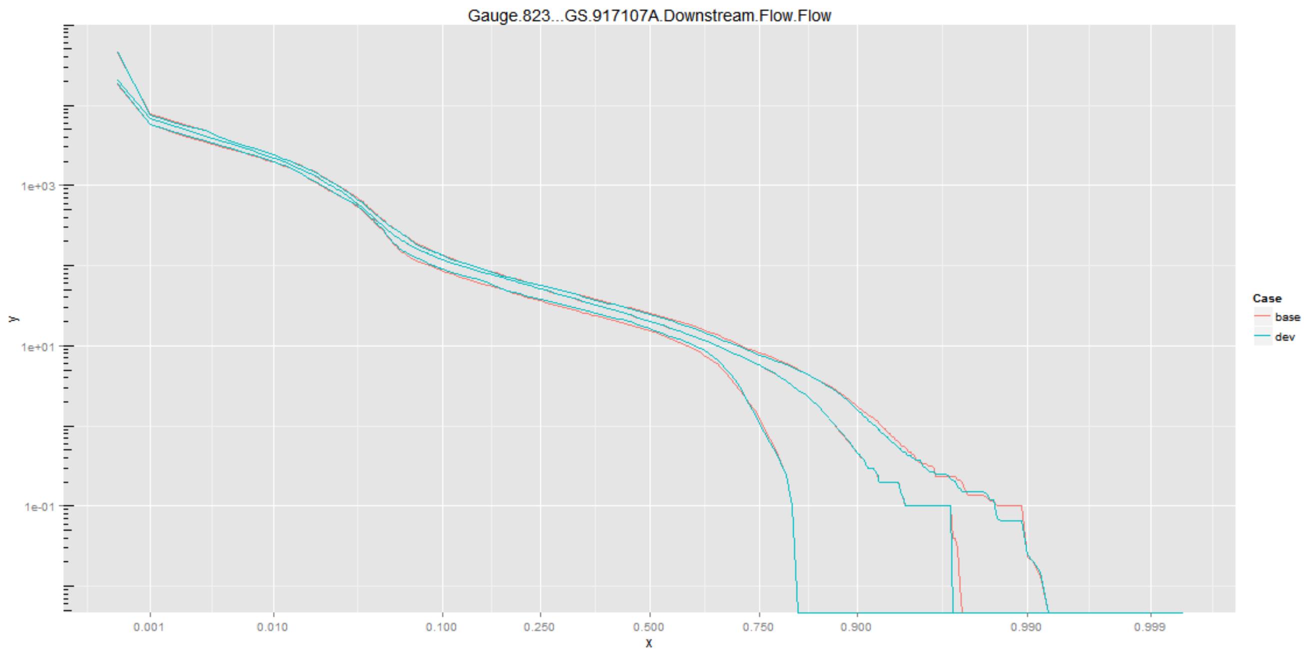

Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

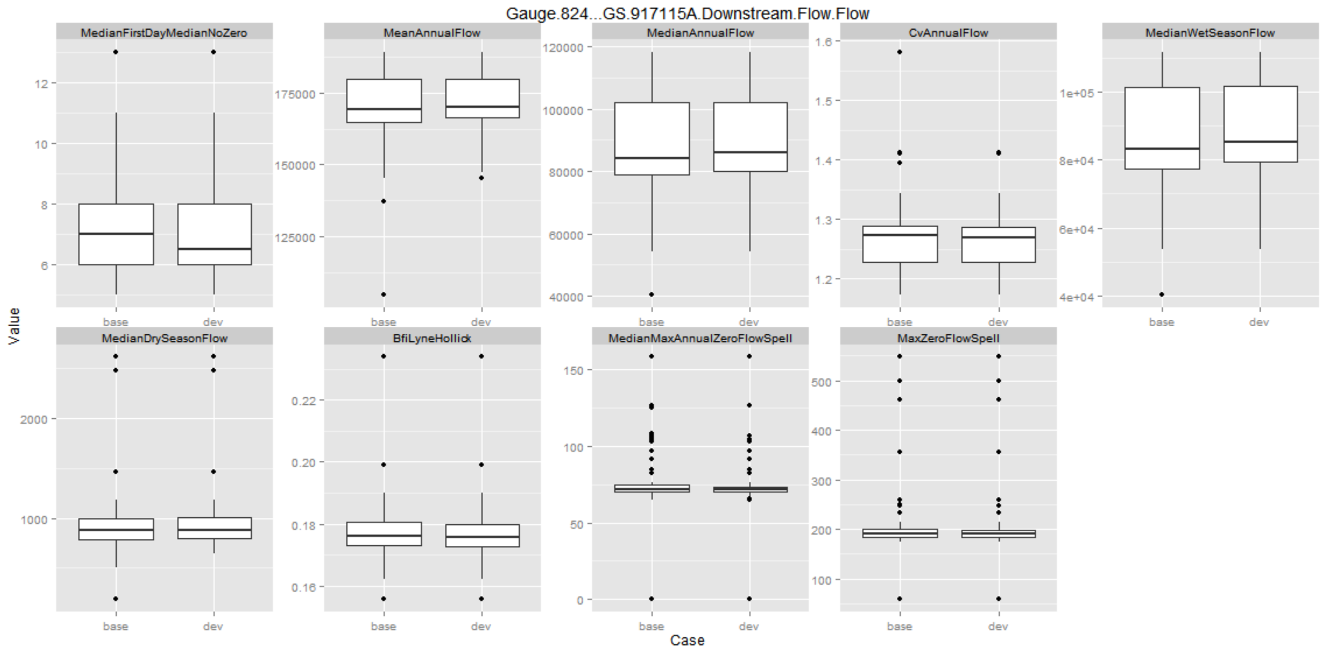

Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

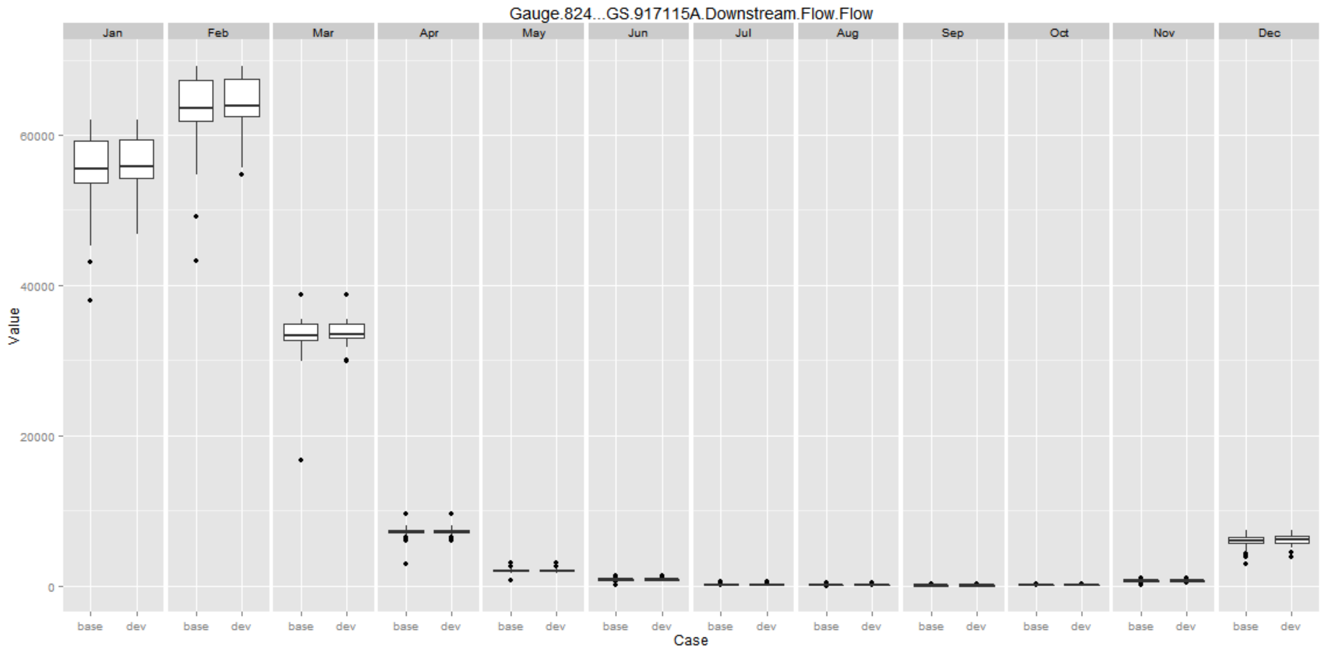

Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow
y
x
Case
base
dev

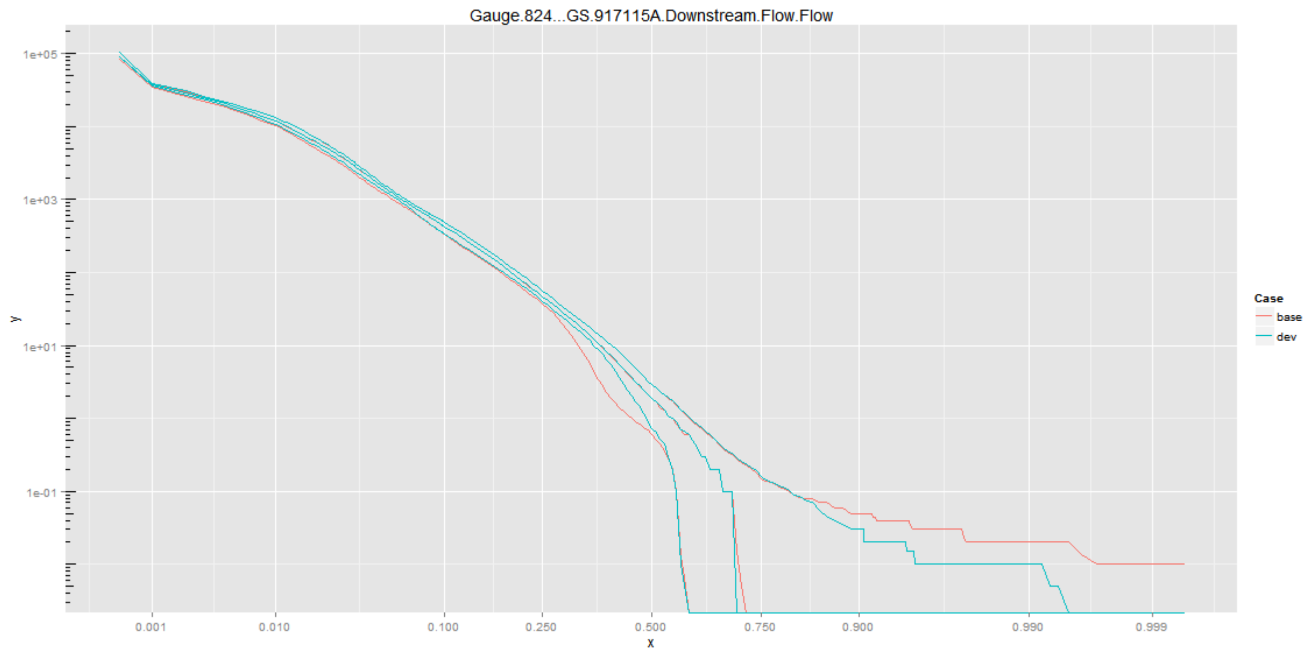

Gauge.823...GS.917107A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.823...GS.917107A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev


Gauge.823...GS.917107A.Downstream.Flow.Flow
y
x
Case
base
dev


Gauge.824...GS.917115A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.824...GS.917115A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev


Gauge.824...GS.917115A.Downstream.Flow.Flow
y
x
Case
base
dev

Appendix

R session information for the generation of this document:

```
sessionInfo()
```

```
## R version 3.0.1 (2013-05-16)
## Platform: i386-w64-mingw32/i386 (32-bit)
##
## locale:
## [1] LC_COLLATE=English_Australia.1252  LC_CTYPE=English_Australia.1252
## [3] LC_MONETARY=English_Australia.1252 LC_NUMERIC=C
## [5] LC_TIME=English_Australia.1252
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] garaHydroMetrics_0.1-4 scales_0.2.3           reshape2_1.2.2
##  [4] lubridate_1.3.1        stringr_0.6.2          ggplot2_0.9.3.1
##  [7] xts_0.9-7              zoo_1.7-10             plyr_1.8
## [10] knitr_1.5
##
## loaded via a namespace (and not attached):
##  [1] colorspace_1.2-4   dichromat_2.0-0    digest_0.6.3
##  [4] evaluate_0.5.1     formatR_0.10       grid_3.0.1
##  [7] gtable_0.1.2       labeling_0.2       lattice_0.20-15
## [10] MASS_7.3-26        munsell_0.4.2      proto_0.3-10
## [13] RColorBrewer_1.0-5 tools_3.0.1
```

FGARA Hydrological Metrics - Dry run on Kidston ensemble runs

About this document

Purpose is to have a dry run on 50 runs ensembles for Dagworth vs Gilbert baseline

This document was generated on 2013-11-21 14:59:23 using among other things the packages 'knitr' and 'garaHydroMetrics' (https://stash.csiro.au/projects/~per202/repos/hydrometrics/browse)

Calculate statistics

Load the package the usual. It includes a fair level of documentation, that should be accessible using the '?' command, shortcut for help(garaHydroMetrics).

```
library(garaHydroMetrics)
```

```
## Warning: package 'garaHydroMetrics' was built under R version 3.0.2
```

```
## Loading required package: plyr
```

```
## Warning: package 'plyr' was built under R version 3.0.2
```

```
## Loading required package: xts
```

```
## Warning: package 'xts' was built under R version 3.0.2
```

```
## Loading required package: zoo
##
## Attaching package: 'zoo'
##
## The following object is masked from 'package:base':
##
##     as.Date, as.Date.numeric
##
## Loading required package: ggplot2
```

```
## Warning: package 'ggplot2' was built under R version 3.0.2
```

```
## Loading required package: stringr
```

```
## Warning: package 'stringr' was built under R version 3.0.2
```

```
## Loading required package: lubridate
```

```
## Warning: package 'lubridate' was built under R version 3.0.2
```

```
##
## Attaching package: 'lubridate'
##
## The following object is masked from 'package:plyr':
##
##     here
##
## Loading required package: reshape2
```

```
## Warning: package 'reshape2' was built under R version 3.0.2
```

```
## Loading required package: scales
```

```
## Warning: package 'scales' was built under R version 3.0.2
## Warning: replacing previous import 'here' when loading 'plyr'
```

```
library(plyr)
```

Mapping \wron\Project\GARA\2_Rivers\3_All\8_Case_Studies to a W: drive to preempt issues to do with too long paths.

```
baselineDir <- "X:/ScenarioB/"
# develDir <-
# 'X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns'
# develDir <-
# 'X:/8_CaveHillDS/_Source_projects_packaged/CaveHill_v3NoImpact_12000_4_Replicates/'
develDir <- "X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles/"

findGaugeFiles <- function(topFolder) {
    pattern <- ".*_Gauge_daily.csv.gz"
    csvfiles <- list.files(path = topFolder, pattern = pattern, all.files = TRUE,
        full.names = TRUE, recursive = TRUE, ignore.case = TRUE)
}
baseFiles <- findGaugeFiles(baselineDir)
develFiles <- findGaugeFiles(develDir)

timeSeries <- lapply(c(baseFiles[c(1, 51)], develFiles[1]), loadXts)
gaugeNames <- lapply(timeSeries, names)
gaugeNames
```

```
## [[1]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[2]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[3]]
##  [1] "Gauge.026...GS.917006A.Downstream.Flow.Flow"
##  [2] "Gauge.034...GS.917013A.Downstream.Flow.Flow"
##  [3] "Gauge.003...GS.917108A.Downstream.Flow.Flow"
##  [4] "Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow"
##  [5] "Gauge.006...GS.917106A.Downstream.Flow.Flow"
##  [6] "Gauge.009...GS.917109A.Downstream.Flow.Flow"
##  [7] "Gauge.018...GS.917113A.Downstream.Flow.Flow"
##  [8] "Gauge.013....GS917112A.Downstream.Flow.Flow"
##  [9] "Gauge.022...GS.917111A.Downstream.Flow.Flow"
## [10] "Gauge.038...GS.917001D.Downstream.Flow.Flow"
## [11] "Gauge.138...GS.917009A.Downstream.Flow.Flow"
## [12] "Gauge.823...GS.917107A.Downstream.Flow.Flow"
## [13] "Gauge.824...GS.917115A.Downstream.Flow.Flow"
```

```
selectedGauges = gaugeNames[[1]][1:5]
subsetGauges <- function(ts, selectedGauges) {
    ts[, selectedGauges]
}
timeSeriesSubset <- lapply(timeSeries, subsetGauges, selectedGauges)
```

It looks like the second and third are matches, i.e.:

```
c(baseFiles[c(51)], develFiles[1])
```

```
## [1]
"X:/ScenarioB//Flinders_runfolders/run_rep_0047_scenarioA_wrpnores_v143_20131811_220632_2934/postpro
## [2]
"X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_baseline_noensemble_
```

So let's roll the stats (circa 15 sec per file, expect around 25 minutes runtime). Given the considerable runtime, this is important to have a caching mechanism i.e. saving the result to an RData file. The file is only 2MB so it is worth caching.

```
scenarioFolders <- c("Gilbert_runfolders", "v5NoImpact_OFS100_4000ha_ensembles")
scenarioTags <- c("base", "dev")

statFile <- "Z:/GARA/2_Rivers/4_Working/per202/Kidston/EnsFiles.RData"
stopifnot(file.exists(dirname(statFile)))

if (!file.exists(statFile)) {
    statList <- univStatsMultiScenario(c(baseFiles, develFiles), scenarioFolders,
        scenarioTags)
    save(statList, file = statFile)
} else {
    load(statFile)
}
```

```
## [1] "2013-11-21 15:00:04
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioA_wrpnores_v27_20132409_130052_20138/postpro

## [1] "2013-11-21 15:00:13
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioCdry_wrpnores_v27_20132409_130054_20144/post

## [1] "2013-11-21 15:00:23
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioCmid_wrpnores_v27_20132409_130056_20151/post

## [1] "2013-11-21 15:00:33
X:/ScenarioB//Gilbert_runfolders/run_baseline_0_scenarioCwet_wrpnores_v27_20132409_130058_20157/post

## [1] "2013-11-21 15:00:42
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_1_scenarioA_wrpnores_v27_20131911_72013_13175

## [1] "2013-11-21 15:00:51
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_10_scenarioA_wrpnores_v27_20131911_72031_1323

## [1] "2013-11-21 15:01:00
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_11_scenarioA_wrpnores_v27_20131911_72033_1324

## [1] "2013-11-21 15:01:09
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_12_scenarioA_wrpnores_v27_20131911_72035_1324

## [1] "2013-11-21 15:01:18
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_13_scenarioA_wrpnores_v27_20131911_72037_1325

## [1] "2013-11-21 15:01:27
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_14_scenarioA_wrpnores_v27_20131911_72039_1326

## [1] "2013-11-21 15:01:37
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_15_scenarioA_wrpnores_v27_20131911_72041_1326

## [1] "2013-11-21 15:01:46
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_16_scenarioA_wrpnores_v27_20131911_72043_1327

## [1] "2013-11-21 15:01:55
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_17_scenarioA_wrpnores_v27_20131911_72045_1327

## [1] "2013-11-21 15:02:03
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_18_scenarioA_wrpnores_v27_20131911_72047_1328

## [1] "2013-11-21 15:02:12
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_19_scenarioA_wrpnores_v27_20131911_72049_1329

## [1] "2013-11-21 15:02:22
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_2_scenarioA_wrpnores_v27_20131911_72015_13181

## [1] "2013-11-21 15:02:34
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_20_scenarioA_wrpnores_v27_20131911_72051_1329

## [1] "2013-11-21 15:02:43
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_21_scenarioA_wrpnores_v27_20131911_72053_1330

## [1] "2013-11-21 15:02:52
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_22_scenarioA_wrpnores_v27_20131911_72055_1331

## [1] "2013-11-21 15:03:01
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_23_scenarioA_wrpnores_v27_20131911_72057_1331

## [1] "2013-11-21 15:03:10
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_24_scenarioA_wrpnores_v27_20131911_72059_1332

## [1] "2013-11-21 15:03:19
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_25_scenarioA_wrpnores_v27_20131911_72101_1333

## [1] "2013-11-21 15:03:28
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_26_scenarioA_wrpnores_v27_20131911_115310_111

## [1] "2013-11-21 15:03:36
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_27_scenarioA_wrpnores_v27_20131911_115312_112

## [1] "2013-11-21 15:03:45
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_28_scenarioA_wrpnores_v27_20131911_115314_113

## [1] "2013-11-21 15:03:54
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_29_scenarioA_wrpnores_v27_20131911_115316_113
```

```
## [1] "2013-11-21 15:04:03
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_3_scenarioA_wrpnores_v27_20131911_72017_13188,

## [1] "2013-11-21 15:04:11
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_30_scenarioA_wrpnores_v27_20131911_115318_114

## [1] "2013-11-21 15:04:20
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_31_scenarioA_wrpnores_v27_20131911_115320_115

## [1] "2013-11-21 15:04:29
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_32_scenarioA_wrpnores_v27_20131911_115322_115

## [1] "2013-11-21 15:04:37
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_33_scenarioA_wrpnores_v27_20131911_115324_116

## [1] "2013-11-21 15:04:46
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_34_scenarioA_wrpnores_v27_20131911_115326_117

## [1] "2013-11-21 15:04:54
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_35_scenarioA_wrpnores_v27_20131911_115328_117

## [1] "2013-11-21 15:05:03
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_36_scenarioA_wrpnores_v27_20131911_115330_118

## [1] "2013-11-21 15:05:12
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_37_scenarioA_wrpnores_v27_20131911_115332_119

## [1] "2013-11-21 15:05:21
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_38_scenarioA_wrpnores_v27_20131911_115334_119

## [1] "2013-11-21 15:05:29
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_39_scenarioA_wrpnores_v27_20131911_115336_120

## [1] "2013-11-21 15:05:38
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_4_scenarioA_wrpnores_v27_20131911_72019_13195,

## [1] "2013-11-21 15:05:47
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_40_scenarioA_wrpnores_v27_20131911_115338_121

## [1] "2013-11-21 15:05:55
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_41_scenarioA_wrpnores_v27_20131911_115340_121

## [1] "2013-11-21 15:06:04
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_42_scenarioA_wrpnores_v27_20131911_115342_122

## [1] "2013-11-21 15:06:13
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_43_scenarioA_wrpnores_v27_20131911_115344_123

## [1] "2013-11-21 15:06:22
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_44_scenarioA_wrpnores_v27_20131911_115346_123

## [1] "2013-11-21 15:06:30
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_45_scenarioA_wrpnores_v27_20131911_115348_124

## [1] "2013-11-21 15:06:39
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_46_scenarioA_wrpnores_v27_20131911_115350_125

## [1] "2013-11-21 15:06:48
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_47_scenarioA_wrpnores_v27_20131911_115352_125

## [1] "2013-11-21 15:06:57
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_48_scenarioA_wrpnores_v27_20131911_115354_126

## [1] "2013-11-21 15:07:06
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_49_scenarioA_wrpnores_v27_20131911_115356_127

## [1] "2013-11-21 15:07:15
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_5_scenarioA_wrpnores_v27_20131911_72021_13201,

## [1] "2013-11-21 15:07:24
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_50_scenarioA_wrpnores_v27_20131911_115358_127

## [1] "2013-11-21 15:07:33
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_6_scenarioA_wrpnores_v27_20131911_72023_13208,

## [1] "2013-11-21 15:07:41
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_7_scenarioA_wrpnores_v27_20131911_72025_13214,

## [1] "2013-11-21 15:07:50
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_8_scenarioA_wrpnores_v27_20131911_72027_13221,

## [1] "2013-11-21 15:07:58
X:/ScenarioB//Gilbert_runfolders/run_baseline_ensemble_9_scenarioA_wrpnores_v27_20131911_72029_13227,

## [1] "2013-11-21 15:08:07
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_baseline_noensemble_0

## [1] "2013-11-21 15:08:16
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_1_scenarioA_w

## [1] "2013-11-21 15:08:24
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_10_scenarioA_

## [1] "2013-11-21 15:08:33
```

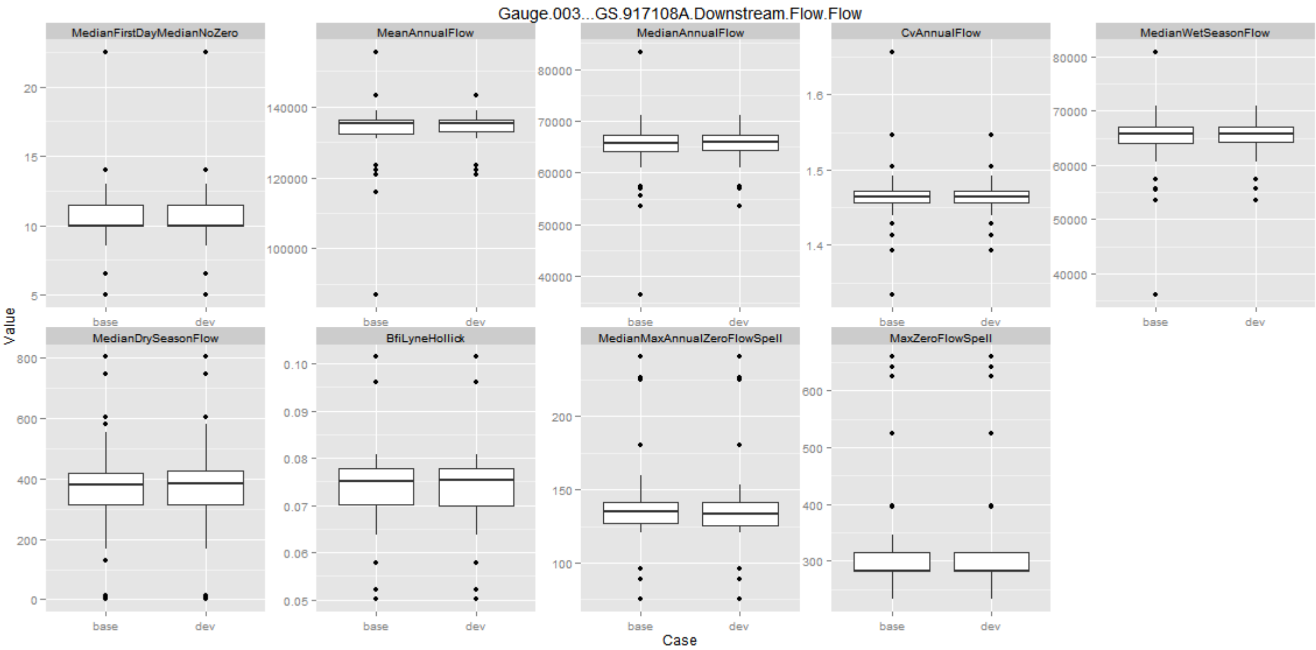
```
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_11_scenarioA_w

## [1] "2013-11-21 15:08:41
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_12_scenarioA_w

## [1] "2013-11-21 15:08:50
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_13_scenarioA_w

## [1] "2013-11-21 15:08:58
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_14_scenarioA_w

## [1] "2013-11-21 15:09:07
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_15_scenarioA_w

## [1] "2013-11-21 15:09:16
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_16_scenarioA_w

## [1] "2013-11-21 15:09:24
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_17_scenarioA_w

## [1] "2013-11-21 15:09:33
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_18_scenarioA_w

## [1] "2013-11-21 15:09:42
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_19_scenarioA_w

## [1] "2013-11-21 15:09:51
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_2_scenarioA_wi

## [1] "2013-11-21 15:09:59
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_20_scenarioA_w

## [1] "2013-11-21 15:10:08
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_21_scenarioA_w

## [1] "2013-11-21 15:10:17
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_22_scenarioA_w

## [1] "2013-11-21 15:10:26
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_23_scenarioA_w

## [1] "2013-11-21 15:10:35
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_24_scenarioA_w

## [1] "2013-11-21 15:10:43
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_25_scenarioA_w

## [1] "2013-11-21 15:10:52
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_26_scenarioA_w

## [1] "2013-11-21 15:11:01
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_27_scenarioA_w

## [1] "2013-11-21 15:11:09
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_28_scenarioA_w

## [1] "2013-11-21 15:11:18
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_29_scenarioA_w

## [1] "2013-11-21 15:11:27
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_3_scenarioA_wi

## [1] "2013-11-21 15:11:36
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_30_scenarioA_w

## [1] "2013-11-21 15:11:46
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_31_scenarioA_w

## [1] "2013-11-21 15:11:55
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_32_scenarioA_w

## [1] "2013-11-21 15:12:03
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_33_scenarioA_w

## [1] "2013-11-21 15:12:12
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_34_scenarioA_w

## [1] "2013-11-21 15:12:21
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_35_scenarioA_w

## [1] "2013-11-21 15:12:29
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_36_scenarioA_w

## [1] "2013-11-21 15:12:38
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_37_scenarioA_w

## [1] "2013-11-21 15:12:47
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_38_scenarioA_w

## [1] "2013-11-21 15:12:56
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_39_scenarioA_w

## [1] "2013-11-21 15:13:04
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_4_scenarioA_wi
```

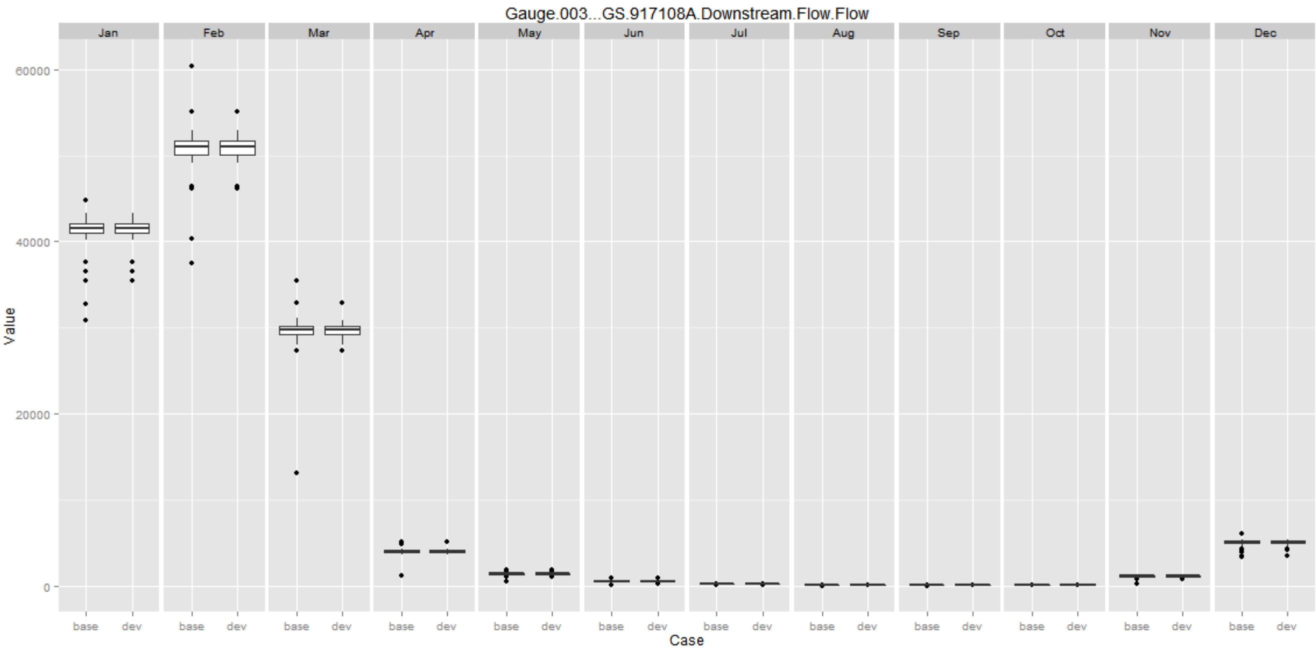
```
## [1] "2013-11-21 15:13:13
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_40_scenarioA_w

## [1] "2013-11-21 15:13:22
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_41_scenarioA_w

## [1] "2013-11-21 15:13:30
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_42_scenarioA_w

## [1] "2013-11-21 15:13:39
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_43_scenarioA_w

## [1] "2013-11-21 15:13:48
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_44_scenarioA_w

## [1] "2013-11-21 15:13:56
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_45_scenarioA_w

## [1] "2013-11-21 15:14:04
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_46_scenarioA_w

## [1] "2013-11-21 15:14:13
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_47_scenarioA_w

## [1] "2013-11-21 15:14:22
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_48_scenarioA_w

## [1] "2013-11-21 15:14:32
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_49_scenarioA_w

## [1] "2013-11-21 15:14:40
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_5_scenarioA_wi

## [1] "2013-11-21 15:14:49
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_50_scenarioA_w

## [1] "2013-11-21 15:14:58
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_6_scenarioA_wi

## [1] "2013-11-21 15:15:06
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_7_scenarioA_wi

## [1] "2013-11-21 15:15:14
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_8_scenarioA_wi

## [1] "2013-11-21 15:15:23
X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles//run_testrep_9_scenarioA_wi
```

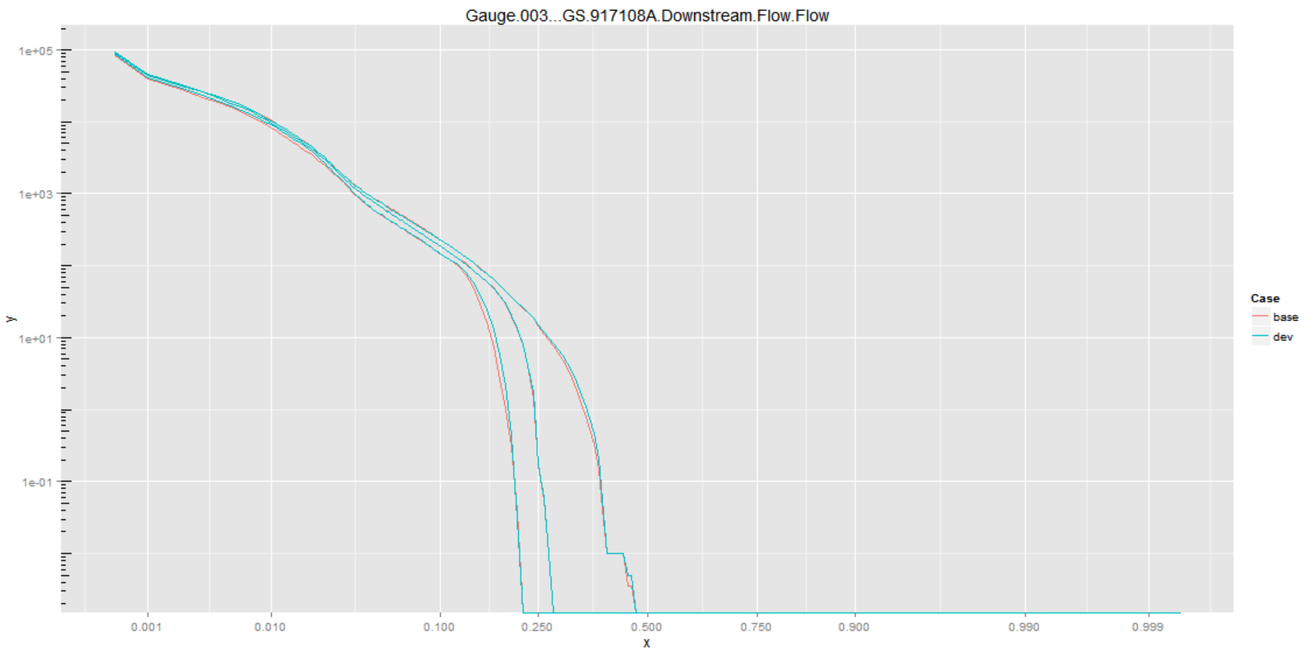
Visualization

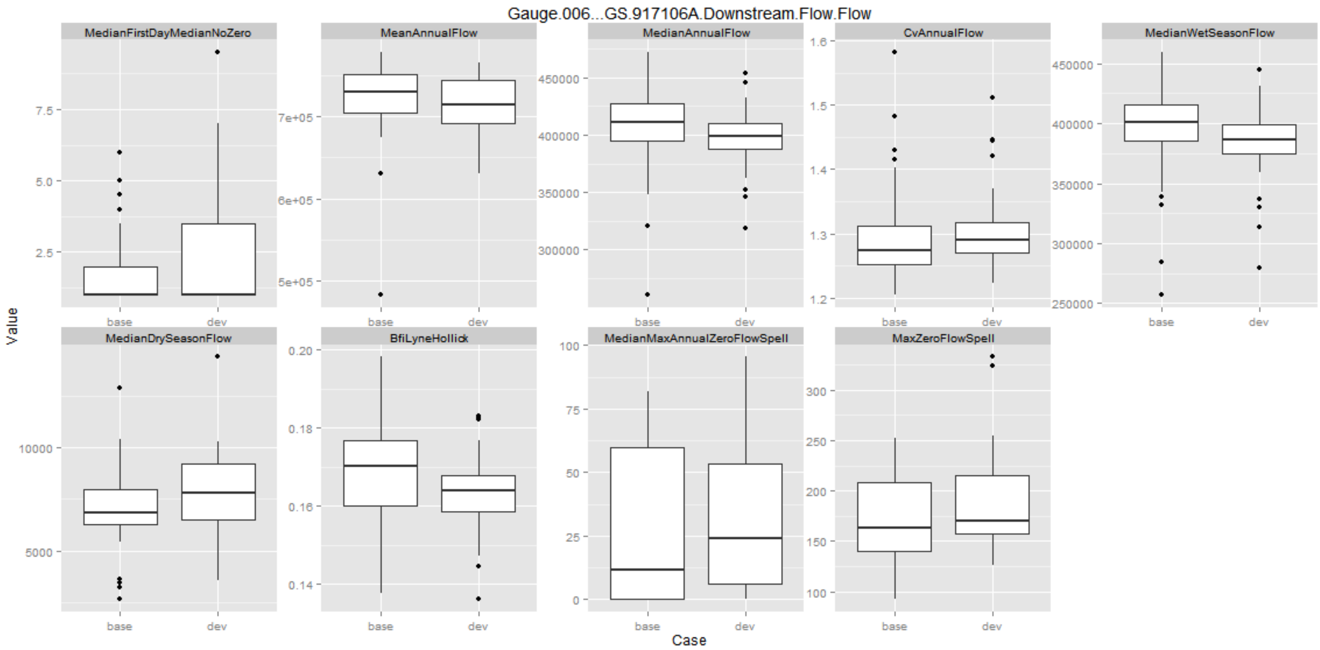
The visualization itself is not all that time comsuming.

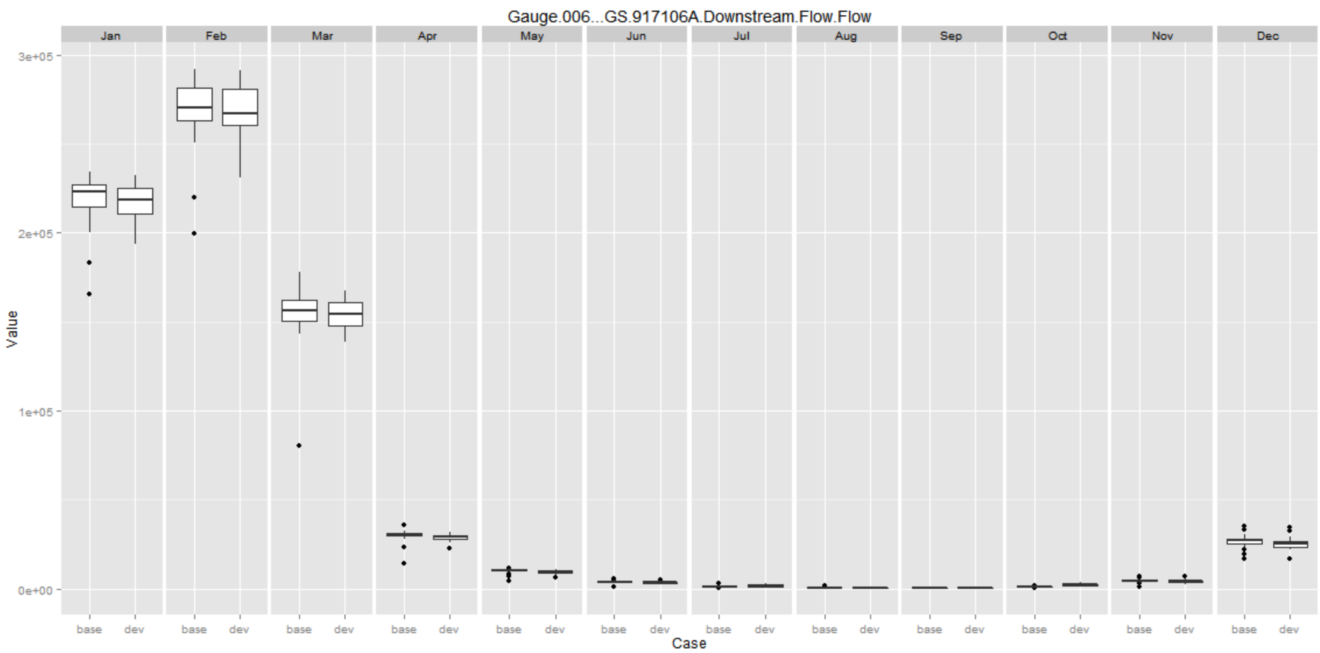
```
d <- listByGauge(rbind(statList[[c(1, 1)]], statList[[c(2, 1)]]))
mthFlows <- listByGauge(rbind(statList[[c(1, 2)]], statList[[c(2, 2)]]))
fdcData <- listByGauge(rbind(statList[[c(1, 3)]], statList[[c(2, 3)]]))
for (gaugename in names(d)) {
    print(getBoxplotsUniv(d[[gaugename]]) + ggtitle(gaugename))
    print(getBoxplotsMthly(mthFlows[[gaugename]], gaugename))
    print(getPlotFdc(fdcData[[gaugename]], gaugename))
}
```

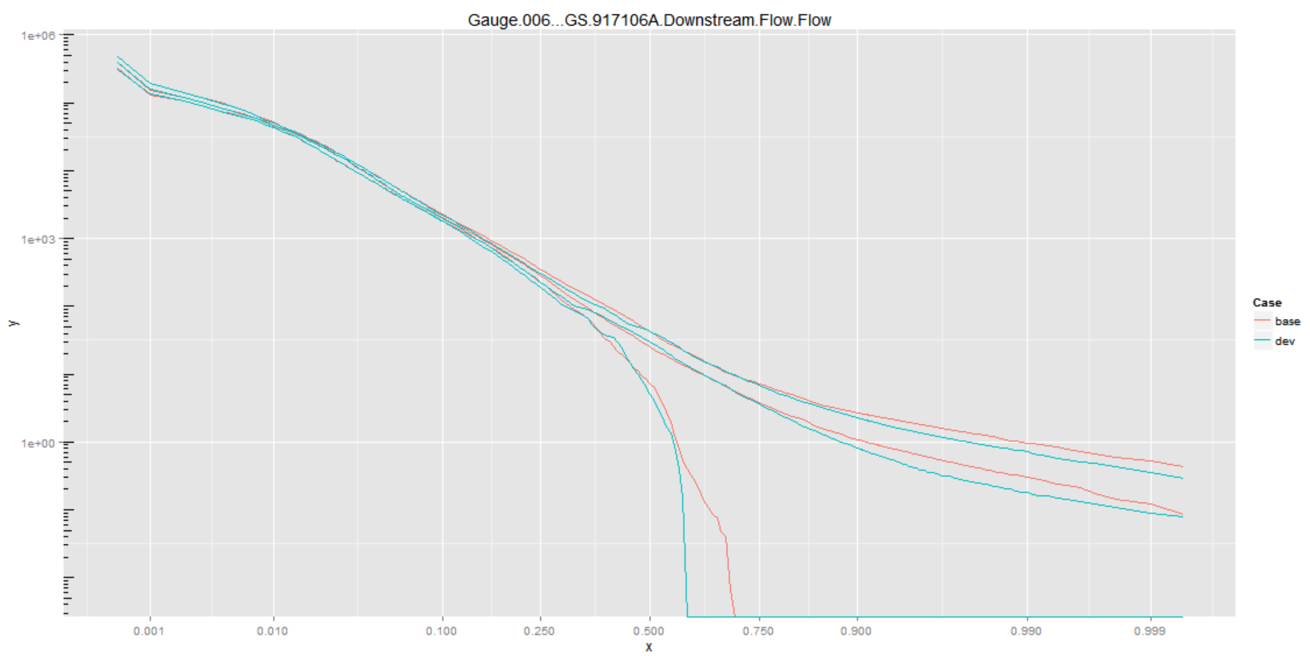

Gauge.003...GS.917108A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

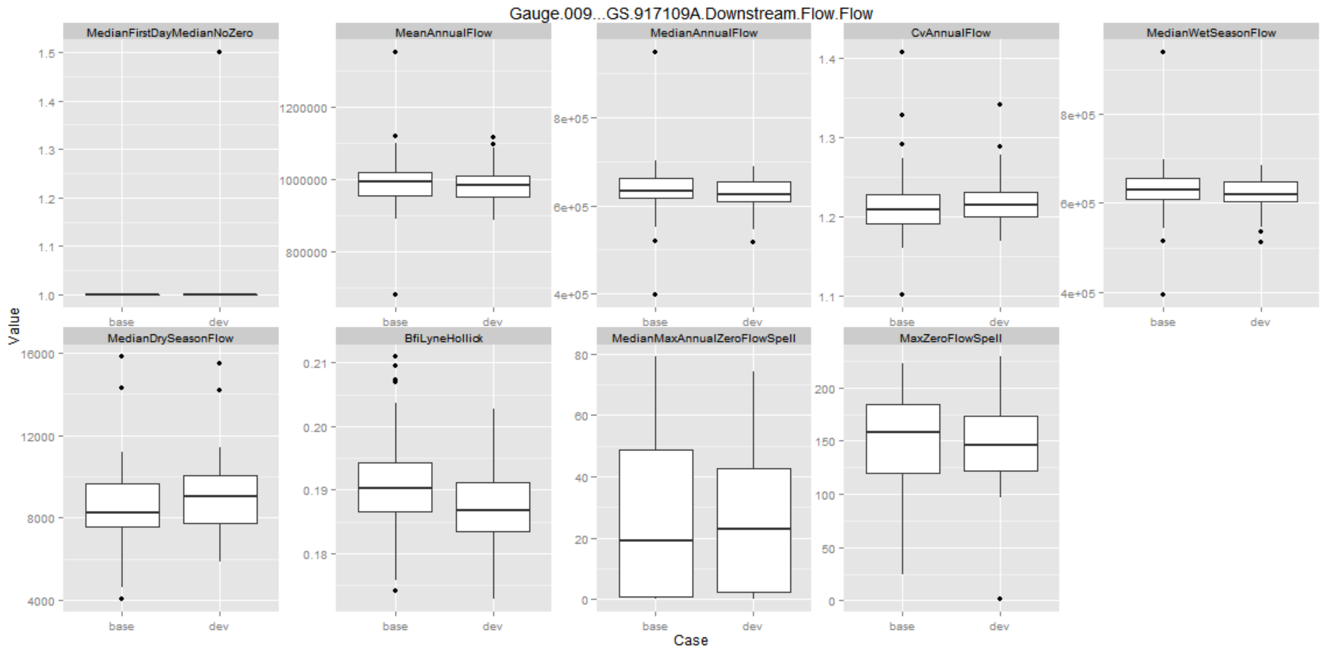

Gauge.003...GS.917108A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

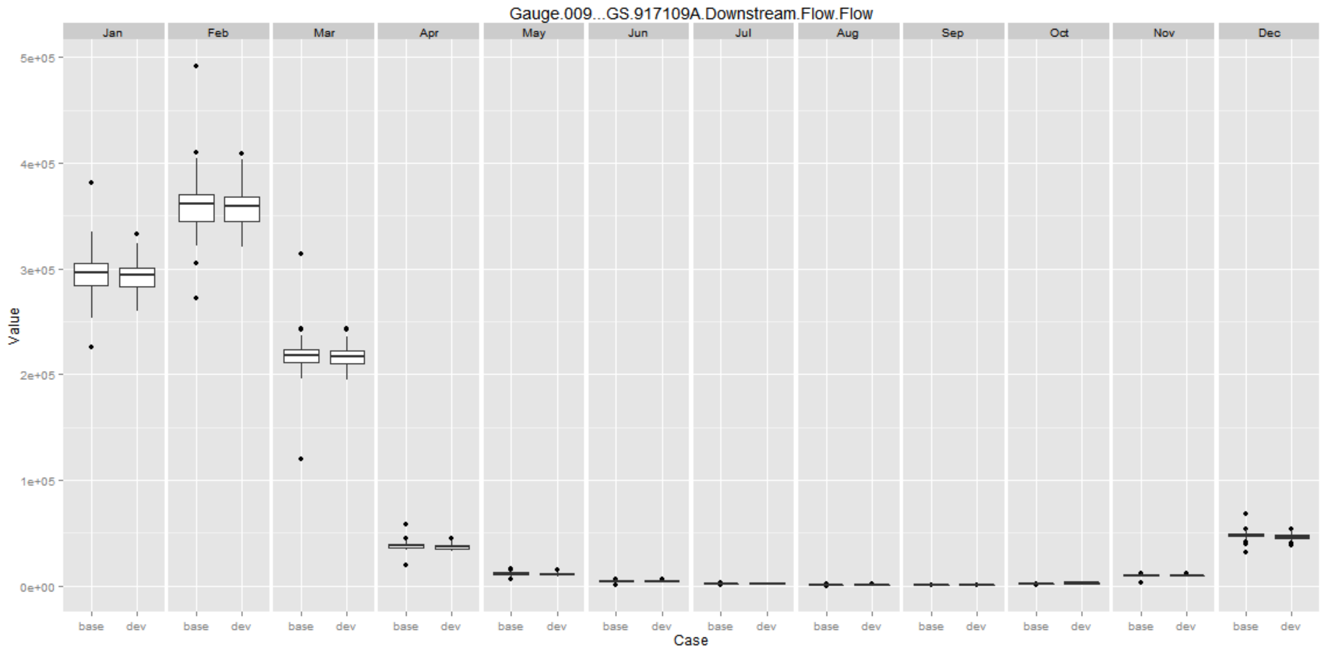

Gauge.003...GS.917108A.Downstream.Flow.Flow
y
x
Case
base
dev

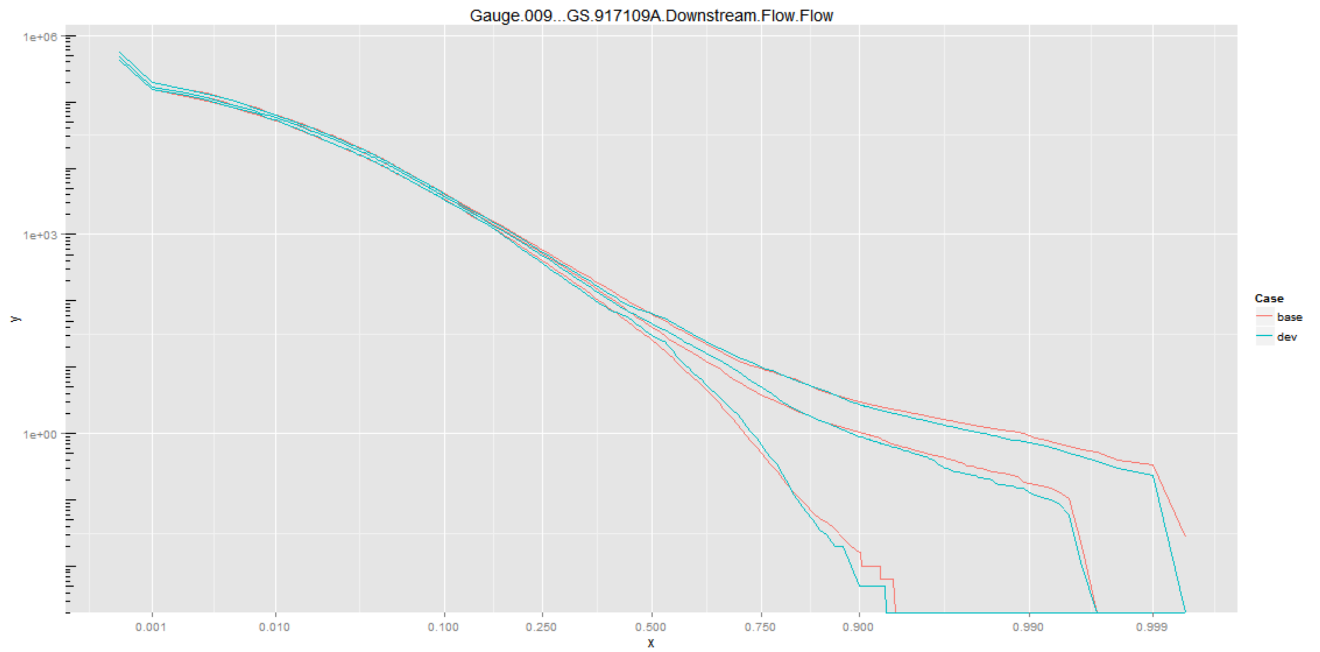

Gauge.006...GS.917106A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

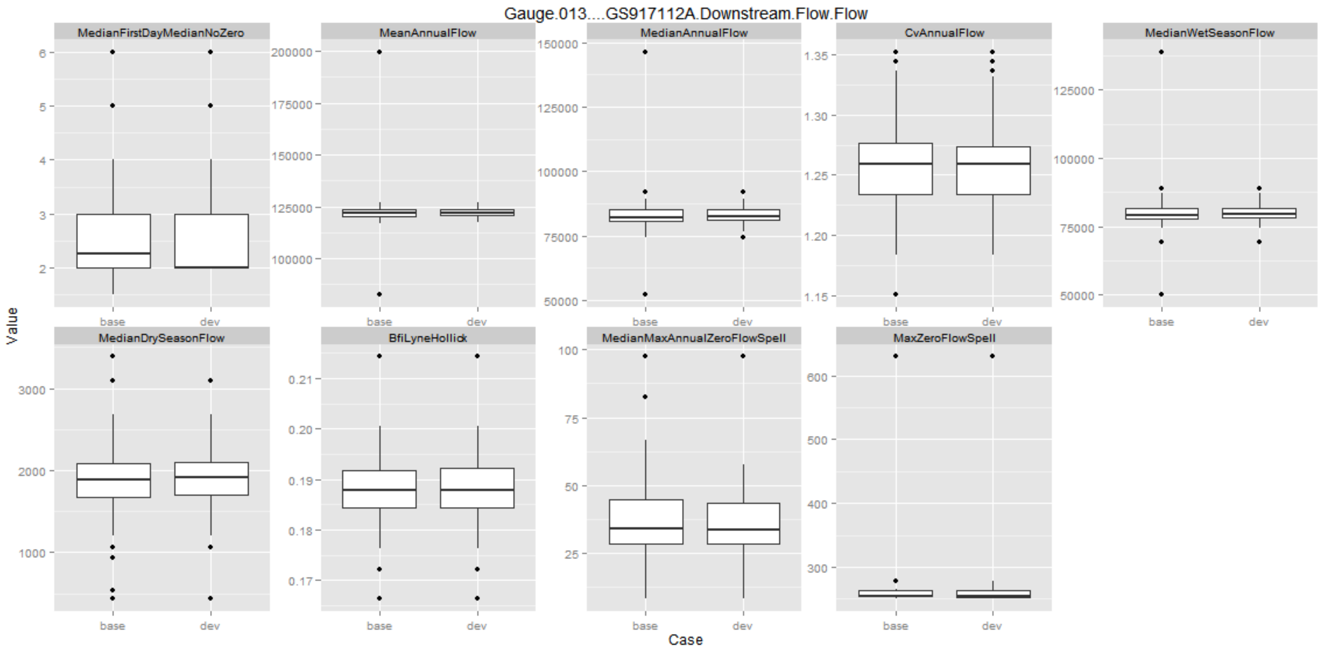

Gauge.006...GS.917106A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

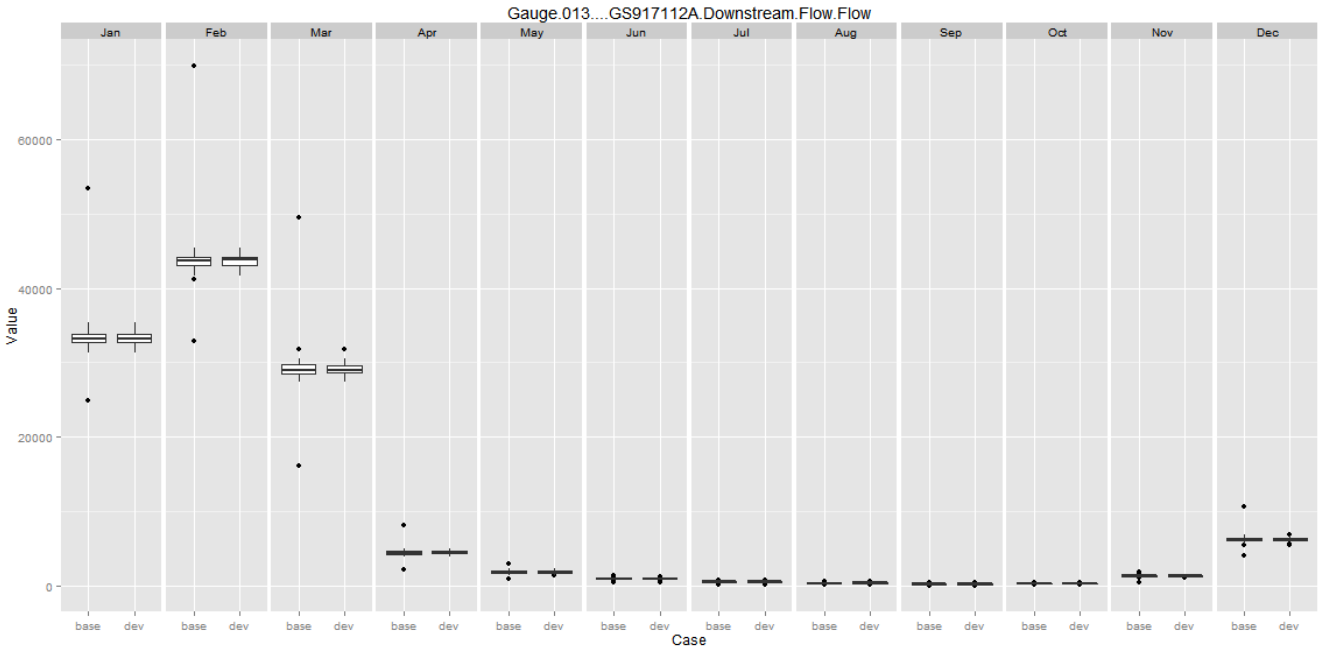

Gauge.006...GS.917106A.Downstream.Flow.Flow
y
x
Case
base
dev

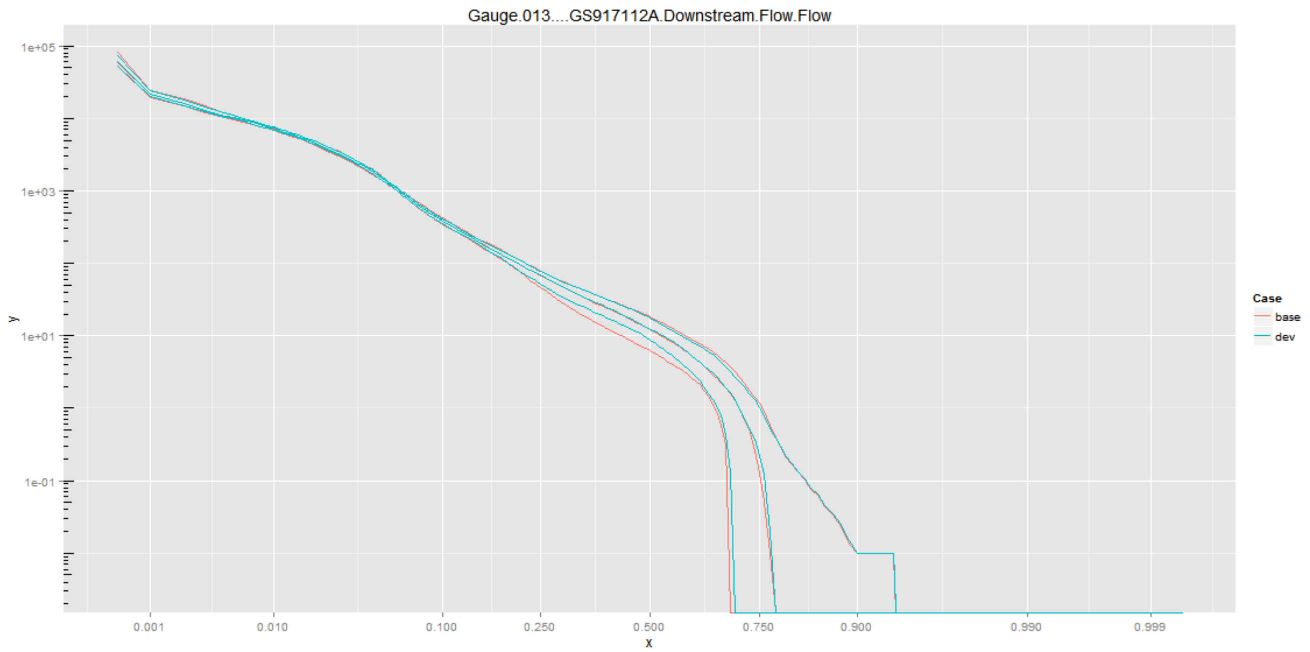

Gauge.009...GS.917109A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

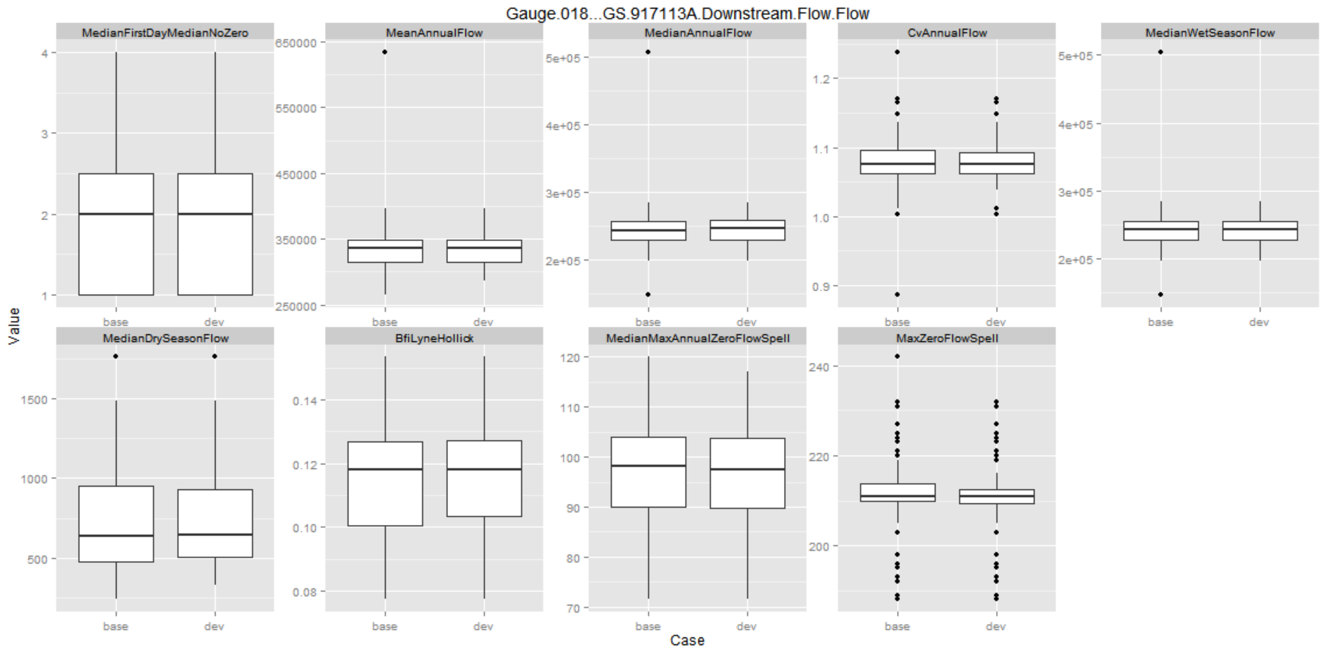

Gauge.009...GS.917109A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

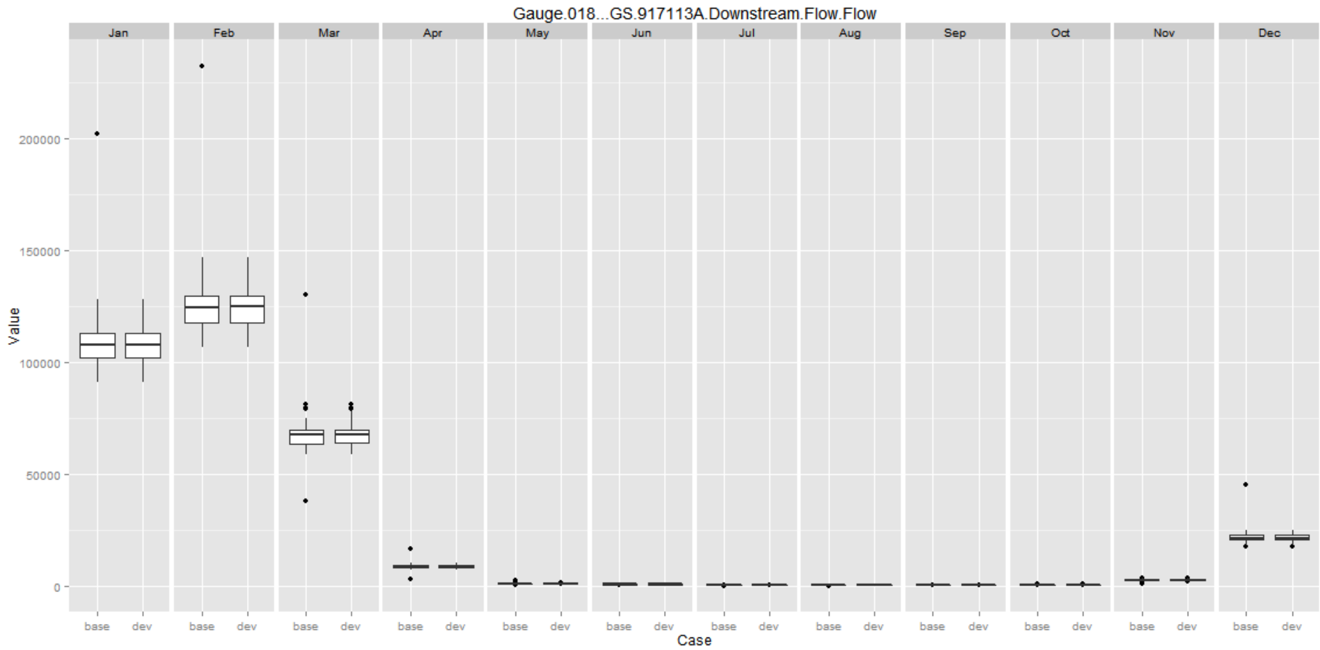

Gauge.009...GS.917109A.Downstream.Flow.Flow
y
x
Case
base
dev

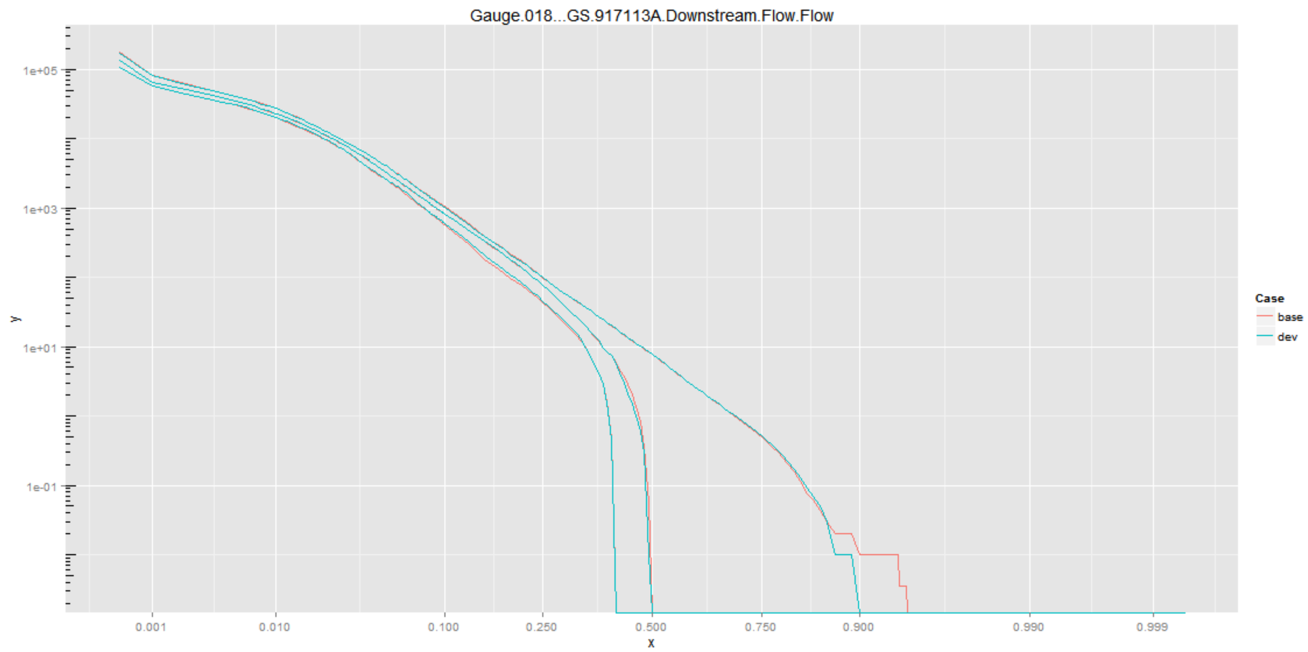

Gauge.013....GS917112A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

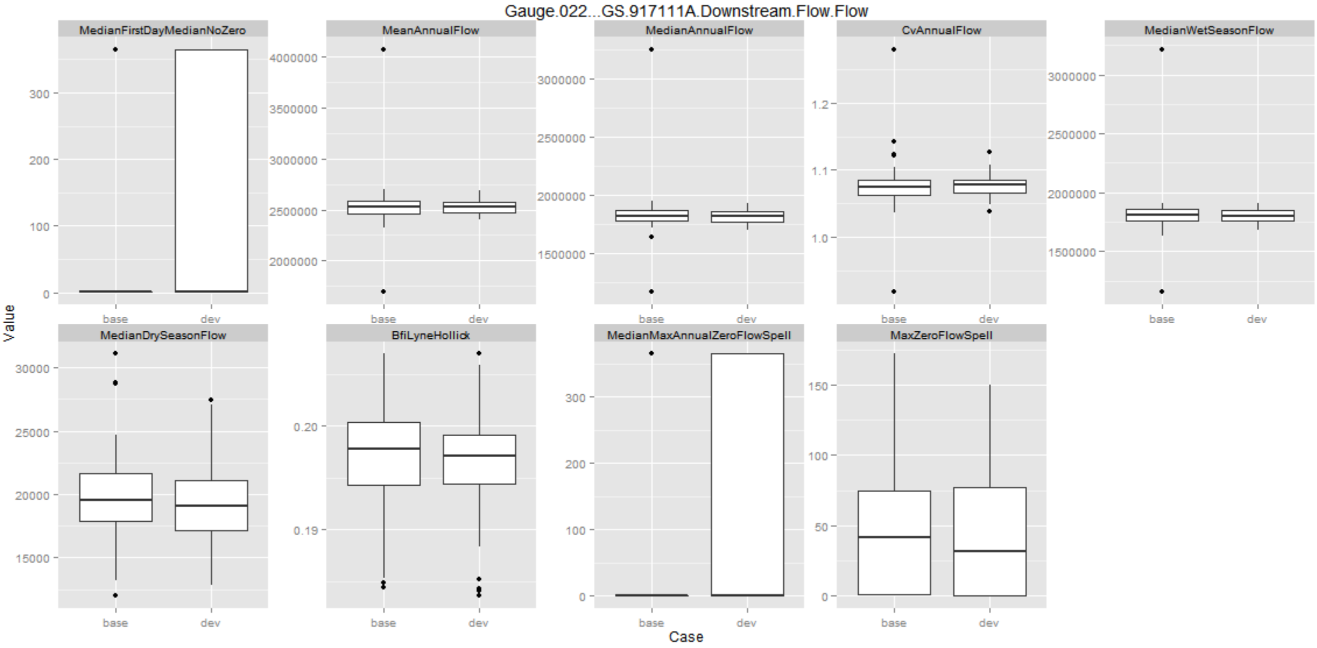

Gauge.013....GS917112A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

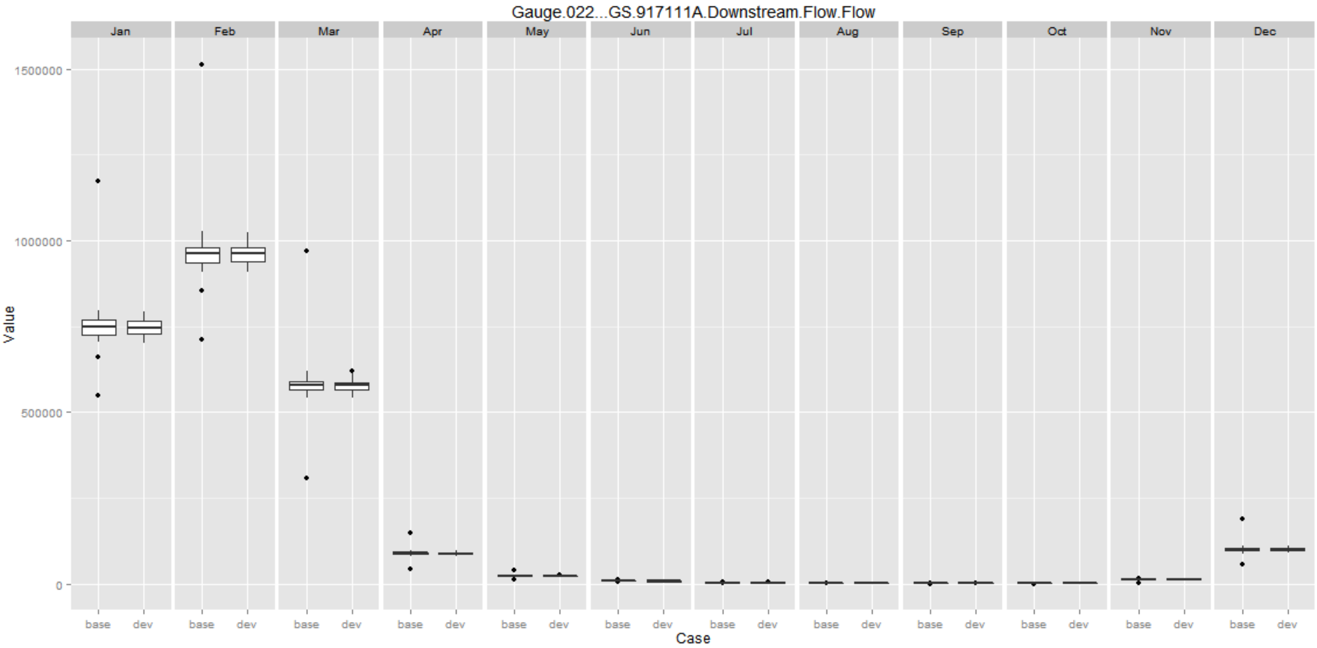

Gauge.013....GS917112A.Downstream.Flow.Flow
y
x
Case
base
dev

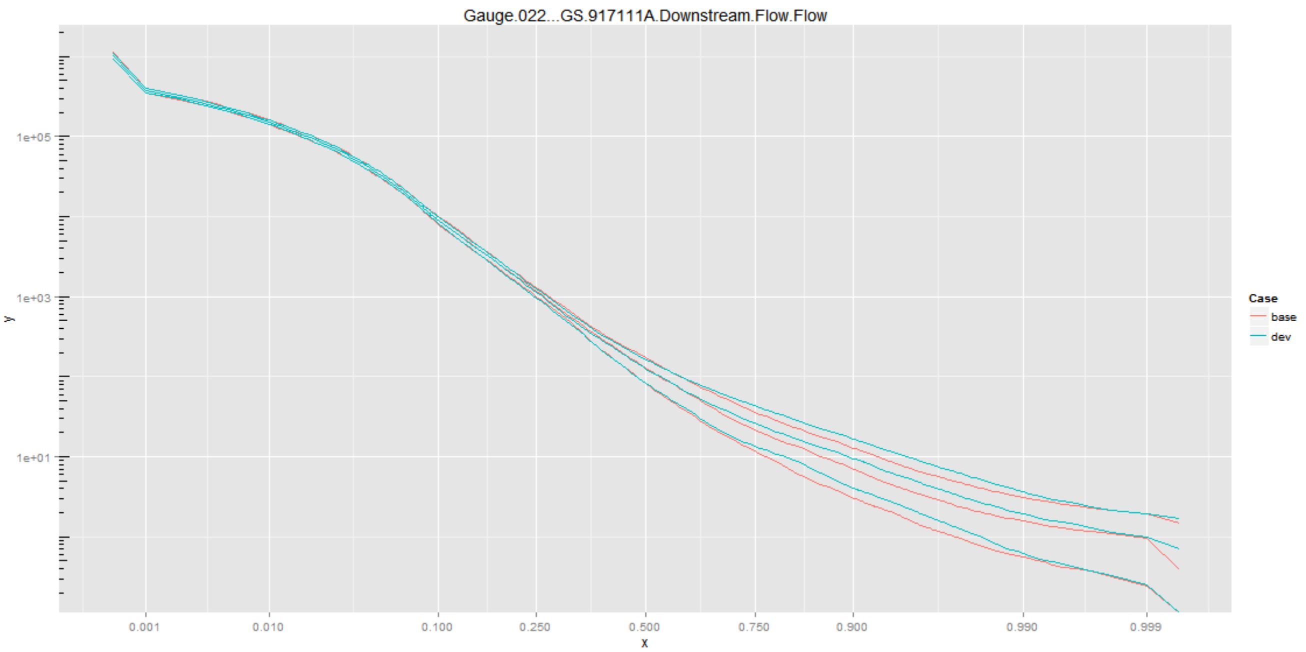

Gauge.018...GS.917113A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

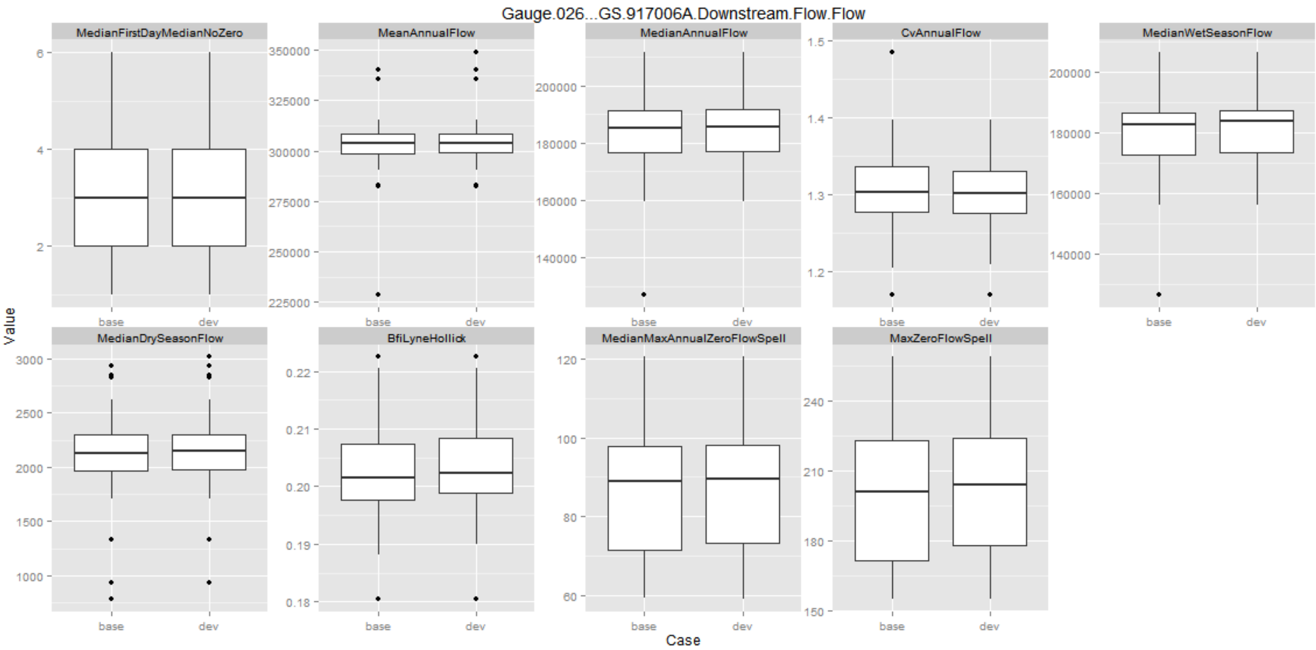

Gauge.018...GS.917113A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

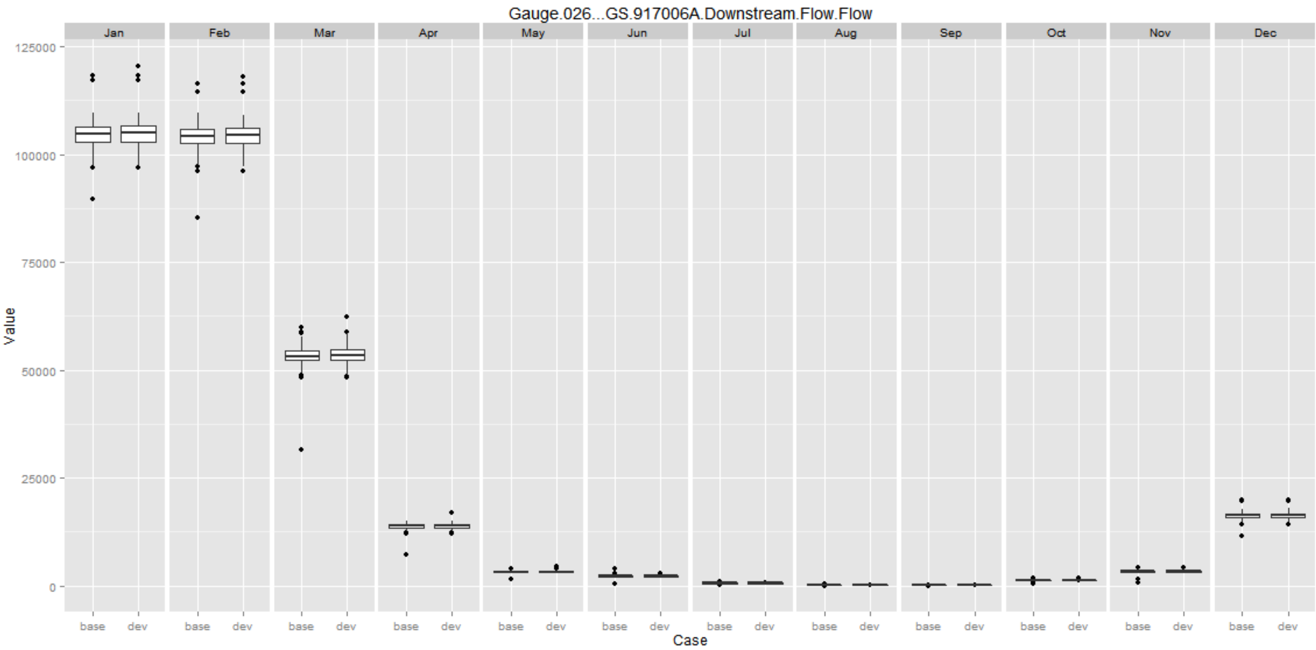

Gauge.018...GS.917113A.Downstream.Flow.Flow
y
x
Case
base
dev

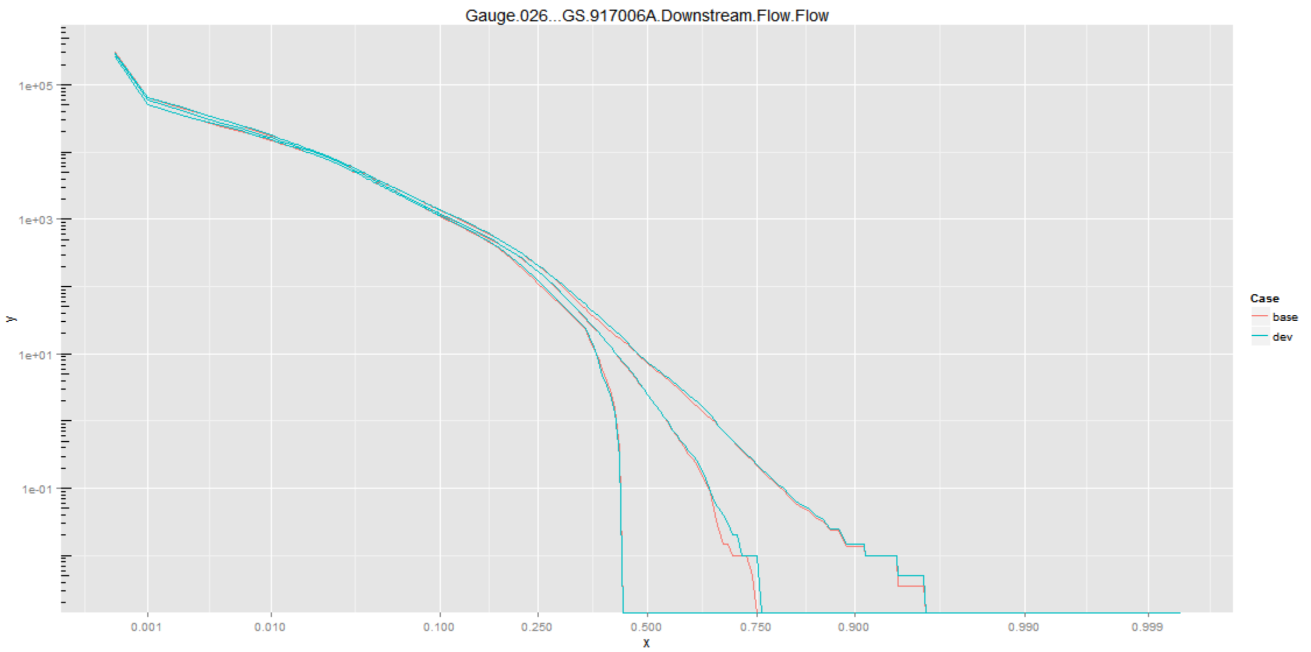

Gauge.022...GS.917111A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

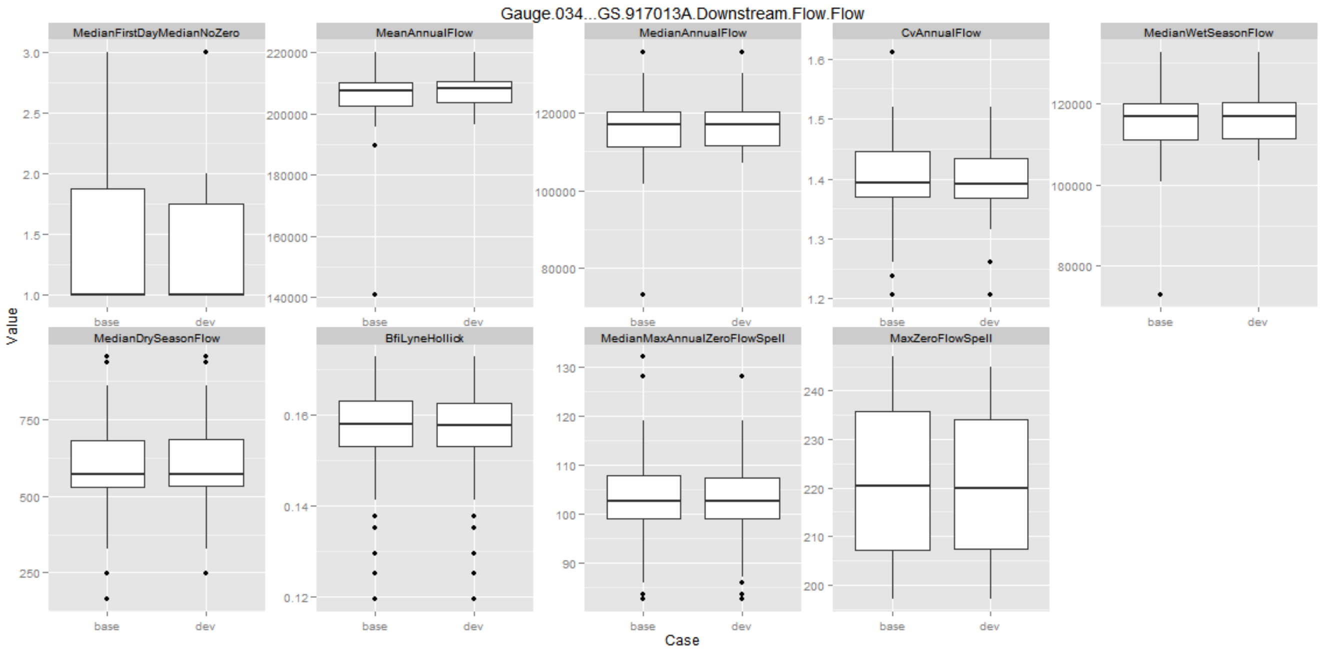

Gauge.022...GS.917111A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

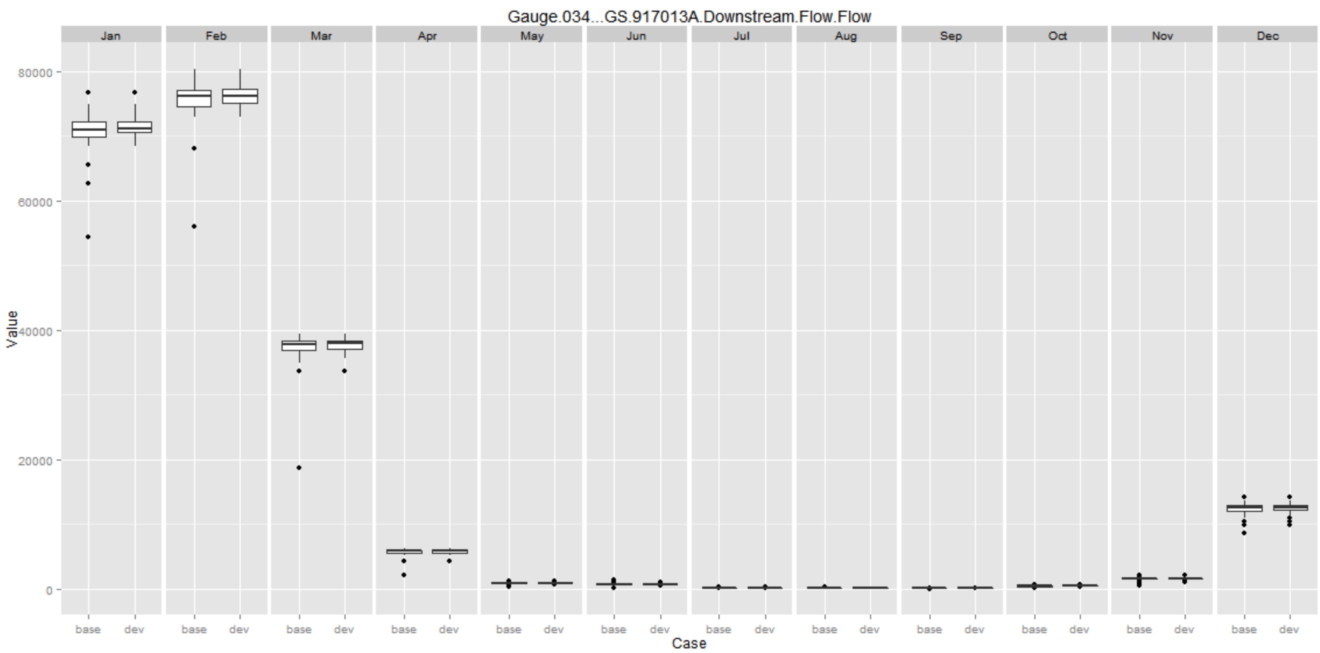

Gauge.022...GS.917111A.Downstream.Flow.Flow
y
x
Case
base
dev

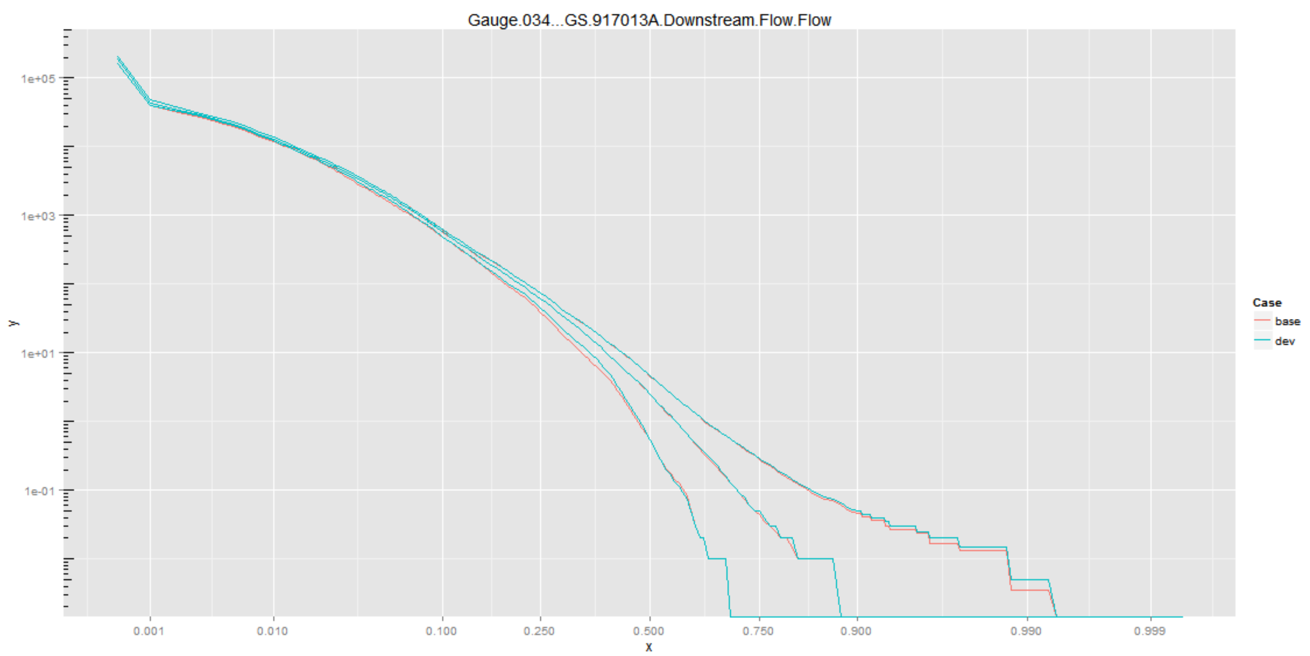

Gauge.026...GS.917006A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

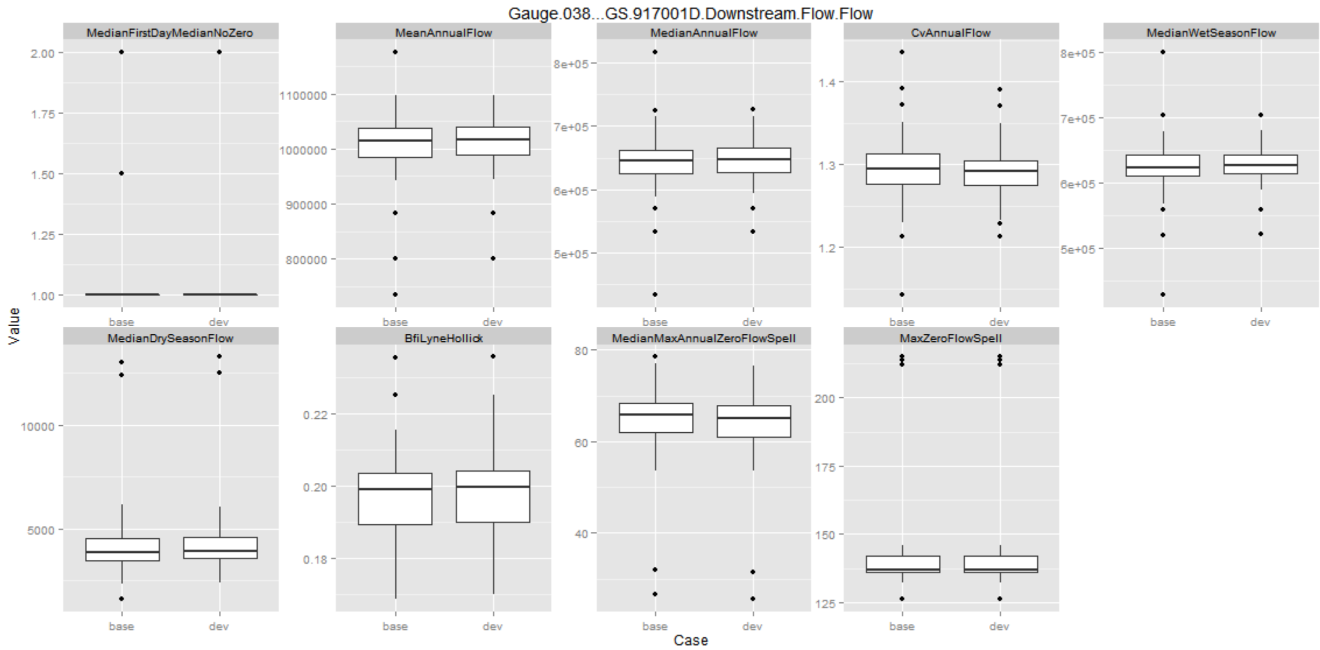

Gauge.026...GS.917006A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

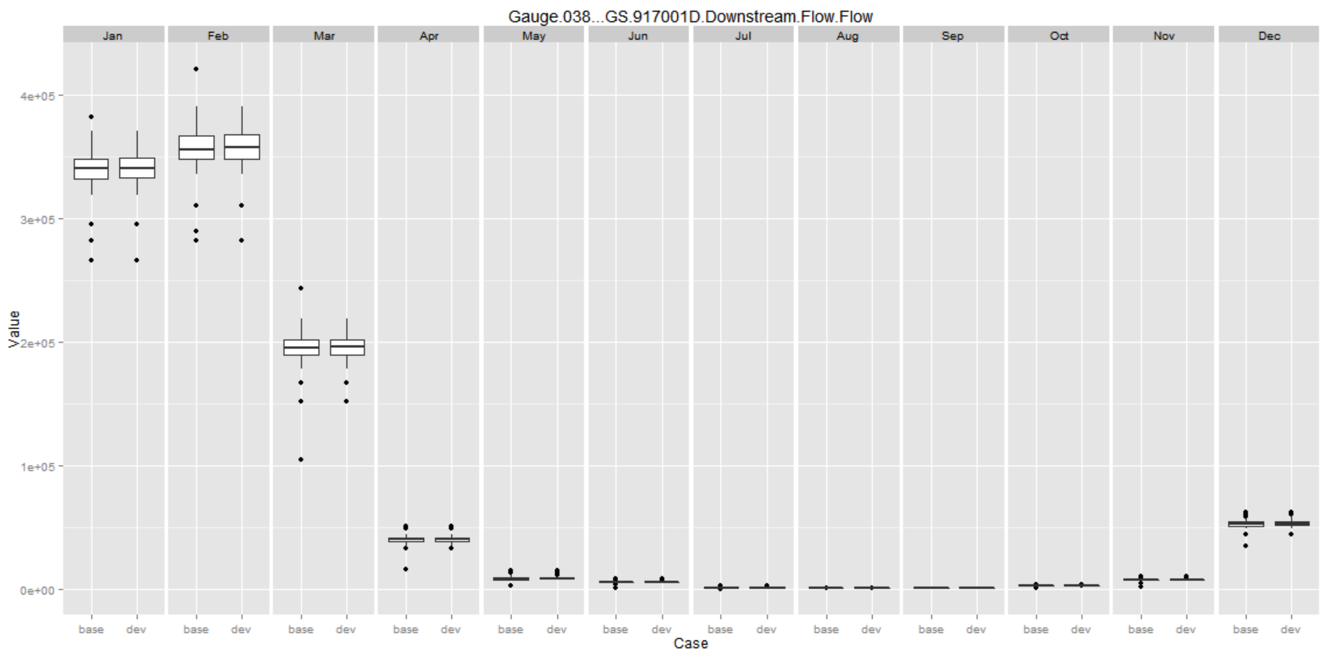

Gauge.026...GS.917006A.Downstream.Flow.Flow
y
x
Case
base
dev

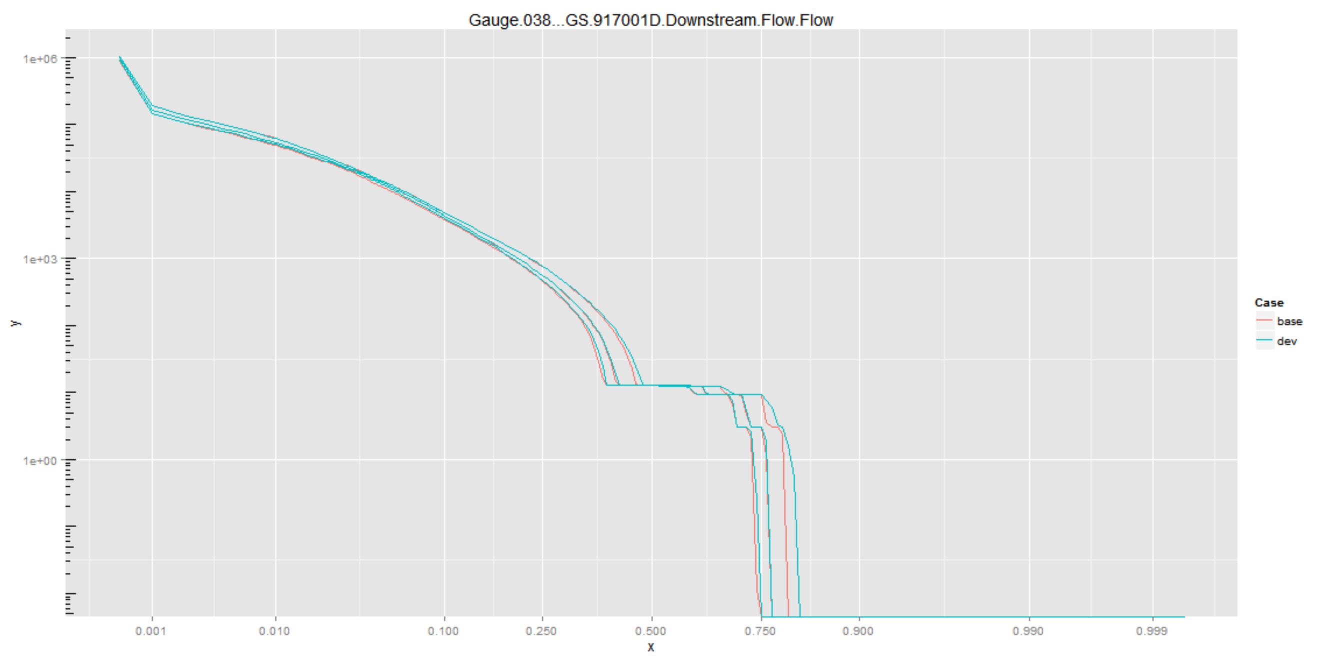

Gauge.034...GS.917013A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

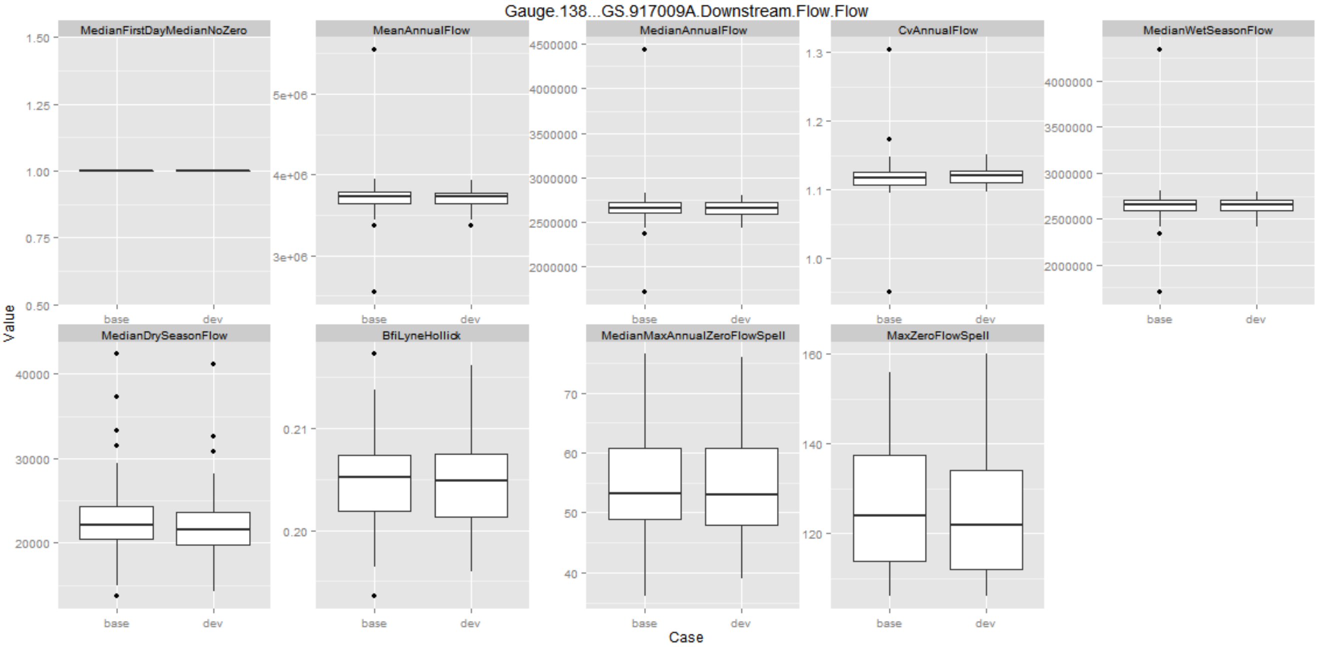

Gauge.034...GS.917013A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

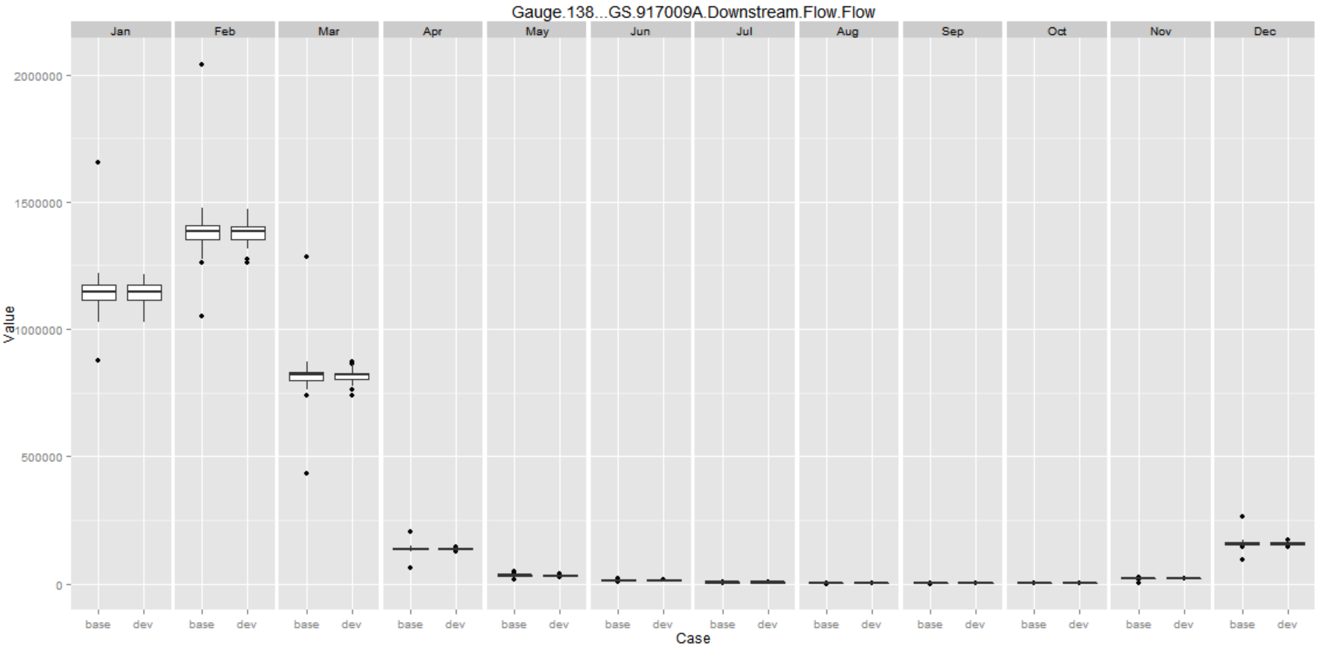

Gauge.034...GS.917013A.Downstream.Flow.Flow
y
x
Case
base
dev

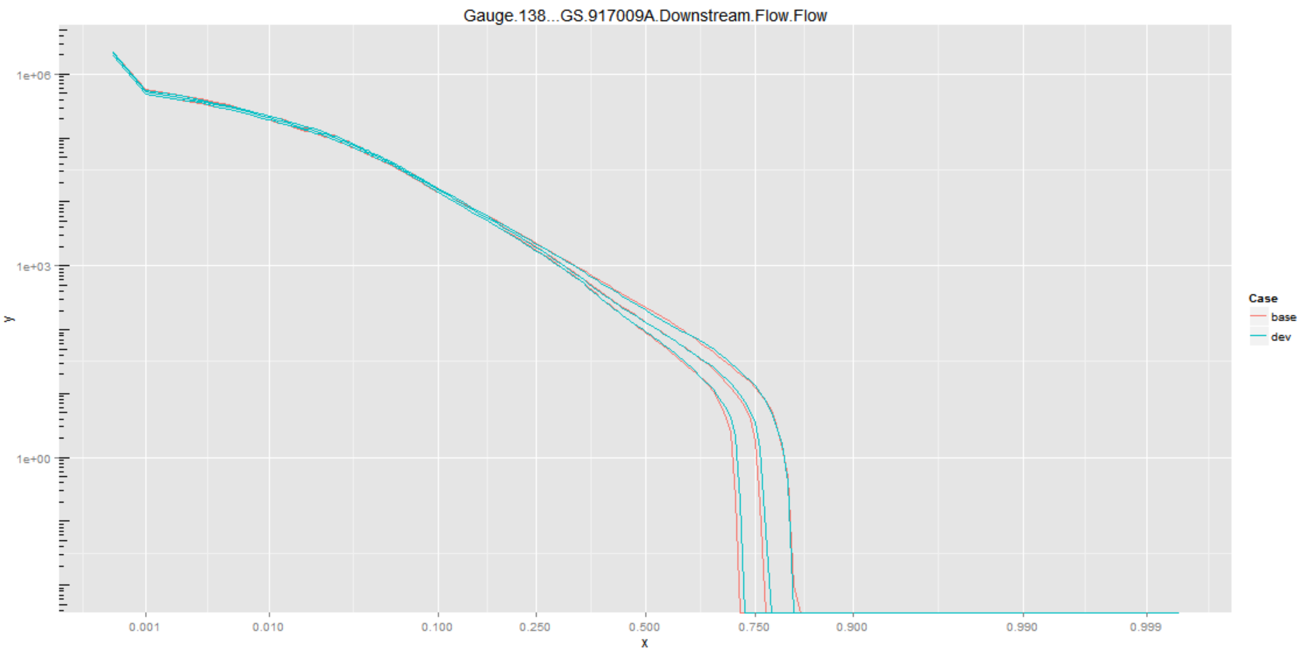

Gauge.038...GS.917001D.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

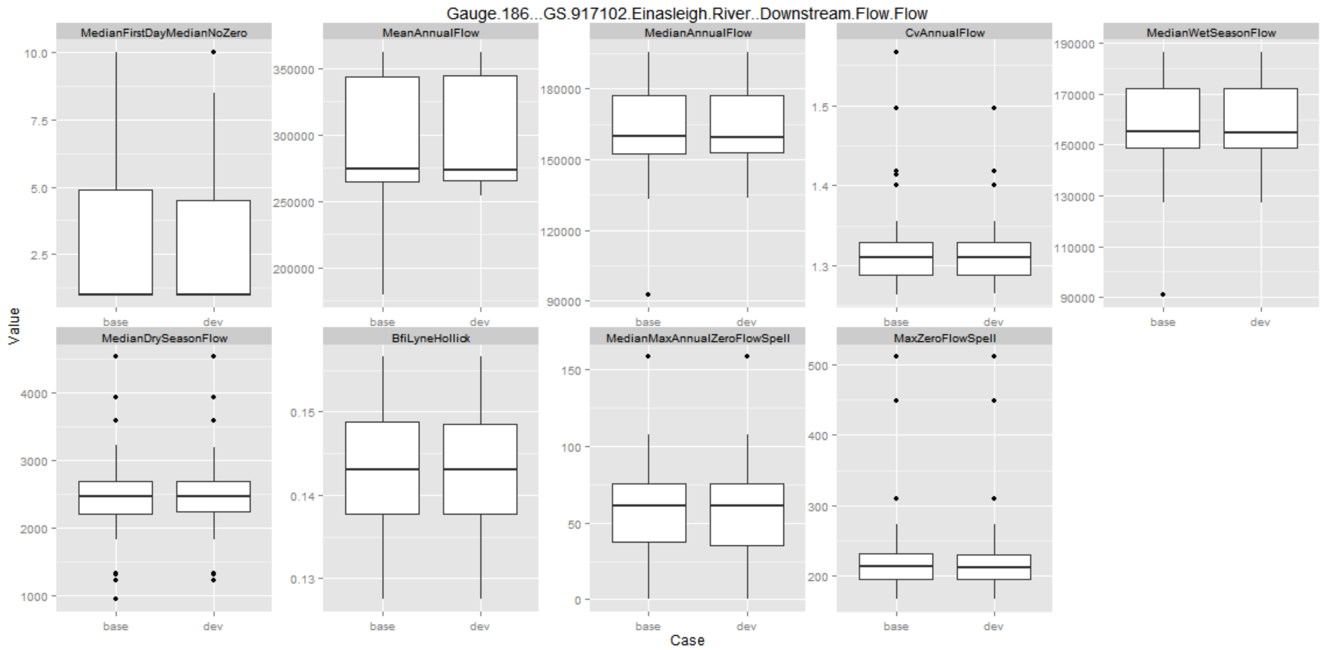

Gauge.038...GS.917001D.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

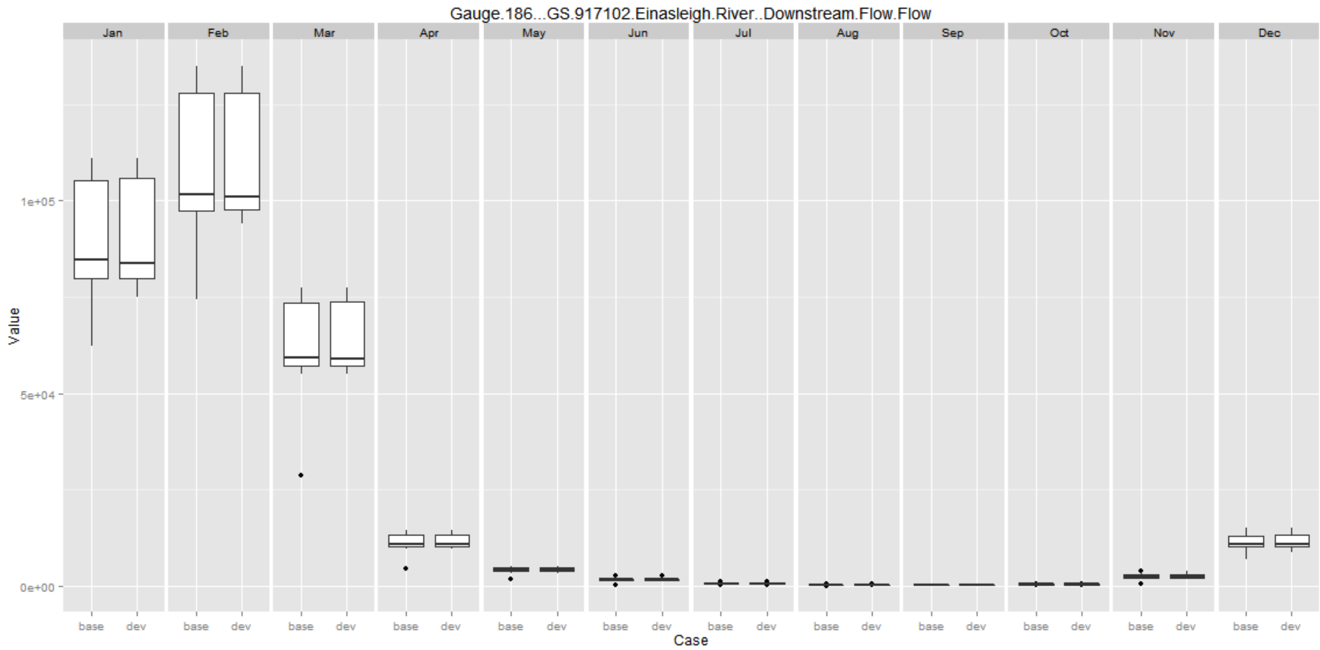

Gauge.038...GS.917001D.Downstream.Flow.Flow
y
x
Case
base
dev

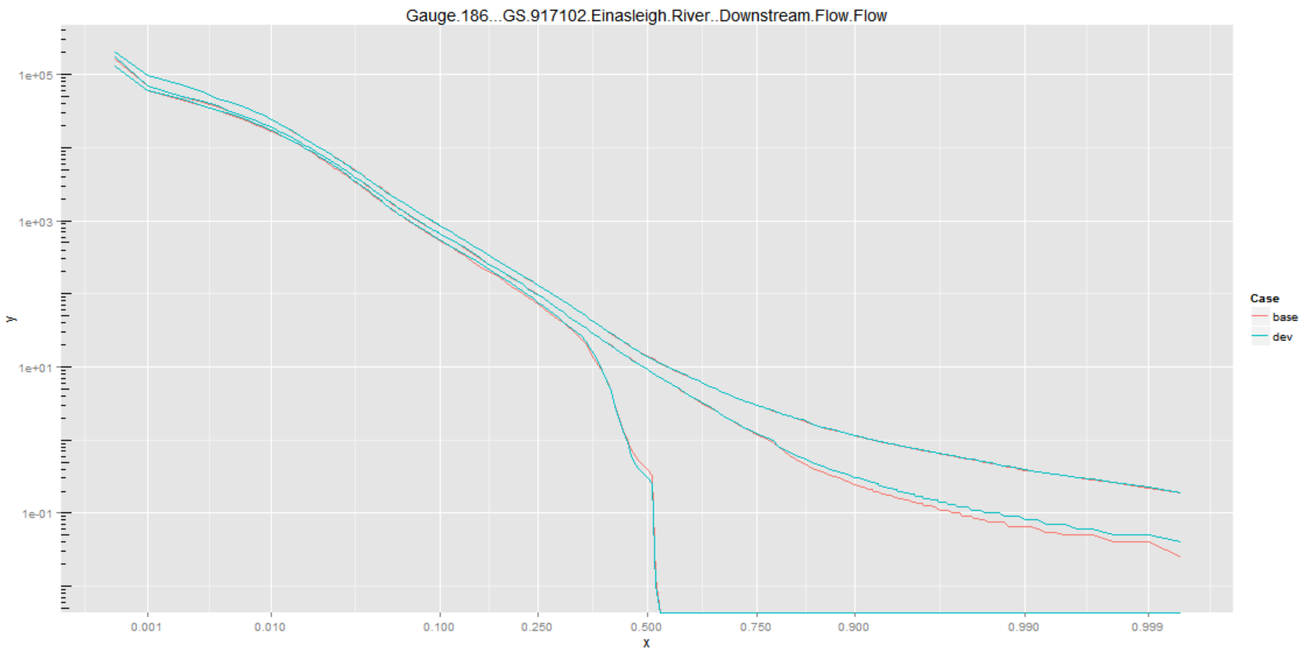

Gauge.138...GS.917009A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

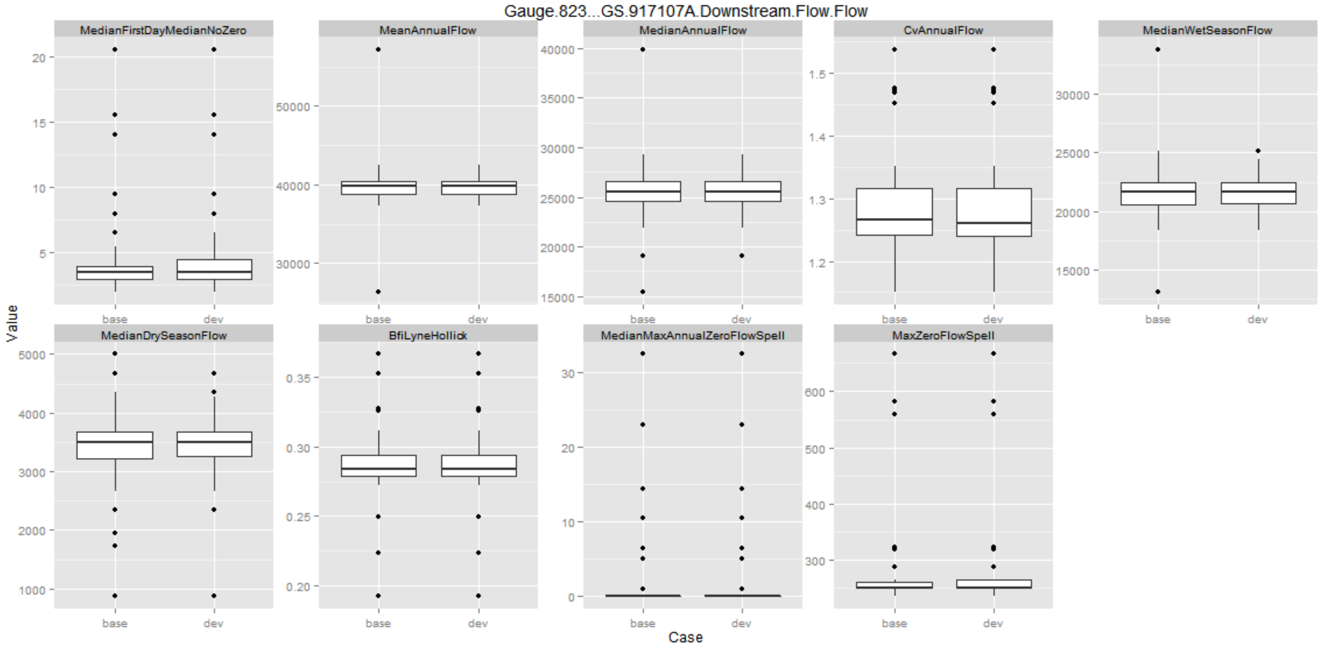

Gauge.138...GS.917009A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

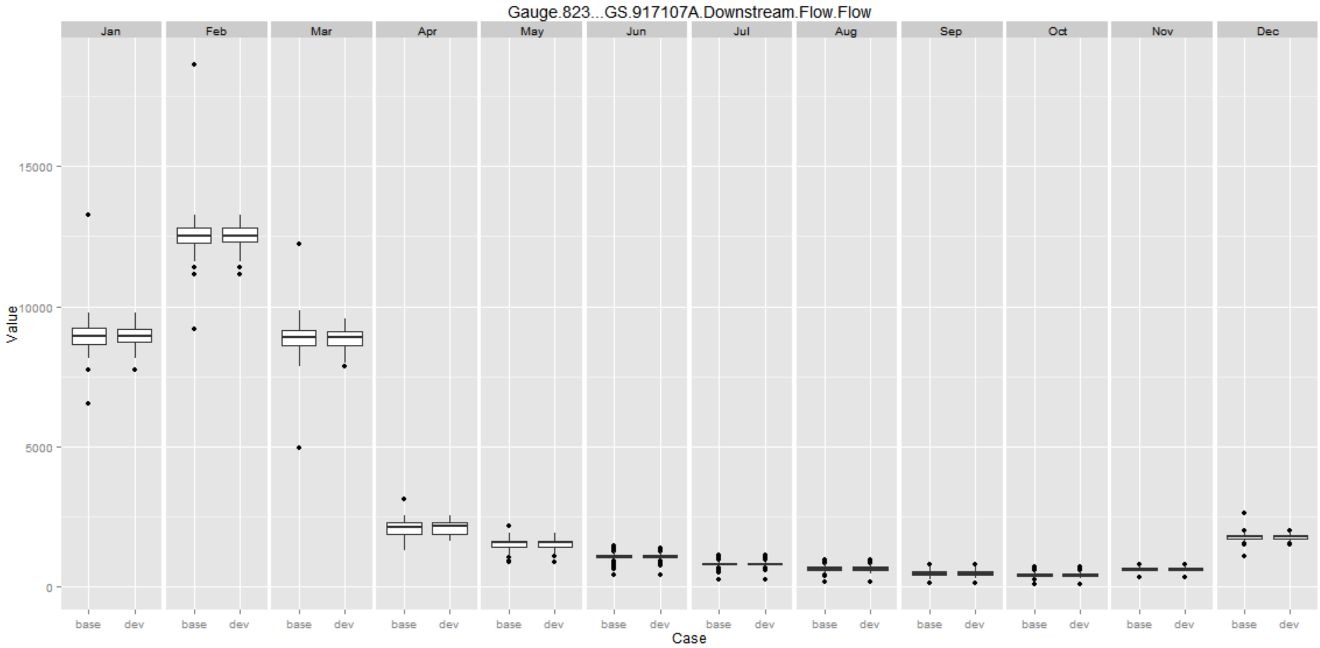

Gauge.138...GS.917009A.Downstream.Flow.Flow
y
x
Case
base
dev

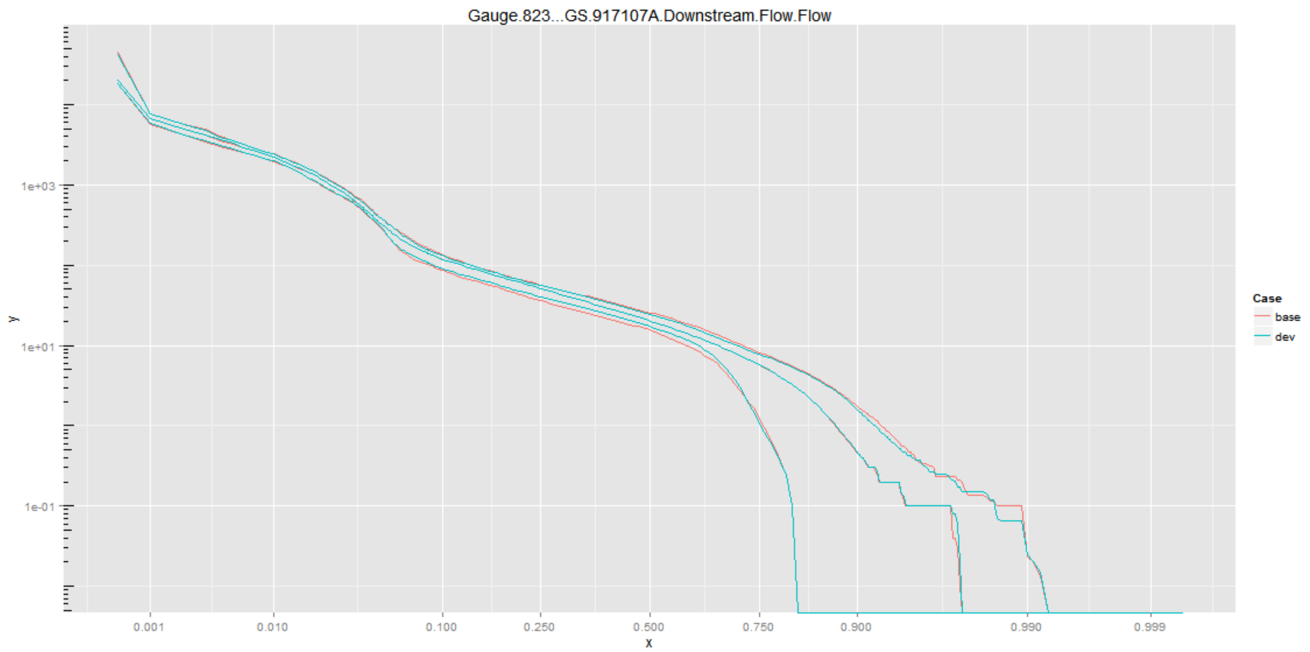

Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

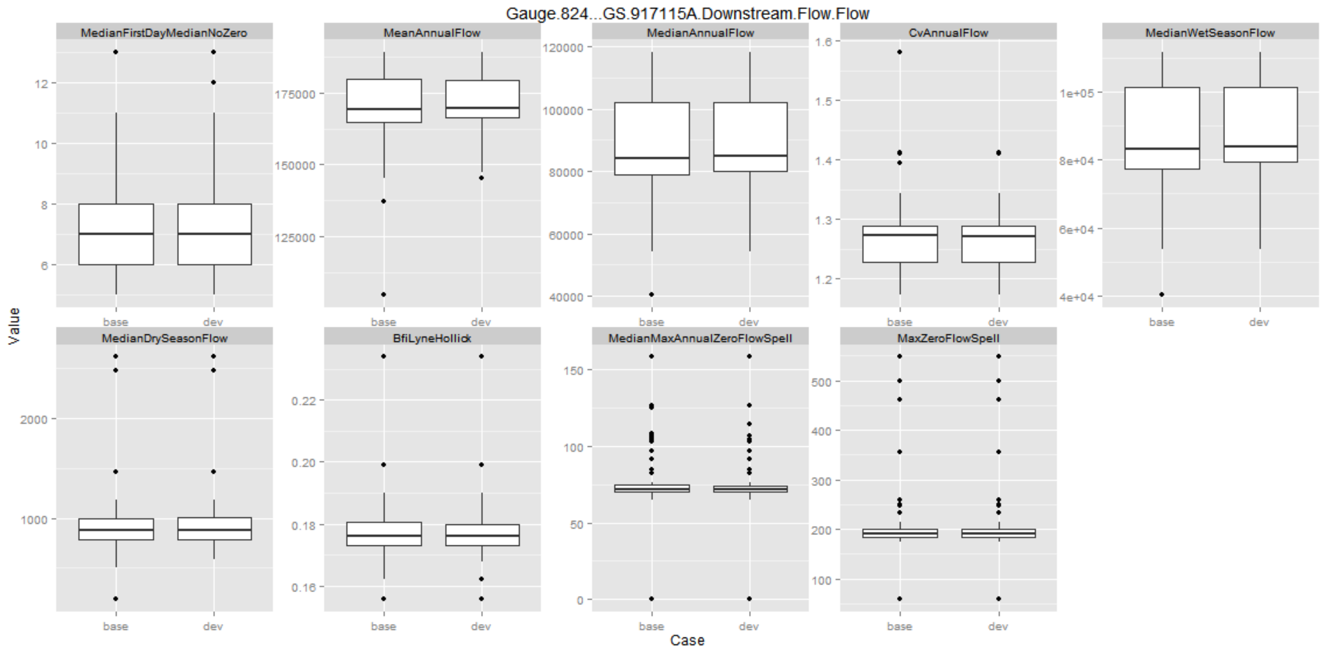

Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

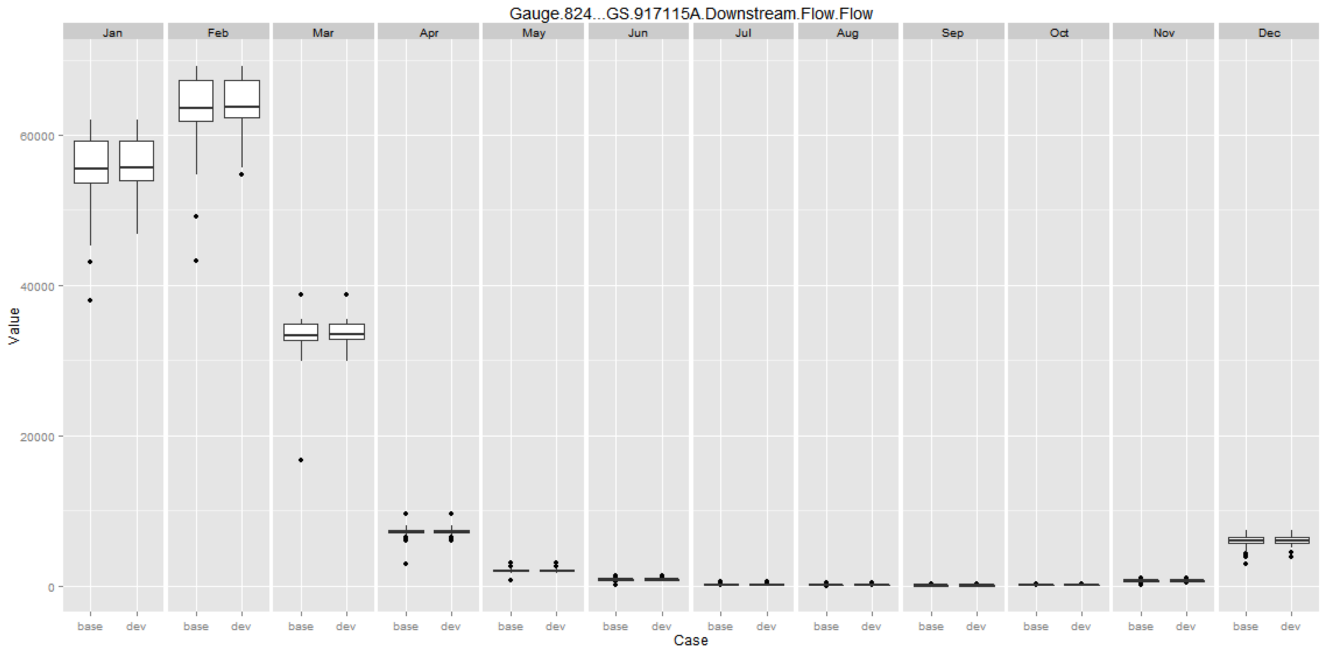

Gauge.186...GS.917102.Einasleigh.River..Downstream.Flow.Flow
y
x
Case
base
dev

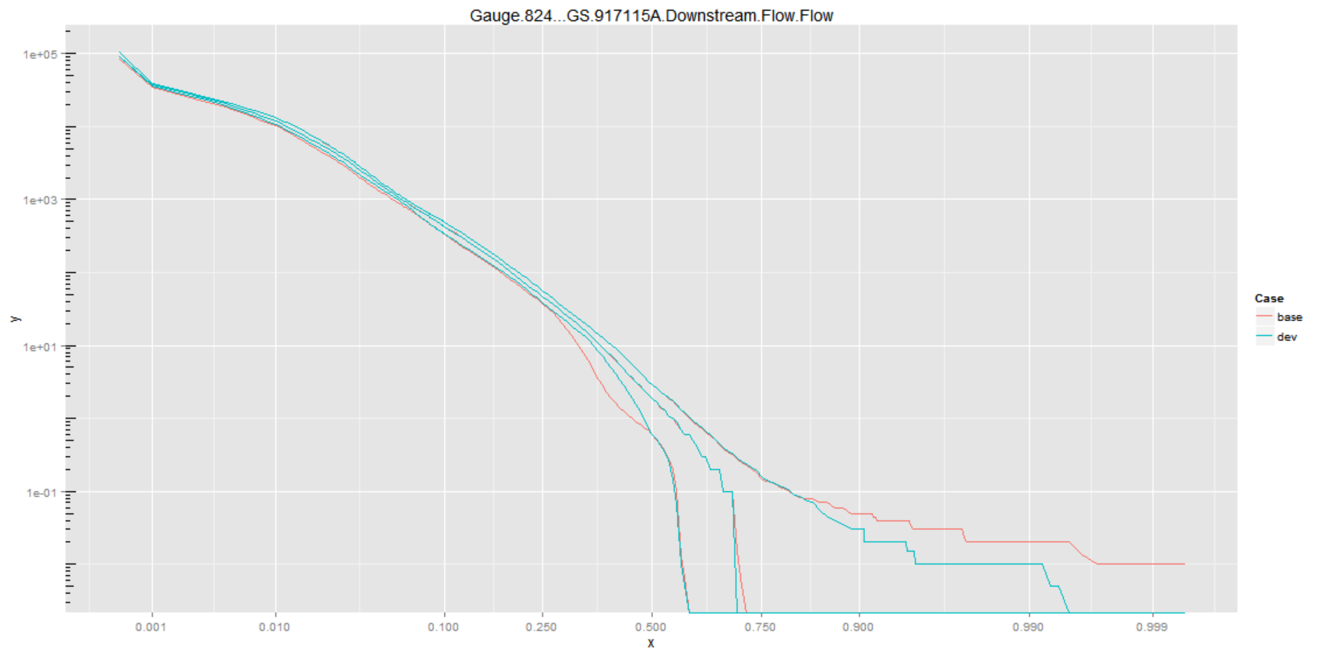

Gauge.823...GS.917107A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.823...GS.917107A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev


Gauge.823...GS.917107A.Downstream.Flow.Flow
y
x
Case
base
dev


Gauge.824...GS.917115A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.824...GS.917115A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev


Gauge.824...GS.917115A.Downstream.Flow.Flow
y
x
Case
base
dev

Appendix

R session information for the generation of this document:

```
sessionInfo()
```

```
## R version 3.0.1 (2013-05-16)
## Platform: i386-w64-mingw32/i386 (32-bit)
##
## locale:
## [1] LC_COLLATE=English_Australia.1252  LC_CTYPE=English_Australia.1252
## [3] LC_MONETARY=English_Australia.1252 LC_NUMERIC=C
## [5] LC_TIME=English_Australia.1252
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] garaHydroMetrics_0.1-4 scales_0.2.3           reshape2_1.2.2
##  [4] lubridate_1.3.1        stringr_0.6.2          ggplot2_0.9.3.1
##  [7] xts_0.9-7              zoo_1.7-10             plyr_1.8
## [10] knitr_1.5
##
## loaded via a namespace (and not attached):
##  [1] colorspace_1.2-4   dichromat_2.0-0    digest_0.6.3
##  [4] evaluate_0.5.1     formatR_0.10       grid_3.0.1
##  [7] gtable_0.1.2       labeling_0.2       lattice_0.20-15
## [10] MASS_7.3-26        munsell_0.4.2      proto_0.3-10
## [13] RColorBrewer_1.0-5 tools_3.0.1
```

FGARA Hydrological Metrics - Dry run on OConnoll ensemble runs

About this document

Purpose is to have a dry run on 50 runs ensembles for Dagworth vs Gilbert baseline

This document was generated on 2013-11-21 14:57:46 using among other things the packages 'knitr' and 'garaHydroMetrics' (https://stash.csiro.au/projects/~per202/repos/hydrometrics/browse)

Calculate statistics

Load the package the usual. It includes a fair level of documentation, that should be accessible using the '?' command, shortcut for help(garaHydroMetrics).

```
library(garaHydroMetrics)
```

```
## Warning: package 'garaHydroMetrics' was built under R version 3.0.2
```

```
## Loading required package: plyr
```

```
## Warning: package 'plyr' was built under R version 3.0.2
```

```
## Loading required package: xts
```

```
## Warning: package 'xts' was built under R version 3.0.2
```

```
## Loading required package: zoo
##
## Attaching package: 'zoo'
##
## The following object is masked from 'package:base':
##
##     as.Date, as.Date.numeric
##
## Loading required package: ggplot2
```

```
## Warning: package 'ggplot2' was built under R version 3.0.2
```

```
## Loading required package: stringr
```

```
## Warning: package 'stringr' was built under R version 3.0.2
```

```
## Loading required package: lubridate
```

```
## Warning: package 'lubridate' was built under R version 3.0.2
```

```
##
## Attaching package: 'lubridate'
##
## The following object is masked from 'package:plyr':
##
##     here
##
## Loading required package: reshape2
```

```
## Warning: package 'reshape2' was built under R version 3.0.2
```

```
## Loading required package: scales
```

```
## Warning: package 'scales' was built under R version 3.0.2
## Warning: replacing previous import 'here' when loading 'plyr'
```

```
library(plyr)
```

Mapping \wron\Project\GARA\2_Rivers\3_All\8_Case_Studies to a W: drive to preempt issues to do with too long paths.

```
baselineDir <- "X:/ScenarioB/"
# develDir <-
# 'X:/3_DagsworthUS/_Source_projects_packaged/Dagworthv3_Noimpact_EnsembleRuns'
develDir <- "X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles/"
# develDir <-
# 'X:/5_Kidston/_Source_projects_packaged/v5NoImpact_OFS100_4000ha_ensembles/'

findGaugeFiles <- function(topFolder) {
    pattern <- ".*_Gauge_daily.csv.gz"
    csvfiles <- list.files(path = topFolder, pattern = pattern, all.files = TRUE,
        full.names = TRUE, recursive = TRUE, ignore.case = TRUE)
}
baseFiles <- findGaugeFiles(baselineDir)
develFiles <- findGaugeFiles(develDir)

timeSeries <- lapply(c(baseFiles[c(1, 51)], develFiles[1]), loadXts)
gaugeNames <- lapply(timeSeries, names)
gaugeNames
```

```
## [[1]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[2]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
##
## [[3]]
##  [1] "Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow"
##  [2] "Gauge.039...GS915203A.Downstream.Flow.Flow"
##  [3] "Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow"
##  [4] "Gauge.004...GS915004A.Downstream.Flow.Flow"
##  [5] "Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow"
##  [6] "Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow"
##  [7] "Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow"
##  [8] "Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow"
##  [9] "Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow"
## [10] "Gauge.300...GS915207A.Downstream.Flow.Flow"
```

```
selectedGauges = gaugeNames[[1]][1:5]
subsetGauges <- function(ts, selectedGauges) {
    ts[, selectedGauges]
}
timeSeriesSubset <- lapply(timeSeries, subsetGauges, selectedGauges)
```

It looks like the second and third are matches, i.e.:

```
c(baseFiles[c(51)], develFiles[1])
```

```
## [1]
"X:/ScenarioB//Flinders_runfolders/run_rep_0047_scenarioA_wrpnores_v143_20131811_220632_2934/postpro
## [2]
"X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_baseline_noensemble_0000_scenarioA_
Splitter_threshold0_20133110_123227_21993/postprocess/results_20133110_123227_21993_Gauge_daily.csv.
```

So let's roll the stats (circa 15 sec per file, expect around 25 minutes runtime). Given the considerable runtime, this is important to have a caching mechanism i.e. saving the result to an RData file. The file is only 2MB so it is worth caching.

```
scenarioFolders <- c("Flinders_runfolders", "splitter_ensembles")
scenarioTags <- c("base", "dev")

statFile <- "Z:/GARA/2_Rivers/4_Working/per202/OConnoll/EnsFiles.RData"
stopifnot(file.exists(dirname(statFile)))

if (!file.exists(statFile)) {
    statList <- univStatsMultiScenario(c(baseFiles, develFiles), scenarioFolders,
        scenarioTags)
    save(statList, file = statFile)
} else {
    load(statFile)
}
```

```
## [1] "2013-11-21 14:58:26
X:/ScenarioB//Flinders_runfolders/run_baseline_noensemble_0000_scenarioA_wrpnores_v143_20131809_1610

## [1] "2013-11-21 14:58:37
X:/ScenarioB//Flinders_runfolders/run_baseline_noensemble_0000_scenarioCdry_wrpnores_v143_20131809_1

## [1] "2013-11-21 14:58:48
X:/ScenarioB//Flinders_runfolders/run_baseline_noensemble_0000_scenarioCmid_wrpnores_v143_20131809_1

## [1] "2013-11-21 14:58:58
X:/ScenarioB//Flinders_runfolders/run_baseline_noensemble_0000_scenarioCwet_wrpnores_v143_20131809_1

## [1] "2013-11-21 14:59:09
X:/ScenarioB//Flinders_runfolders/run_rep_0001_scenarioA_wrpnores_v143_20131811_150355_18492/postpro

## [1] "2013-11-21 14:59:19
X:/ScenarioB//Flinders_runfolders/run_rep_0002_scenarioA_wrpnores_v143_20131811_150357_18498/postpro

## [1] "2013-11-21 14:59:30
X:/ScenarioB//Flinders_runfolders/run_rep_0003_scenarioA_wrpnores_v143_20131811_150400_18505/postpro

## [1] "2013-11-21 14:59:41
X:/ScenarioB//Flinders_runfolders/run_rep_0004_scenarioA_wrpnores_v143_20131811_150402_18511/postpro

## [1] "2013-11-21 14:59:53
X:/ScenarioB//Flinders_runfolders/run_rep_0005_scenarioA_wrpnores_v143_20131811_150404_18518/postpro

## [1] "2013-11-21 15:00:04
X:/ScenarioB//Flinders_runfolders/run_rep_0006_scenarioA_wrpnores_v143_20131811_150405_18524/postpro

## [1] "2013-11-21 15:00:15
X:/ScenarioB//Flinders_runfolders/run_rep_0007_scenarioA_wrpnores_v143_20131811_150407_18531/postpro

## [1] "2013-11-21 15:00:26
X:/ScenarioB//Flinders_runfolders/run_rep_0008_scenarioA_wrpnores_v143_20131811_150409_18538/postpro

## [1] "2013-11-21 15:00:37
X:/ScenarioB//Flinders_runfolders/run_rep_0009_scenarioA_wrpnores_v143_20131811_150411_18544/postpro

## [1] "2013-11-21 15:00:48
X:/ScenarioB//Flinders_runfolders/run_rep_0010_scenarioA_wrpnores_v143_20131811_150413_18551/postpro

## [1] "2013-11-21 15:00:59
X:/ScenarioB//Flinders_runfolders/run_rep_0011_scenarioA_wrpnores_v143_20131811_150415_18557/postpro

## [1] "2013-11-21 15:01:10
X:/ScenarioB//Flinders_runfolders/run_rep_0012_scenarioA_wrpnores_v143_20131811_150417_18564/postpro

## [1] "2013-11-21 15:01:22
X:/ScenarioB//Flinders_runfolders/run_rep_0013_scenarioA_wrpnores_v143_20131811_150420_18570/postpro

## [1] "2013-11-21 15:01:33
X:/ScenarioB//Flinders_runfolders/run_rep_0014_scenarioA_wrpnores_v143_20131811_150421_18577/postpro

## [1] "2013-11-21 15:01:44
X:/ScenarioB//Flinders_runfolders/run_rep_0015_scenarioA_wrpnores_v143_20131811_150423_18583/postpro

## [1] "2013-11-21 15:01:55
X:/ScenarioB//Flinders_runfolders/run_rep_0016_scenarioA_wrpnores_v143_20131811_150425_18590/postpro

## [1] "2013-11-21 15:02:06
X:/ScenarioB//Flinders_runfolders/run_rep_0017_scenarioA_wrpnores_v143_20131811_150427_18596/postpro

## [1] "2013-11-21 15:02:17
X:/ScenarioB//Flinders_runfolders/run_rep_0018_scenarioA_wrpnores_v143_20131811_150429_18603/postpro

## [1] "2013-11-21 15:02:34
X:/ScenarioB//Flinders_runfolders/run_rep_0019_scenarioA_wrpnores_v143_20131811_150431_18609/postpro

## [1] "2013-11-21 15:02:44
X:/ScenarioB//Flinders_runfolders/run_rep_0020_scenarioA_wrpnores_v143_20131811_150433_18616/postpro

## [1] "2013-11-21 15:02:55
X:/ScenarioB//Flinders_runfolders/run_rep_0021_scenarioA_wrpnores_v143_20131811_150435_18622/postpro

## [1] "2013-11-21 15:03:06
X:/ScenarioB//Flinders_runfolders/run_rep_0022_scenarioA_wrpnores_v143_20131811_150437_18629/postpro
```

```
## [1] "2013-11-21 15:03:17
X:/ScenarioB//Flinders_runfolders/run_rep_0023_scenarioA_wrpnores_v143_20131811_150439_18636/postpro

## [1] "2013-11-21 15:03:27
X:/ScenarioB//Flinders_runfolders/run_rep_0024_scenarioA_wrpnores_v143_20131811_150442_18645/postpro

## [1] "2013-11-21 15:03:37
X:/ScenarioB//Flinders_runfolders/run_rep_0025_scenarioA_wrpnores_v143_20131811_150443_18649/postpro

## [1] "2013-11-21 15:03:48
X:/ScenarioB//Flinders_runfolders/run_rep_0026_scenarioA_wrpnores_v143_20131811_220456_2680/postproc

## [1] "2013-11-21 15:03:59
X:/ScenarioB//Flinders_runfolders/run_rep_0027_scenarioA_wrpnores_v143_20131811_220458_2686/postproc

## [1] "2013-11-21 15:04:10
X:/ScenarioB//Flinders_runfolders/run_rep_0028_scenarioA_wrpnores_v143_20131811_220500_2693/postproc

## [1] "2013-11-21 15:04:20
X:/ScenarioB//Flinders_runfolders/run_rep_0029_scenarioA_wrpnores_v143_20131811_220503_2699/postproc

## [1] "2013-11-21 15:04:30
X:/ScenarioB//Flinders_runfolders/run_rep_0030_scenarioA_wrpnores_v143_20131811_220504_2706/postproc

## [1] "2013-11-21 15:04:41
X:/ScenarioB//Flinders_runfolders/run_rep_0031_scenarioA_wrpnores_v143_20131811_220506_2712/postproc

## [1] "2013-11-21 15:04:52
X:/ScenarioB//Flinders_runfolders/run_rep_0032_scenarioA_wrpnores_v143_20131811_220508_2719/postproc

## [1] "2013-11-21 15:05:03
X:/ScenarioB//Flinders_runfolders/run_rep_0033_scenarioA_wrpnores_v143_20131811_220510_2725/postproc

## [1] "2013-11-21 15:05:13
X:/ScenarioB//Flinders_runfolders/run_rep_0034_scenarioA_wrpnores_v143_20131811_220520_2732/postproc

## [1] "2013-11-21 15:05:23
X:/ScenarioB//Flinders_runfolders/run_rep_0035_scenarioA_wrpnores_v143_20131811_220526_2738/postproc

## [1] "2013-11-21 15:05:33
X:/ScenarioB//Flinders_runfolders/run_rep_0036_scenarioA_wrpnores_v143_20131811_220526_2748/postproc

## [1] "2013-11-21 15:05:43
X:/ScenarioB//Flinders_runfolders/run_rep_0037_scenarioA_wrpnores_v143_20131811_220526_2755/postproc

## [1] "2013-11-21 15:05:54
X:/ScenarioB//Flinders_runfolders/run_rep_0038_scenarioA_wrpnores_v143_20131811_220526_2761/postproc

## [1] "2013-11-21 15:06:04
X:/ScenarioB//Flinders_runfolders/run_rep_0039_scenarioA_wrpnores_v143_20131811_220526_2774/postproc

## [1] "2013-11-21 15:06:15
X:/ScenarioB//Flinders_runfolders/run_rep_0040_scenarioA_wrpnores_v143_20131811_220548_2781/postproc

## [1] "2013-11-21 15:06:26
X:/ScenarioB//Flinders_runfolders/run_rep_0041_scenarioA_wrpnores_v143_20131811_220548_2791/postproc

## [1] "2013-11-21 15:06:36
X:/ScenarioB//Flinders_runfolders/run_rep_0042_scenarioA_wrpnores_v143_20131811_220548_2807/postproc

## [1] "2013-11-21 15:06:47
X:/ScenarioB//Flinders_runfolders/run_rep_0043_scenarioA_wrpnores_v143_20131811_220548_2814/postproc

## [1] "2013-11-21 15:06:58
X:/ScenarioB//Flinders_runfolders/run_rep_0044_scenarioA_wrpnores_v143_20131811_220548_2833/postproc

## [1] "2013-11-21 15:07:09
X:/ScenarioB//Flinders_runfolders/run_rep_0045_scenarioA_wrpnores_v143_20131811_220550_2853/postproc

## [1] "2013-11-21 15:07:19
X:/ScenarioB//Flinders_runfolders/run_rep_0046_scenarioA_wrpnores_v143_20131811_220613_2895/postproc

## [1] "2013-11-21 15:07:30
X:/ScenarioB//Flinders_runfolders/run_rep_0047_scenarioA_wrpnores_v143_20131811_220632_2934/postproc

## [1] "2013-11-21 15:07:40
X:/ScenarioB//Flinders_runfolders/run_rep_0048_scenarioA_wrpnores_v143_20131811_220633_2970/postproc

## [1] "2013-11-21 15:07:50
X:/ScenarioB//Flinders_runfolders/run_rep_0049_scenarioA_wrpnores_v143_20131811_220632_2993/postproc

## [1] "2013-11-21 15:08:01
X:/ScenarioB//Flinders_runfolders/run_rep_0050_scenarioA_wrpnores_v143_20131811_220634_3000/postproc

## [1] "2013-11-21 15:08:11
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_baseline_noensemble_0000_scenarioA_w
Splitter_threshold0_20133110_123227_21993/postprocess/results_20133110_123227_21993_Gauge_daily.csv.

## [1] "2013-11-21 15:08:21
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0001_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_163912_6511/postprocess/results_20130511_163912_6511_Gauge_daily.csv.gz

## [1] "2013-11-21 15:08:32
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0002_scenarioA_wrpnores_v143_OCo
```

```
Splitter_threshold0_20130511_163914_6517/postprocess/results_20130511_163914_6517_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:08:42
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0003_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163916_6524/postprocess/results_20130511_163916_6524_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:08:52
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0004_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163918_6530/postprocess/results_20130511_163918_6530_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:09:02
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0005_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163920_6537/postprocess/results_20130511_163920_6537_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:09:13
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0006_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163922_6543/postprocess/results_20130511_163922_6543_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:09:23
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0007_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163924_6550/postprocess/results_20130511_163924_6550_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:09:34
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0008_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163926_6556/postprocess/results_20130511_163926_6556_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:09:44
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0009_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163928_6563/postprocess/results_20130511_163928_6563_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:09:55
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0010_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163930_6569/postprocess/results_20130511_163930_6569_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:10:06
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0011_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163932_6576/postprocess/results_20130511_163932_6576_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:10:16
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0012_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163934_6582/postprocess/results_20130511_163934_6582_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:10:27
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0013_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163936_6589/postprocess/results_20130511_163936_6589_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:10:37
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0014_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163938_6595/postprocess/results_20130511_163938_6595_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:10:48
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0015_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163940_6602/postprocess/results_20130511_163940_6602_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:10:58
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0016_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163942_6609/postprocess/results_20130511_163942_6609_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:11:09
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0017_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163944_6615/postprocess/results_20130511_163944_6615_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:11:19
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0018_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163946_6622/postprocess/results_20130511_163946_6622_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:11:30
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0019_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163948_6628/postprocess/results_20130511_163948_6628_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:11:41
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0020_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163950_6635/postprocess/results_20130511_163950_6635_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:11:52
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0021_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163952_6641/postprocess/results_20130511_163952_6641_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:12:02
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0022_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163954_6648/postprocess/results_20130511_163954_6648_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:12:13
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0023_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163956_6654/postprocess/results_20130511_163956_6654_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:12:24
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0024_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_163958_6661/postprocess/results_20130511_163958_6661_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:12:34
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0025_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_164000_6667/postprocess/results_20130511_164000_6667_Gauge_daily.csv.gz'
```

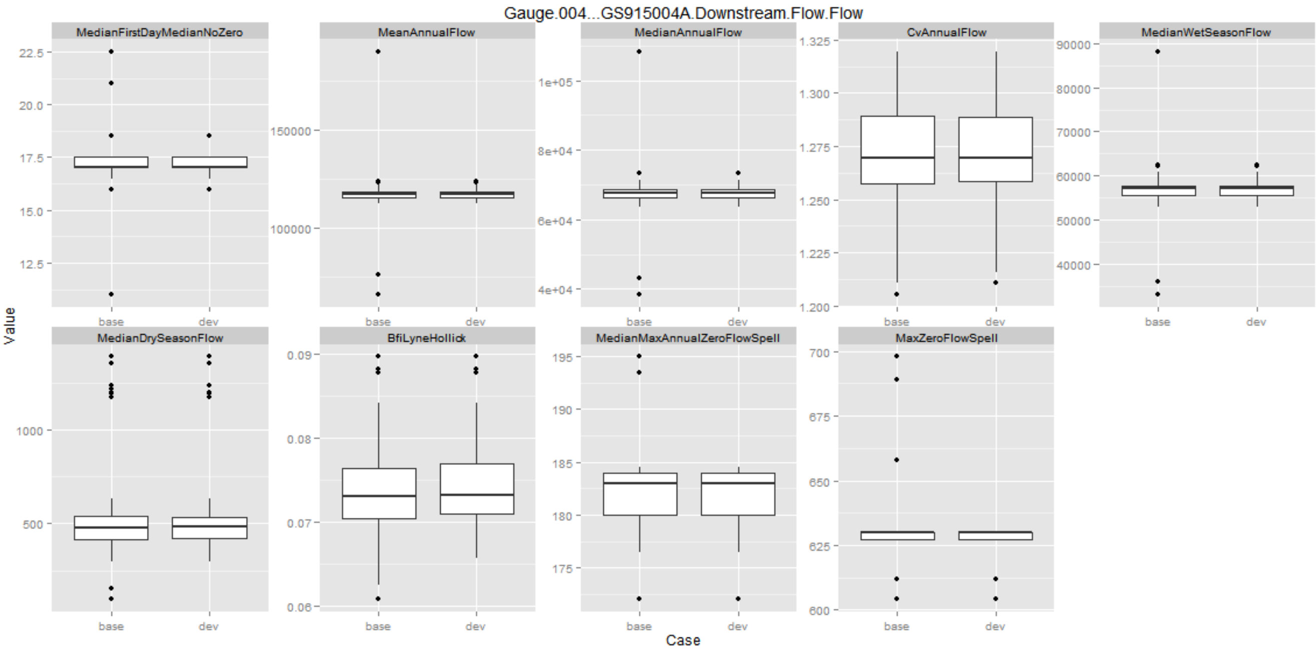
```
## [1] "2013-11-21 15:12:45
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0026_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222613_8967/postprocess/results_20130511_222613_8967_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:12:55
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0027_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222615_8974/postprocess/results_20130511_222615_8974_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:13:05
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0028_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222617_8980/postprocess/results_20130511_222617_8980_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:13:16
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0029_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222619_8987/postprocess/results_20130511_222619_8987_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:13:26
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0030_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222621_8993/postprocess/results_20130511_222621_8993_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:13:36
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0031_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222623_9000/postprocess/results_20130511_222623_9000_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:13:47
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0032_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222625_9006/postprocess/results_20130511_222625_9006_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:13:58
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0033_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222627_9013/postprocess/results_20130511_222627_9013_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:14:08
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0034_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222629_9019/postprocess/results_20130511_222629_9019_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:14:19
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0035_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222631_9026/postprocess/results_20130511_222631_9026_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:14:30
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0036_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222633_9033/postprocess/results_20130511_222633_9033_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:14:40
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0037_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222635_9039/postprocess/results_20130511_222635_9039_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:14:51
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0038_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222637_9046/postprocess/results_20130511_222637_9046_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:15:01
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0039_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222639_9052/postprocess/results_20130511_222639_9052_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:15:11
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0040_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222641_9059/postprocess/results_20130511_222641_9059_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:15:21
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0041_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222643_9065/postprocess/results_20130511_222643_9065_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:15:31
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0042_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222645_9072/postprocess/results_20130511_222645_9072_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:15:42
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0043_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222647_9078/postprocess/results_20130511_222647_9078_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:15:52
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0044_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222649_9085/postprocess/results_20130511_222649_9085_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:16:03
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0045_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222651_9091/postprocess/results_20130511_222651_9091_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:16:13
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0046_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222653_9098/postprocess/results_20130511_222653_9098_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:16:24
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0047_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222655_9104/postprocess/results_20130511_222655_9104_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:16:34
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0048_scenarioA_wrpnores_v143_OCo
Splitter_threshold0_20130511_222657_9111/postprocess/results_20130511_222657_9111_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:16:44
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0049_scenarioA_wrpnores_v143_OCo
```

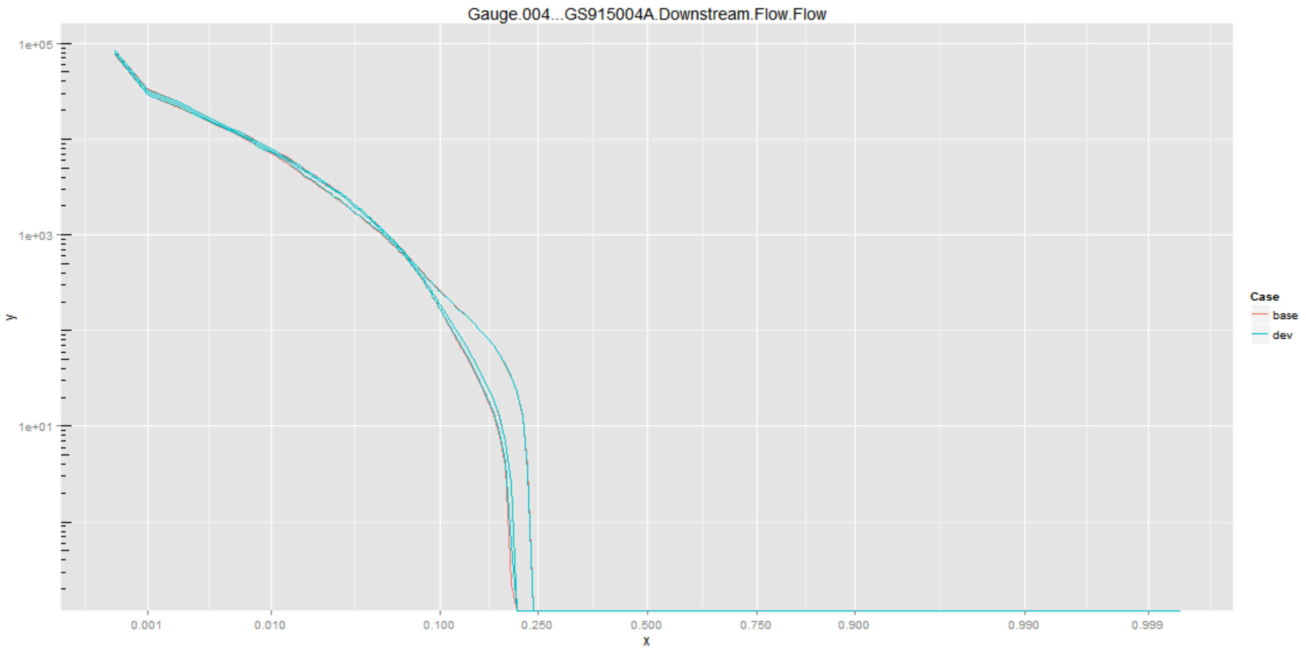
```
Splitter_threshold0_20130511_222659_9117/postprocess/results_20130511_222659_9117_Gauge_daily.csv.gz'

## [1] "2013-11-21 15:16:54
X:/6_Oconnell/_Source_projects_packaged/splitter_ensembles//run_rep_0050_scenarioA_wrpnores_v143_OCon
Splitter_threshold0_20130511_222701_9124/postprocess/results_20130511_222701_9124_Gauge_daily.csv.gz'
```

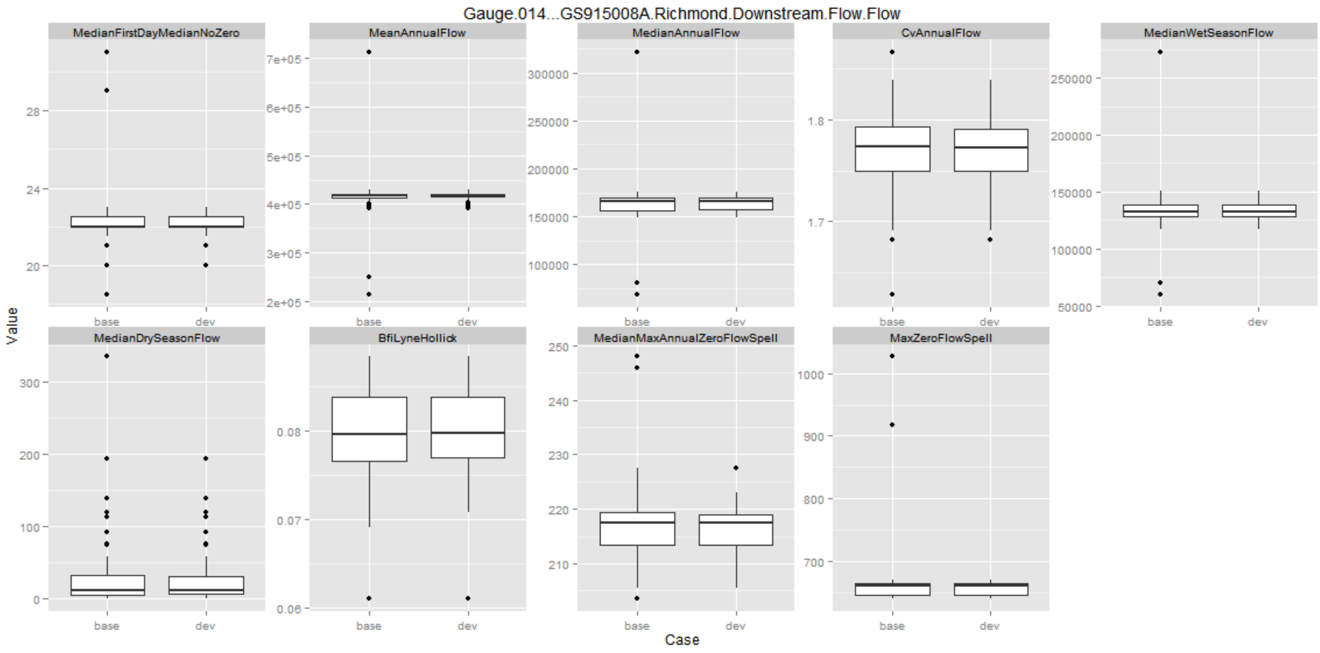
Visualization

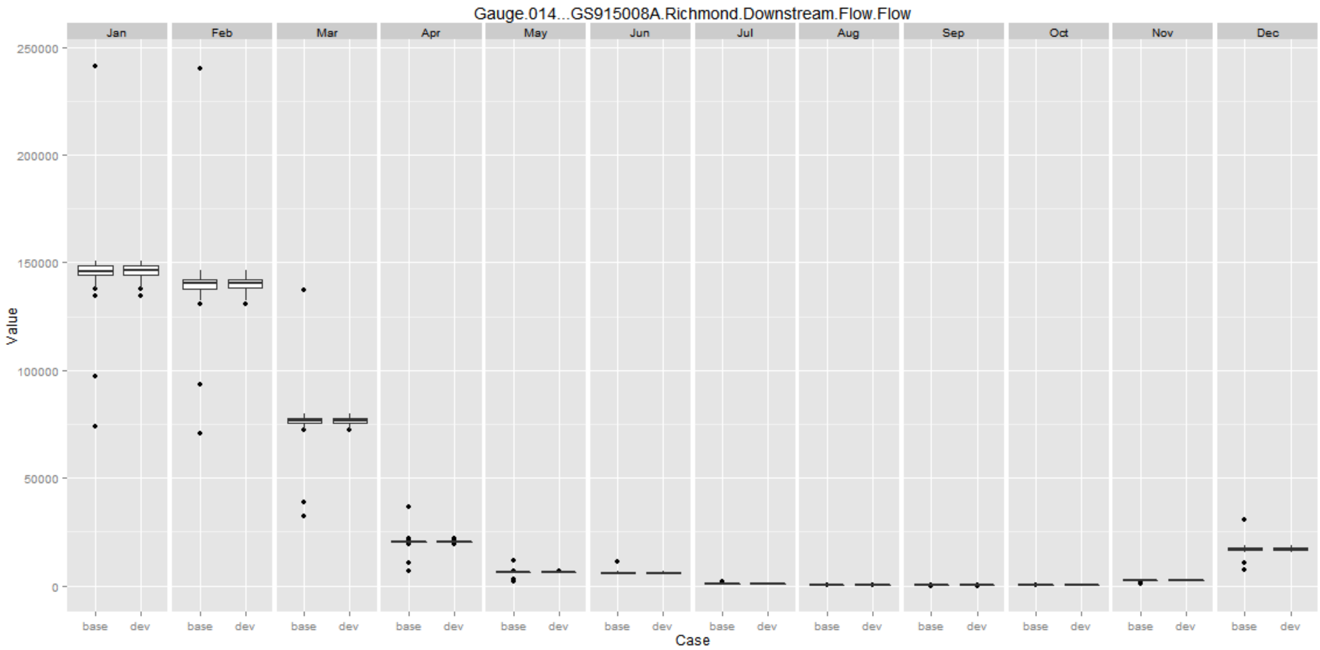
The visualization itself is not all that comsuming.

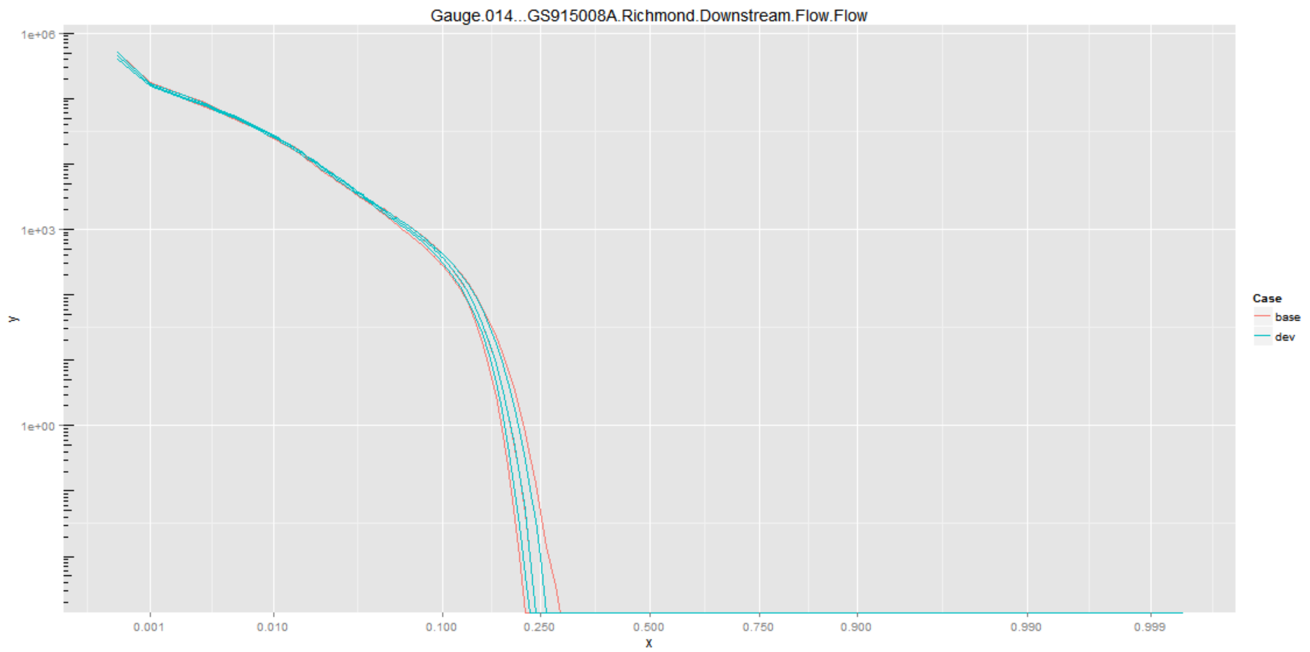
```
d <- listByGauge(rbind(statList[[c(1, 1)]], statList[[c(2, 1)]]))
mthFlows <- listByGauge(rbind(statList[[c(1, 2)]], statList[[c(2, 2)]]))
fdcData <- listByGauge(rbind(statList[[c(1, 3)]], statList[[c(2, 3)]]))
for (gaugename in names(d)) {
    print(getBoxplotsUniv(d[[gaugename]]) + ggtitle(gaugename))
    print(getBoxplotsMthly(mthFlows[[gaugename]], gaugename))
    print(getPlotFdc(fdcData[[gaugename]], gaugename))
    # print(getPlotFdcNormal(fdcData[[gaugename]], gaugename))
}
```

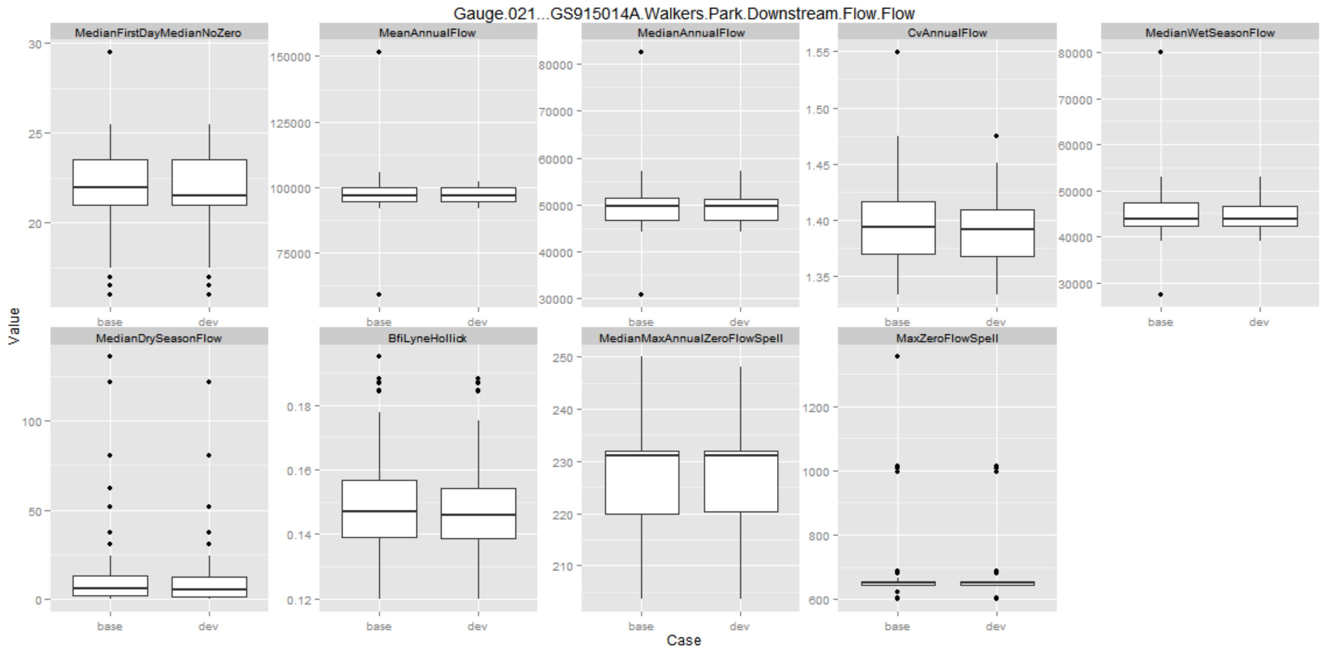


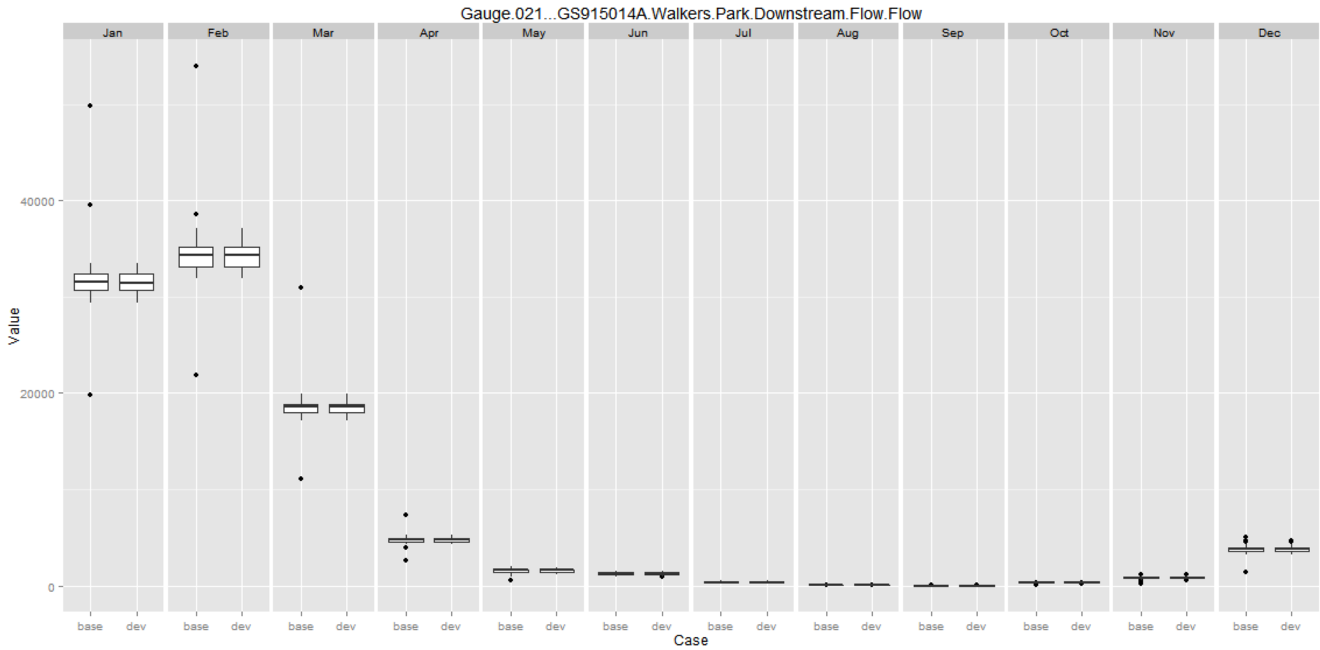


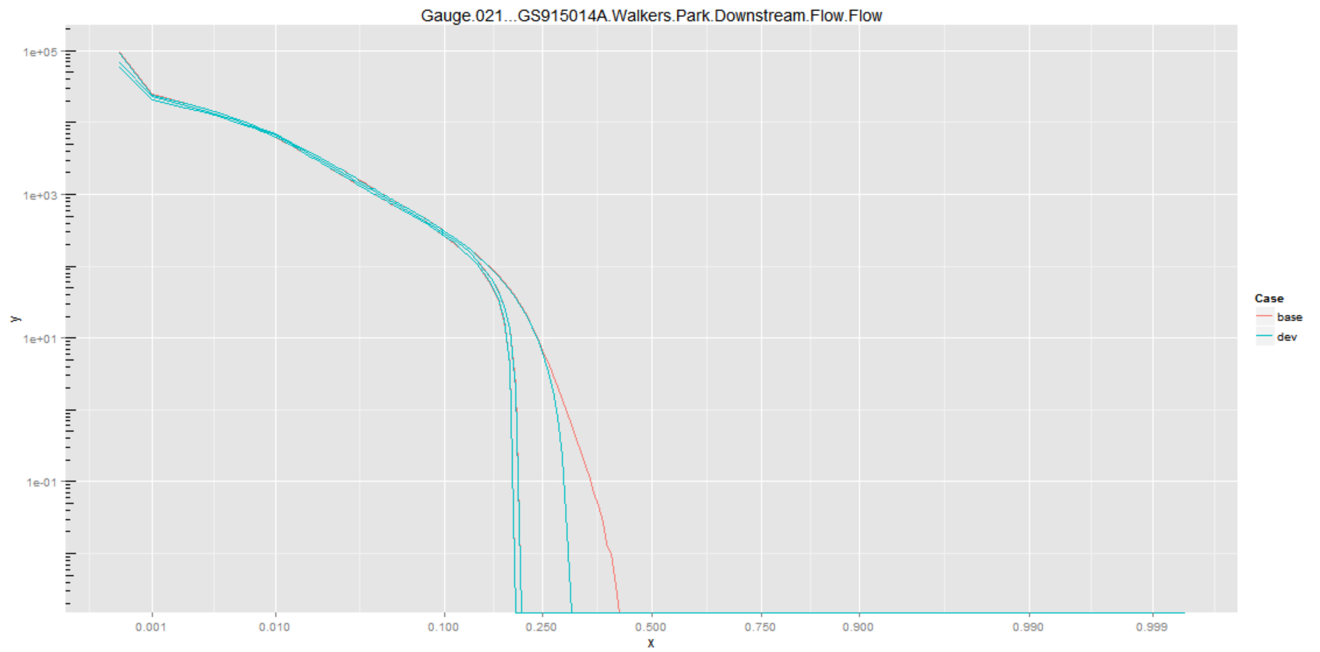

Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

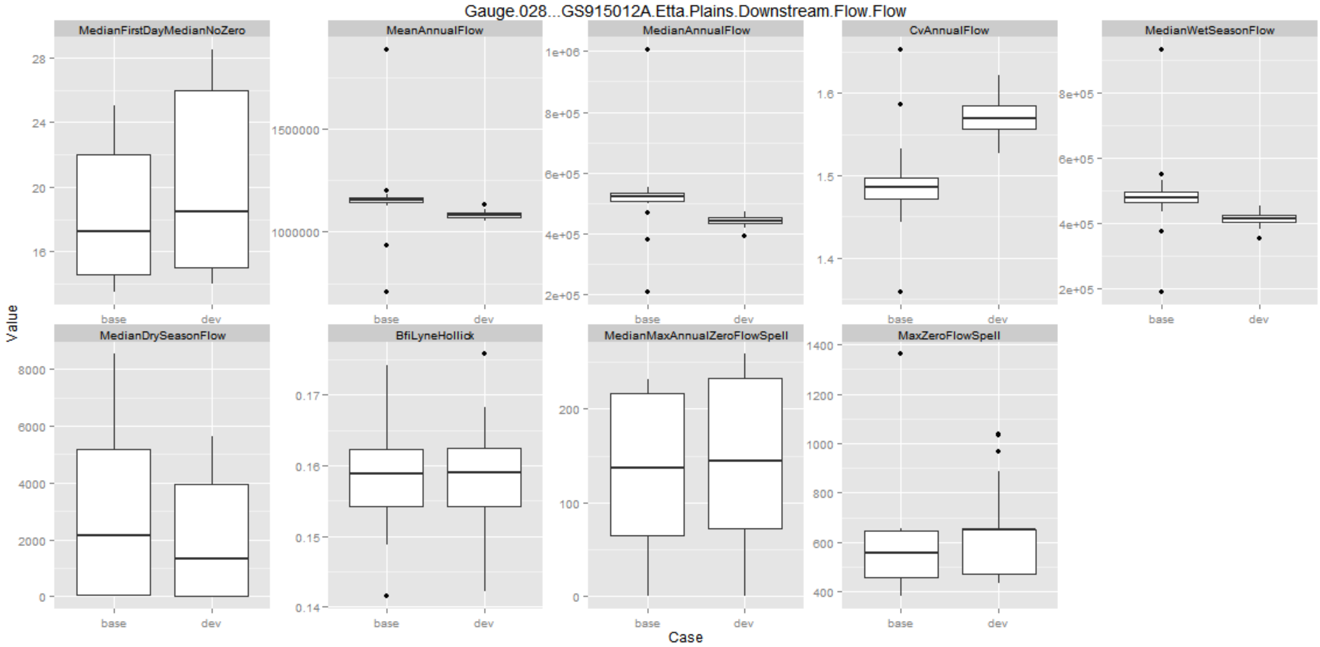

Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

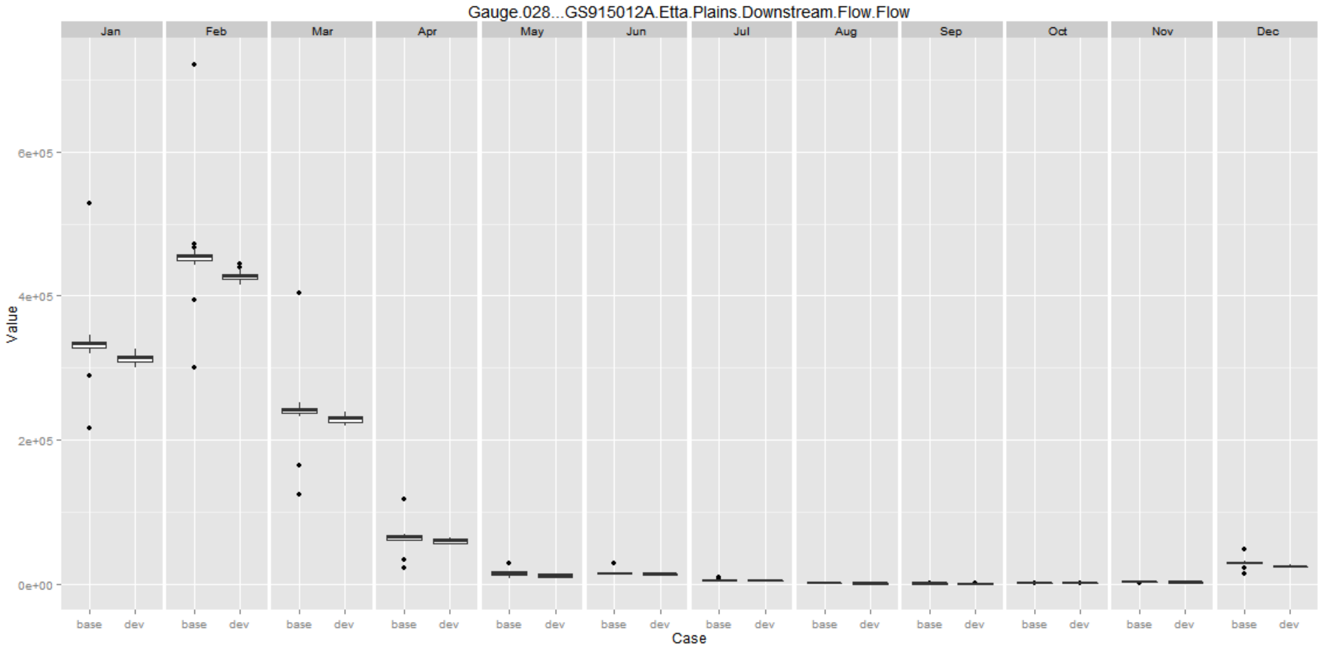

Gauge.014...GS915008A.Richmond.Downstream.Flow.Flow
y
x
Case
base
dev

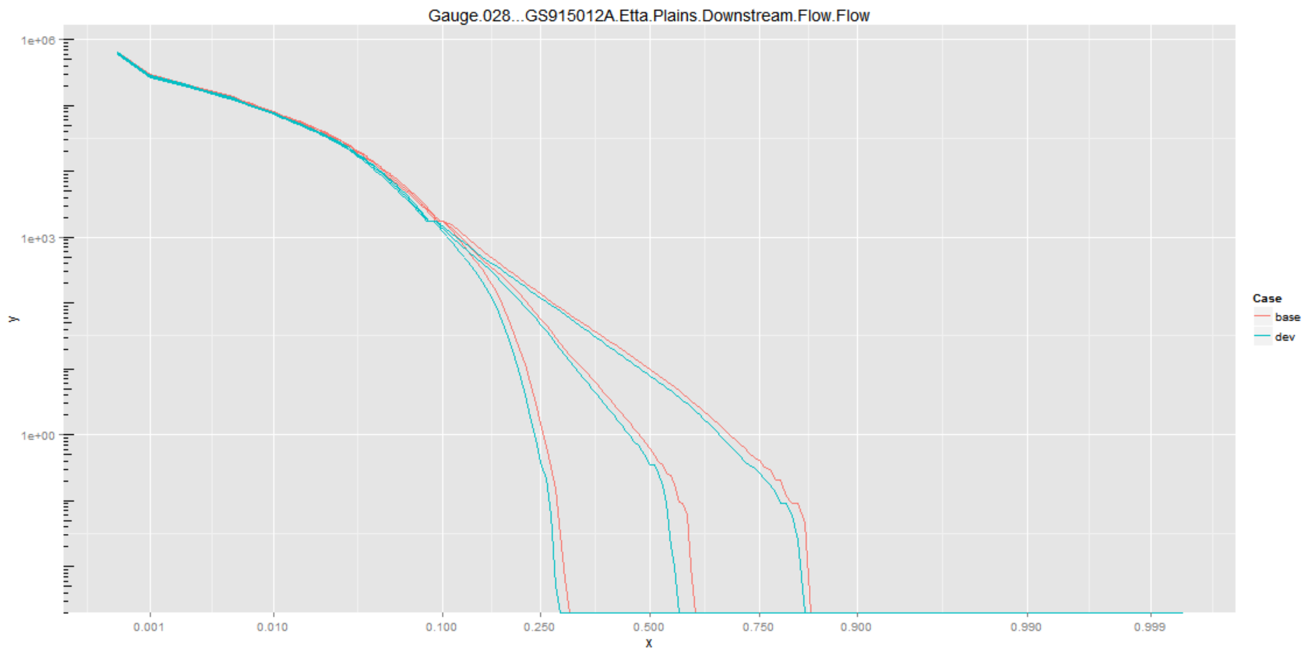

Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev

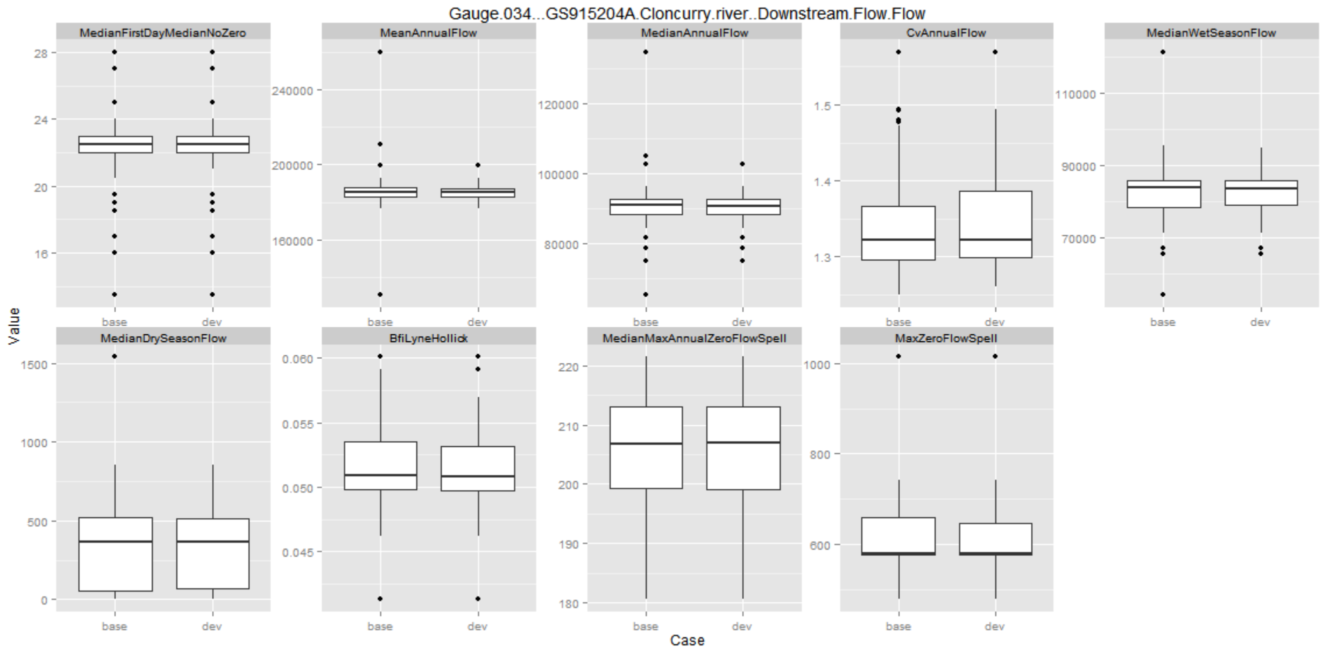

Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev

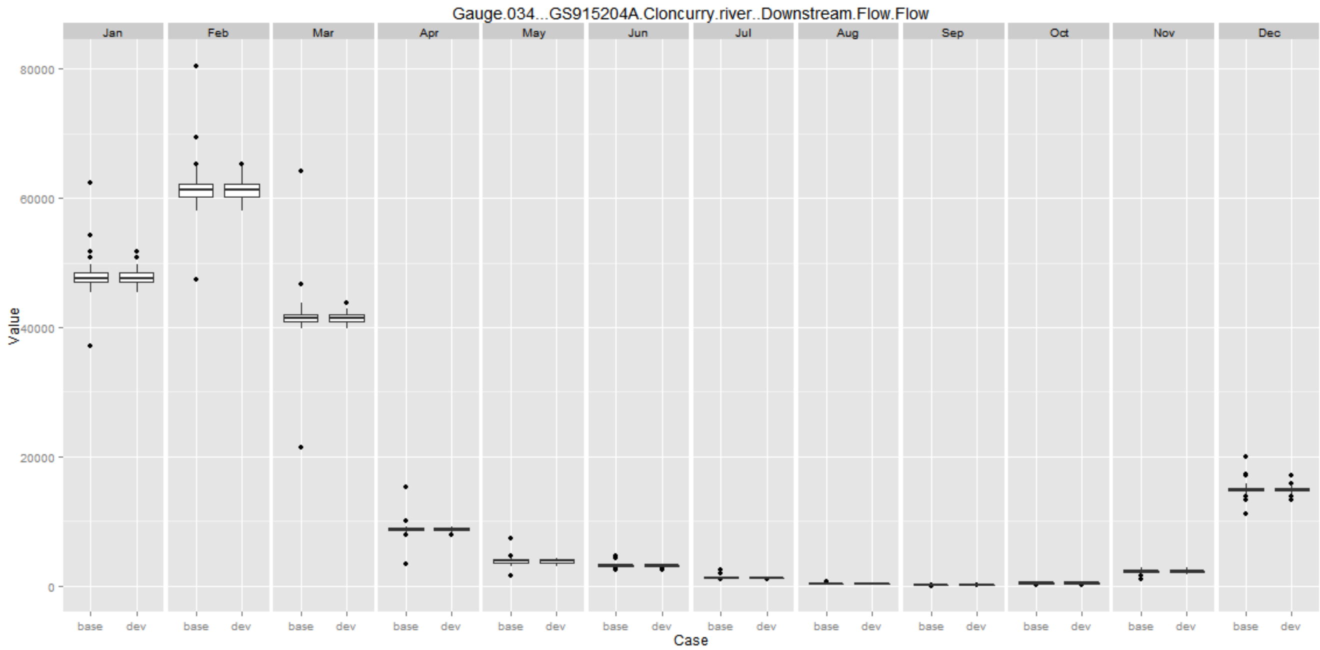

Gauge.021...GS915014A.Walkers.Park.Downstream.Flow.Flow
y
x
Case
base
dev


Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev


Gauge.028...GS915012A.Etta.Plains.Downstream.Flow.Flow
y
x
Case
base
dev


Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow
Jan
Feb
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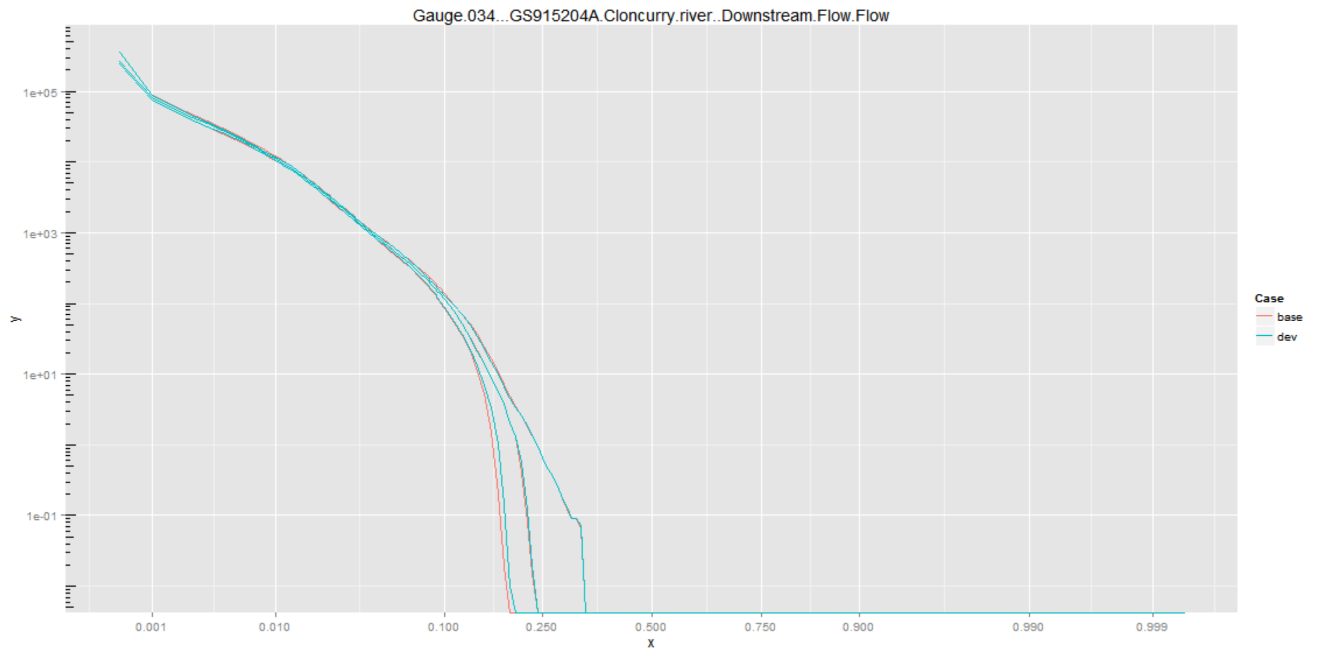
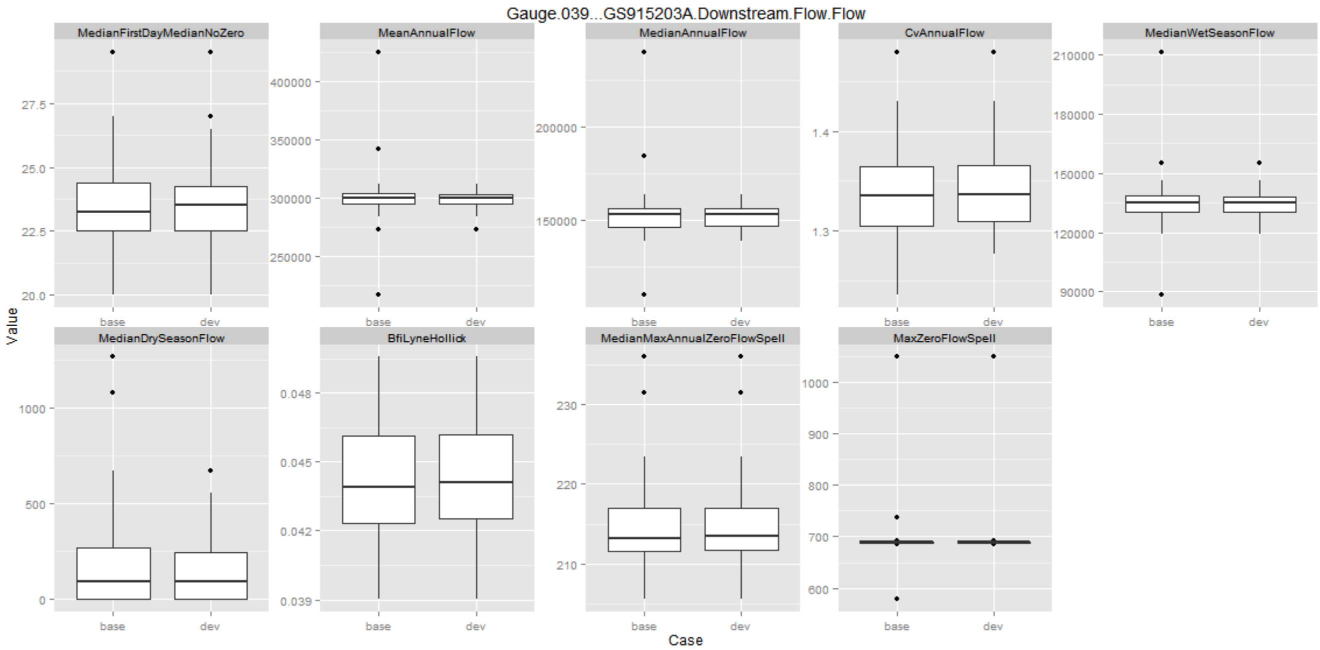
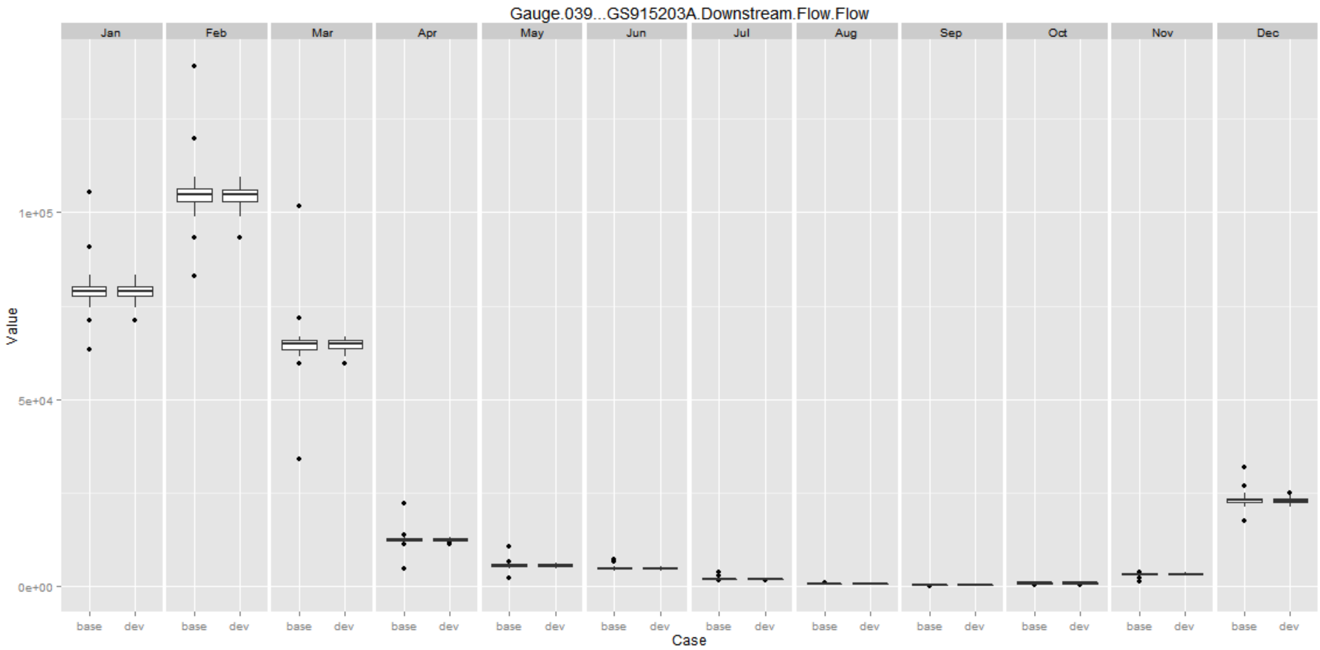
Dec
Value
Case
base
dev


Gauge.034...GS915204A.Cloncurry.river..Downstream.Flow.Flow
y
x
Case
base
dev



Gauge.039...GS915203A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev



Gauge.039...GS915203A.Downstream.Flow.Flow
Jan
Feb
Mar
Apr
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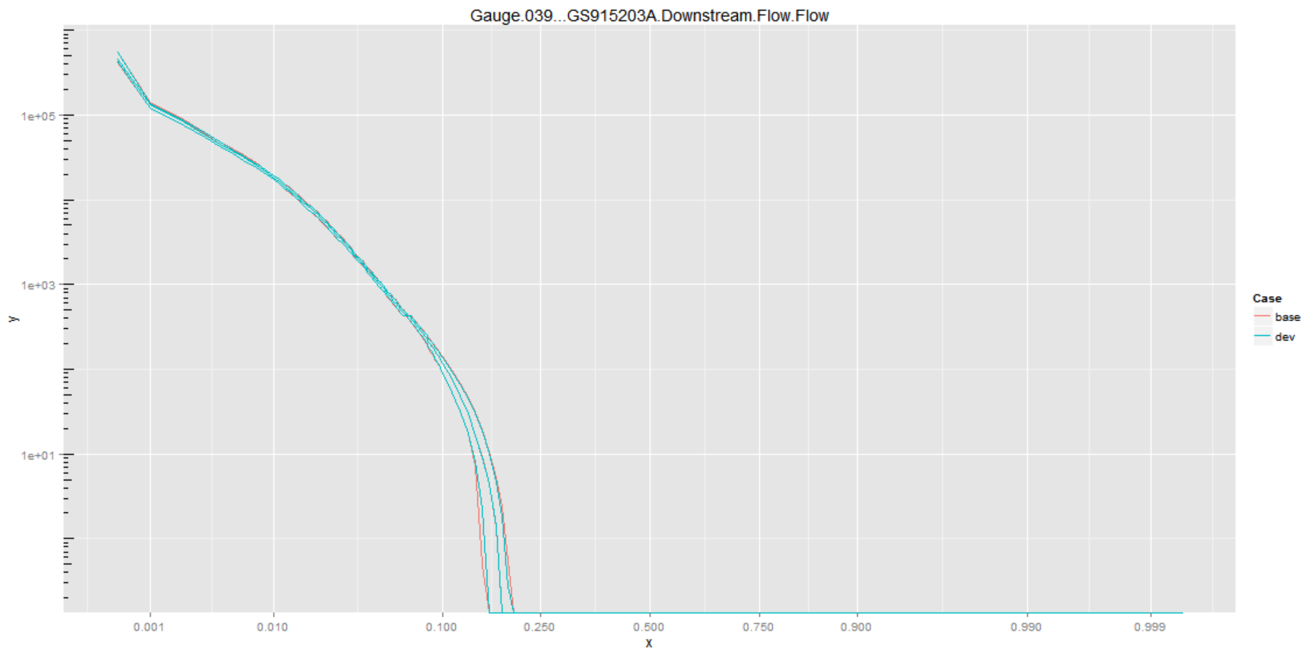
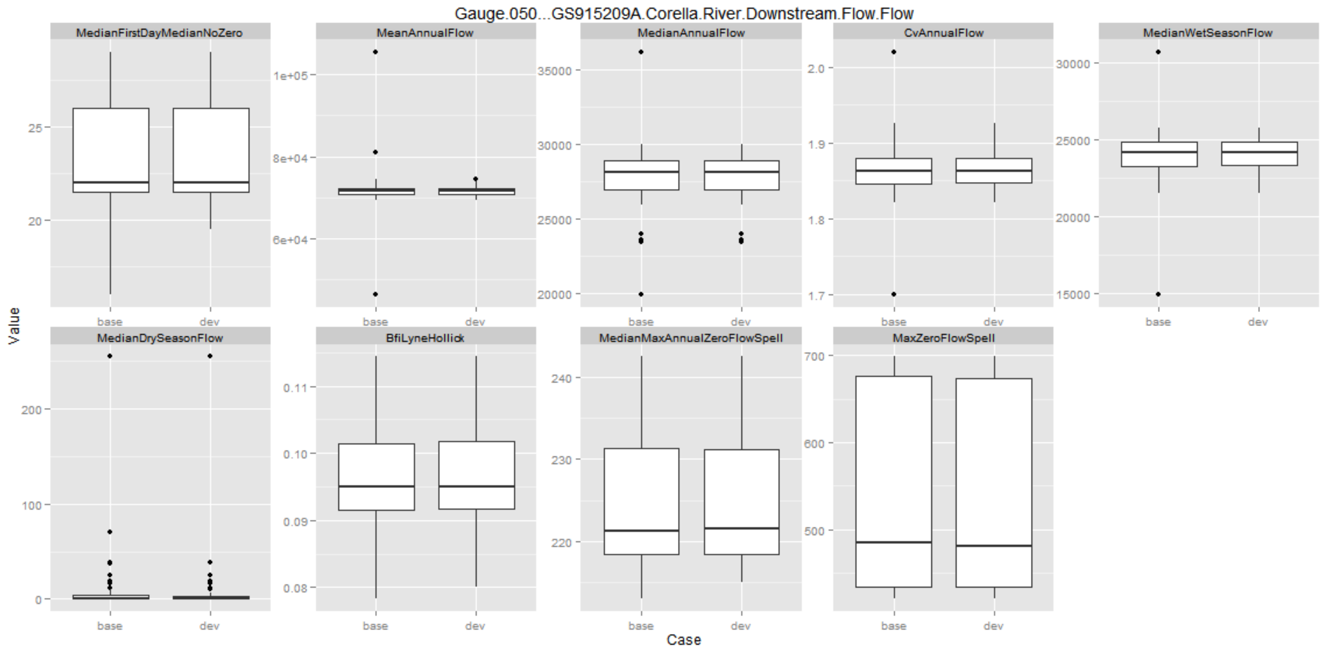
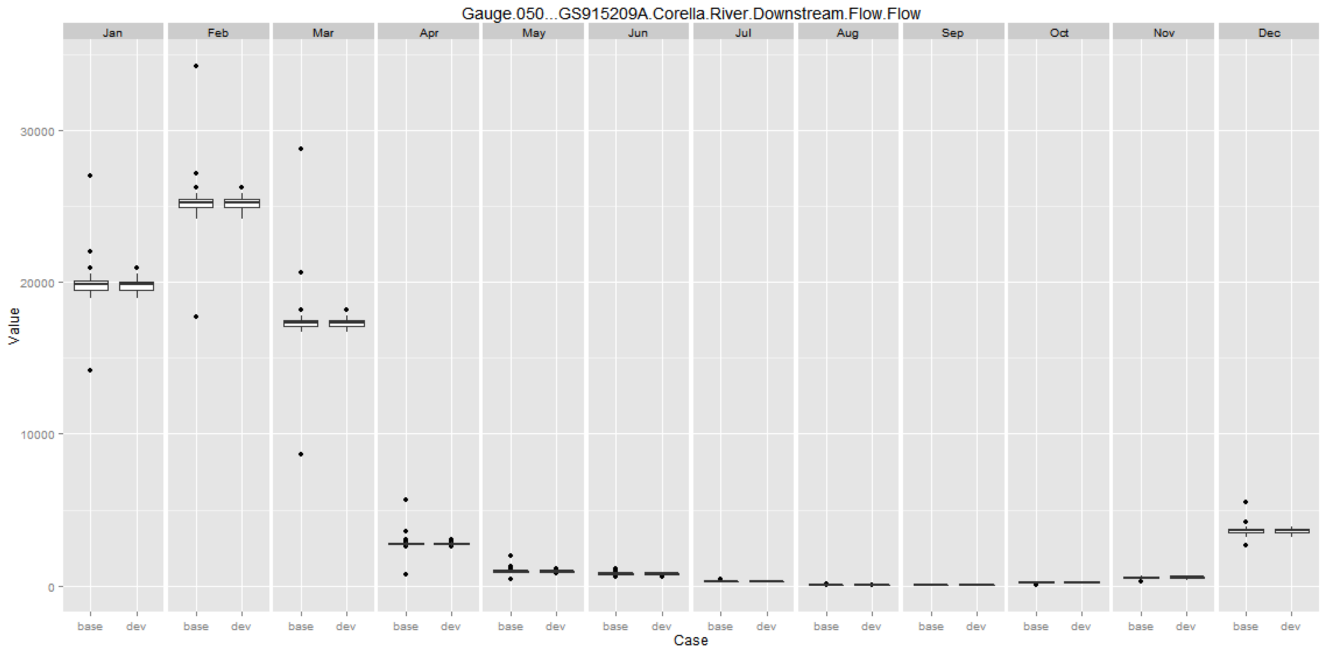
Dec
Value
Case
base
dev



Gauge.039...GS915203A.Downstream.Flow.Flow
y
x
Case
base
dev


Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow
Jan
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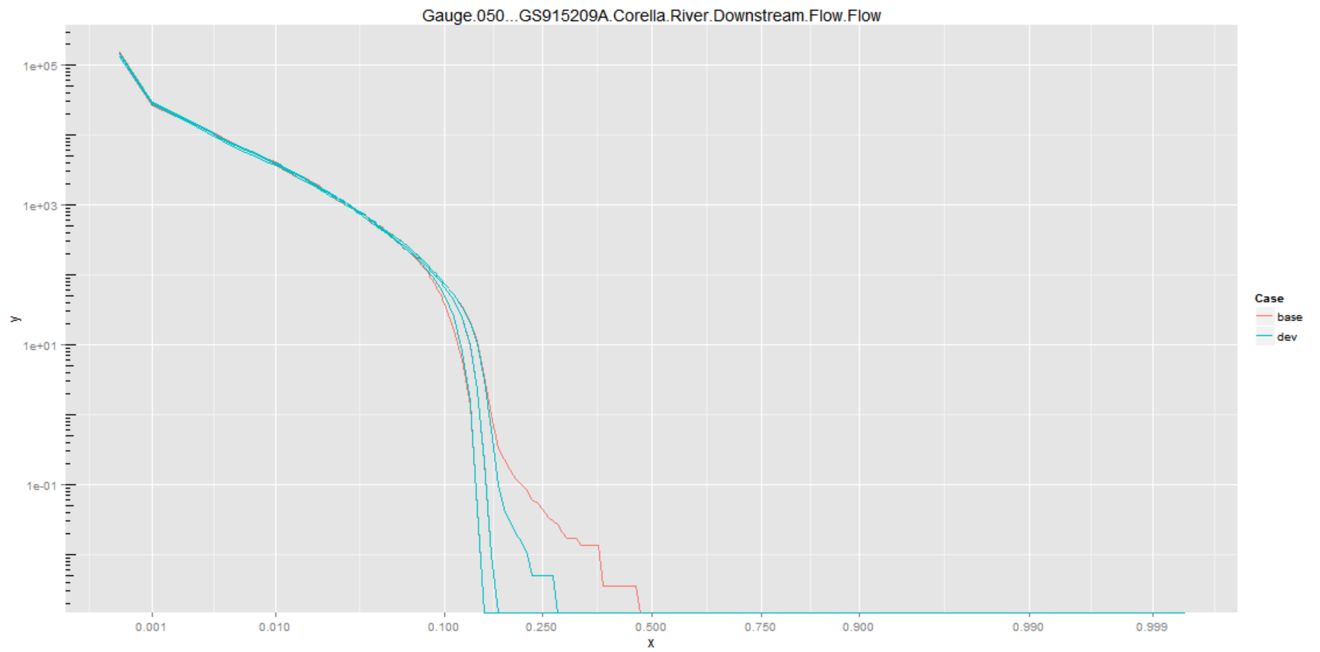
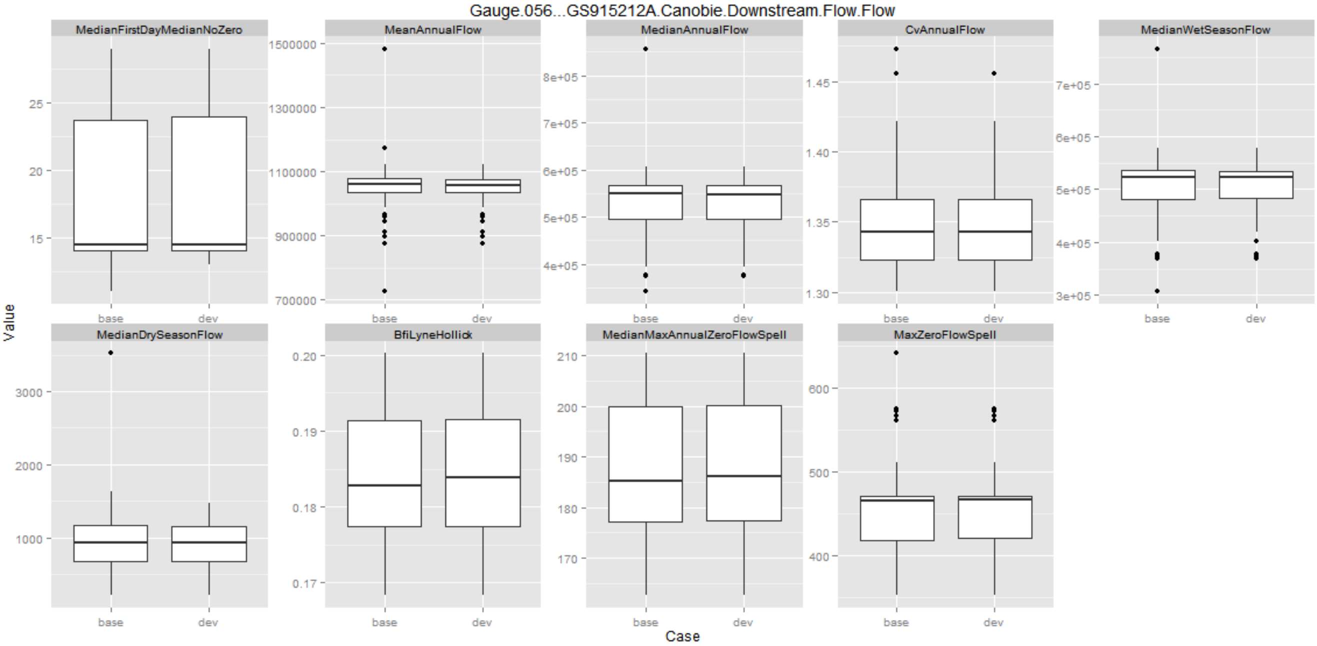
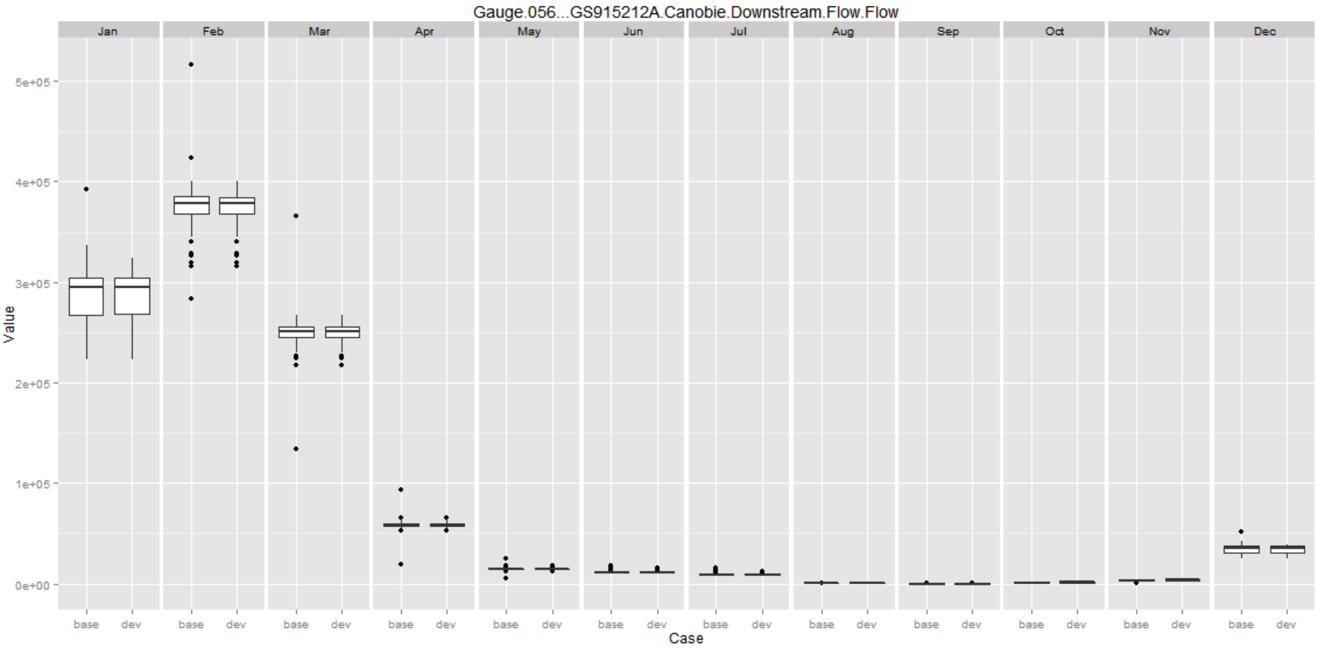
Dec
Value
Case
base
dev


Gauge.050...GS915209A.Corella.River.Downstream.Flow.Flow
y
x
Case
base
dev


Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow
Jan
Feb
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Jul
Aug
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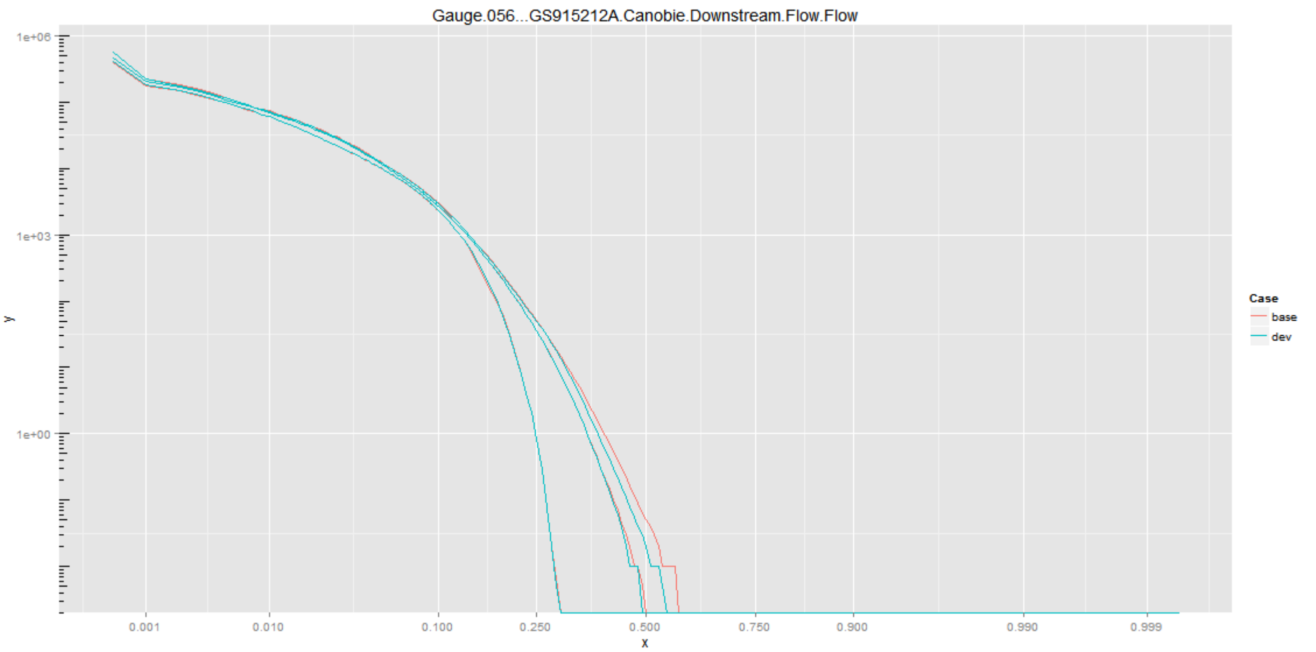
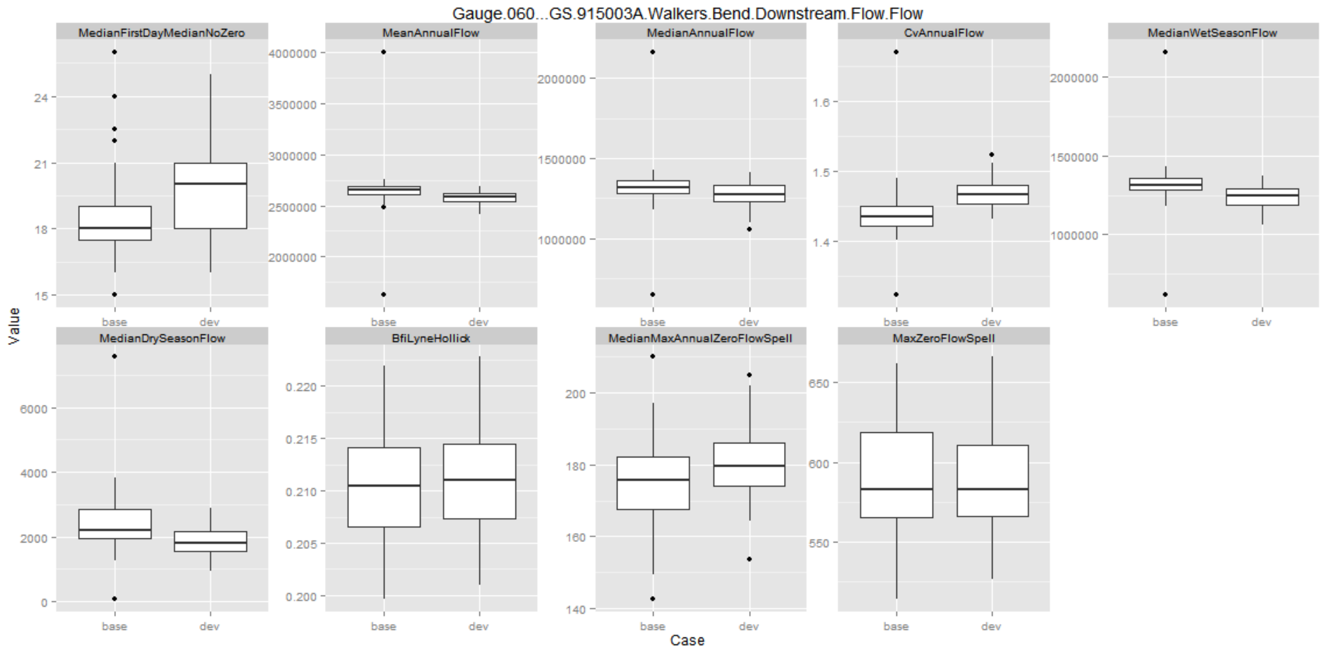
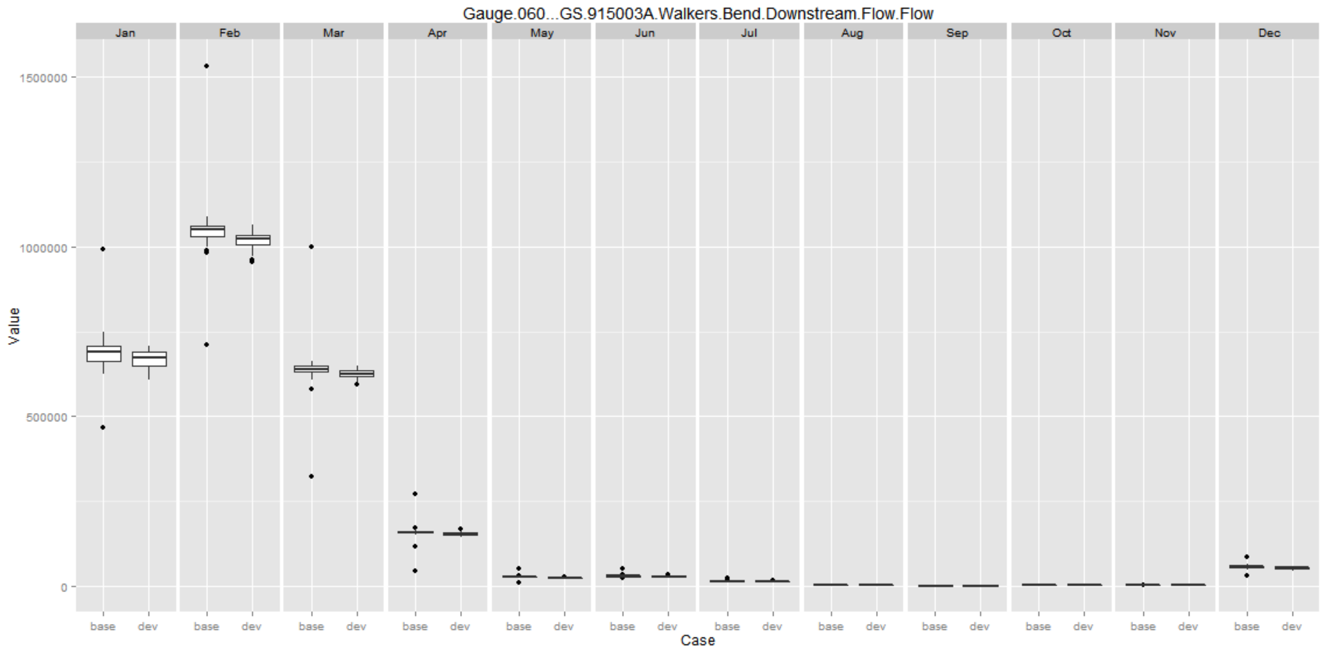
Oct
Nov
Dec
Value
Case
base
dev


Gauge.056...GS915212A.Canobie.Downstream.Flow.Flow
y
x
Case
base
dev


Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev


Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow
Jan
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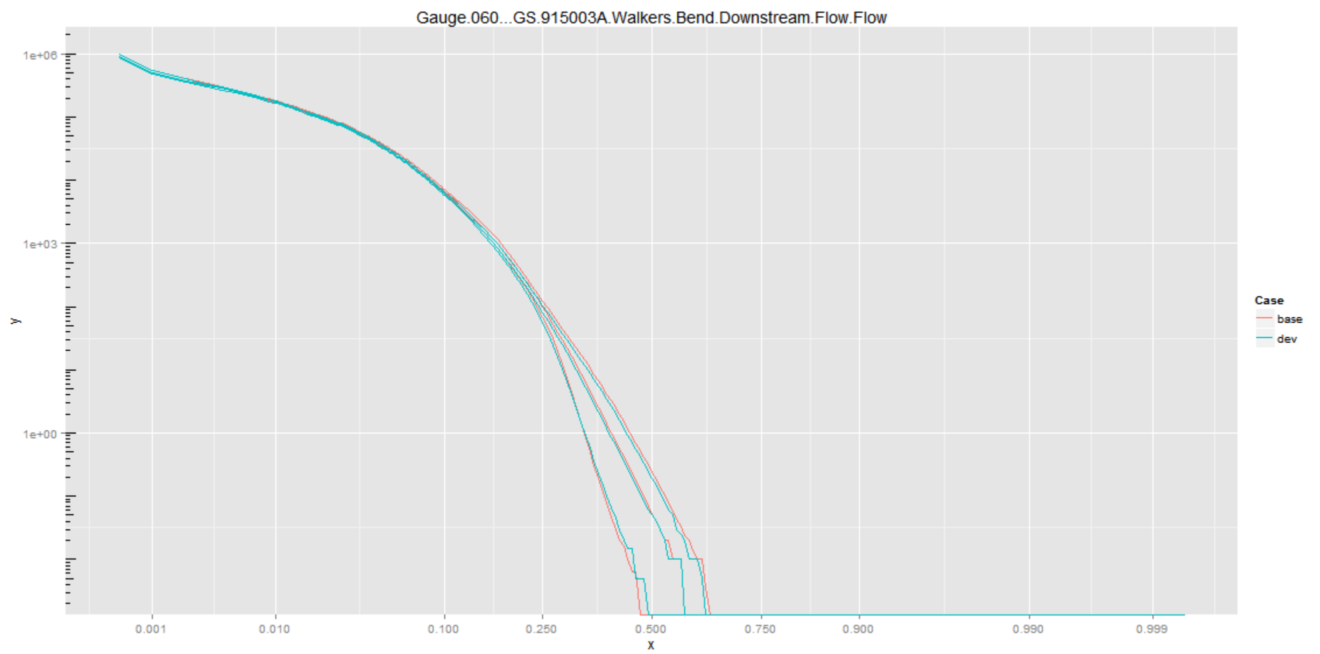
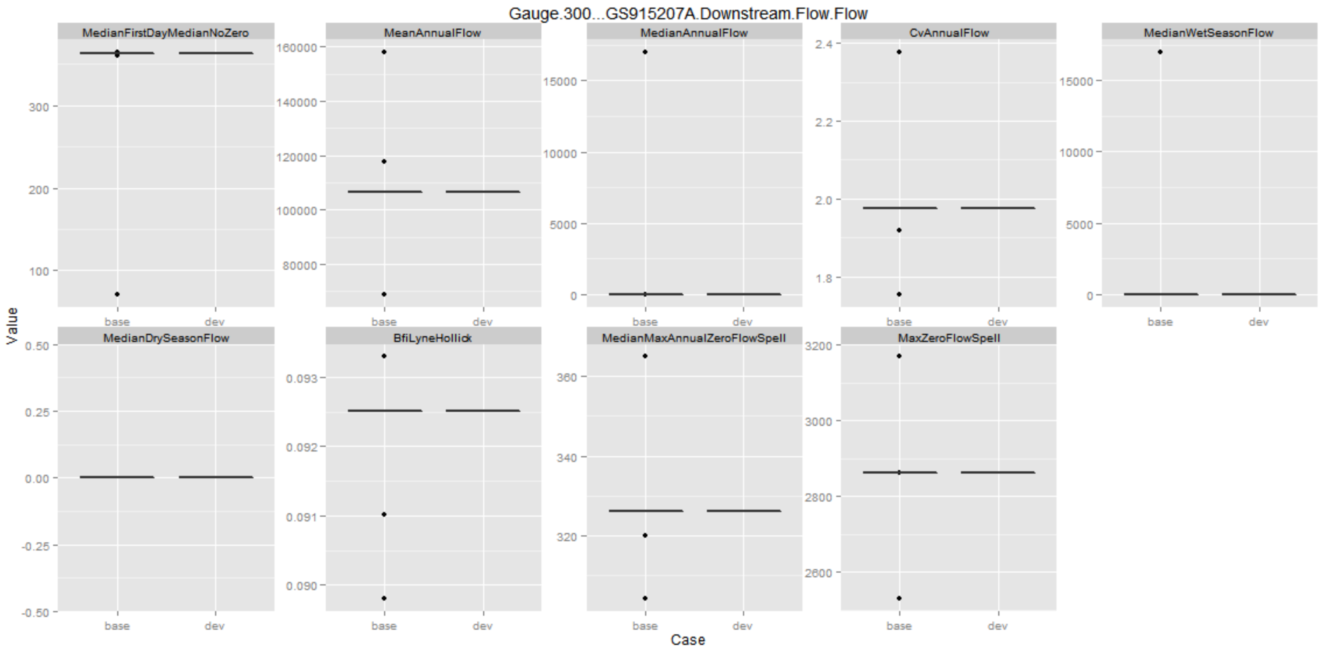
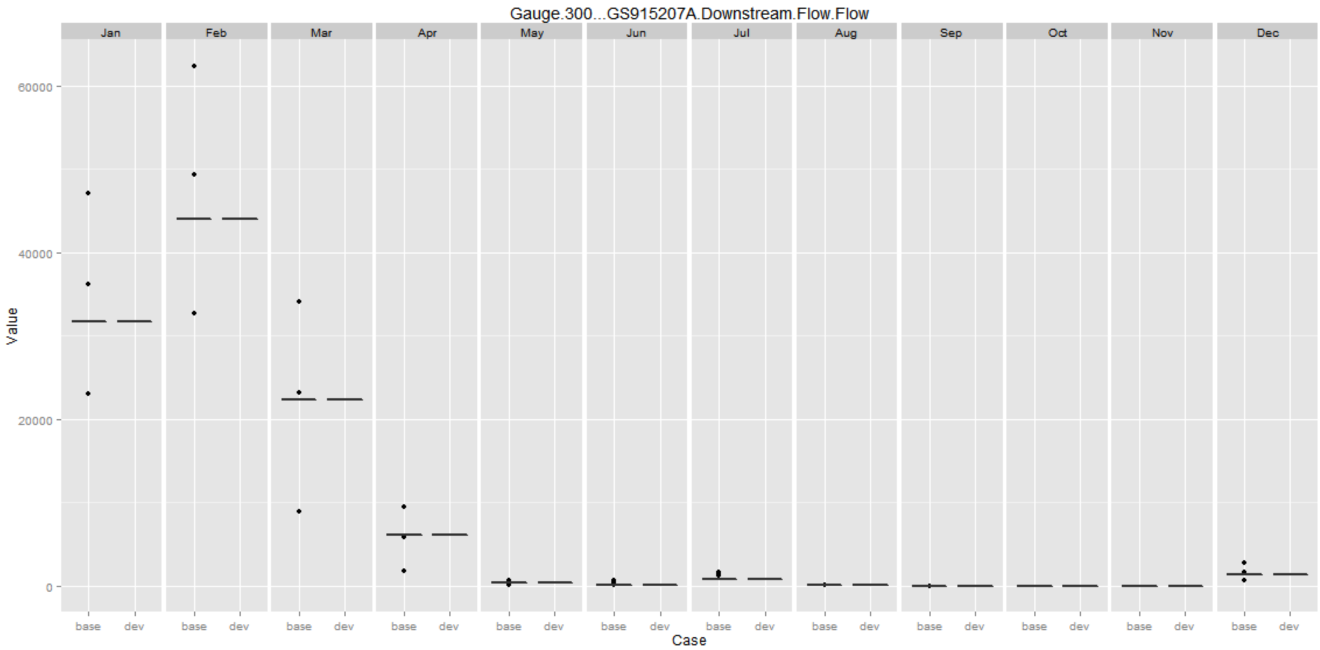
Nov
Dec
Value
Case
base
dev


Gauge.060...GS.915003A.Walkers.Bend.Downstream.Flow.Flow
y
x
Case
base
dev



Gauge.300...GS915207A.Downstream.Flow.Flow
MedianFirstDayMedianNoZero
MeanAnnualFlow
MedianAnnualFlow
CvAnnualFlow
MedianWetSeasonFlow
MedianDrySeasonFlow
BfiLyneHollick
MedianMaxAnnualZeroFlowSpell
MaxZeroFlowSpell
Value
Case
base
dev



Gauge.300...GS915207A.Downstream.Flow.Flow
Jan
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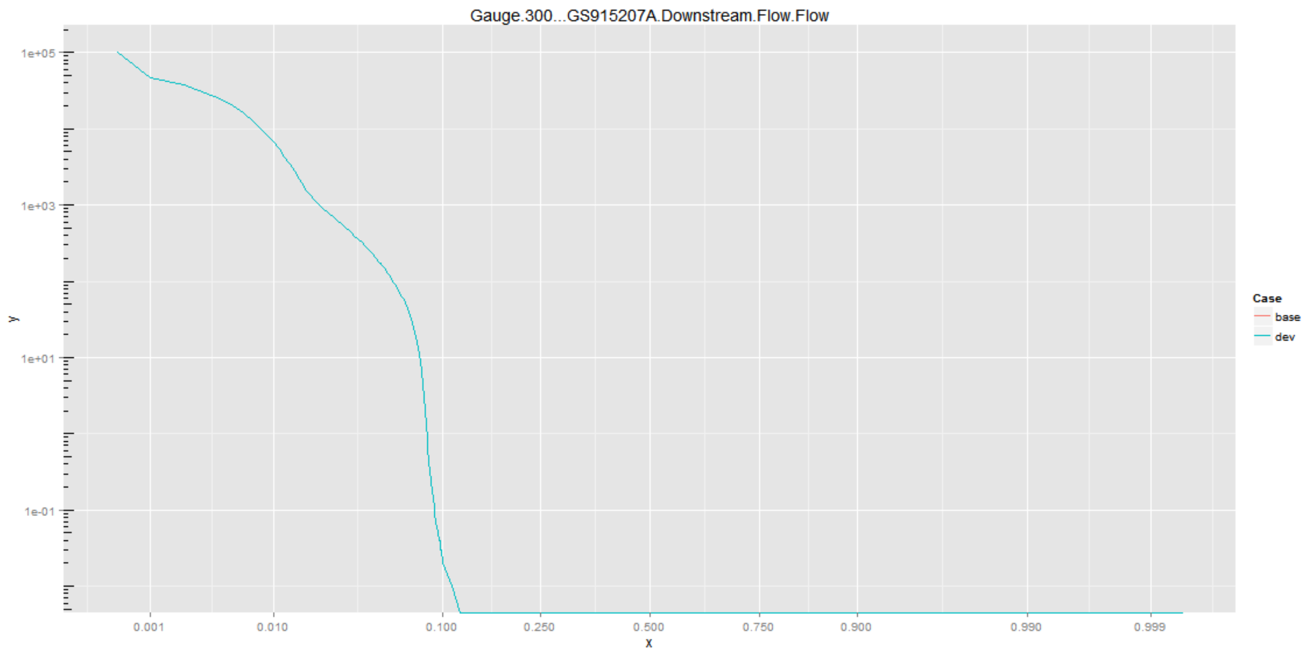
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Value
Case
base
dev



Gauge.300...GS915207A.Downstream.Flow.Flow
y
x
Case
base
dev

Appendix

R session information for the generation of this document:

```
sessionInfo()
```

```
## R version 3.0.1 (2013-05-16)
## Platform: i386-w64-mingw32/i386 (32-bit)
##
## locale:
## [1] LC_COLLATE=English_Australia.1252  LC_CTYPE=English_Australia.1252
## [3] LC_MONETARY=English_Australia.1252 LC_NUMERIC=C
## [5] LC_TIME=English_Australia.1252
##
## attached base packages:
## [1] stats     graphics  grDevices utils     datasets  methods   base
##
## other attached packages:
##  [1] garaHydroMetrics_0.1-4 scales_0.2.3           reshape2_1.2.2
##  [4] lubridate_1.3.1        stringr_0.6.2          ggplot2_0.9.3.1
##  [7] xts_0.9-7              zoo_1.7-10             plyr_1.8
## [10] knitr_1.5
##
## loaded via a namespace (and not attached):
##  [1] colorspace_1.2-4   dichromat_2.0-0    digest_0.6.3
##  [4] evaluate_0.5.1     formatR_0.10       grid_3.0.1
##  [7] gtable_0.1.2       labeling_0.2       lattice_0.20-15
## [10] MASS_7.3-26        munsell_0.4.2      proto_0.3-10
## [13] RColorBrewer_1.0-5 tools_3.0.1
```

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FOR FURTHER INFORMATION

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