How to model impacts of climate change on groundwater systems in South Australia?

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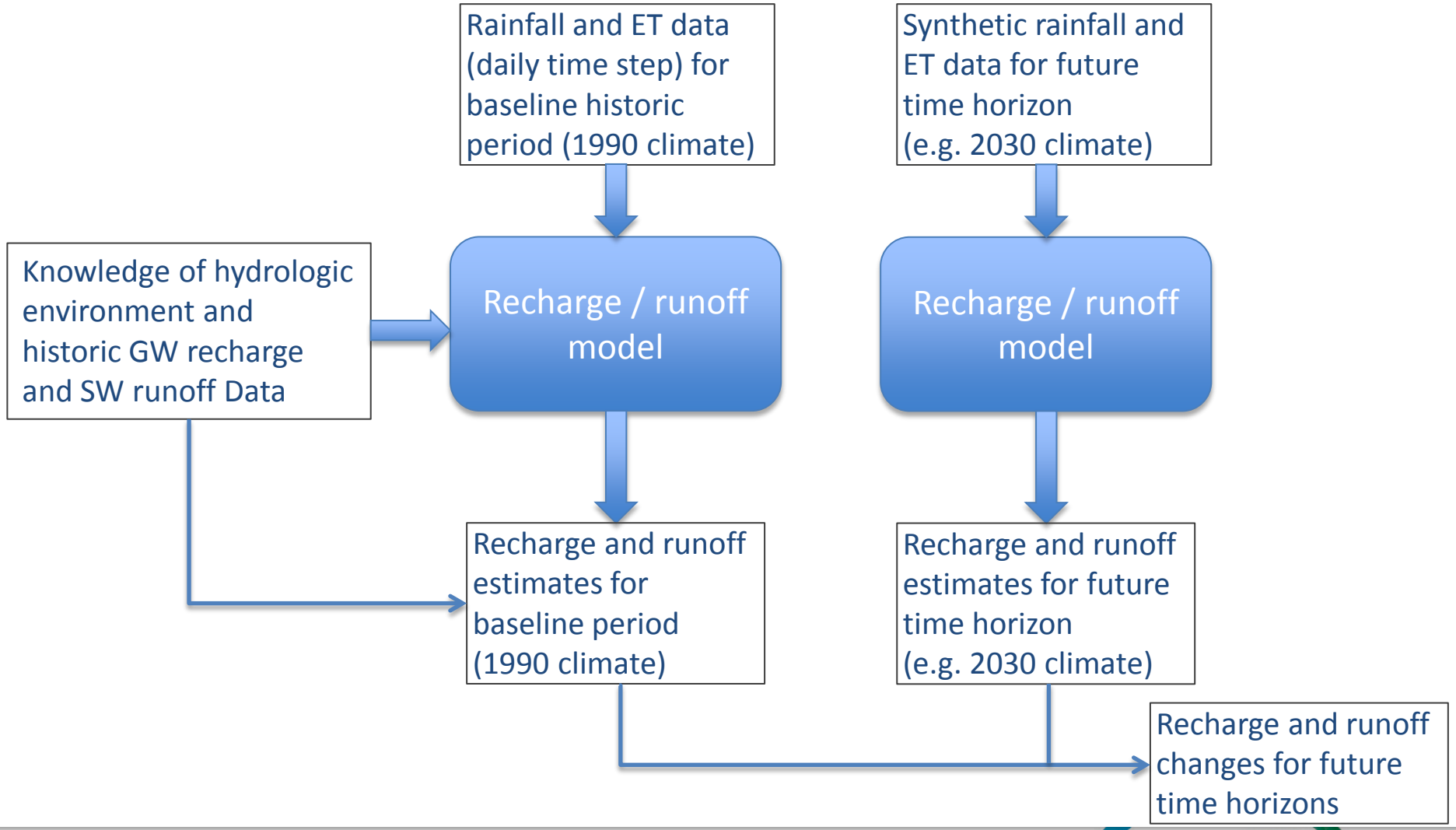
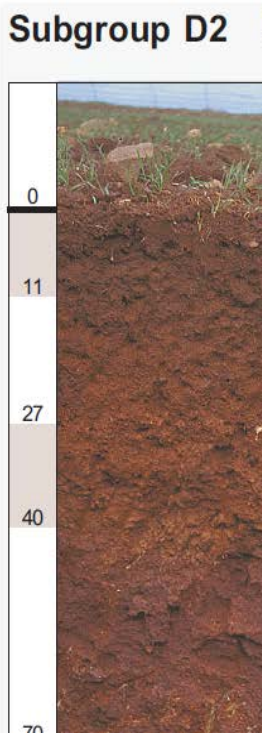
Department of Environment, Water and Natural Resources

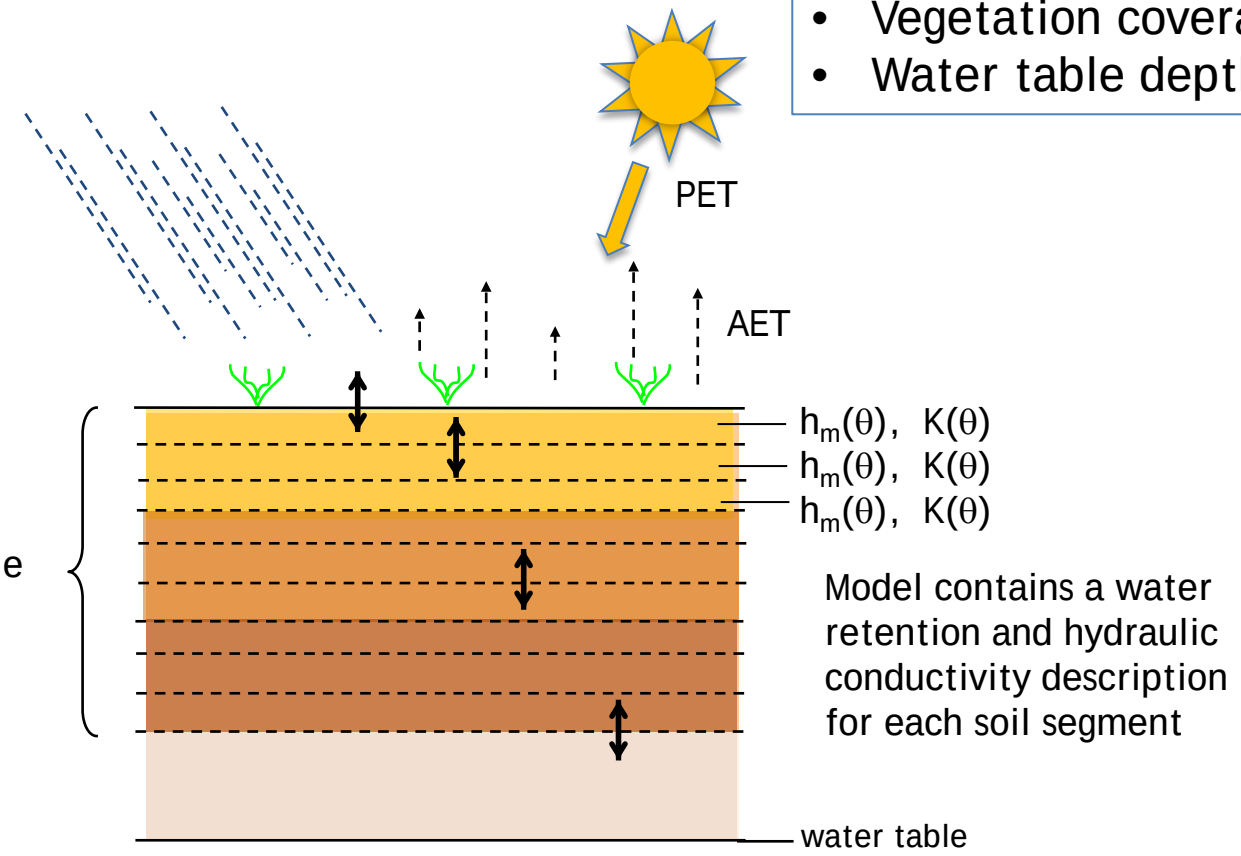
Climate impact modelling concepts



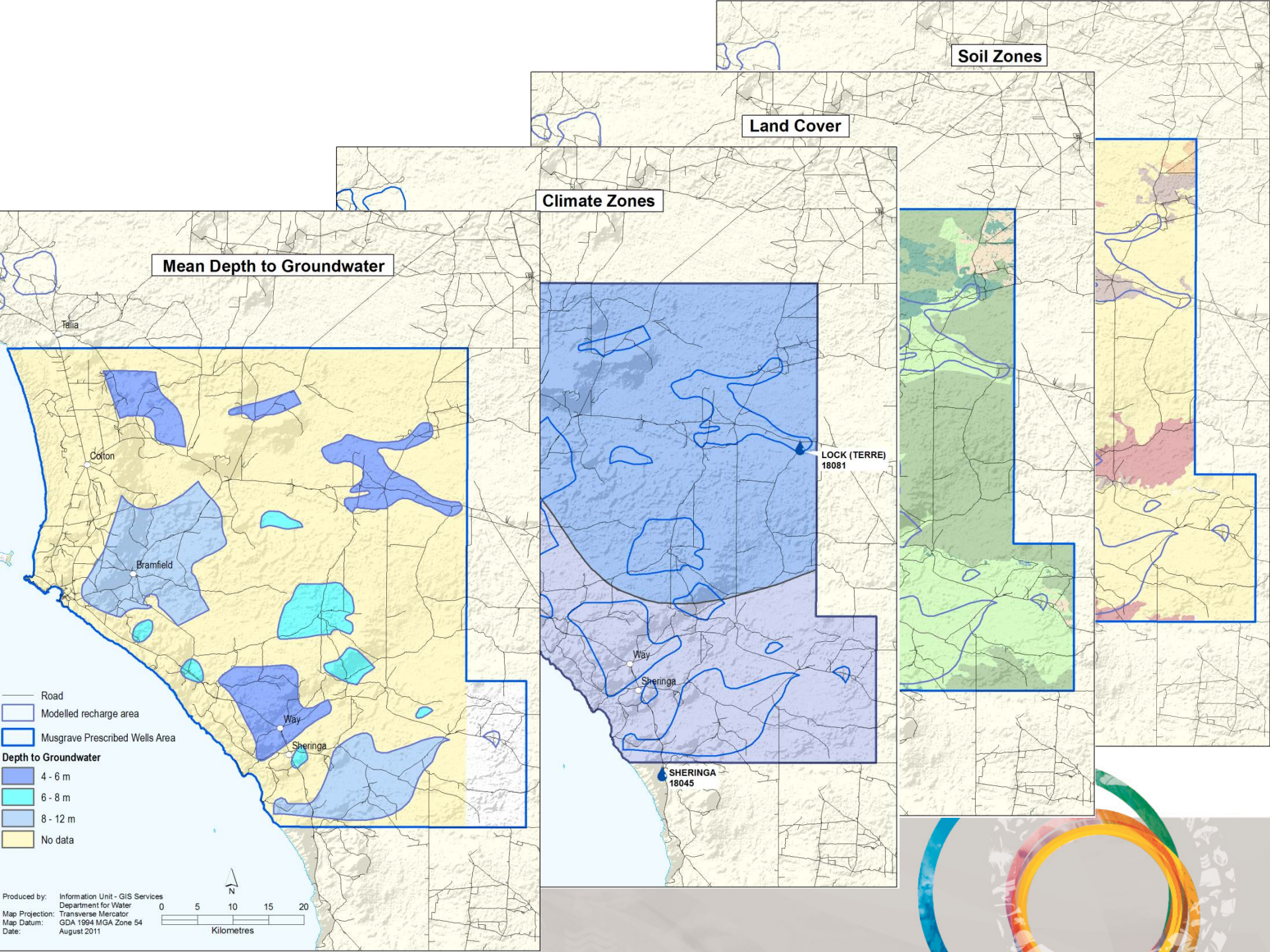
Recharge modelling concepts

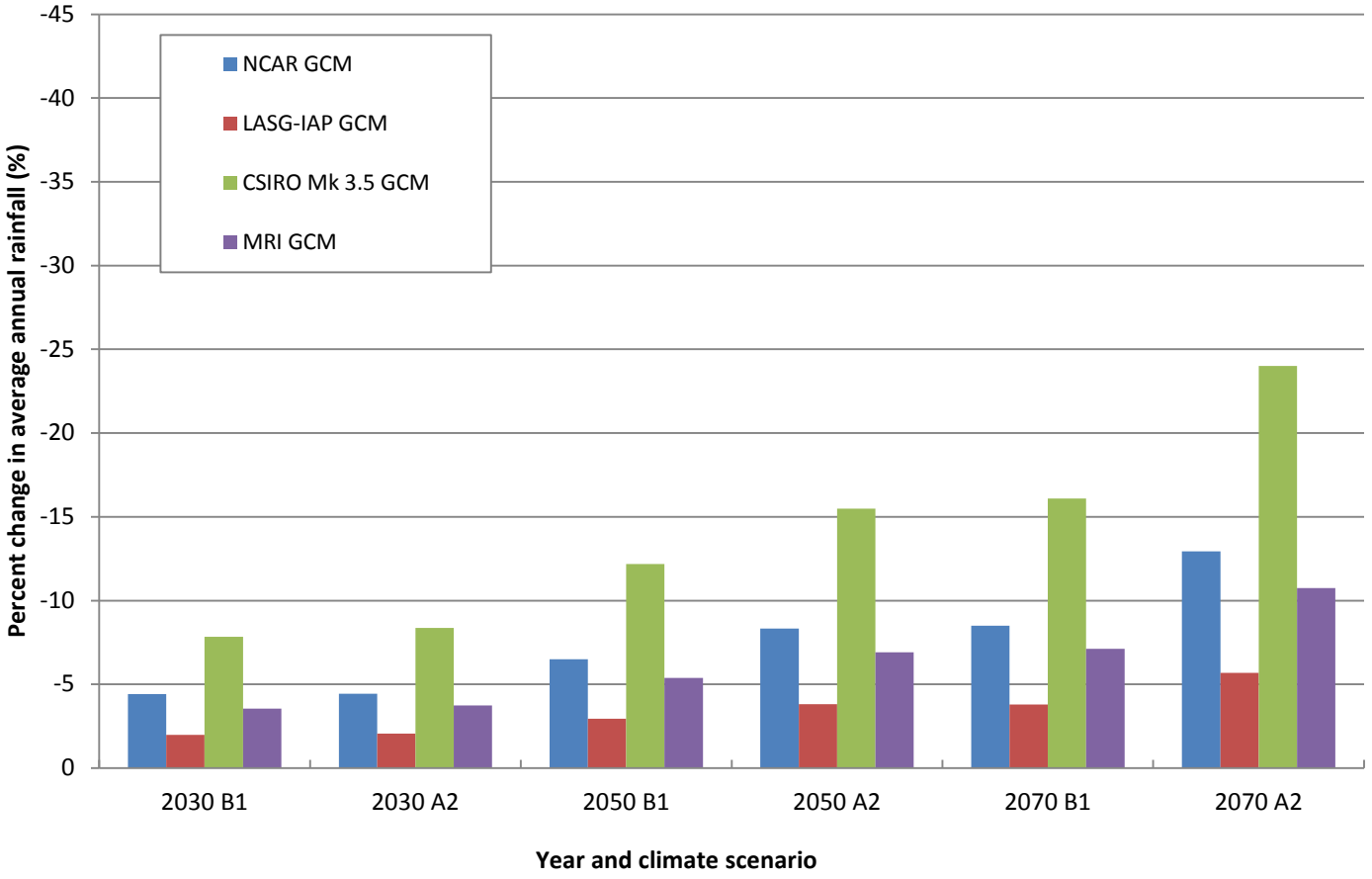
- Rainfall & PET
- Soil hydrology
- Vegetation coverage
- Water table depth



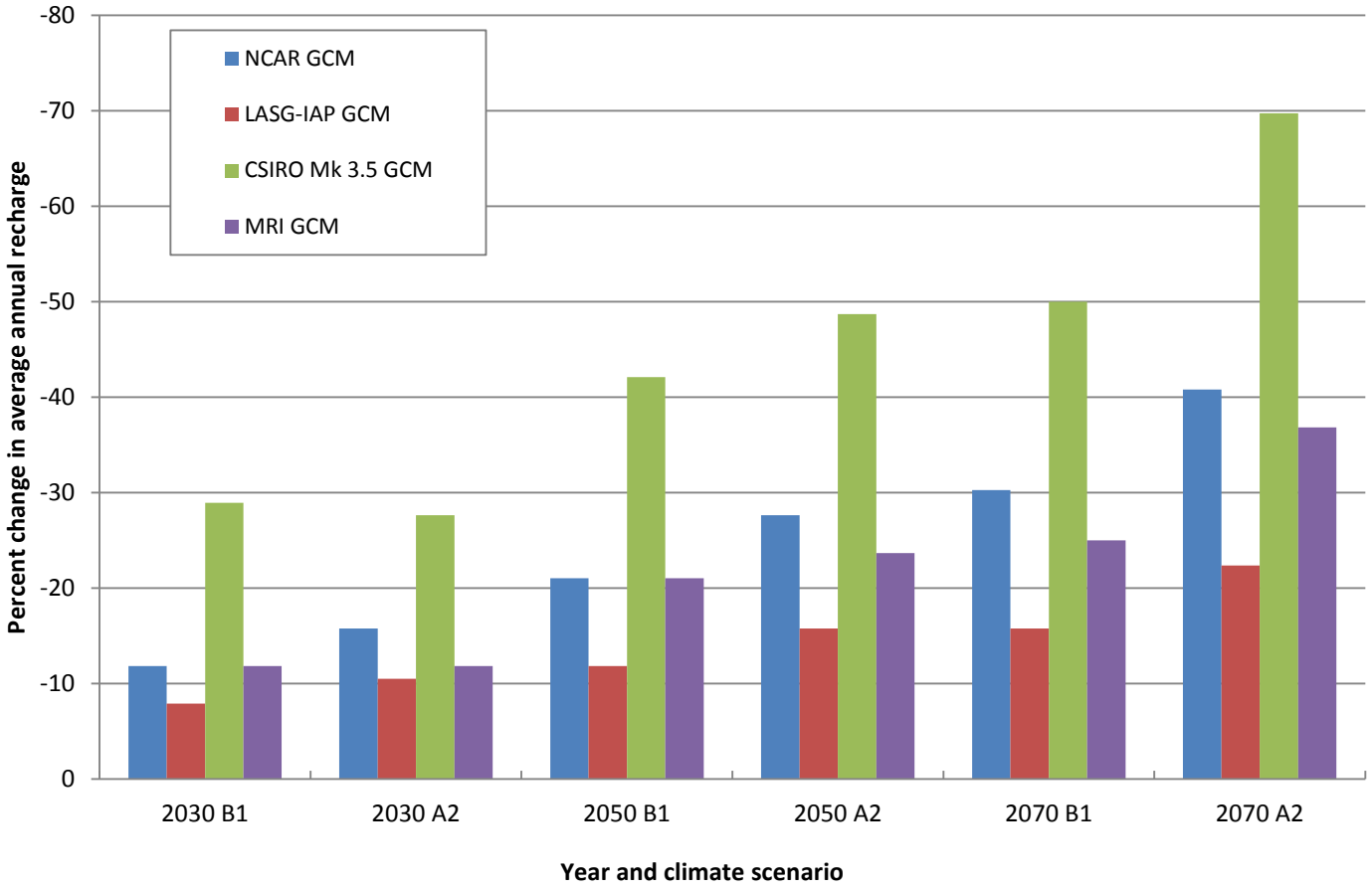


Net downward flux through the lowest soil segment is considered to be the flux to groundwater.

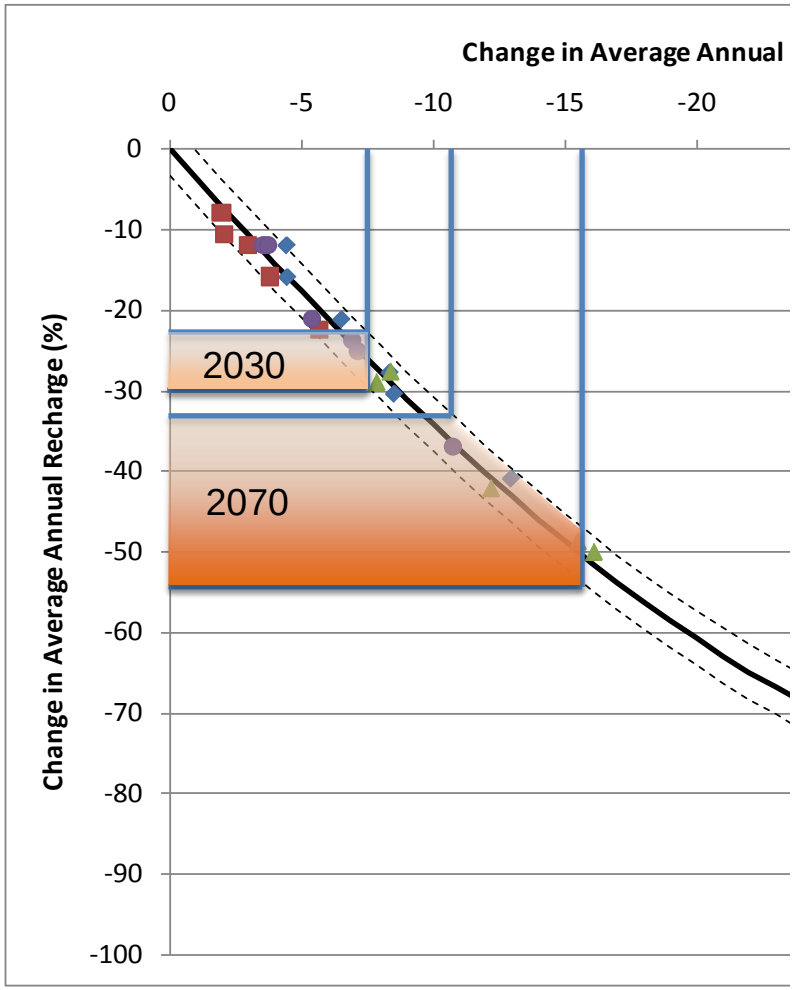

Soil Zones
Land Cover
Climate Zones
Mean Depth to Groundwater
Talia
Colton
Bramfield
Way
Sheringa
LOCK (TERRE)
18081
SHERINGA
18045
Road
Modelled recharge area
Musgrave Prescribed Wells Area
Depth to Groundwater
4 - 6 m
6 - 8 m
8 - 12 m
No data
N
0 5 10 15 20
Kilometres
Produced by: Information Unit - GIS Services
Department for Water
Map Projection: Transverse Mercator
Map Datum: GDA 1994 MGA Zone 54
Date: August 2011



Reduction in average annual rainfall produced by the four different GCMs under the B1 and A2 emissions scenarios. **Results are based on historic rainfall data taken from the Sheringa weather station (BoM station #18045) located within the Musgrave PWA**



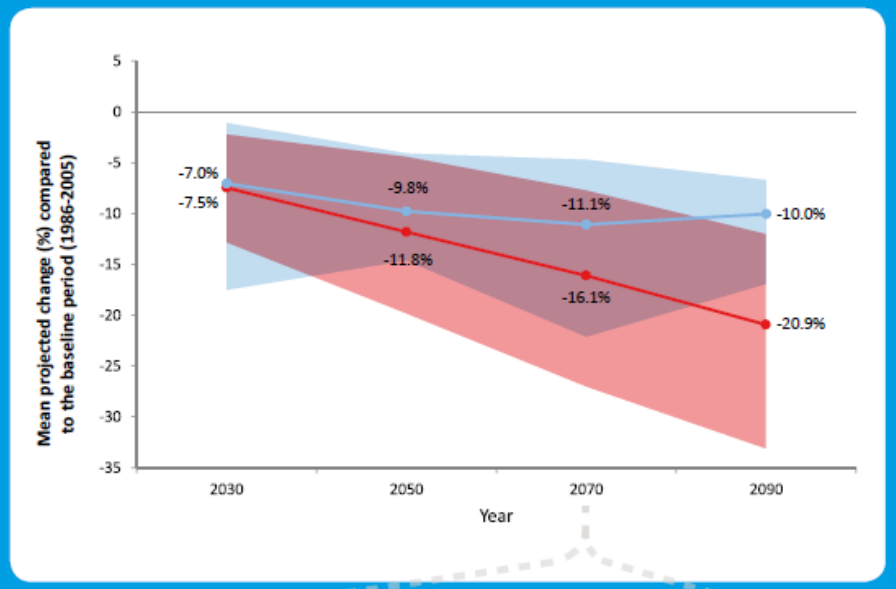
Modelled changes in average annual recharge for the Musgrave PWA for the different GCMs, emissions scenarios and time horizons considered, as estimated by the LEACHG models

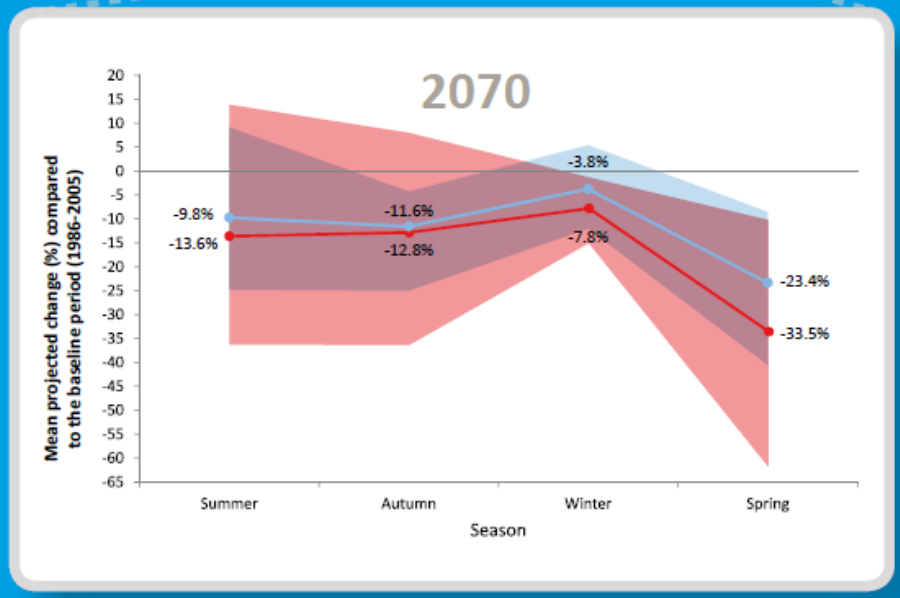


Changes in average annual rainfall versus the Musgrave PWA.

Trend line is a tanh relationship, dashed lines show the

Projected percent change in average annual and seasona





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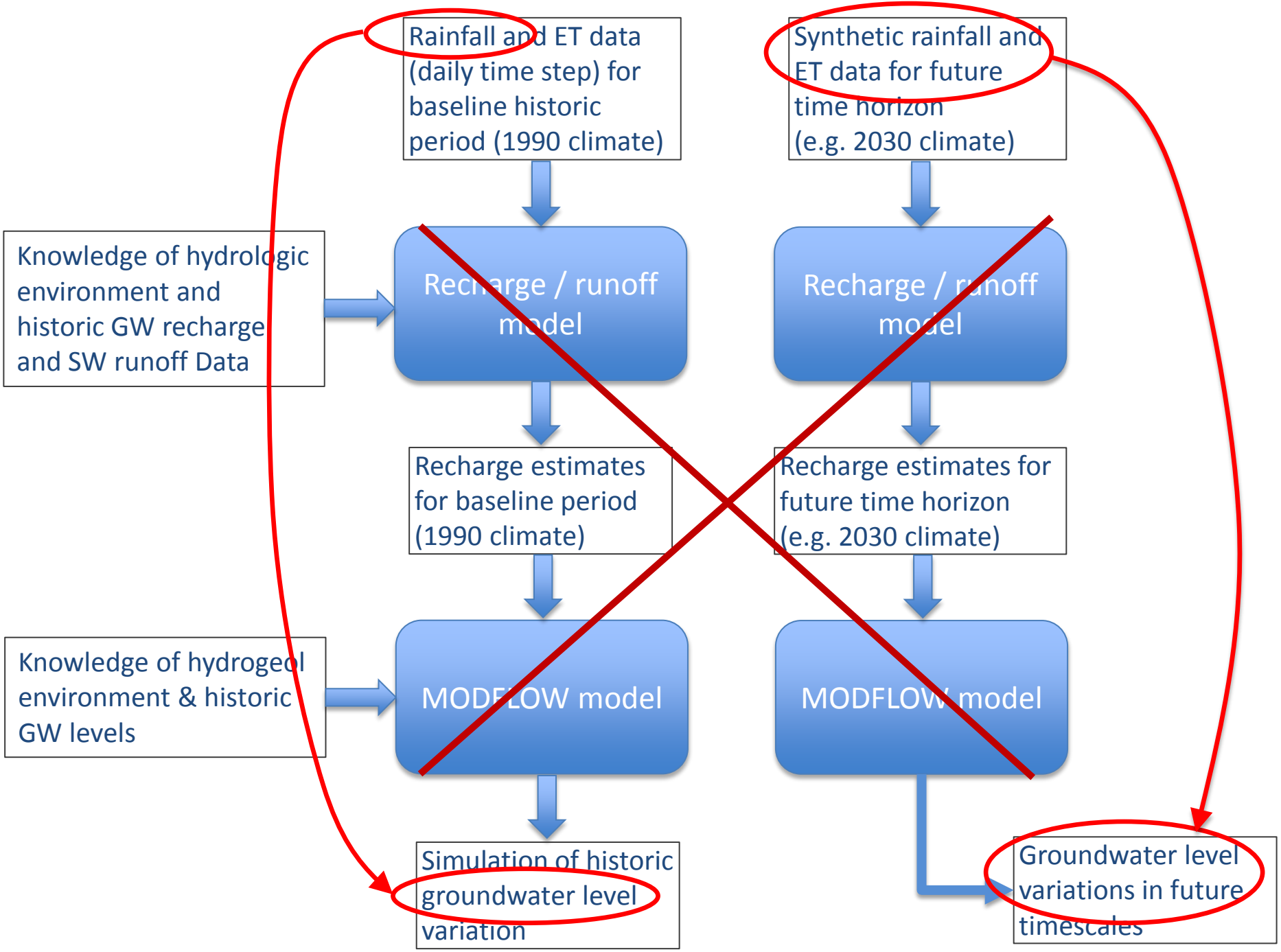

Rainfall and ET data (daily time step) for baseline historic period (1990 climate)
Synthetic rainfall and ET data for future time horizon (e.g. 2030 climate)
Knowledge of hydrologic environment and historic GW recharge and SW runoff Data
Recharge / runoff model
Recharge / runoff model
Recharge estimates for baseline period (1990 climate)
Recharge estimates for future time horizon (e.g. 2030 climate)
Knowledge of hydrogeol environment & historic GW levels
MODFLOW model
MODFLOW model
Simulation of historic groundwater level variation
Groundwater level variations in future timescales

HARTT model: Hydrograph and Rainfall Time Trend

Cumulative deviation from mean rainfall → Variation in groundwater level

$$Depth_t = k_0 + (k_1 \times AARR_t) + (k_2 \times t)$$

Starting water level/depth

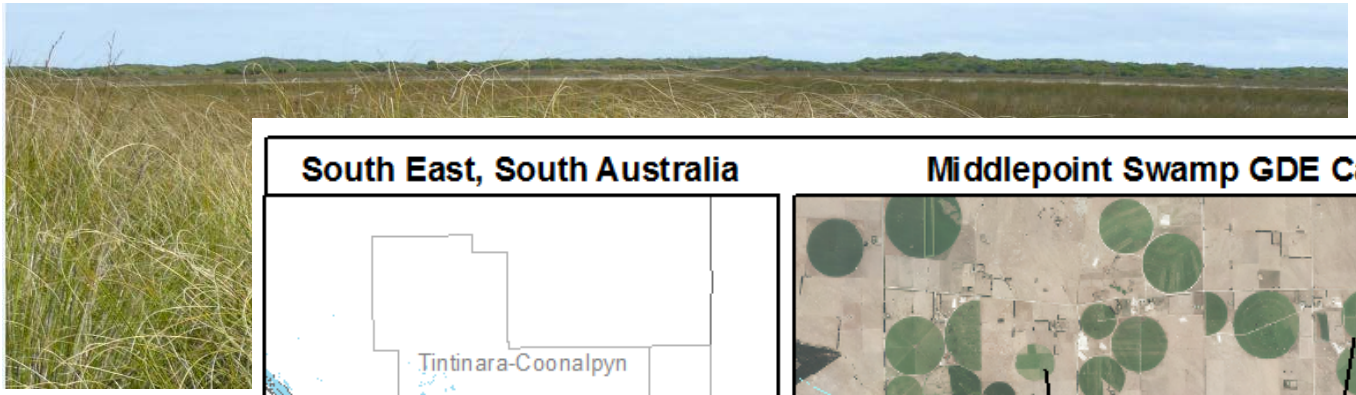
Rainfall-dependent water level factor

Background trend
- Time-dependent
- Independent of rainfall variation

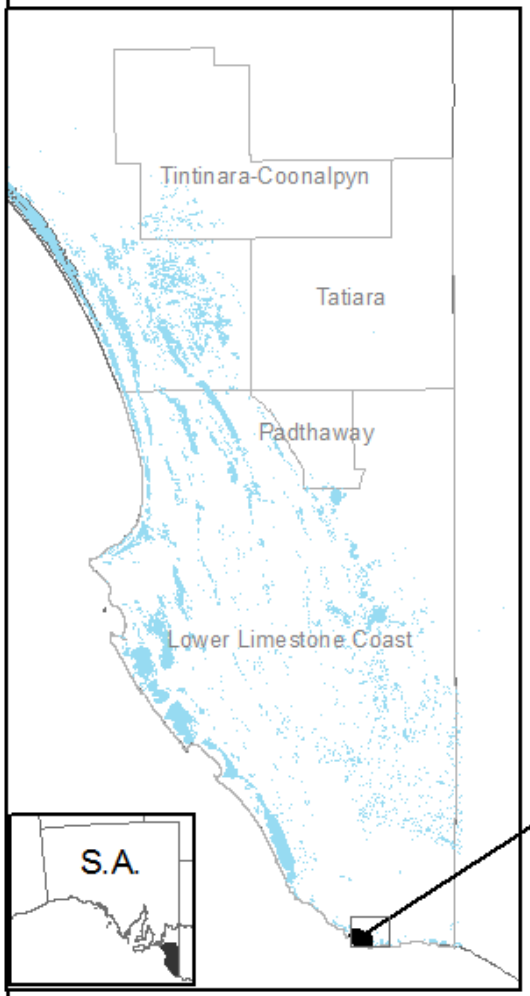
$AARR_t$ = Accumulative Annual Rainfall Residual at time t

$$AARR_t = \Sigma(M_i - A/12)$$

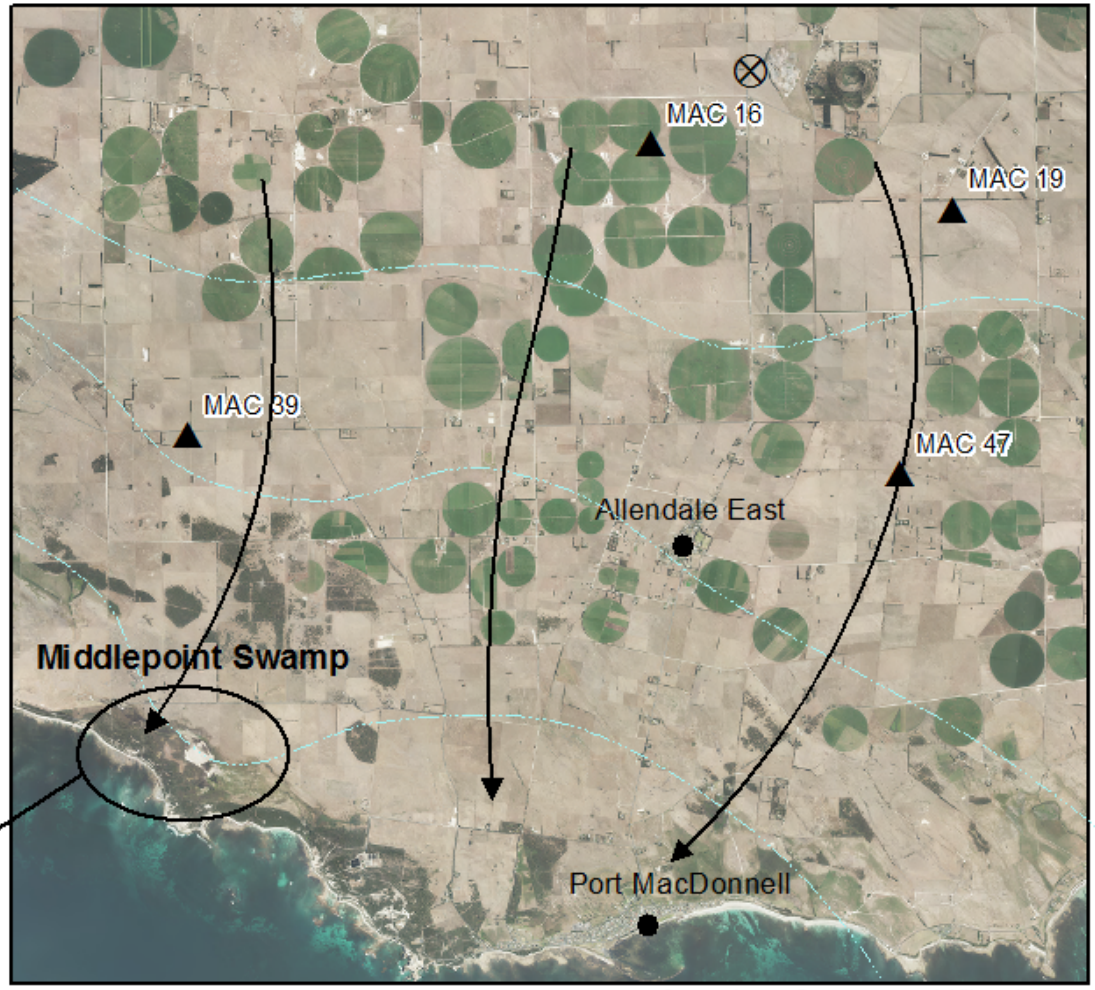
$Depth_t$ = Groundwater standing water level at time t



South East, South Australia



Middlepoint Swamp GDE Case Study Site Location



Case Study GDE
Wetland GDEs
SE Prescribed Wells Areas

Observation wells with long-term records
BoM weather station (026067 Jethia, Mount Schank)
Groundwater elevation contours (TLA)
Inferred groundwater flow direction (TLA)
2013 aerial imagery

Produced by: Department of Environment, Water and Natural Resources
Date: June 2014

Unconsolidated white bioclastic quartz-carbonate sand of modern beaches and transgressive dune fields

Peat/Clay

Sand

Limestone, fossiliferous. Open marine shelf

Limestone with some flint at the top of sequence

Groundwater Elevation (mAHD)

Maximum (Sept-Oct '09)

Minimum (Mar '10)

Surfacewater Elevation (mAHD)

May '10

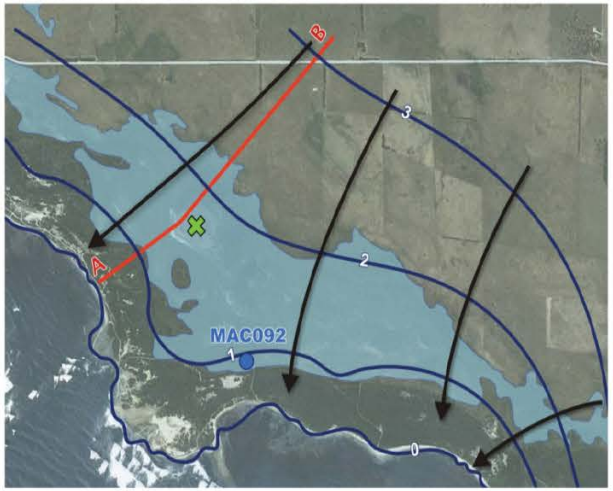
Note: No surfacewater reading during Sept-Oct '09. Wetland damp during Mar '10

Observation bore

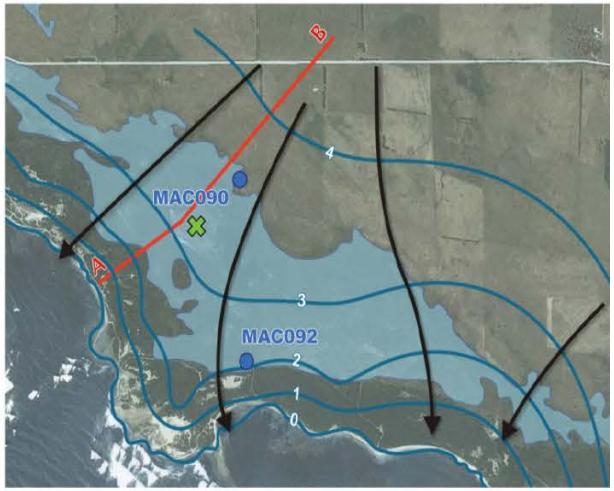
Surface water gauge boards

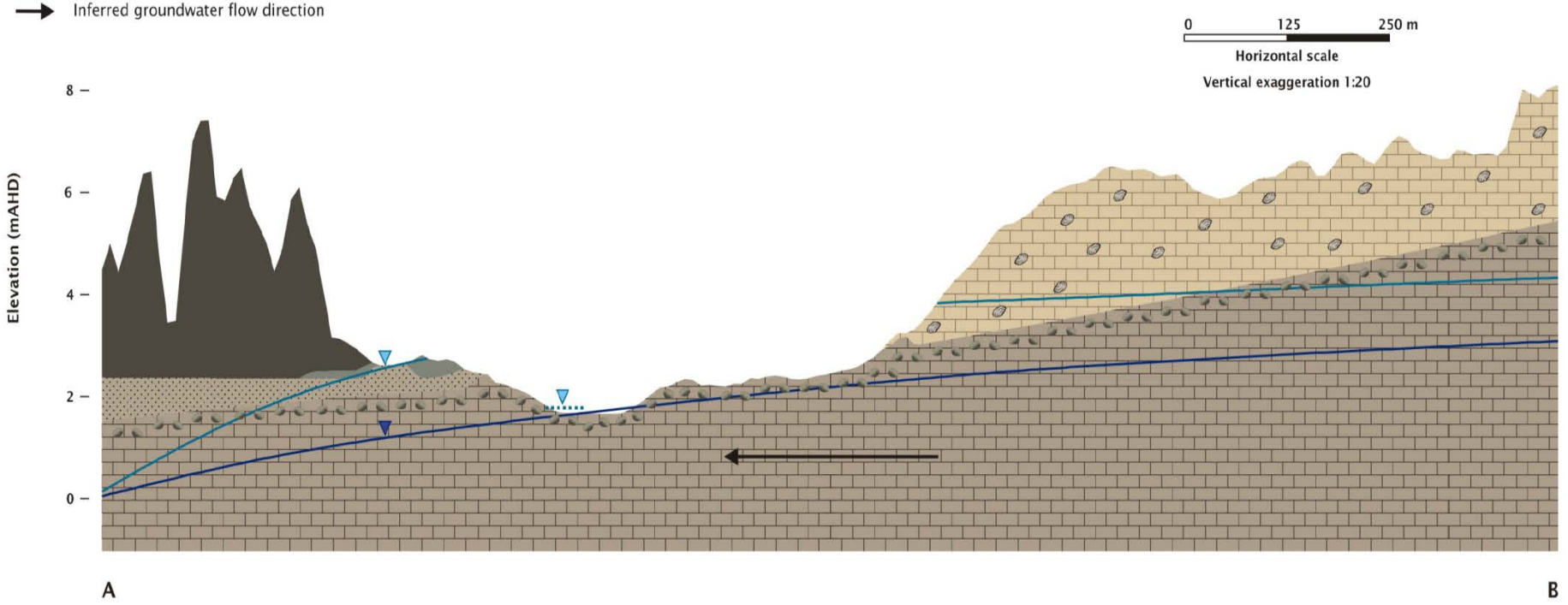
Inferred groundwater flow direction

GROUNDWATER ELEVATION CONTOURS - Mar '10

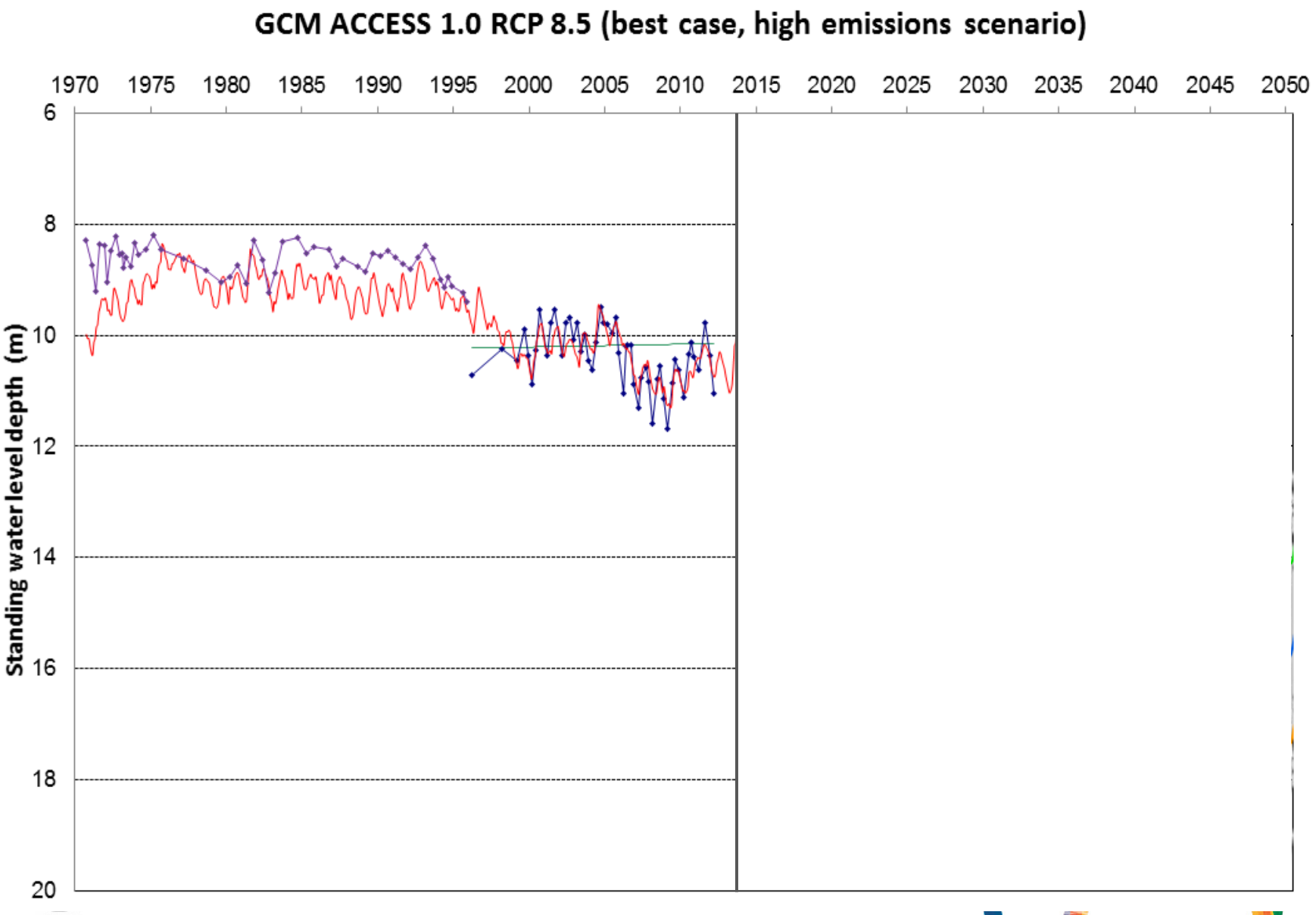


GROUNDWATER ELEVATION CONTOURS - Sept-Oct '09





Projecting wetland levels into the future…



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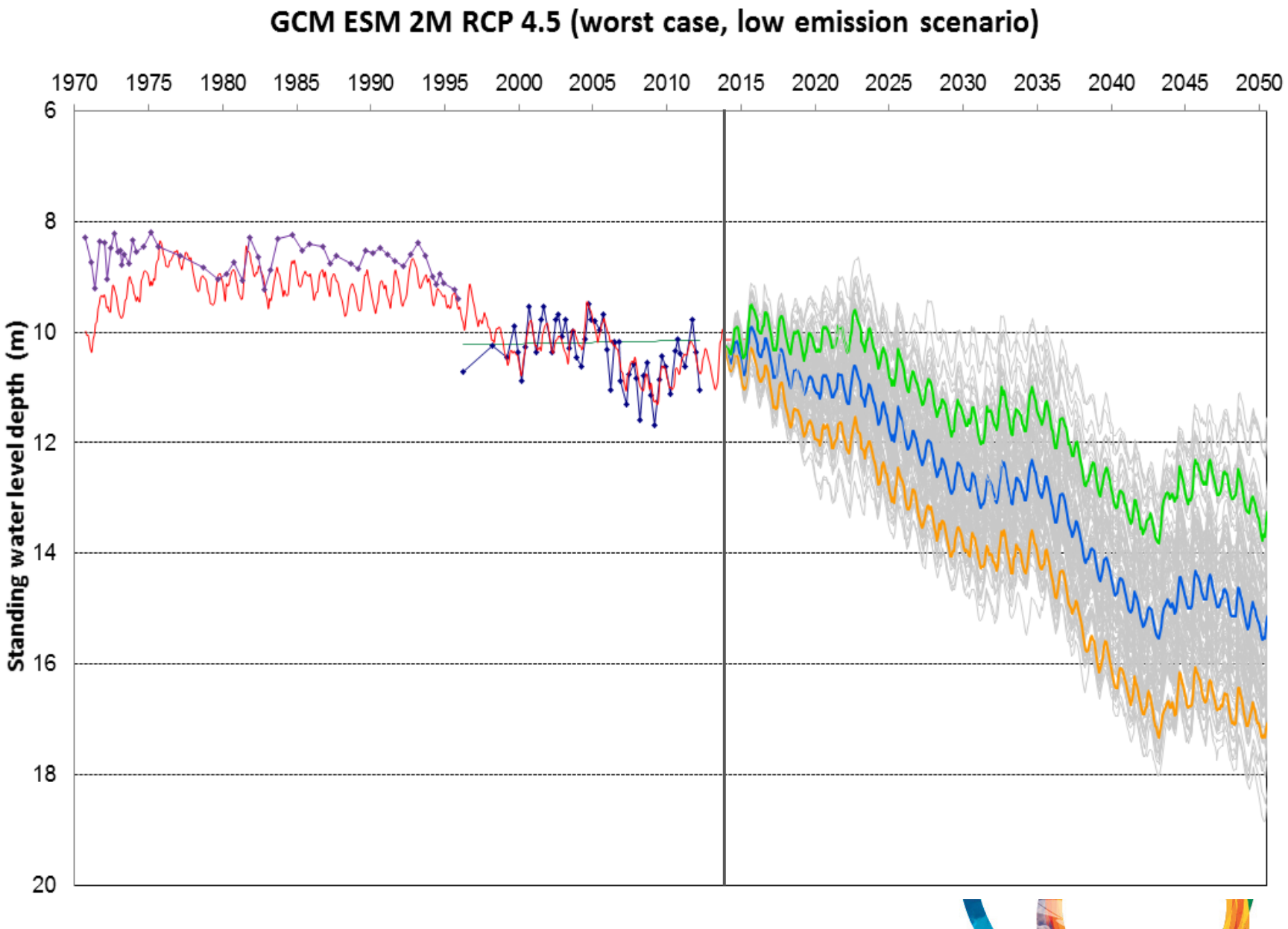
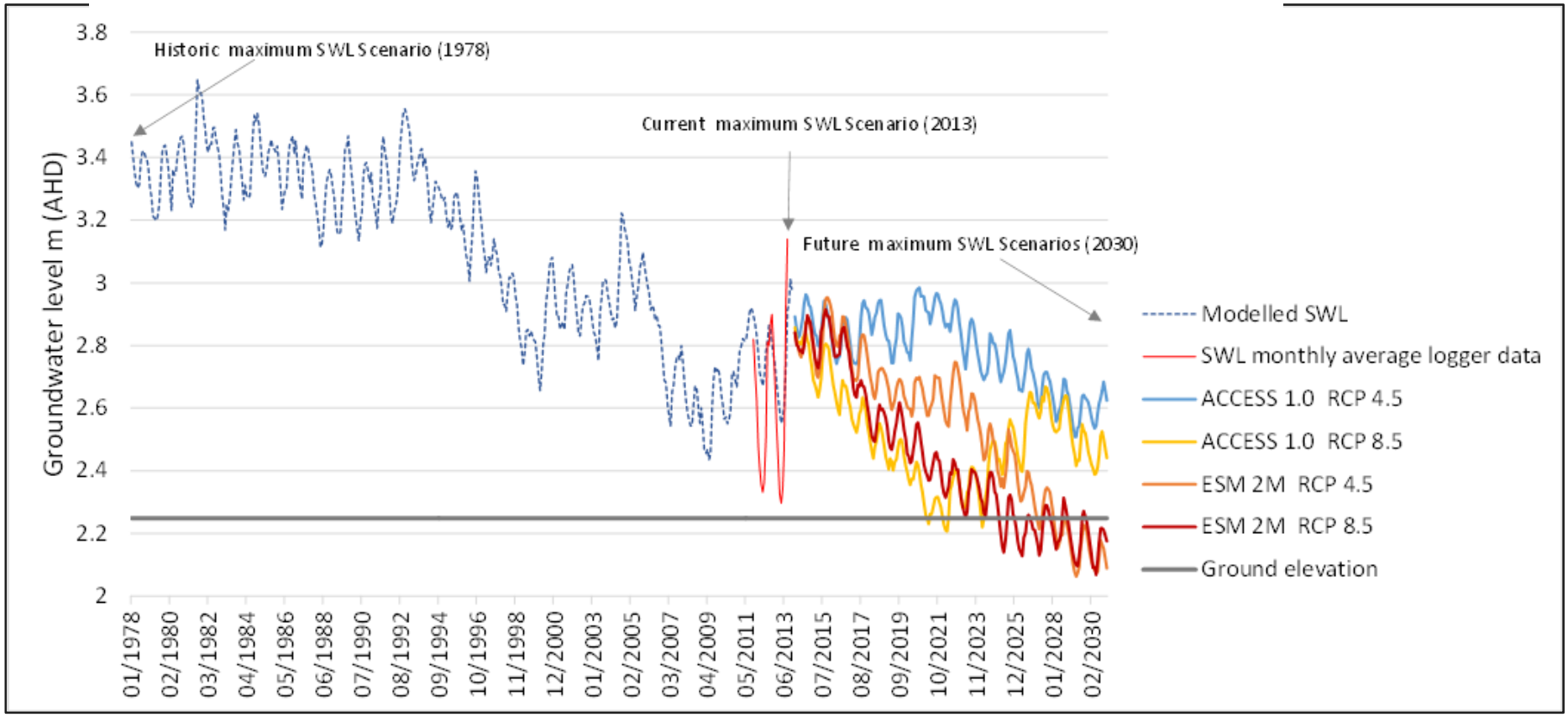
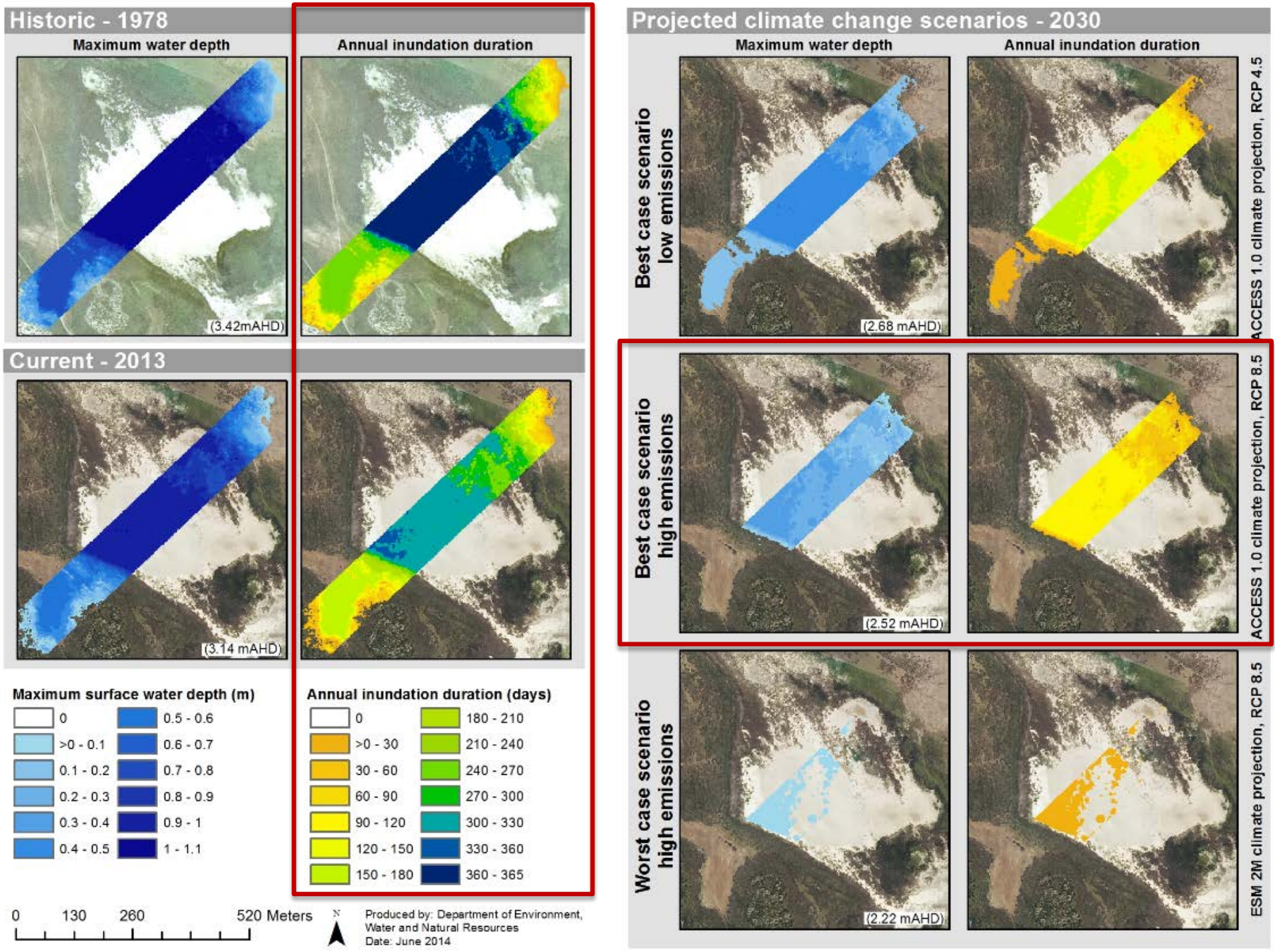


Projecting wetland levels into the future…

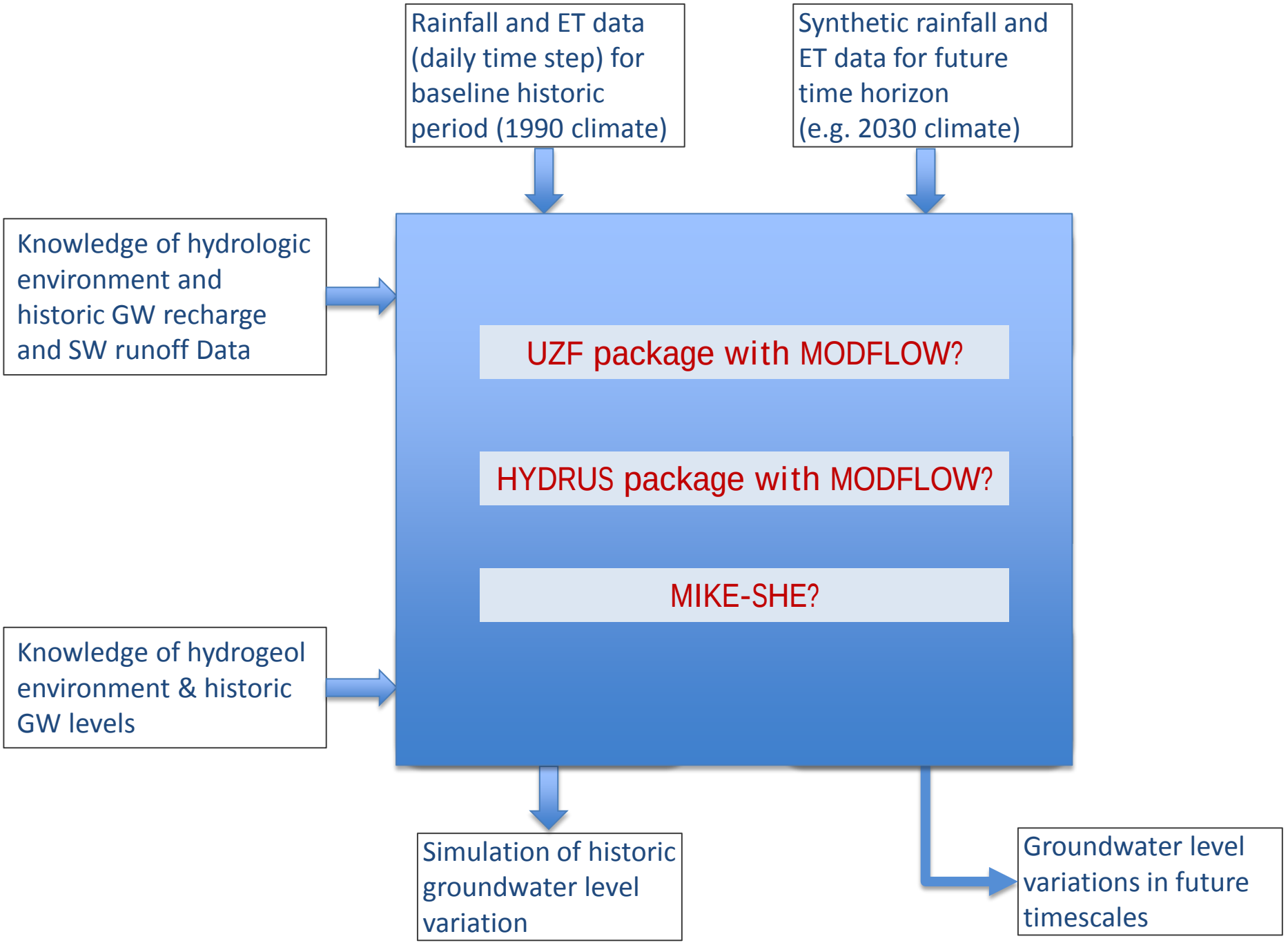


Projected surface water levels for Middlepoint Swamp for selected climate change scenarios to 2030


Historic - 1978
Maximum water depth
Annual inundation duration
(3.42mAHD)
Current - 2013
(3.14 mAHD)
Projected climate change scenarios - 2030
Maximum water depth
Annual inundation duration
Best case scenario low emissions
(2.68 mAHD)
ACCESS 1.0 climate projection, RCP 4.5
Best case scenario high emissions
(2.52 mAHD)
ACCESS 1.0 climate projection, RCP 8.5
Worst case scenario high emissions
(2.22 mAHD)
ESM 2M climate projection, RCP 8.5
Maximum surface water depth (m)
0
>0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1
1 - 1.1
Annual inundation duration (days)
0
>0 - 30
30 - 60
60 - 90
90 - 120
120 - 150
150 - 180
180 - 210
210 - 240
240 - 270
270 - 300
300 - 330
330 - 360
360 - 365
0
130
260
520 Meters
N
Produced by: Department of Environment, Water and Natural Resources
Date: June 2014

However…

- This model shows what happens to GW levels only if they continue to respond to variations in rainfall in the same way as they have for the past 15-20 years
- Unquantified part of historic response is due to irrigators also responding to rainfall variations
- Model does not include change in ET due to higher temperatures in future
- Model is used here to project levels outside of the range in which it was calibrated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Knowledge of hydrologic environment and historic GW recharge and SW runoff Data
UZF package with MODFLOW?
HYDRUS package with MODFLOW?
MIKE-SHE?
Knowledge of hydrogeol environment & historic GW levels
Simulation of historic groundwater level variation
Groundwater level variations in future timescales

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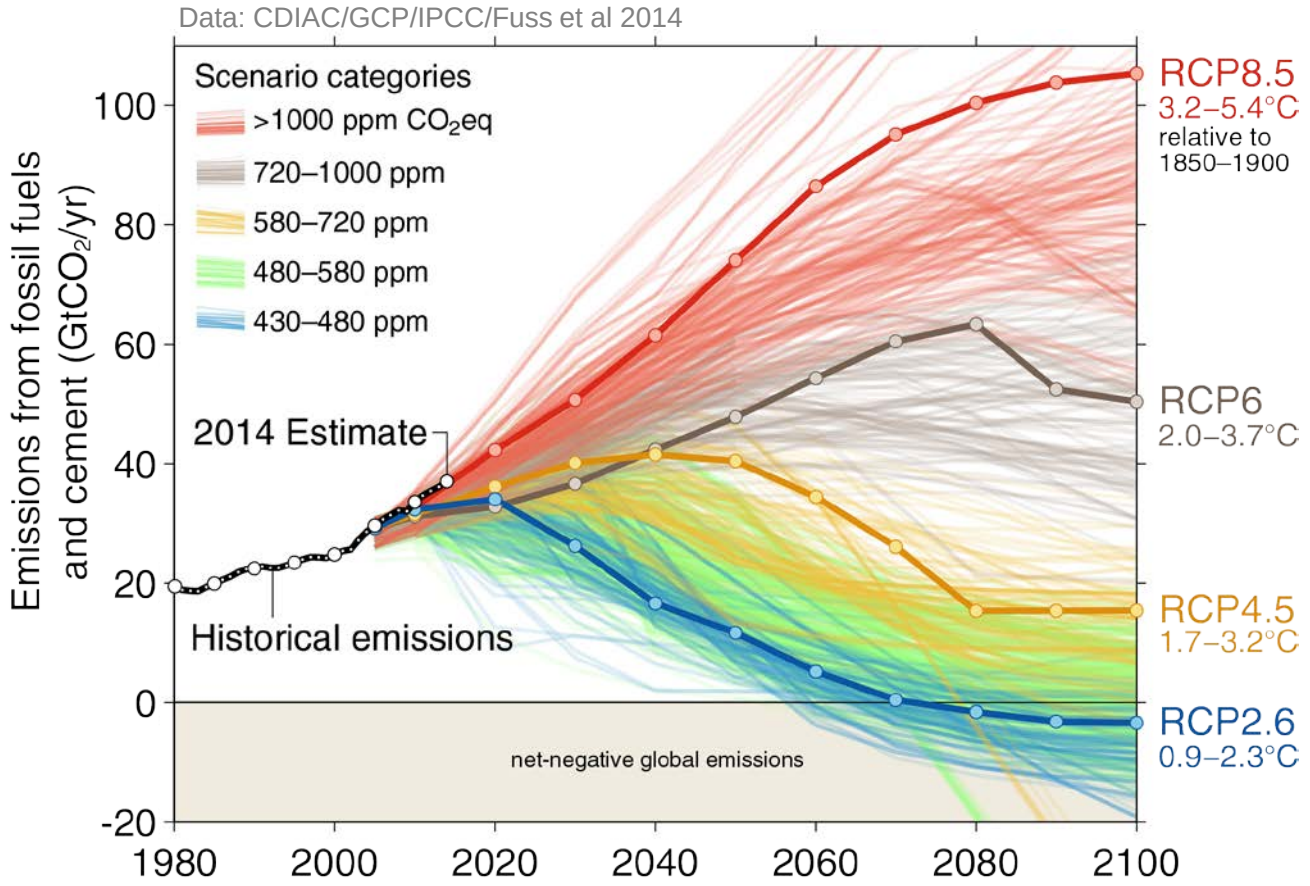
Applications for resource planning

Data requirement	Analysis tool	Unknown	Planning example
Rainfall and PET in Onkaparinga catchment: past and future	Mt Bold Reservoir catchment model	Likely change in supply capacity of Mount Bold Reservoir?	Water security planning for Adelaide
Rainfall in the Southeast: past and future	Wetland water level model Vegetation response model	Likely change in wetland vegetation composition in response to drying climate?	Conservation planning for wetland ecosystems in south east SA
Rainfall in western Adelaide past and future	Groundwater level variation model	Likely change in groundwater table depth in western Adelaide?	Infrastructure design: lowered section of South Road upgrade (Adelaide North-South Corridor)

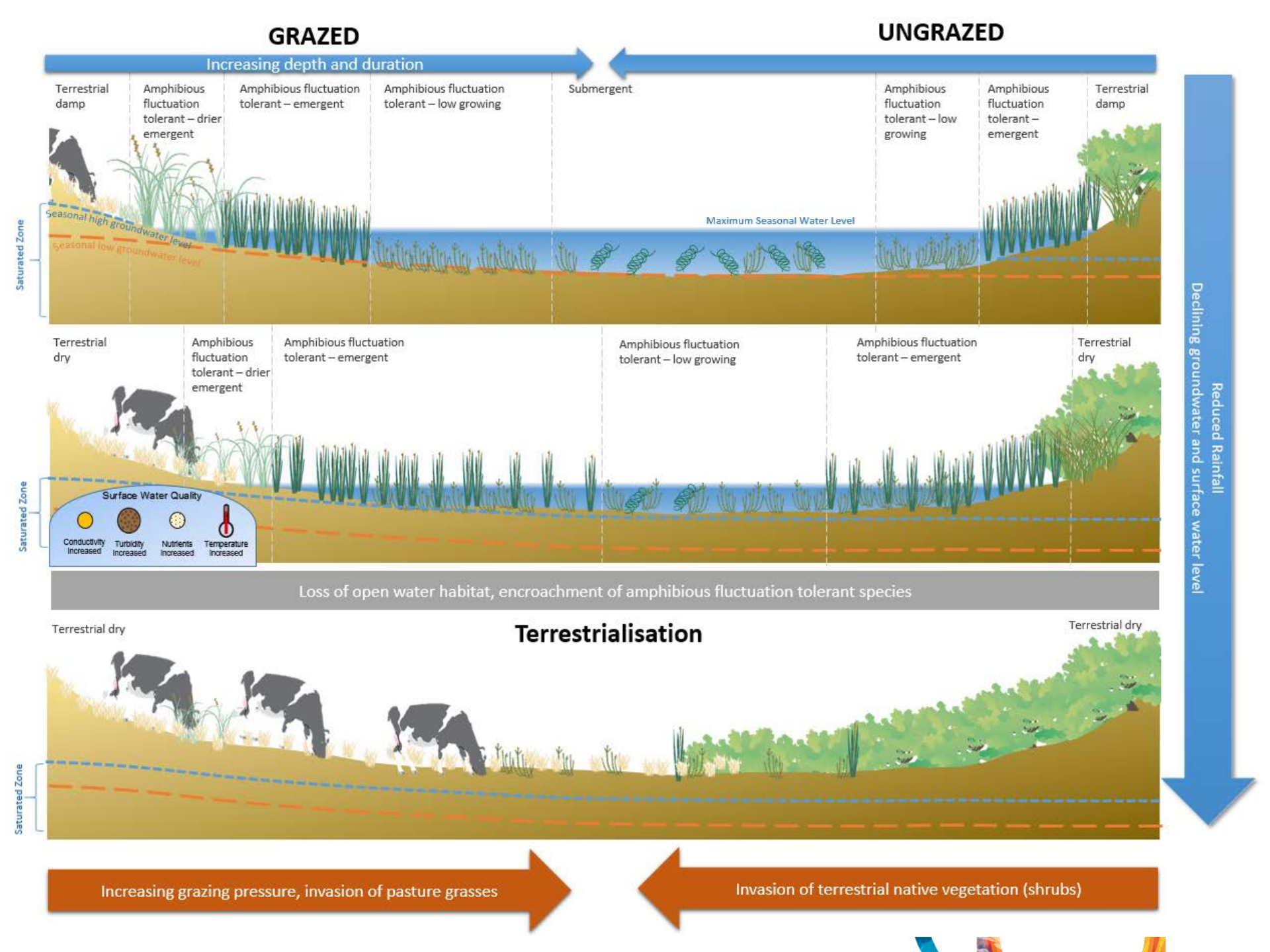
Observed Emissions and Emissions Scenarios

Emissions are on track for 3.2–5.4ºC "likely" increase in temperature above pre-industrial
Large and sustained mitigation is required to keep below 2ºC



Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2014


GRAZED
UNGRAZED
Increasing depth and duration
Terrestrial damp
Amphibious fluctuation tolerant – drier emergent
Amphibious fluctuation tolerant – emergent
Amphibious fluctuation tolerant – low growing
Submergent
Amphibious fluctuation tolerant – low growing
Amphibious fluctuation tolerant – emergent
Terrestrial damp
Saturated Zone
Seasonal high groundwater level
Seasonal low groundwater level
Maximum Seasonal Water Level
Terrestrial dry
Amphibious fluctuation tolerant – drier emergent
Amphibious fluctuation tolerant – emergent
Amphibious fluctuation tolerant – low growing
Amphibious fluctuation tolerant – emergent
Terrestrial dry
Surface Water Quality
Conductivity Increased
Turbidity Increased
Nutrients Increased
Temperature Increased
Loss of open water habitat, encroachment of amphibious fluctuation tolerant species
Terrestrial dry
Terrestrialisation
Terrestrial dry
Reduced Rainfall
Declining groundwater and surface water level
Increasing grazing pressure, invasion of pasture grasses
Invasion of terrestrial native vegetation (shrubs)