



# Using Bayesian Networks to make good decisions in complex systems

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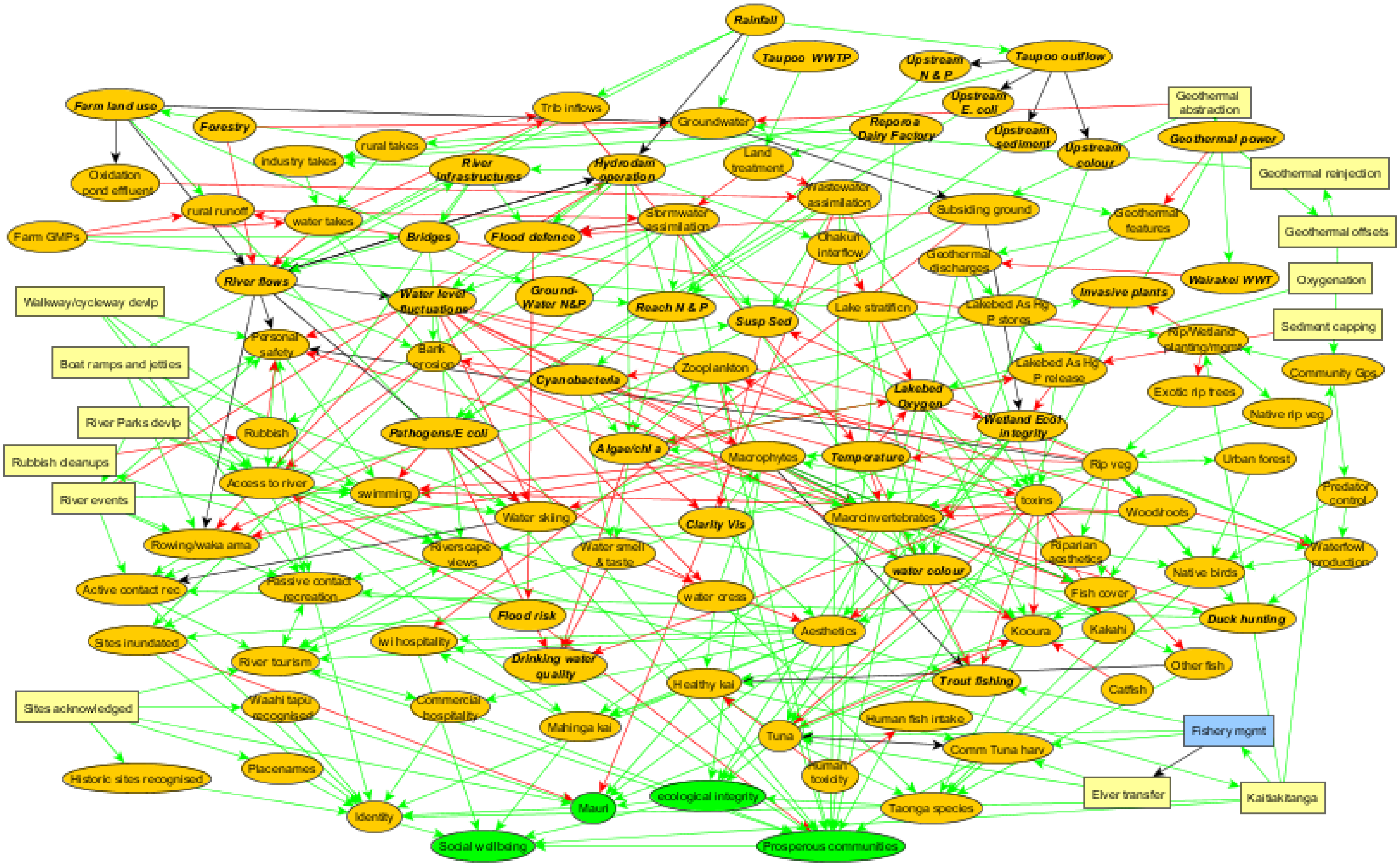
# River catchments support many different values

# River systems are complex

## Waikato River between Taupo gates and Ohakuri



# Questions a collaborative stakeholder group may ask

- How would different “minimum river flow” levels affect regional economic growth, native fish abundance and suitability of the river for swimming? How certain are we of these outcomes?
- How do different policy options affect freshwater values?

| | **Option A:**<br>**Raise min. flow**<br>**Nutrient cap** | **Option B**<br>**Current min. flow**<br>**Riparian planting** | **Option C**<br>**Lower min. flow**<br>**Stock exclusion** |
|---|---|---|---|
| Native fish OK? | Yes (80%) | Yes (70%) | Yes (50%) |
| Suitability for swimming | Good (70%) | Fair (80%) | Fair-Poor (70 %) |
| Fulltime jobs in horticulture & farming | Loss of jobs (80%) | No change in no. of jobs (65%) | Gain in jobs (80%) |

# The challenges for a CSG

- How to make decisions that achieve a range of objectives and balance different interests?
- How to determine effects of different management options for achieving objectives?
- How can science inform the decision-making process without dominating or bamboozling?

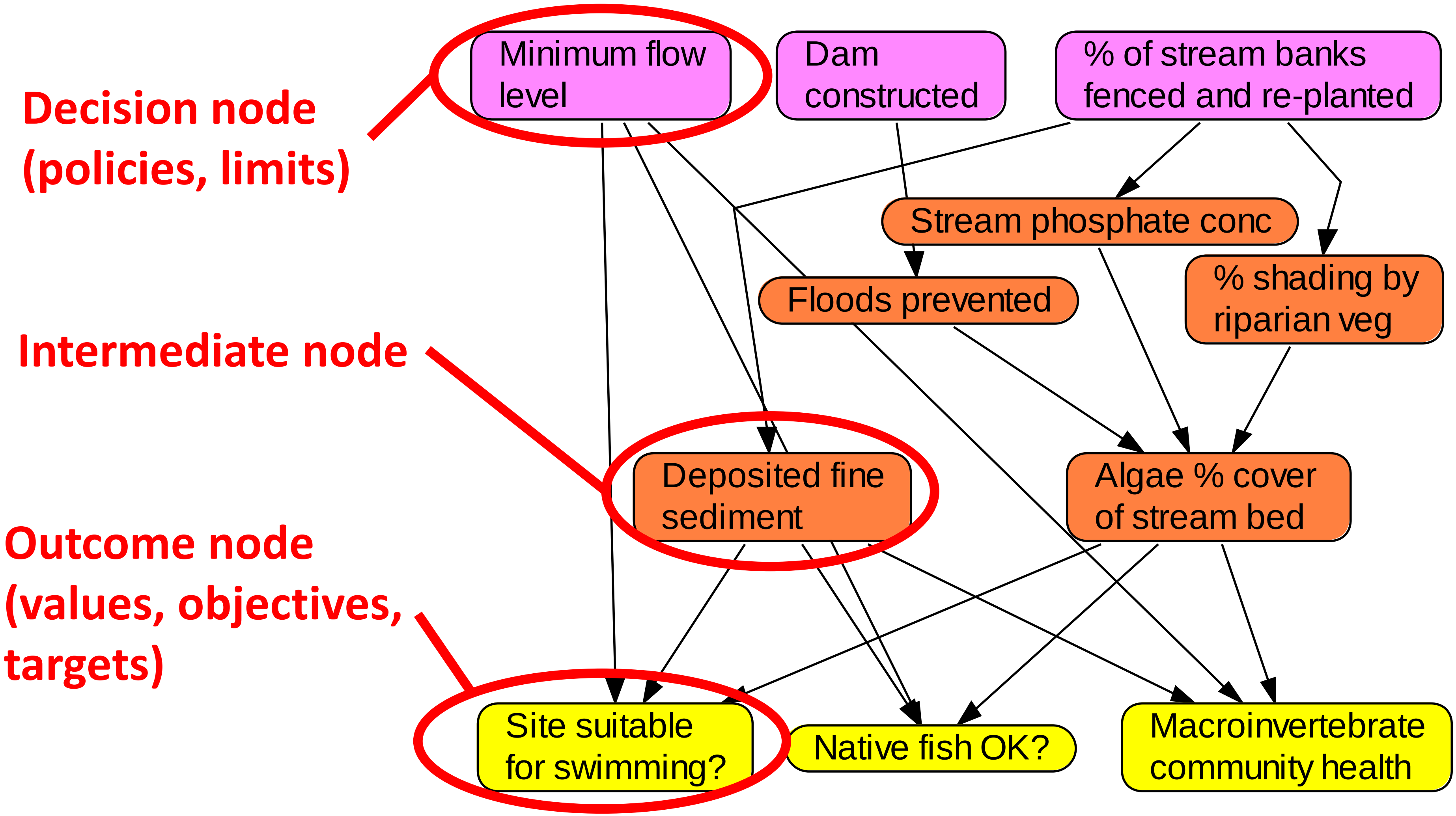
# Bayesian Networks for resource planning

- a way of determining the chance that certain management decisions will lead to particular outcomes
- Based on knowledge of:
  - How one variable affects another.
  - The state of some variables (decisions, fixed scenarios, observations)

"if 50% of streams in the Ruamahanga catchment are fenced and planted, then there is an 80% chance that native fish index will increase"

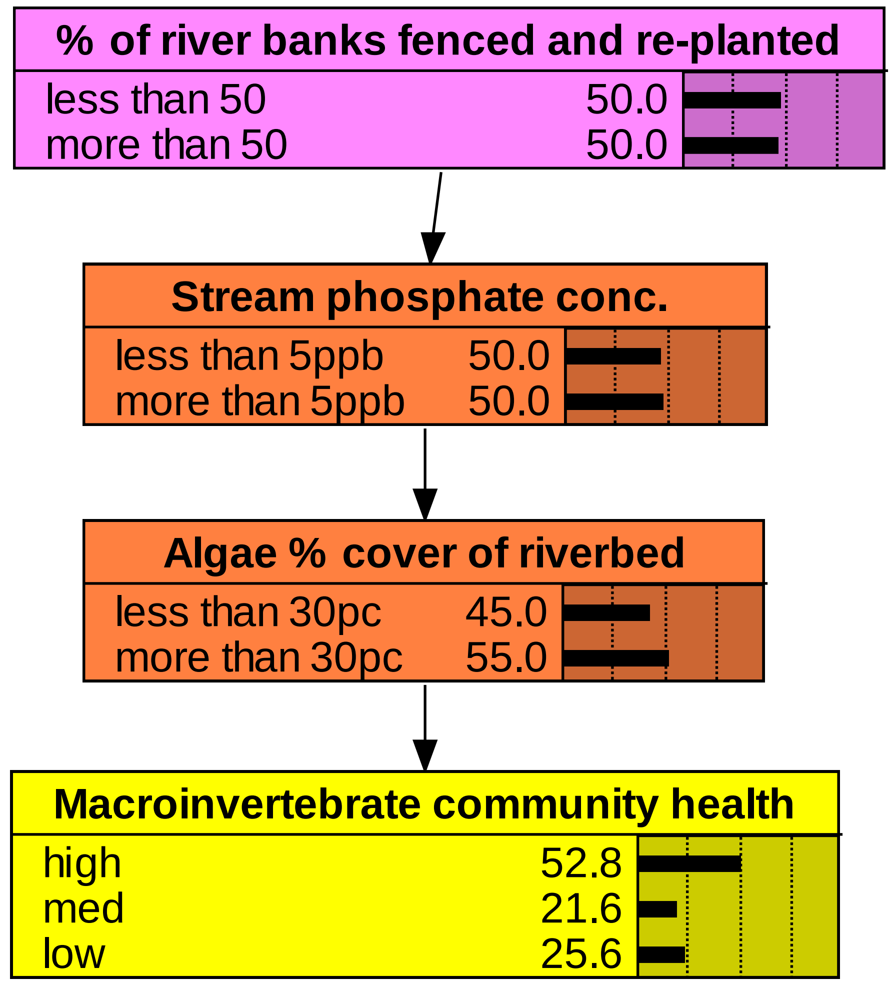
# Stage 1: influence diagram

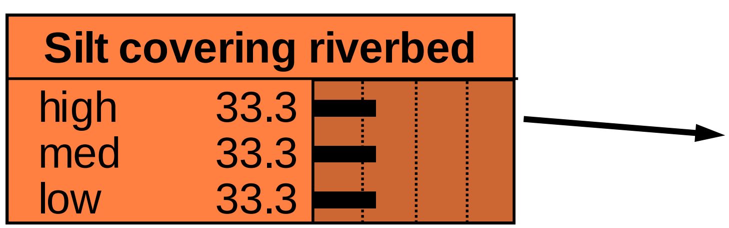
- Represents how we think one thing affects another



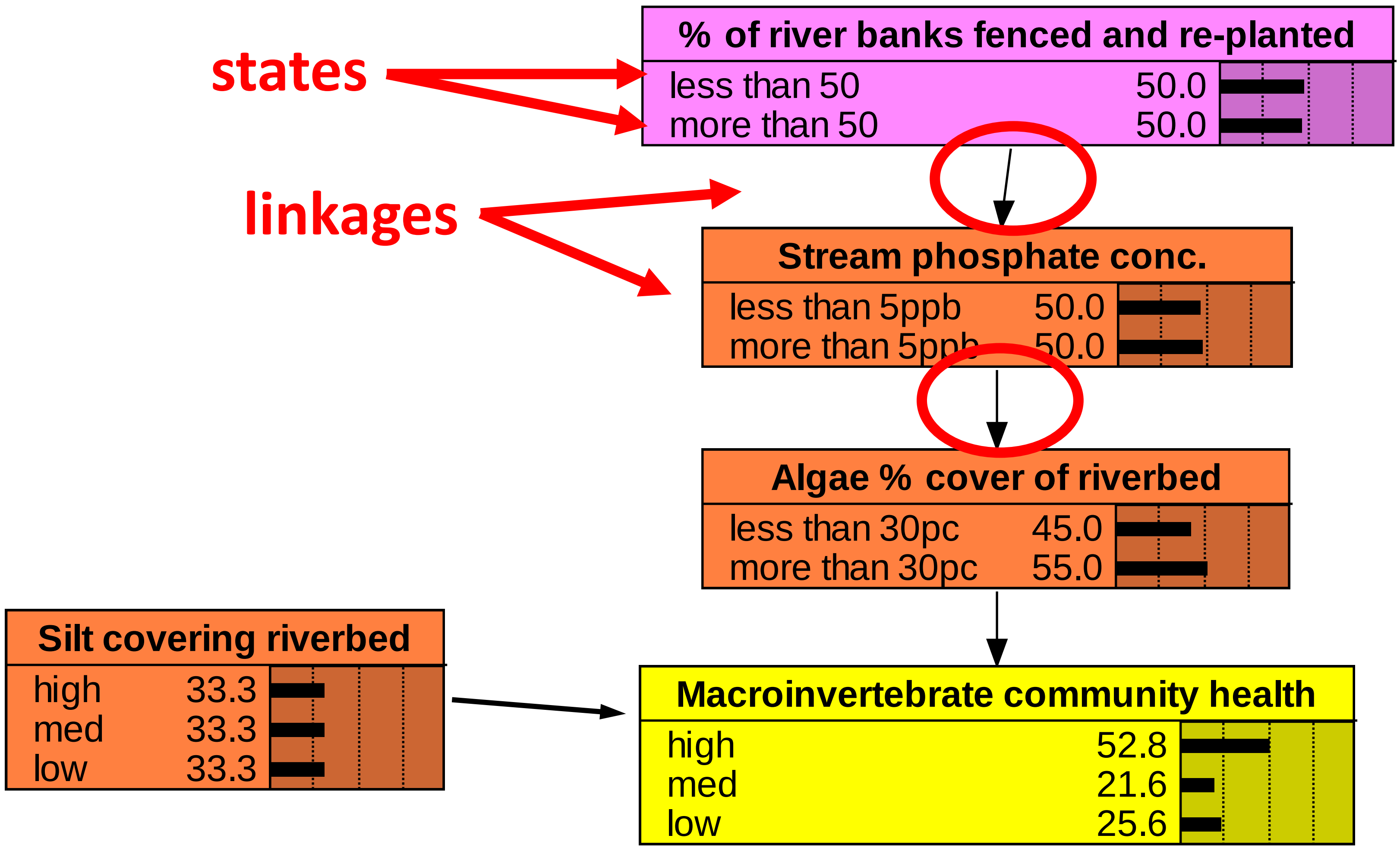
# Bayesian Networks

- How much one node affects others
- Based on probabilities: represent incomplete knowledge
- Probabilities combined according to Bayes theorem: $P(A,B) = P(A|B)*P(B)$



# How BNs work



states
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 dependency tables

## Strong dependency

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

## Weak dependency

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

# CPTs combining 2 parents

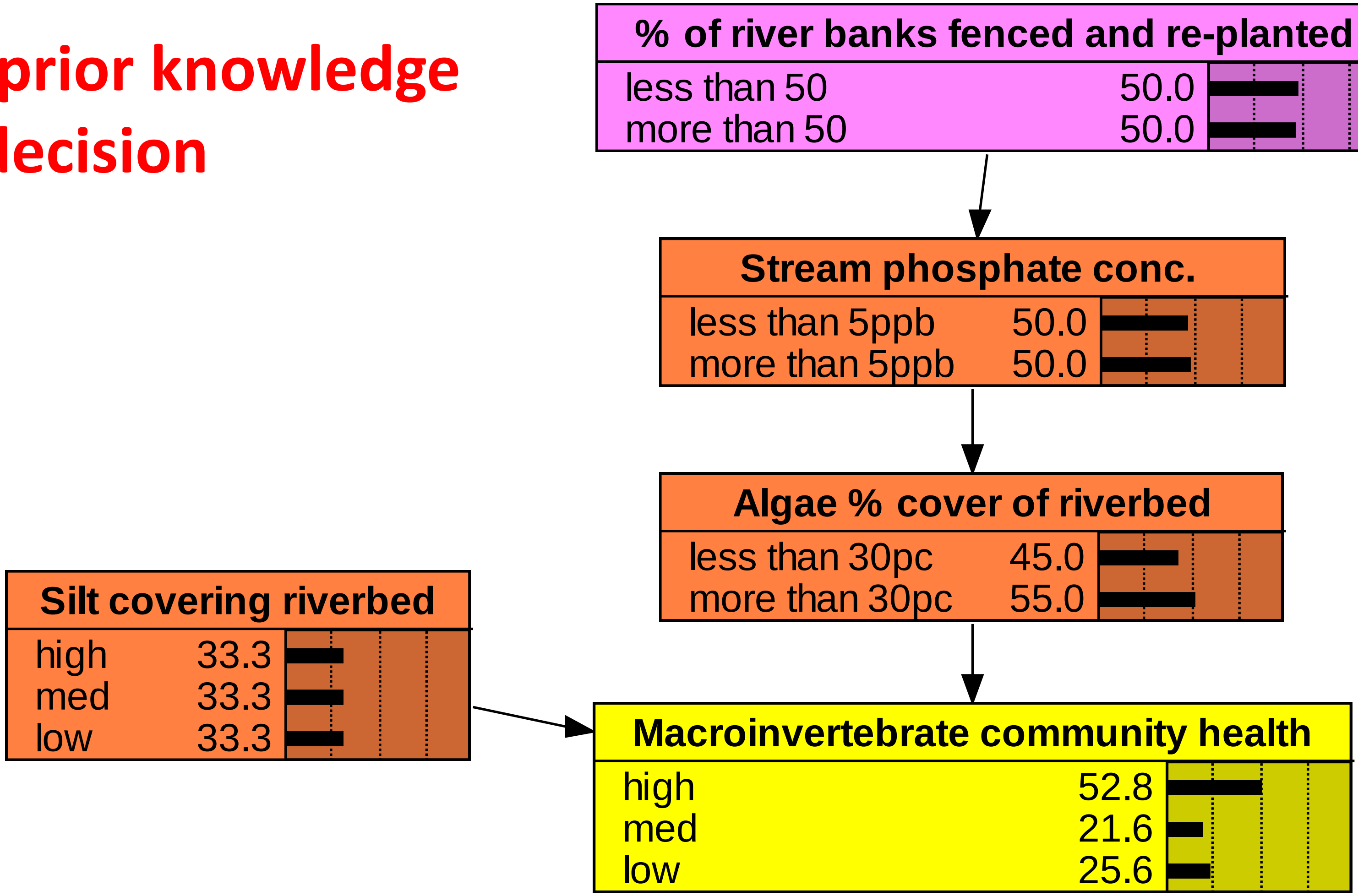
Parent node 1 (2 states) | Parent node 2 (3 states) | Child node

| 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 |

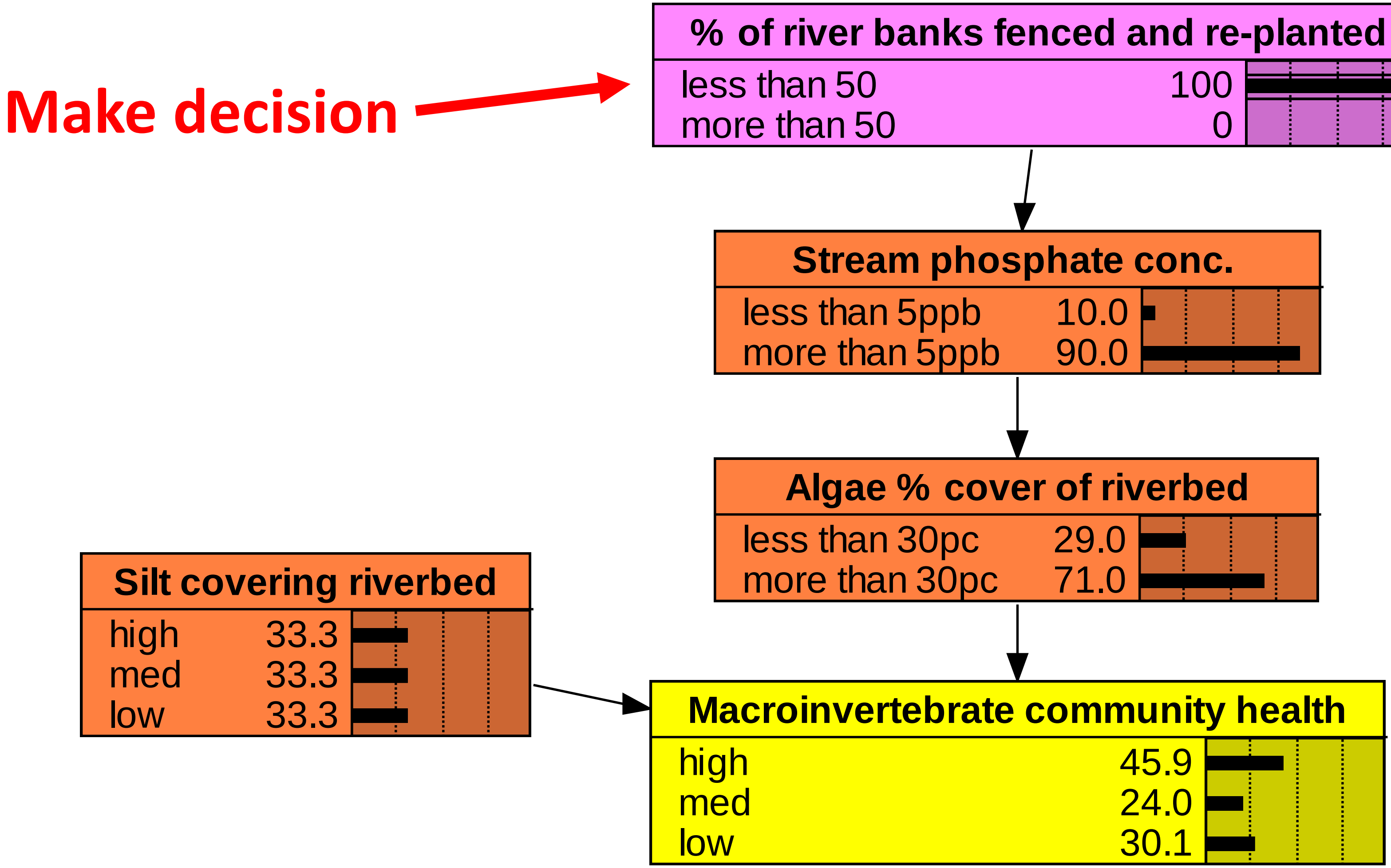
Set manually, by equation or by probability function

# How BNs work

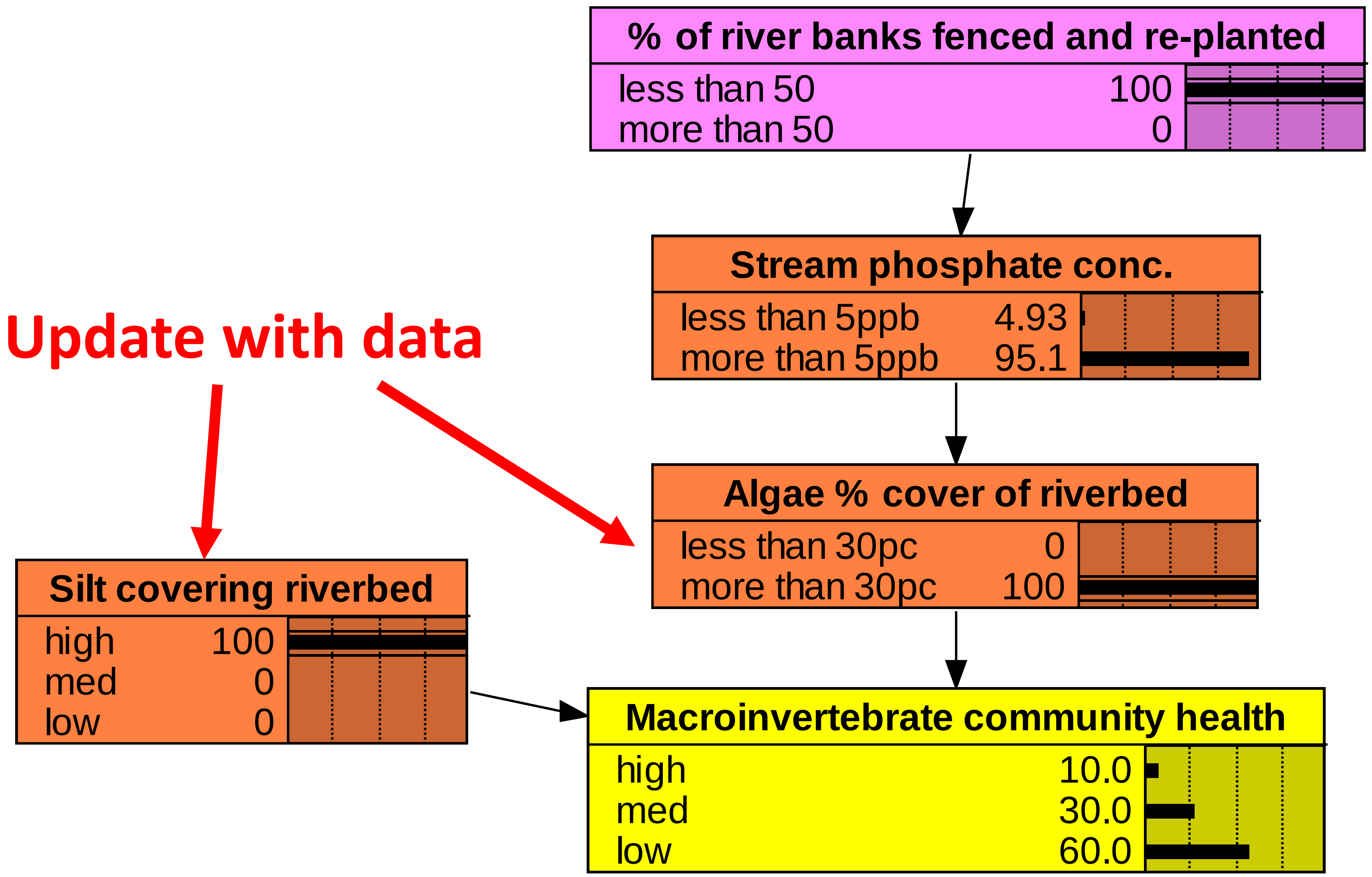
**No prior knowledge or decision**



# 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

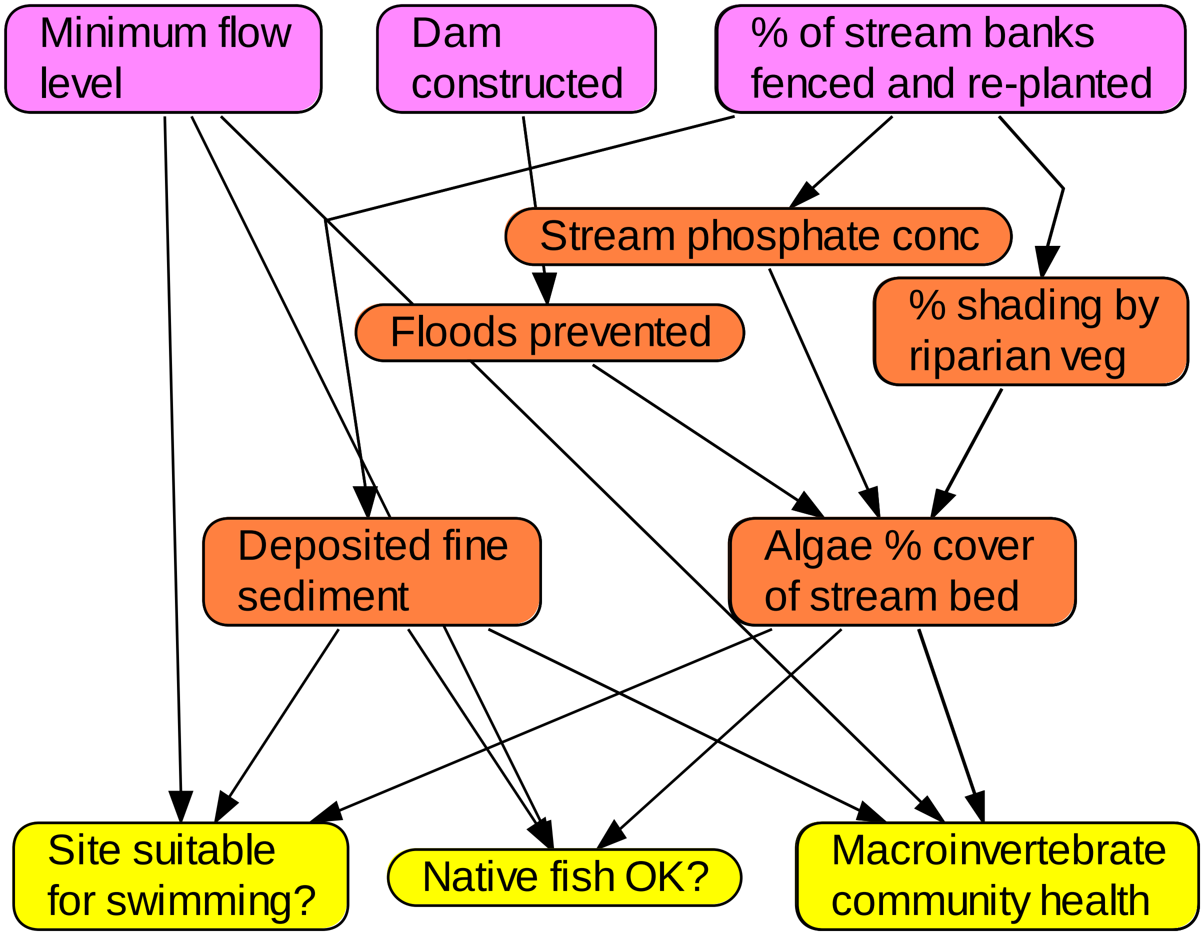
# How BNs work



% 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

# BNs in resource management

- Multiple influences
- Multiple decisions
- Range of diverse values
- Variety of info sources
- Uncertain behaviour
- Incomplete data
- Used by individuals or groups



# How BNs are used in collaborative processes

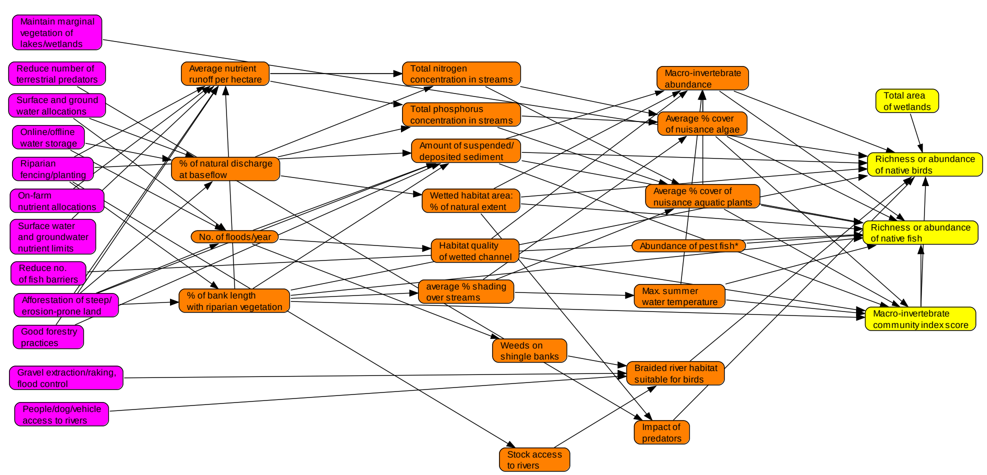
## 1. Whaitua committee

- Identifies values > objectives > "performance measures"
- Identifies key issues
- Identifies management options
- draws "influence diagrams"

## 2. Experts refine the diagrams: realistic, relevant, functional

- Set states for each node
- Set probabilities for each linkage

Present BN back to RWC

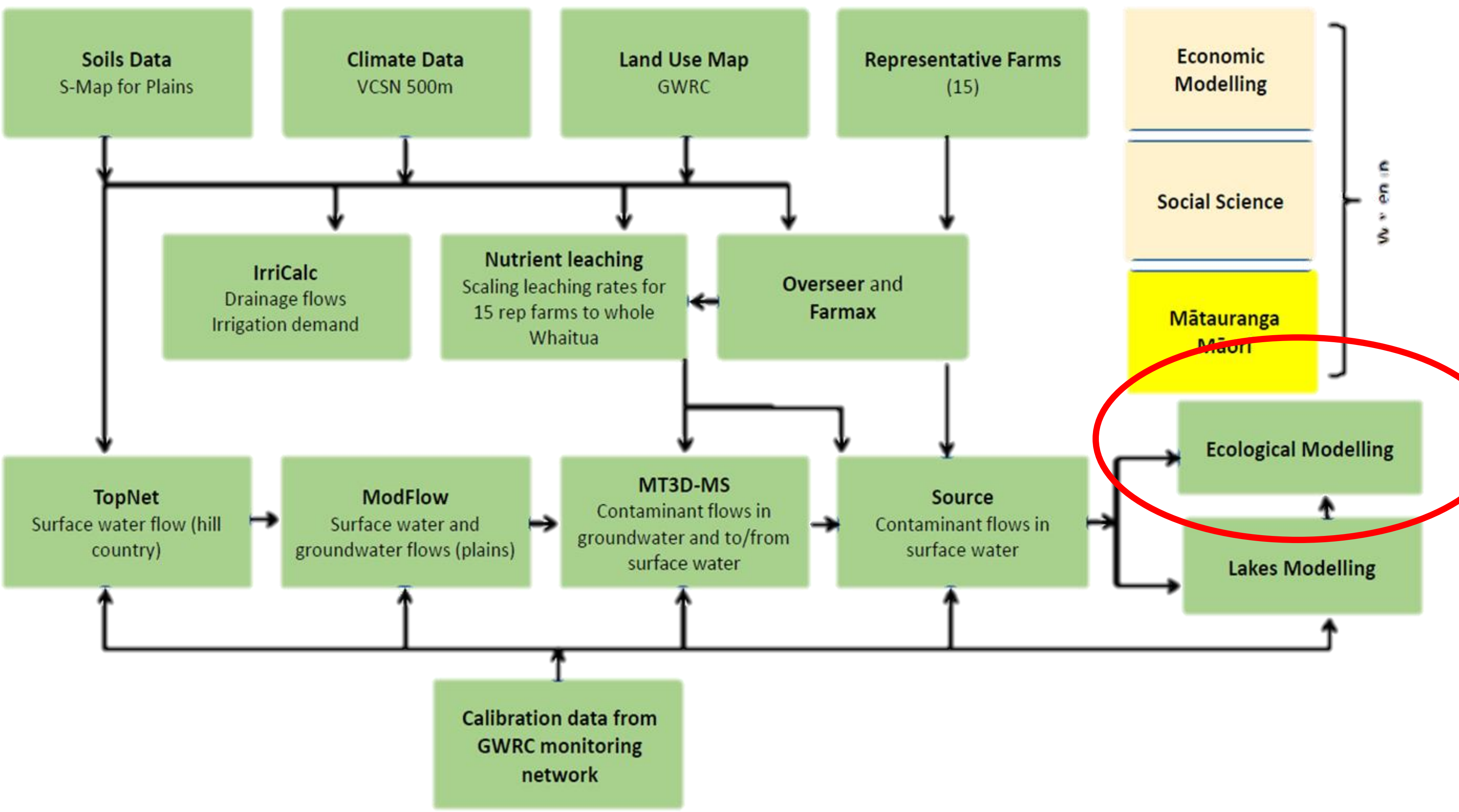


# Purpose of Bayesian Network for RWC

Support decision-making on key issues by

- Showing consequences of policies and limits on different values
- Helping to compare different policy "packages":
  - which one gives the best result for the greatest number of values?

# How does the BN fit with other modelling?



# Group exercise

- Choose an issue
- Together, build an influence diagram.
  - What values may be affected? What attributes can be used to measure the outcomes?
  - What decisions (policies, limits) are available?
  - How are the attributes affected by the decisions?

- If time allows: choose connected 3 nodes
  - Decide on 2-3 “states” for each node
  - Draw a probability table to show how each affects the others