Bayesian Networks to support TANK group decision-making

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TANK Decision process

Possible Values, Objectives, Performance Measures and Management Variables For Policy Options

Values =>	**Objectives =>**	**Performance Measures**	**Management Variables** **(for Policy Options)**
Primary Production	Create new jobs in Hawke's Bay	New full-time jobs in horticulture & farming	Minimum flow; allocation regime & volume
Trout fishing	Improve river for trout fishing	Trout habitat as % of maximum	Minimum flow; nutrient levels; riparian vegetation
Mauri of river	Restore mauri of river	Cultural health index	Minimum flow; stock exclusion; nutrient levels

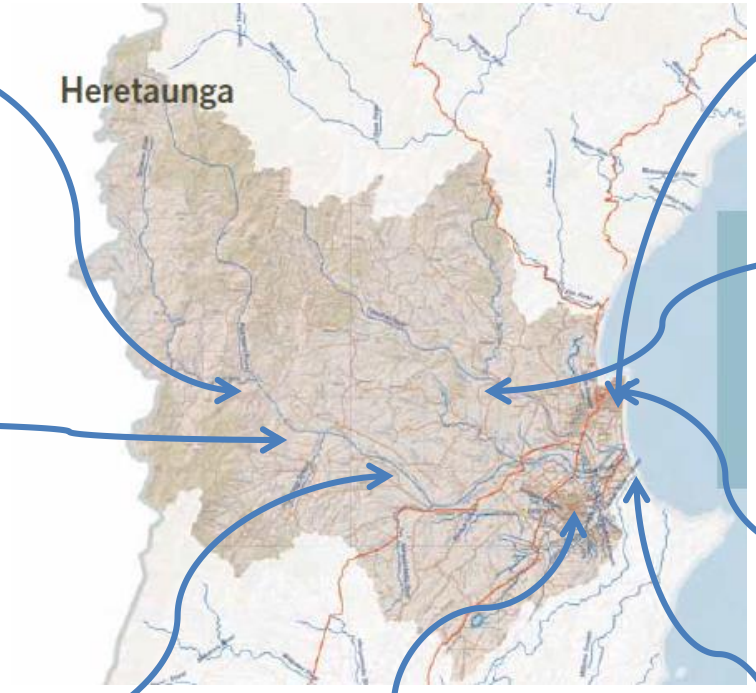
Consequences Table

Performance Measures	*Policy option A:* Raise min flow Nutrient cap	*Policy option B:* Current min flow Stock exclusion	*Policy option C:* Current min flow Stock exclusion
Full-time jobs in hort & farming	Loss of x jobs (how many?)	No change in jobs	Gain of x jobs (how many?)
Trout habitat as % of maximum	90% of habitat	70% of habitat	50% of habitat
Cultural health index	Good	Fair	Fair – Poor

* How certain are we of each consequence?

River catchments are complex systems

How to predict the effects of different management actions/policies on a range of values?



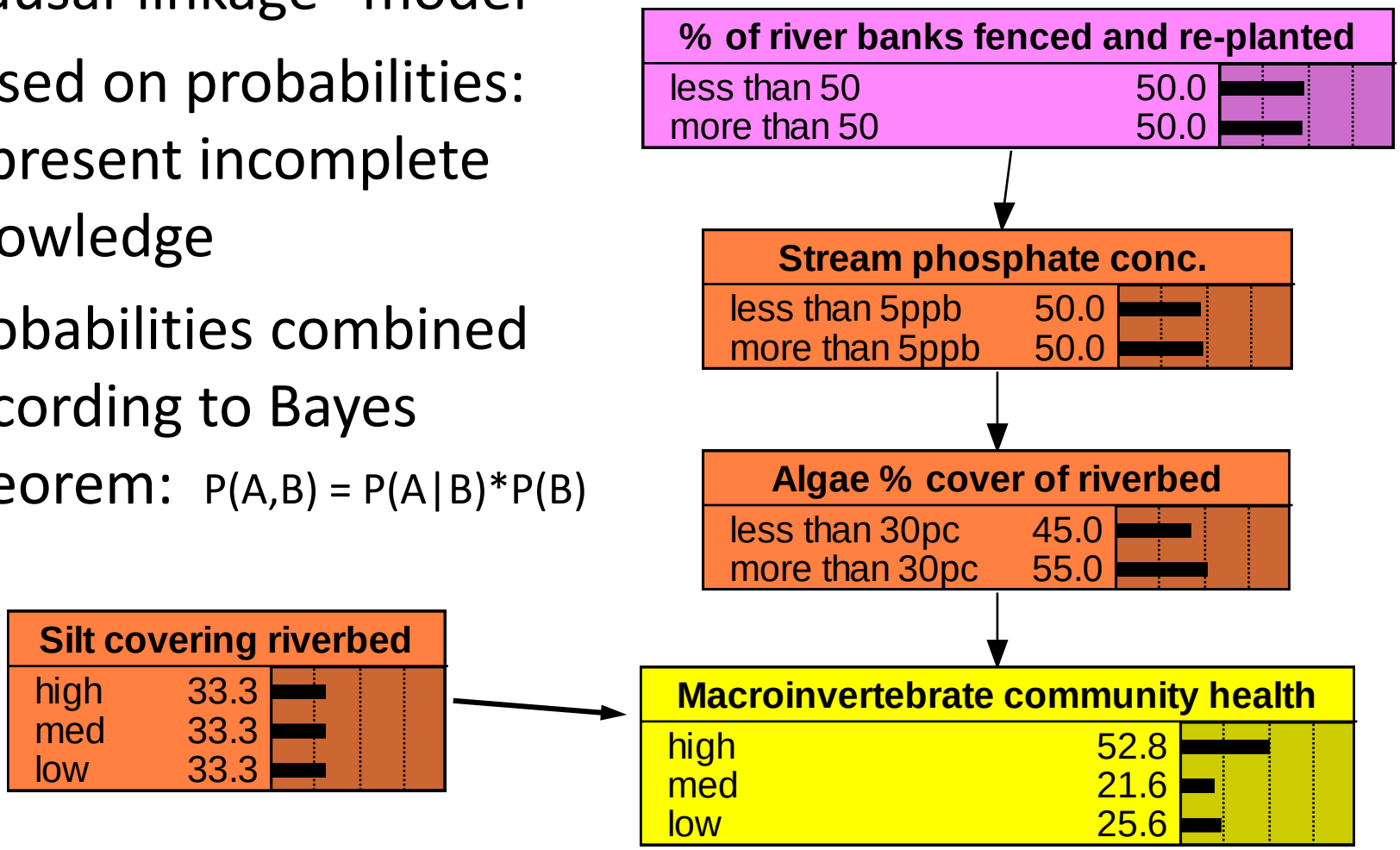
What is a Bayesian Belief Network?

- a way of determining the probability of outcome x from decision y
  - given all the knowledge and beliefs about the system.
- What can we know or believe about a system?
  - How one variable affects another.
  - The state of some variables (decisions, fixed scenarios, observations)

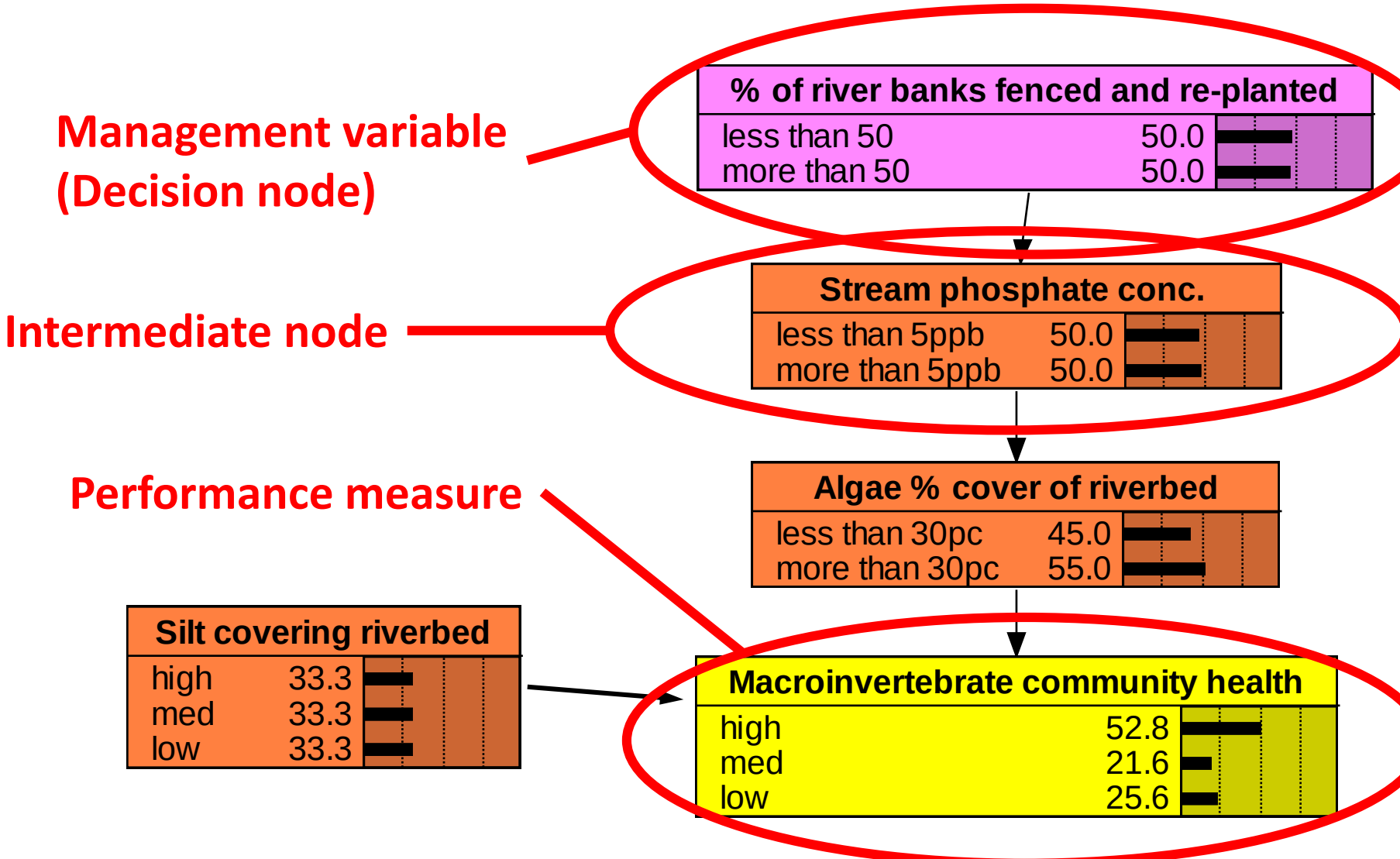
"if 50% of streams in the Tutaekuri catchment are fenced and planted, then there is an 80% chance that trout abundance will increase"

Bayesian Networks

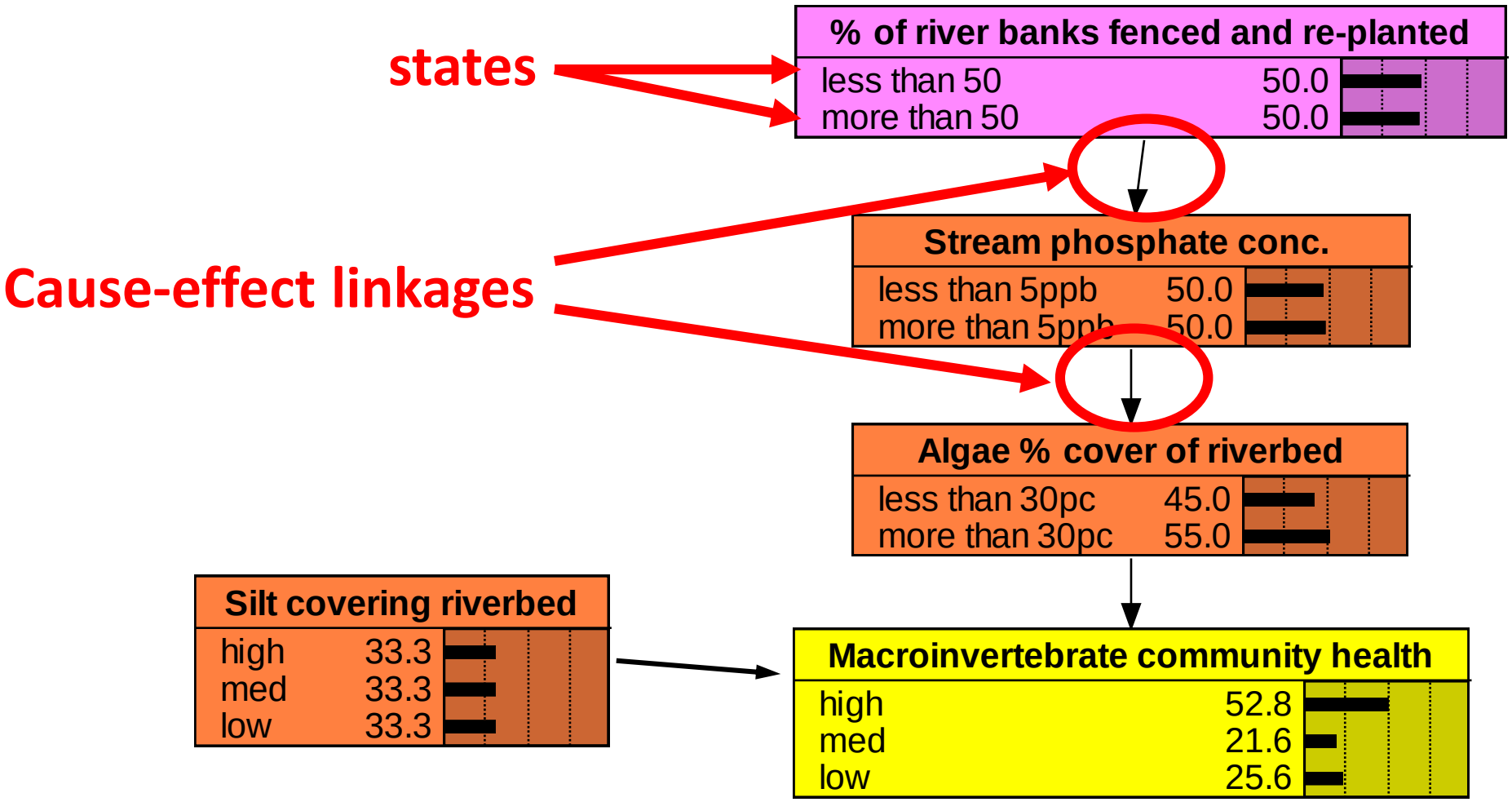
- "causal-linkage" model
- Based on probabilities: represent incomplete knowledge
- Probabilities combined according to Bayes theorem: $P(A,B) = P(A|B)*P(B)$



How BNs work


Management variable
(Decision node)
% of river banks fenced and re-planted
less than 50 50.0
more than 50 50.0
Intermediate node
Stream phosphate conc.
less than 5ppb 50.0
more than 5ppb 50.0
Performance measure
Algae % cover of riverbed
less than 30pc 45.0
more than 30pc 55.0
Silt covering riverbed
high 33.3
med 33.3
low 33.3
Macroinvertebrate community health
high 52.8
med 21.6
low 25.6

How BNs work


states
Cause-effect linkages
% of river banks fenced and re-planted
less than 50 50.0
more than 50 50.0
Stream phosphate conc.
less than 5ppb 50.0
more than 5ppb 50.0
Algae % cover of riverbed
less than 30pc 45.0
more than 30pc 55.0
Silt covering riverbed
high 33.3
med 33.3
low 33.3
Macroinvertebrate community health
high 52.8
med 21.6
low 25.6

Conditional probability tables

Strong dependency

		Phosphate concentration	
		<5 ppb	>5 ppb
% of banks fenced	<50%	**10**	**90**
	>50%	**90**	**10**

- Strong influence
- Few other influencing factors
- Precise knowledge

Weak dependency

		Algae cover of river bed	
		<30%	>30%
Phosphate concentration	<5 ppb	**65**	**35**
	>5 ppb	**25**	**75**

- Weak influence
- other important influences
- Knowledge poor/imprecise

CPTs combining 2 parents

Parent node 1 (2 states)

Parent node 2 (3 states)

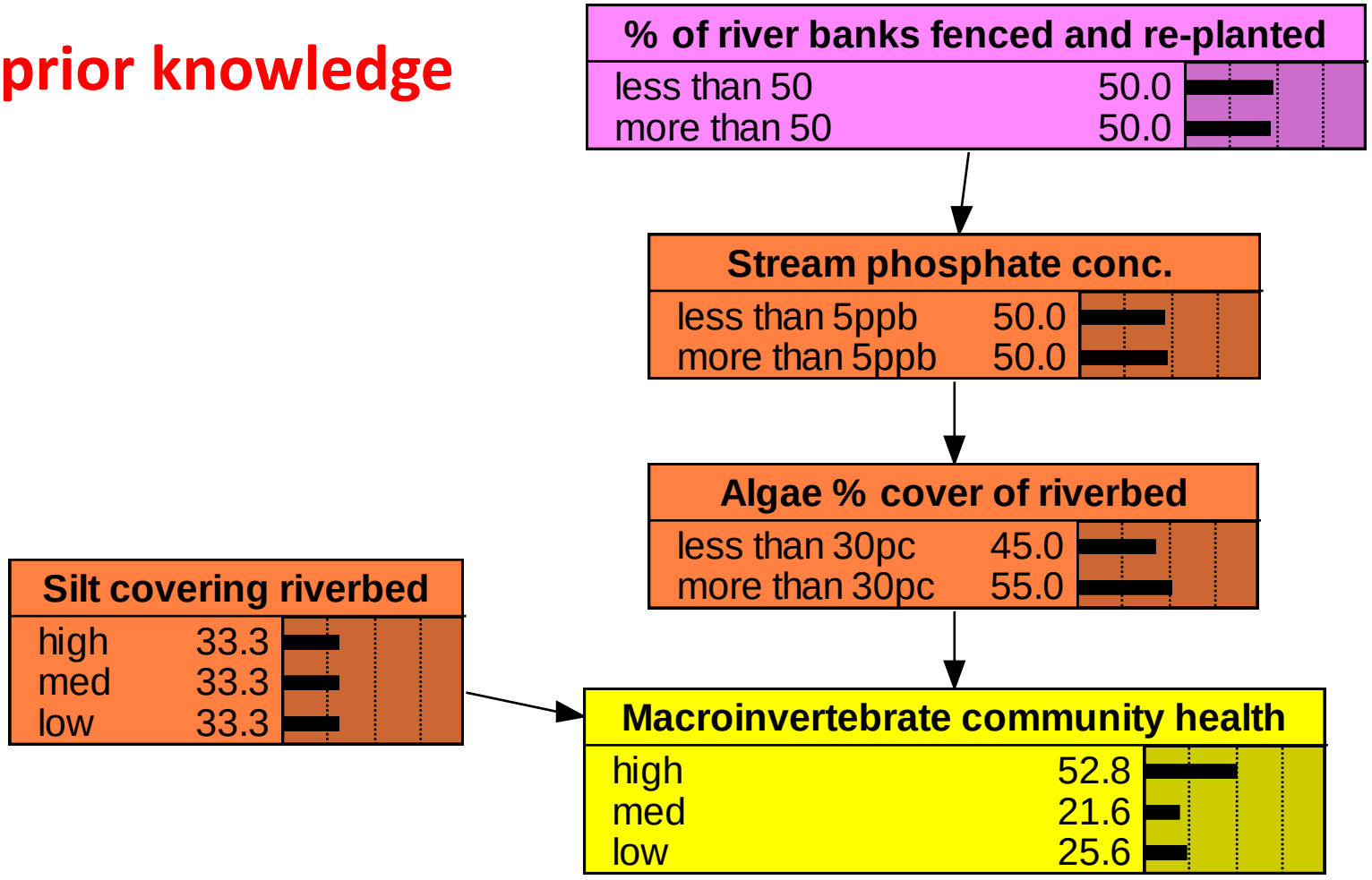
Child node

Algae cover	Silt on river bed	Macroinvertebrate community health		
		High	Med	Low
<30%	High	60	20	20
<30%	Med	80	10	10
<30%	Low	90	10	0
>30%	High	10	30	40
>30%	Med	40	30	30
>30%	Low	50	25	25

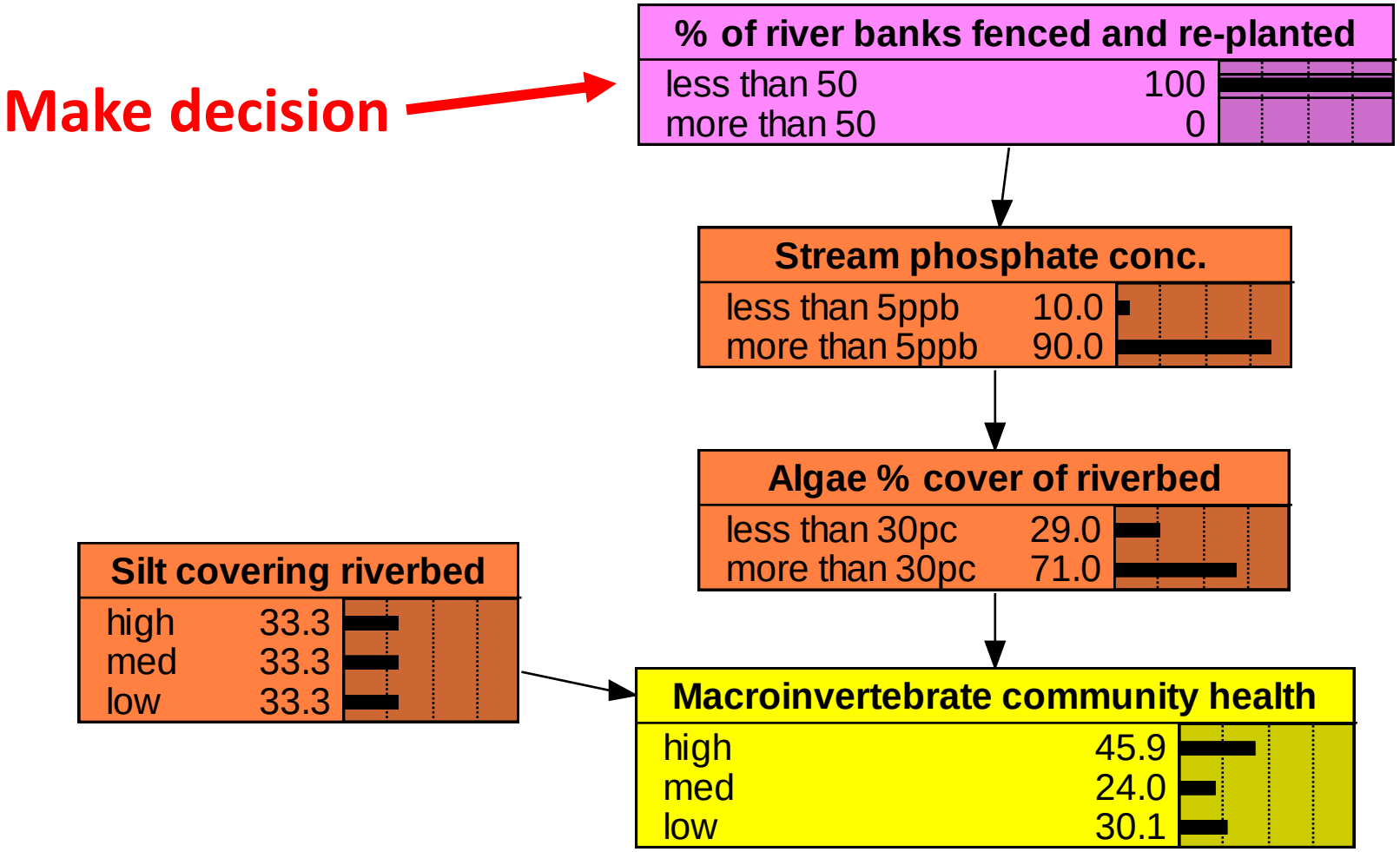
Set manually, by equation or by probability function

How BNs work

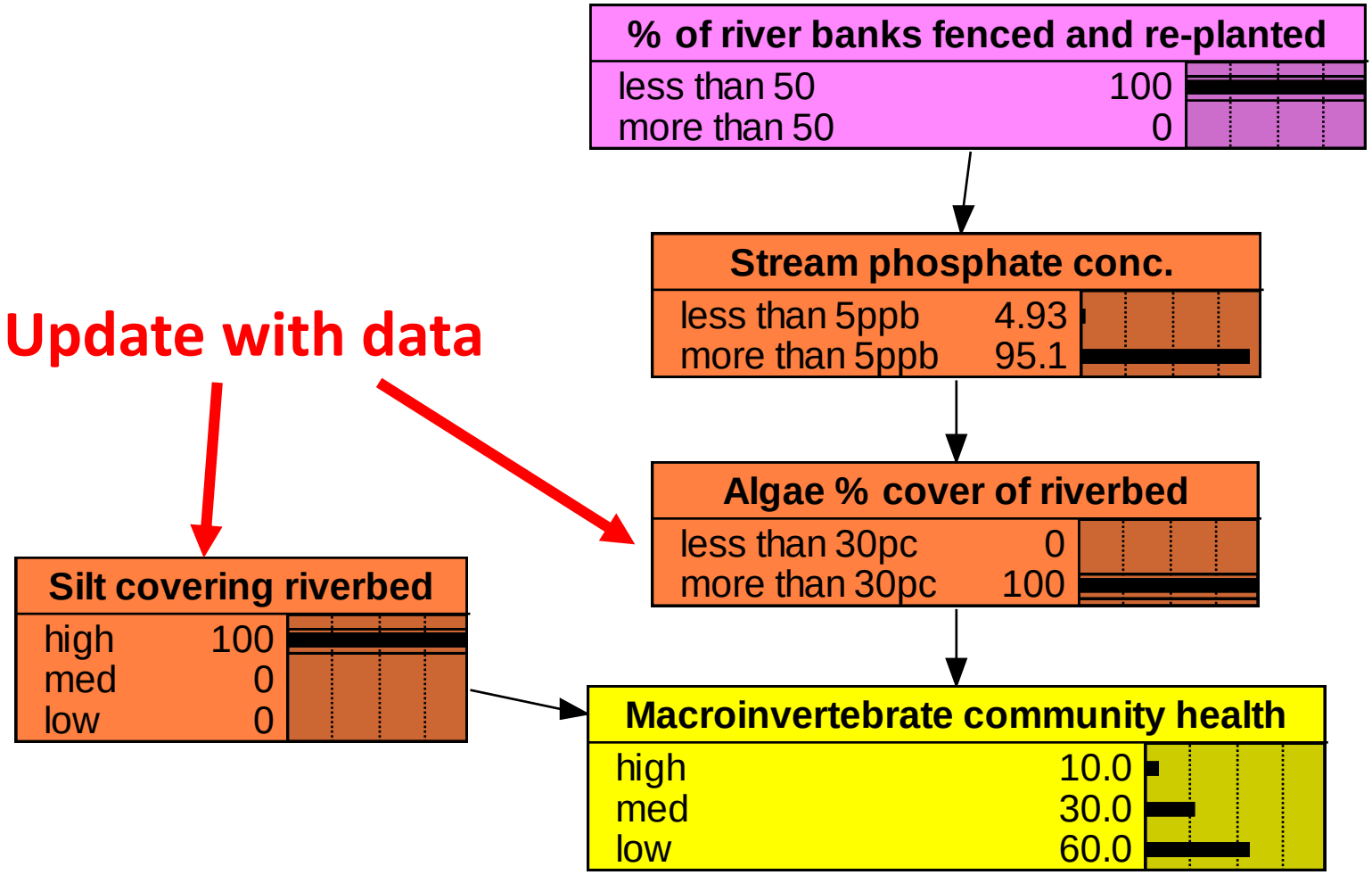
No prior knowledge



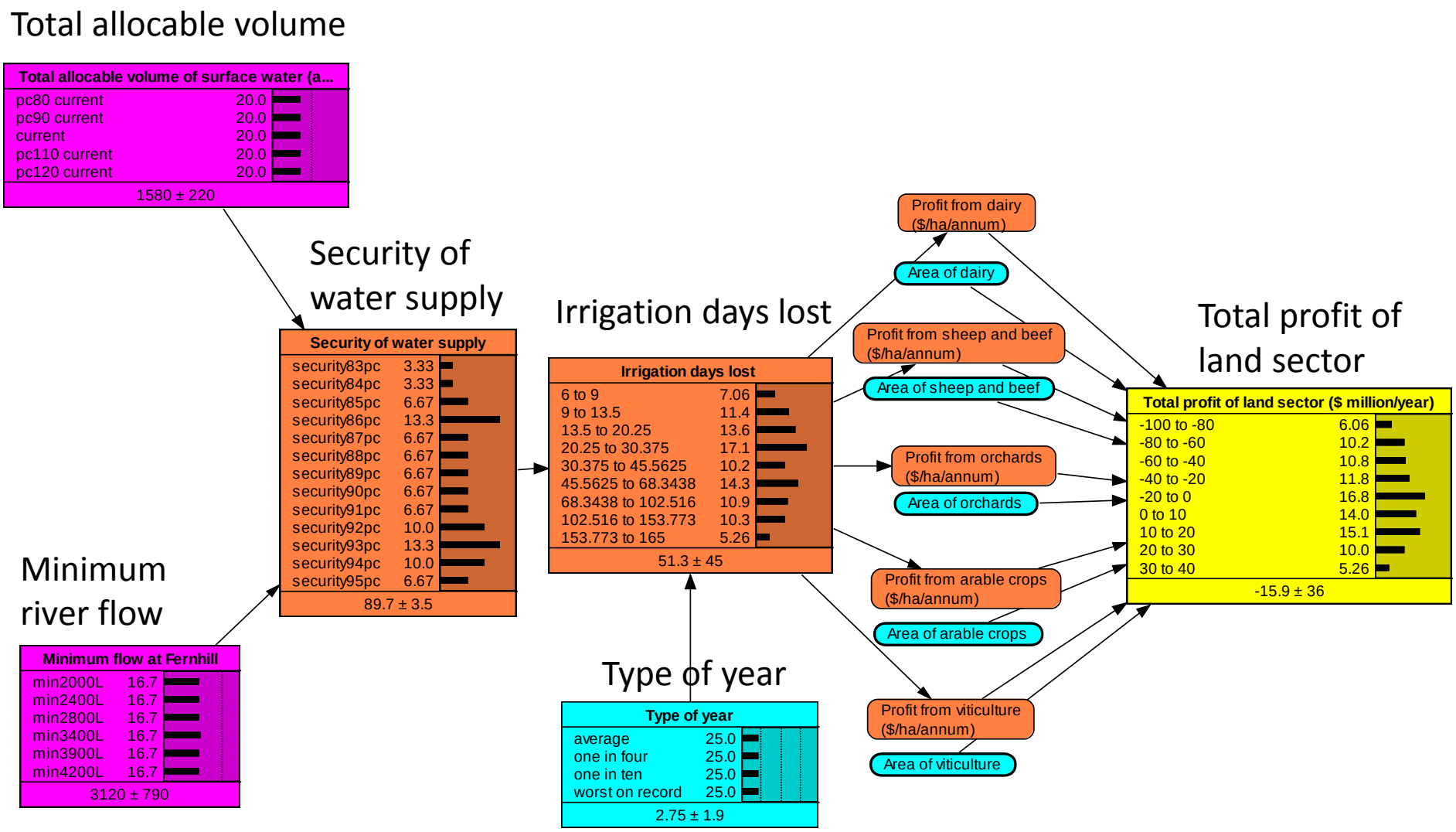
How BNs work


Make decision
% of river banks fenced and re-planted
less than 50 100
more than 50 0
Stream phosphate conc.
less than 5ppb 10.0
more than 5ppb 90.0
Algae % cover of riverbed
less than 30pc 29.0
more than 30pc 71.0
Silt covering riverbed
high 33.3
med 33.3
low 33.3
Macroinvertebrate community health
high 45.9
med 24.0
low 30.1

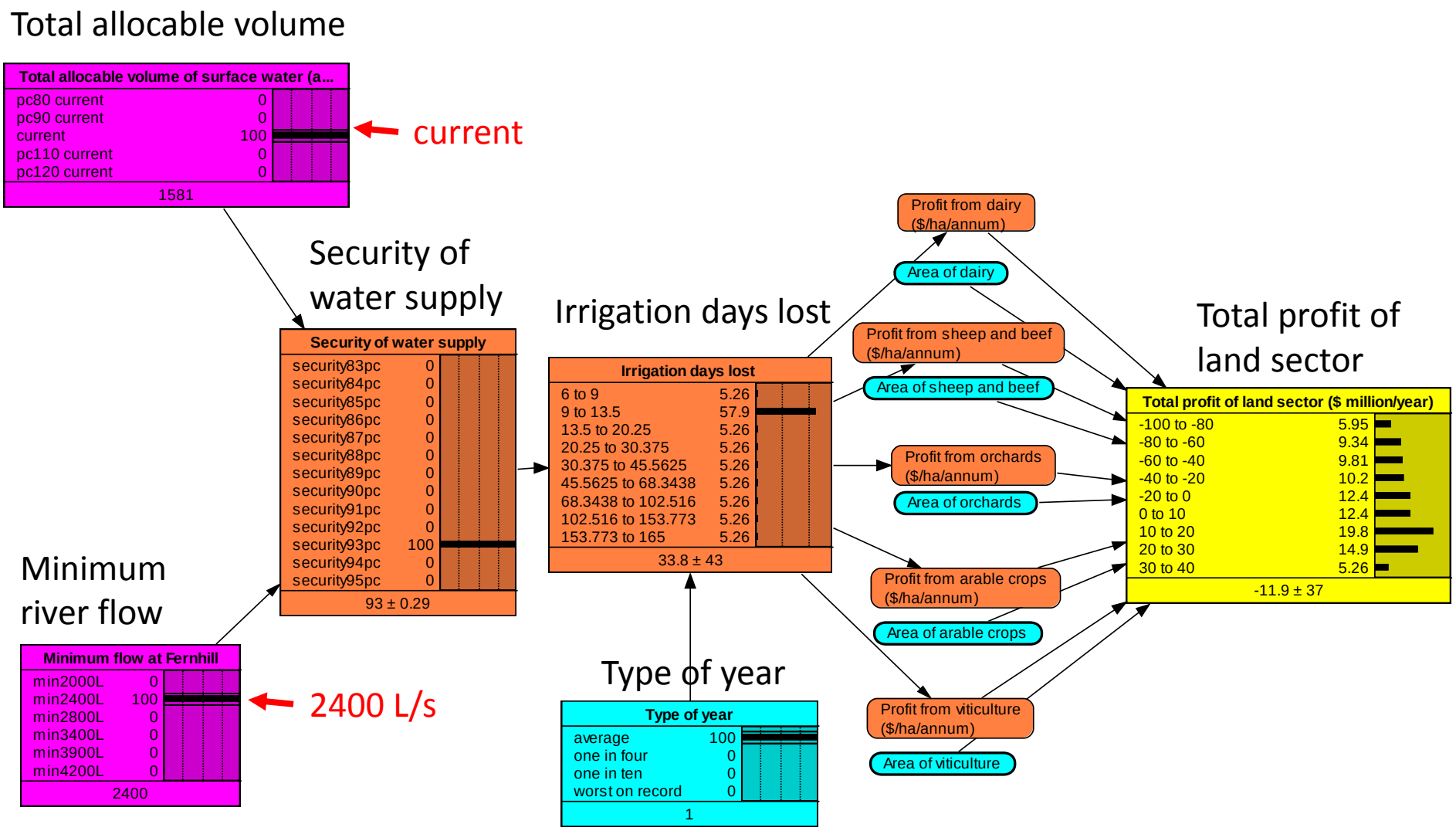
How BNs work


% of river banks fenced and re-planted
less than 50 100
more than 50 0
Stream phosphate conc.
less than 5ppb 4.93
more than 5ppb 95.1
Update with data
Algae % cover of riverbed
less than 30pc 0
more than 30pc 100
Silt covering riverbed
high 100
med 0
low 0
Macroinvertebrate community health
high 10.0
med 30.0
low 60.0

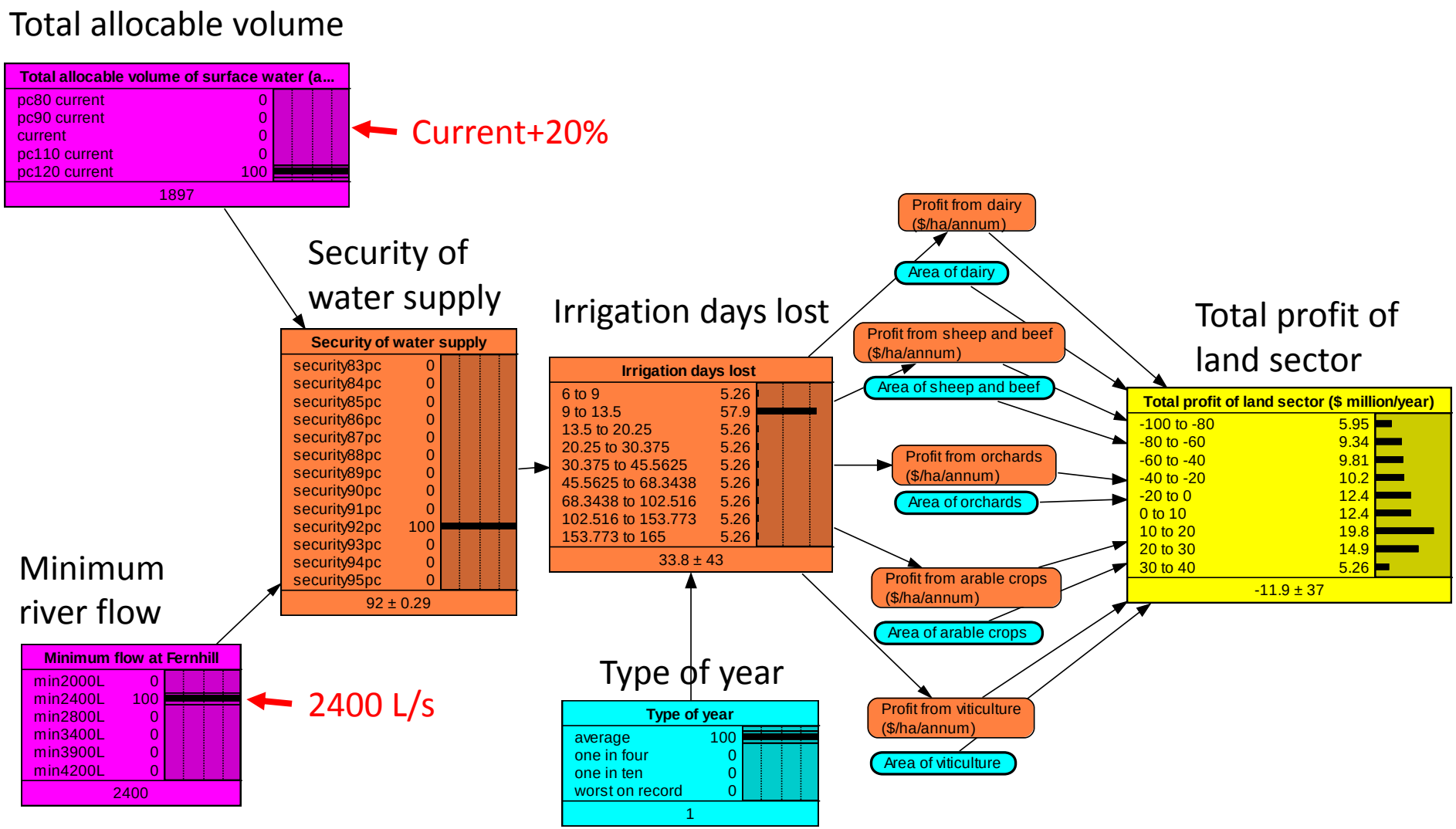
Economic outcomes



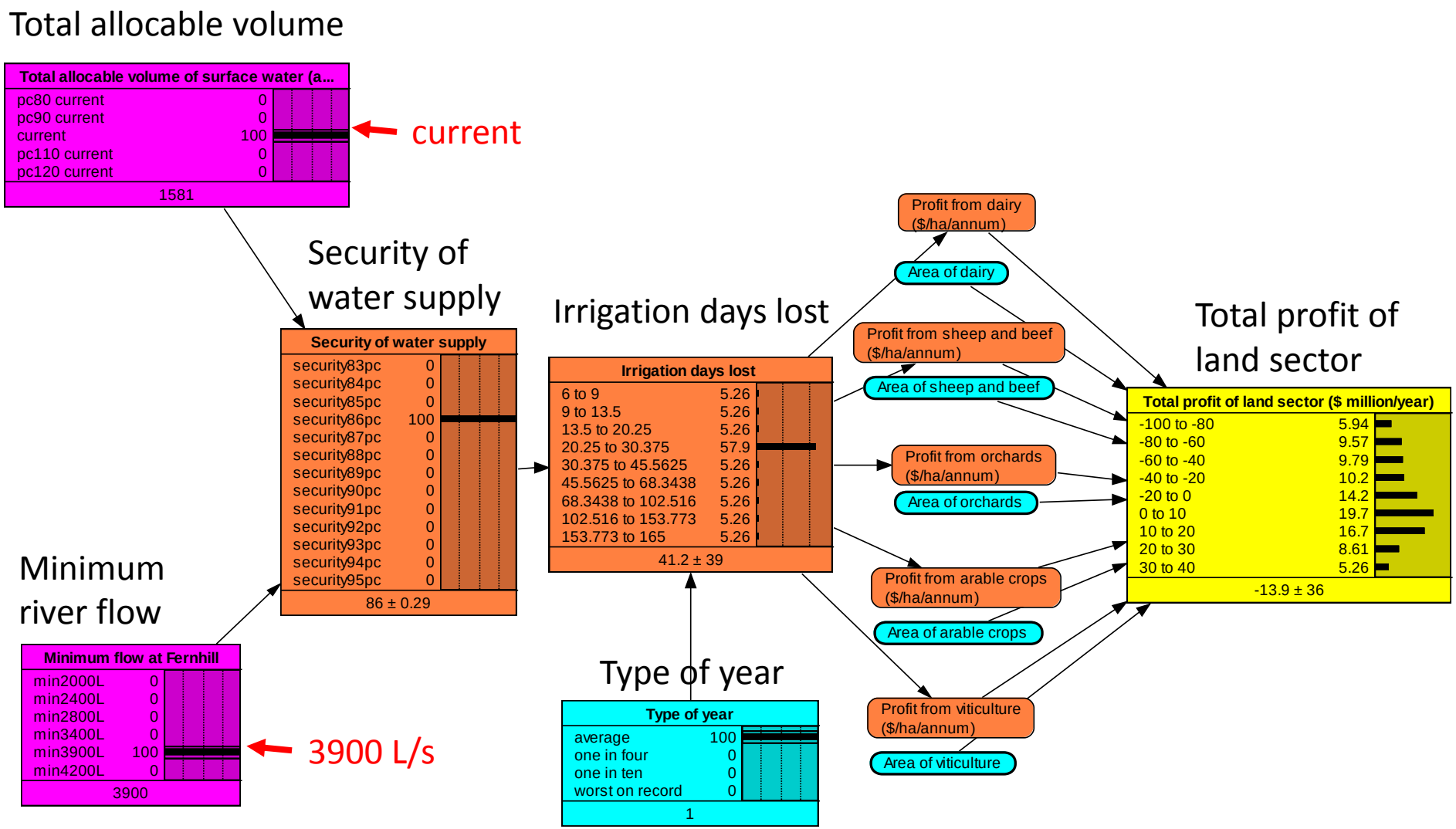
Economic outcomes



Economic outcomes



Economic outcomes



Why use BNs for the TANK planning process?

- BNs organise all the relevant knowledge.
- incorporate different types of knowledge:
  - expert scientific judgment, numerical model output, monitoring data and stakeholder experience.
  - Precise, imprecise
- graphical layout makes them suitable for communicating.
- Scenarios can be run quickly so implications of different management options are rapidly understood.
- The probabilities of various outcomes show stakeholders and decision makers the chances of achieving goals.

Additional benefits of BNs for the TANK process

- Identify knowledge gaps
- clarify level of detail required for decision-making

Conclusions

- BN is a decision-support tool
- It is a model that shows effects of policy decisions on the suite of agreed objectives.
- Places outputs of other models alongside other sources of knowledge in decision-making framework
- BN is information-hungry. Will require considerable effort by many people.

Conclusions

- BN is not essential, but if not used then:
  - How do you ensure shared understanding?
  - How do you compare different policy options wrt wide range of objectives?
  - How do you deliver relevant science so it is useful for decision-making

- BN provides a structured way of doing these