A SYSTEMS ANALYSIS OF THE 1998 SYDNEY WATER CRISIS

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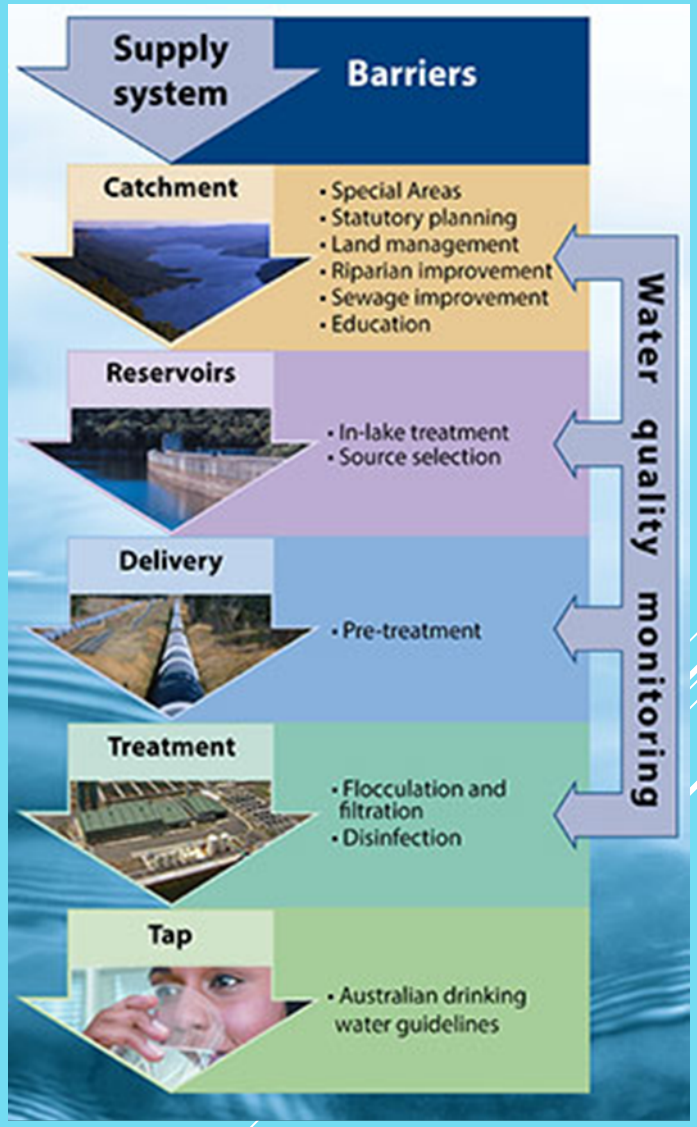
PRESENTATION OVERVIEW

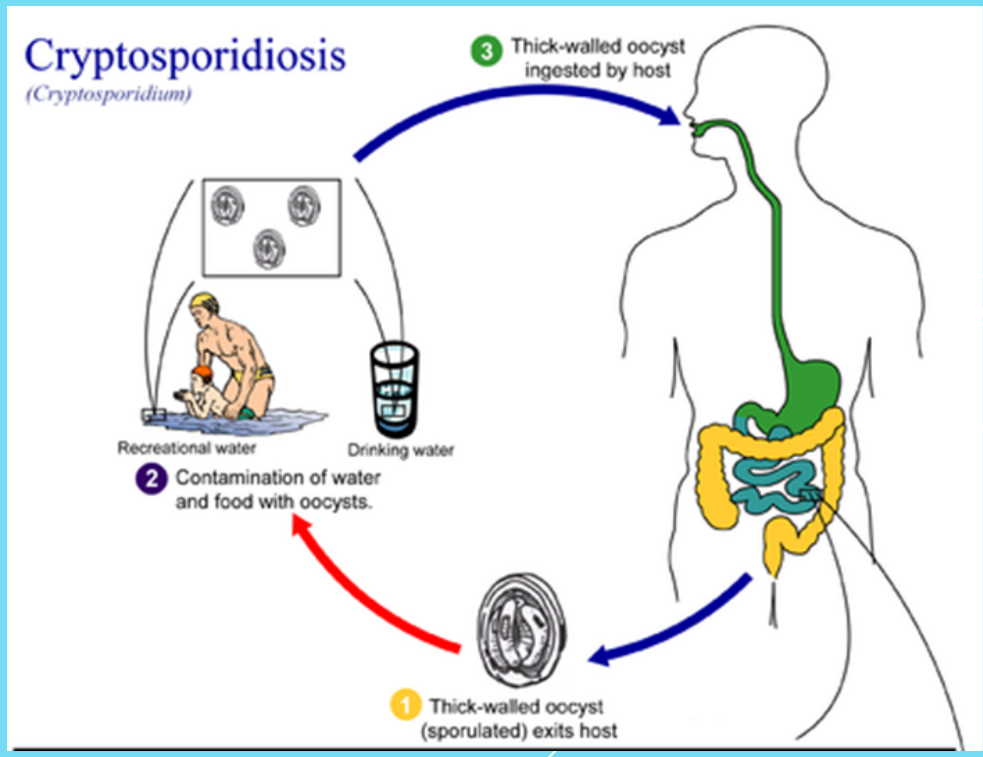
- Background
- Scheme Description
- Accident Description
- Results
- Findings
- Conclusion



Source: NSW Water

BACKGROUND

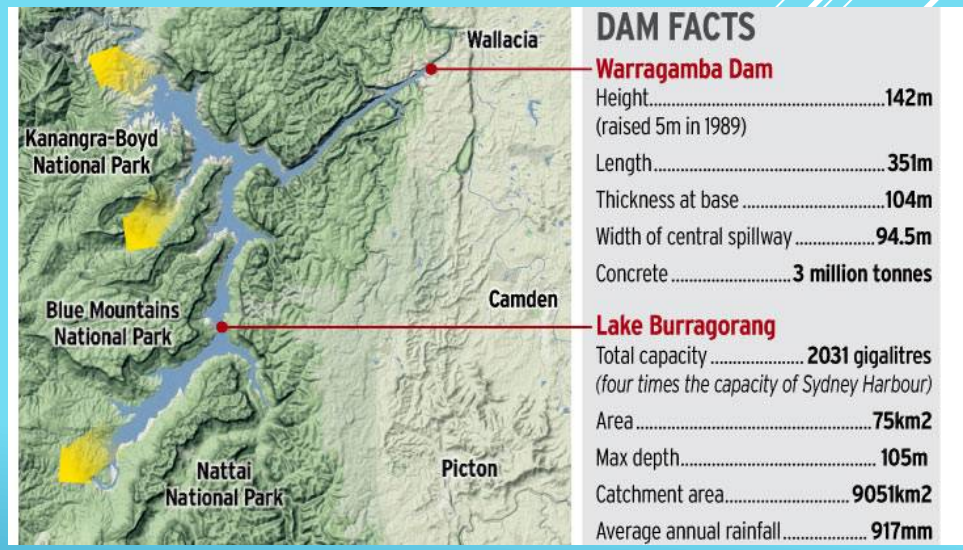
- High levels of Cryptosporidium and Giardia Detected in the drinking water supply for Sydney Australia
- Three separate Boiled Water Advisories were issued
- Considered a false positive event – absence of increased disease levels in community
- Resulted in significant restructure of drinking water supply organizations
- Outcomes and learnings from this incident have influenced the practices of water utilities across Australia



SCHEME DESCRIPTION

Warragamba Catchment
Upper Nepean Catchments
→
Water storage reservoirs
→
Prospect Water Treatment Plant
→
Drinking Water Distribution

- The water supply scheme for Sydney supplies around 4 million people
- The water supply scheme for Sydney is a complex mix of sources and treatment plants
- Prospect Water Treatment Plant supplies 85% of Sydney's drinking water and the district that was affected by the crisis
- Prospect Water Treatment Plant is supplied by the Warragamba and Upper Nepean catchment areas



Source: NSW Water

KEY EVENTS

- The drinking water distribution system sampling on the 7/21/1998 and 7/22/1998 showed low level detections of Cryptosporidium and Giardia
- Detections resulted in further investigation and notification to the NSW Department of Health.
- Then from 7/22/1998 onwards continued detections of Cryptosporidium and Giardia resulted in three Boiled Water Advisories (BWA) issued over 3 months
- Cryptosporidium and Giardia detected in raw water, filtration plant and distribution system water samples.
- Formal Inquiry held to determine the causes of the crisis and determine accountability

ACCIDENT, HAZARD AND SAFETY SYSTEM CONSTRAINTS

Accident:

Loss of confidence in the safety of drinking water supplied to the public

General System hazard:

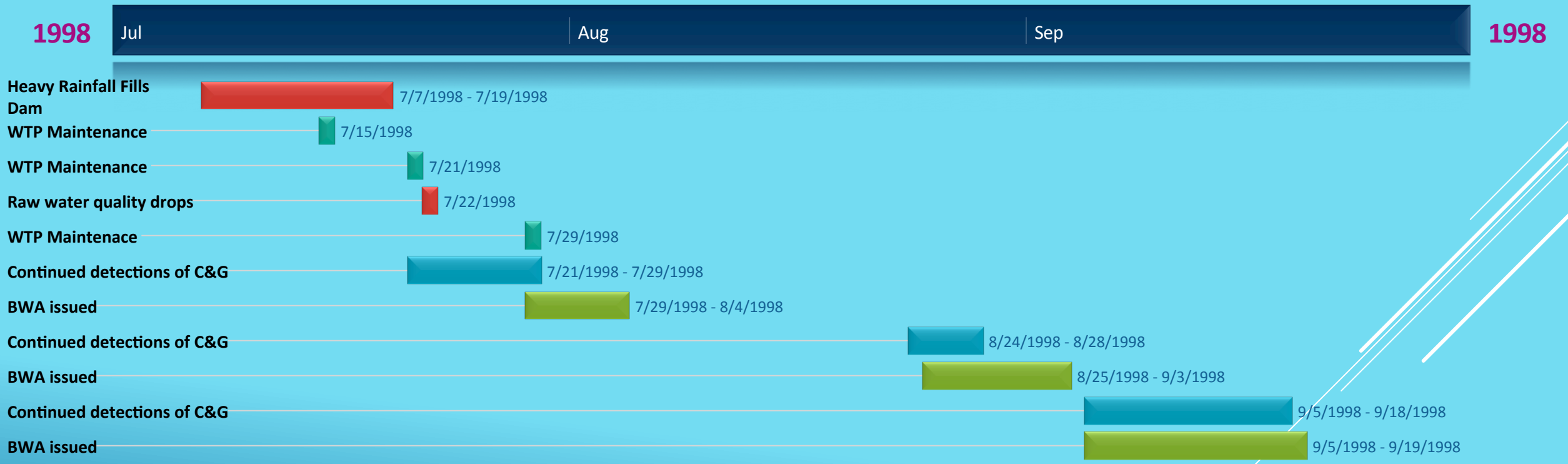
Public exposed to unsafe drinking water

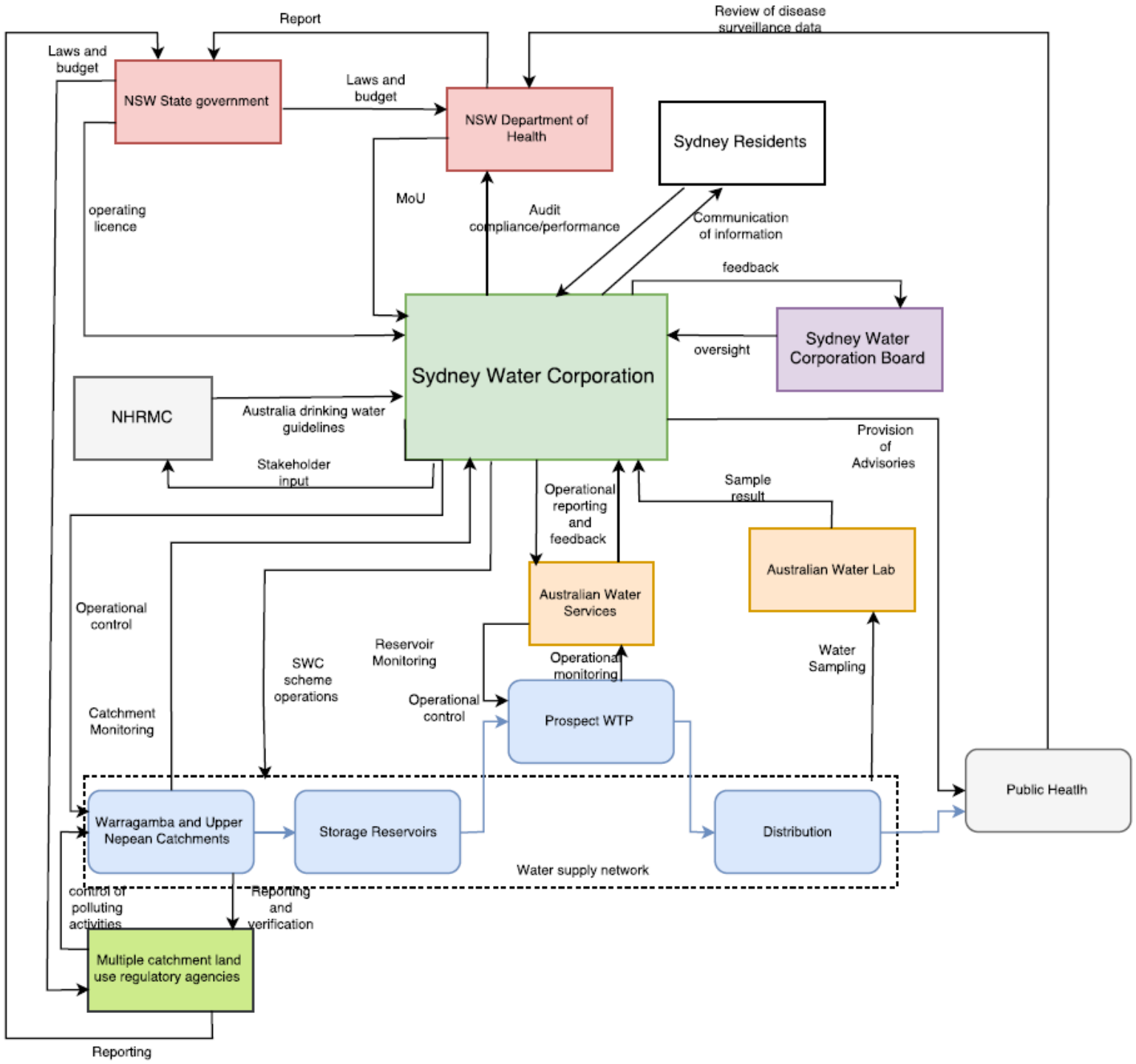
Safety System Constraints:

The public must not be exposed to pathogens in drinking water

Public health measures must reduce risk of public exposure to unsafe water during incidents

INCIDENT TIMELINE

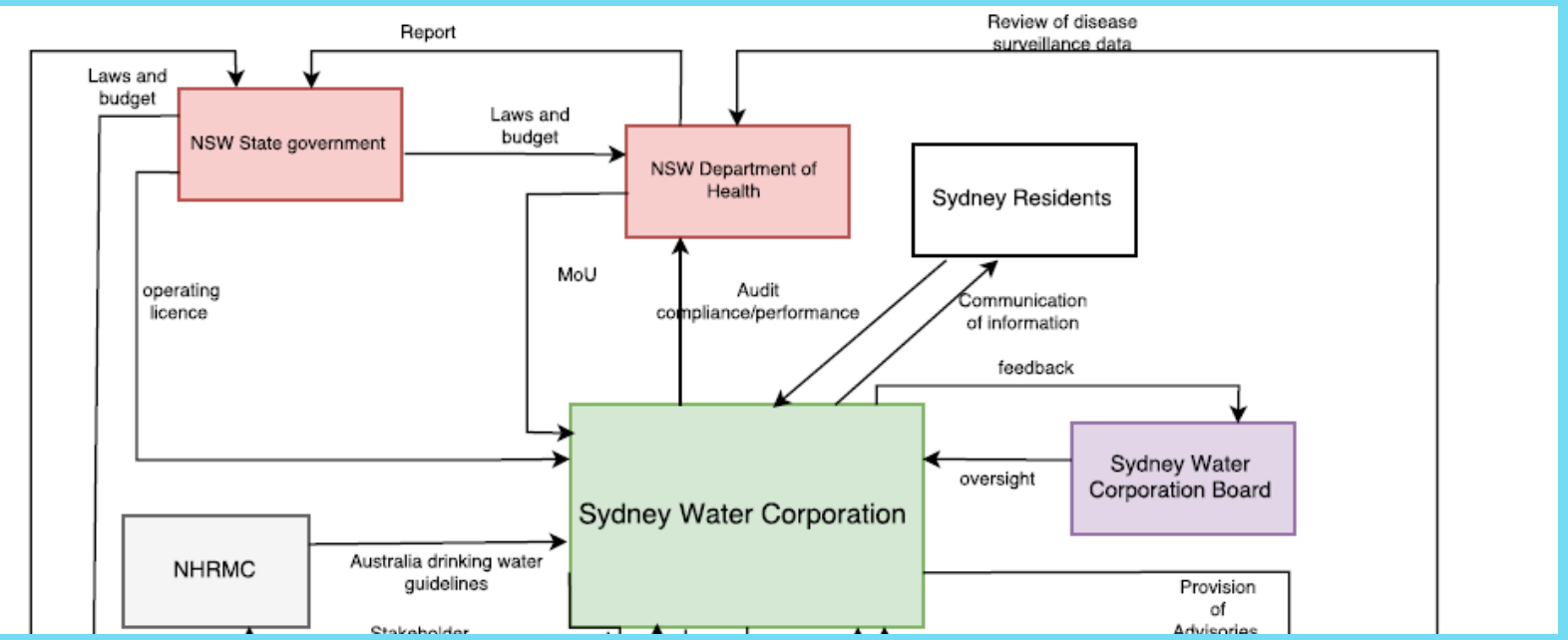




PRE-CRISIS CONTROL STRUCTURE – FULL SYSTEM

- The control structure in place at the time of the crisis

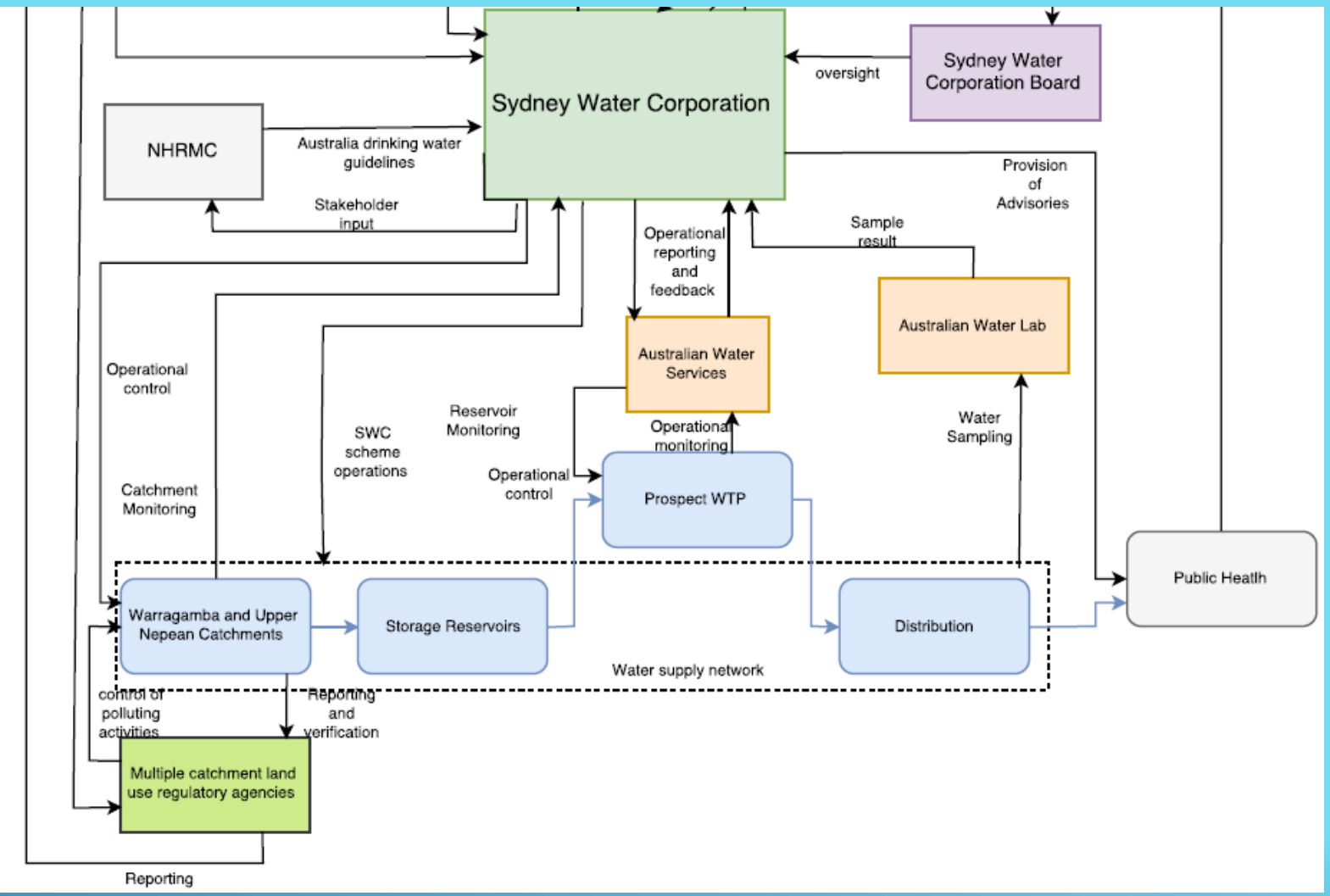
CONTROL STRUCTURE AT TIME OF CRISIS – REGULATORY



Main Regulators of drinking water

- NSW government – operating License
- NSW Department of Health – MoU for supply of drinking water

PRE-CRISIS CONTROL STRUCTURE – OPERATIONAL



- The key operational components of the control structure at the time of the crisis
- Single agency managing drinking water quality from catchment to tap
- Multiple statutory agencies managing catchment land use

SUMMARY OF ACCIDENT CAUSAL FACTORS - DRINKING WATER CATCHMENTS

SAFETY REQUIREMENTS AND CONSTRAINTS VIOLATED

- Monitor **point source and non-point source pollution**.
- Implement **best practice management of land uses** within the catchment

CONTEXT IN WHICH DECISIONS WERE MADE

- SWC source protection **staffing numbers reduced** and some **functions outsourced**
- Extended drought and grazing had **reduced the effectiveness of vegetated stream buffers**
- Catchment area is largely undeveloped with some long term private land tenure

FAILURES AND INADEQUATE CONTROLS

- The c**atchment condition** had been allowed to **slowly degrade** over time
- **Multiple agencies** involved in land use policy and regulations **without central coordination.**

PROCESS MODEL FLAWS

- A **number of regulated land uses** in the catchment were known to be noncompliant
- **Loss of organizational knowledge** from Sydney Water Corporation
- **Multiple government agencies** with **no centralized planning** or administration focused on drinking water quality outcomes

SUMMARY OF ACCIDENT CAUSAL FACTORS - WARRAGAMBA RESERVOIR

SYSTEM REQUIREMENTS AND CONSTRAINTS VIOLATED

- Detention and settling time sufficient for **sedimentation and microbial die off**
- Offtake levels set to **abstract highest quality water from reservoir body**

CONTEXT IN WHICH DECISIONS WERE MADE

- Reservoir is normally mixed at that time of year with equal water quality at all depths
- The **heavy rain** resulted dam levels raising from **58% to 100% in 2 weeks**.
- A high-resolution thermistor chain was installed in reservoir and was actively recording data

FAILURES AND INADEQUATE CONTROLS

- **Offtake levels were not raised in time** to avoid abstracting the recent runoff water causing abstraction of high turbidity water with high potentially high pathogen concentrations

PROCESS MODEL FLAWS

- Reservoir operators were unaware of the **degraded catchment condition and poor quality of runoff water**.

SUMMARY OF ACCIDENT CAUSAL FACTORS - WATER TREATMENT

SYSTEM REQUIREMENTS AND CONSTRAINTS VIOLATED

- **Treatment barrier will meet the water quality challenge** of the raw water quality
- The **treatment system can handle raw water pathogen levels** when operating within design limits

CONTEXT IN WHICH DECISIONS WERE MADE

- **Plant was operating as expected** and seasonal demand was low as expected for winter
- The plant was challenged by **higher than usual levels of turbidity** in the raw water.
- reduced effectiveness of coagulant mixing due to **plant maintenance** (first BWA).

FAILURES AND INADEQUATE CONTROLS

- Sampling showed **cysts and oocysts moving through the treatment system**.
- Abnormal water quality to the plant **challenged the effectiveness of filtration and pathogen removal**.

PROCESS MODEL FLAWS

- Operational **turbidity limits** in place were considered an **effective surrogate to indicate effective pathogen removal**.
- During the scheduled maintenance activities **deviations from normal operations** could allow passage of pathogens through the treatment plant

SUMMARY OF ACCIDENT CAUSAL FACTORS - SAMPLE ANALYSIS

SYSTEM REQUIREMENTS AND CONSTRAINTS VIOLATED

- Provide accurate **count of pathogens in water samples** within a specified time

CONTEXT IN WHICH DECISIONS WERE MADE

- The analysis methods in place were **regularly used for operational sampling** by SWC
- Staff had been **trained and a QC system** in place
- Some of the pathogen concentrations were at **levels normally seen in wastewater**
- **Massive increase in samples** to be processed during crisis requiring additional staff and resources

FAILURES AND INADEQUATE CONTROLS

- The analytical methods used can potentially include **counts of dead and decaying cysts and oocysts**
- The analytical methods were **not suitable for telling if** the cysts and oocysts were **active or pathogenic** in the time required

PROCESS MODEL FLAWS

- believed the analysis results were **quantitatively representative of water quality**
- Believed the **analysis results represented gross contamination** of pathogenic Cryptosporidium and Giardia

SUMMARY OF ACCIDENT CAUSAL FACTORS –– NSW DEPARTMENT OF HEALTH

SAFETY REQUIREMENTS

- **Set requirements for** verification and validation of **drinking water safety**
- **Provide advice** on public health protection during drinking water **contamination incidents**

CONTEXT IN WHICH DECISIONS WERE MADE

- Previous studies show a **risk of Cryptosporidium and Giardia** in the catchment
- Some reputable literature recommends operational **pathogen monitoring to measure barrier performance**

FAILURES AND INADEQUATE CONTROLS

- Set a requirement for **operational monitoring** for Cryptosporidium and Giardia **without appropriate guidelines/limits** or complete response protocol

MENTAL MODEL FLAWS

- **unaware of the complexities and limitations** of operational Cryptosporidium and Giardia monitoring
- **inadequate knowledge** of staff on how to deal with **large-scale water quality incidents**

SUMMARY OF ACCIDENT CAUSAL FACTORS –– SWC WATER QUALITY OPERATIONS

SAFETY REQUIREMENTS

- **Implement a water quality management system** based on the 1996 ADWG.
- **Monitor Water quality** across the system to ensure it meets the **regulatory requirements**.

CONTEXT IN WHICH DECISIONS WERE MADE

- Previous studies have highlighted the **risk of pathogens in the catchment**
- New **treatment plant** in place should **meet the challenges** from the raw water
- **No previous detections** of high levels of Cryptosporidium and Giardia in the distribution system
- **Long term degradation in catchment** and rapid filling of the reservoir
- **1996 ADWG did not require operational monitoring or set limits** for Cryptosporidium and Giardia due to complexities with analysis methods.

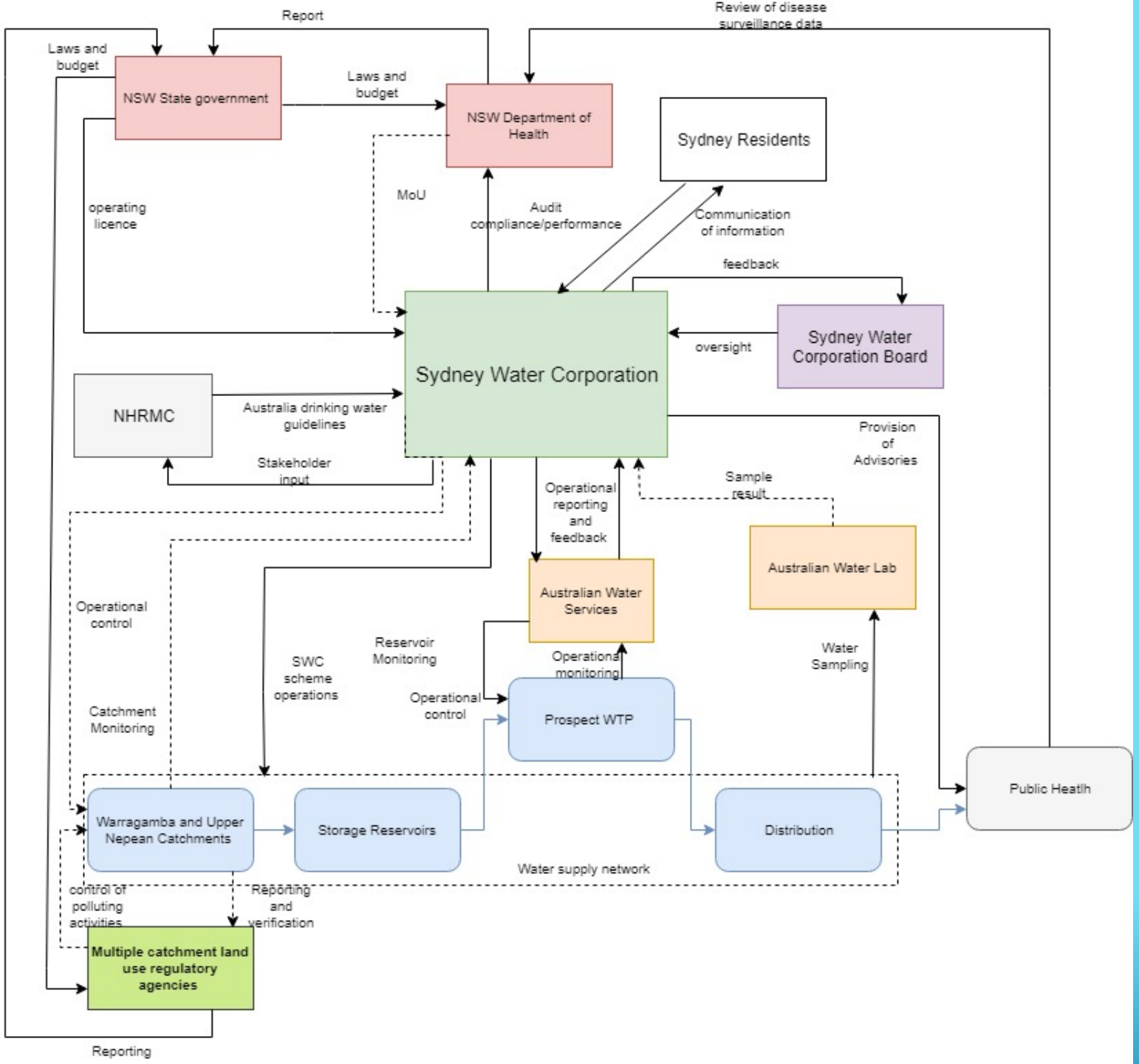
FAILURES AND INADEQUATE CONTROLS

- **Response actions** were primarily based on Cryptosporidium and Giardia **sampling results**
- **No mention of sampling or investigation using of other contamination indicators** such as thermotolerant coliforms (e.g. *Escherichia. coli*) or chlorine demand

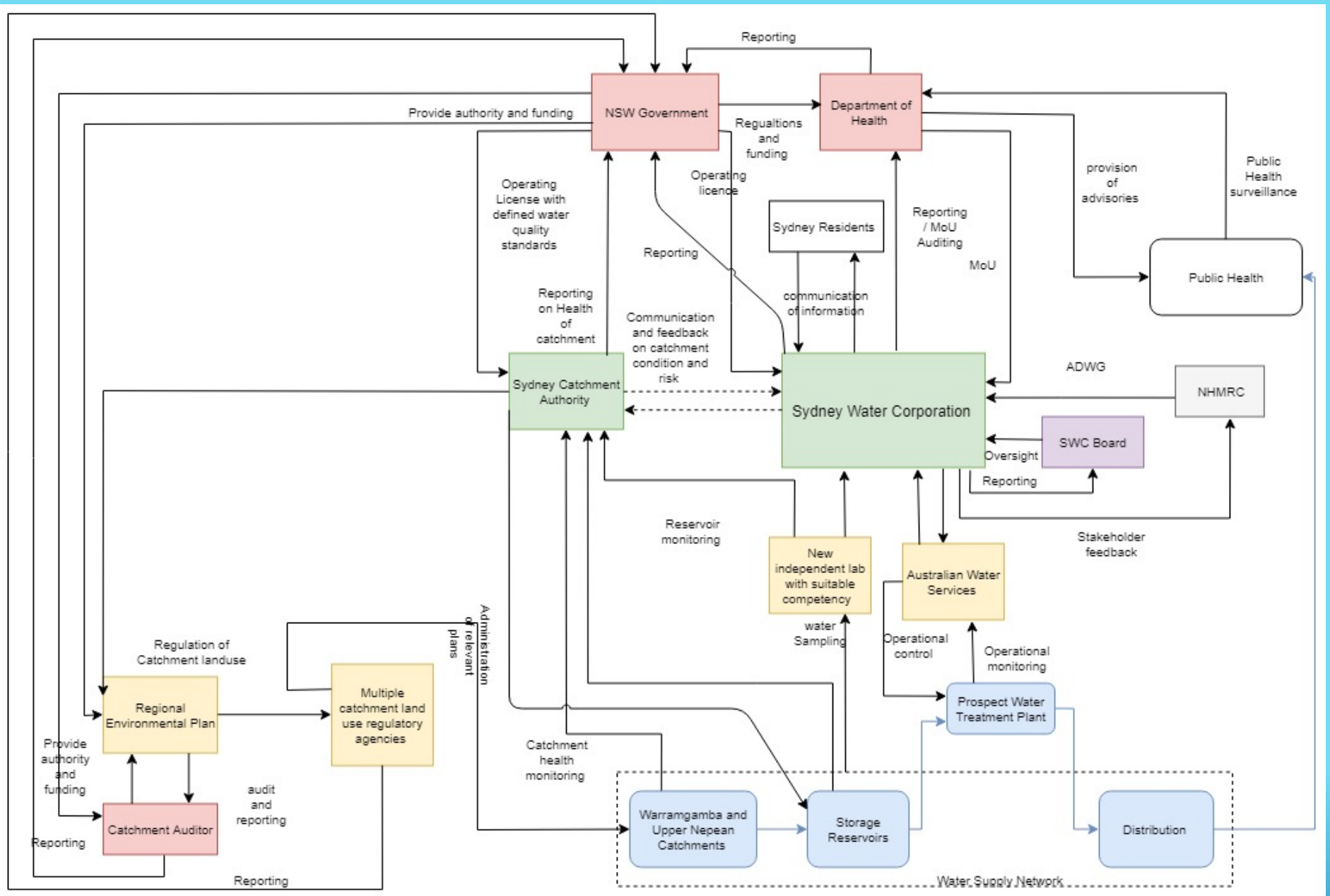
MENTAL MODEL FLAWS

- Was **unaware of the state of the catchment** which had seriously degraded
- Didn't initially consider the **rapid filling of the reservoir and associated water quality impacts**
- Assumed all results equated Cryptosporidium and Giardia when the **analysis method was prone to false positives**

FLAWS IN CONTROL STRUCTURE



POST CRISIS – FORMAL INQUIRY RECOMMENDATIONS

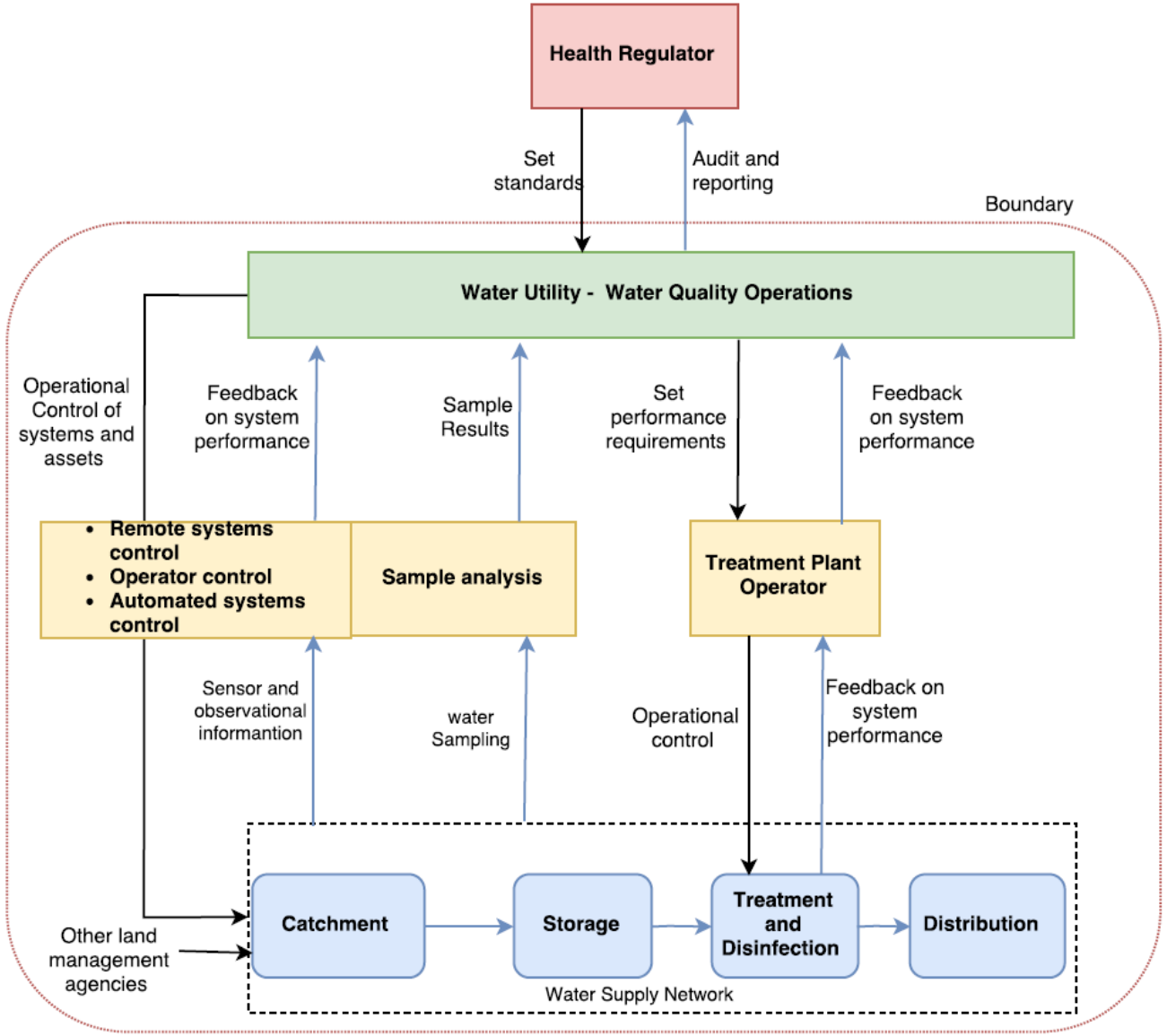


- Formation of new agency for source water management
- Additional verification and validation of source protection controls
- Improved incident response protocols

CAST - KEY FINDINGS

- There were no sudden failures of the barriers in operation
- Decline in catchment health and protection resulting in reduced resilience to large rainfall events.
- Water Treatment Plant was challenged by the sudden change in water quality
- Delayed response actions to avoid abstracting contaminated reservoir water
- Concerns raised regarding the accuracy of results from operational sampling for Cryptosporidium and Giardia
- Focus on sampling results, not on the overall measures of system performance
- Incident management plans were not adequate for such a large scale event

STPA – HAZARD ANALYSIS OF DRINKING WATER SYSTEMS



- Drinking water incidents still continue to occur in developed countries
- Drinking water systems are becoming more complex with greater automation
- Using STPA as a tool to develop control systems for operational management of drinking water systems
- Main loss considered is **Public illness from drinking water contamination**
- Layered hazards based on barriers in the supply network

CONCLUSIONS

- Considered a false positive event – Cryptosporidium and Giardia sampling showed a public health risk, however no increase in illness was identified
- Drinking water systems are prone to conflicting information on barrier performance
- Water sampling alone is not the best indicator of drinking water supply performance
- Effective risk management requires a catchment to tap systems approach
- Further work on drinking water systems risk management based on systems theory (STPA) and indicators of system performance

THANK YOU

- **Questions?**