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Developing Technical Guidelines for MAR in Beijing-Tianjin-Hebei- Region

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OUTLINE

1.Regulation and guidelines for MAR

2.Demand and Risk of MAR in Beijing-Tianjin-Hebei

3. Policy and guidelines for MAR in Beijing-Tianjin-Hebei

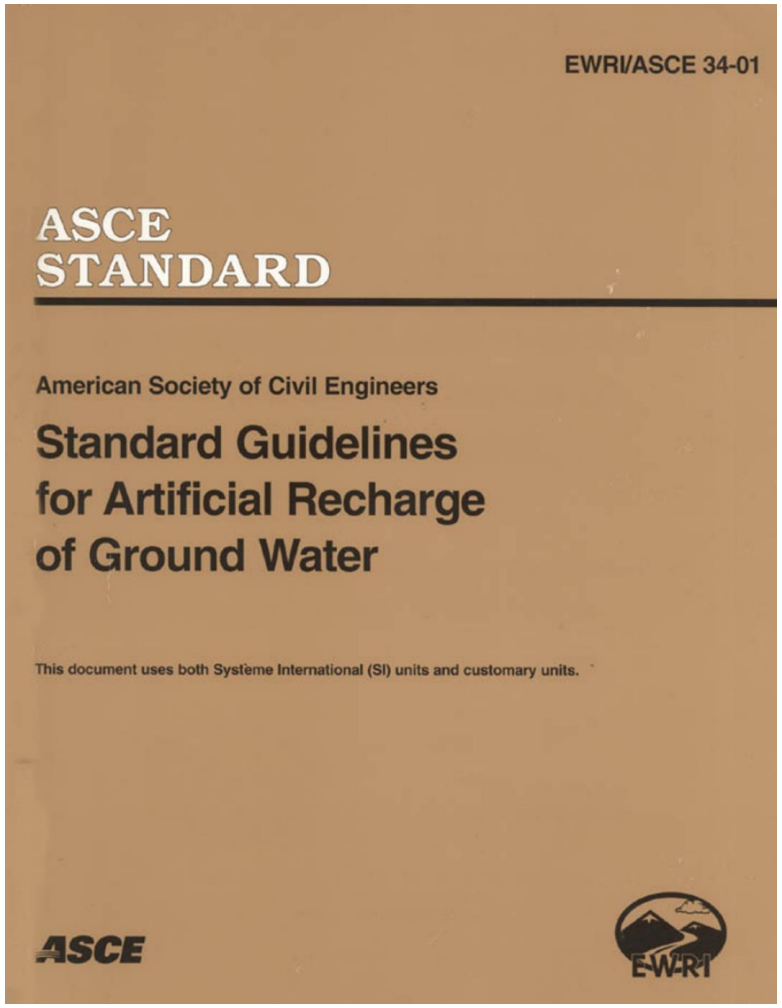
01 Regulation and guideline For MAR

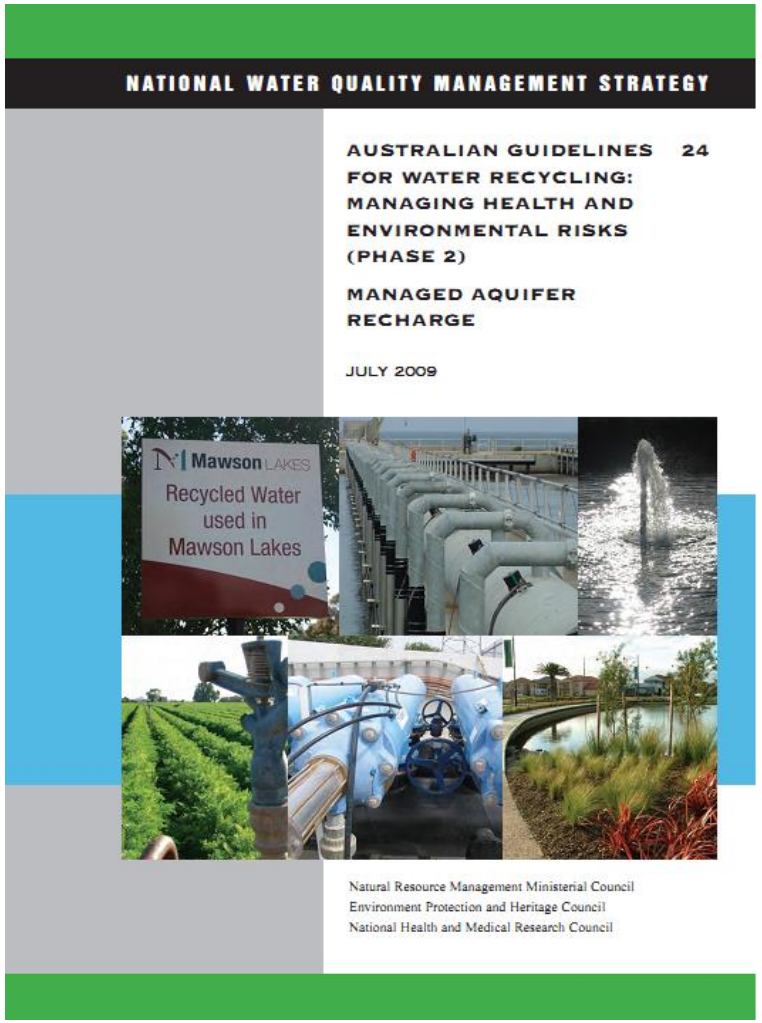
Regulations and guidelines on water quality requirements for MAR

Country	Scope	Soft/hard	Type	Year	MACs	Most used MAR techniques
Arizona (USA)	Regional	Hard	Guidelines	1994		ASR*, basins
Australia	National	Soft	Guidelines	2009	X	ASR, basins
California (USA)	Regional	Hard	Guidelines	2012	X	ASR, SAT-MAR
Chile	National	Soft	Regulation	2013		Multiple
Florida (USA)	Regional	Soft	Guidelines	1999	X	ASR, basins
India	National	Soft	Draft Guidelines	2014		Multiple
Italy	National	Hard	Regulation	2016	X	RBF**
Mexico	National	Hard	Regulation	2003 & 2009	X	Basins
Portugal	National	Hard	Regulation	2000		Multiple
South Africa	National	Hard	Draft regulation	2004		Basins, ASR
Spain	National	Hard	Regulation	2007	X	SAT-MAR*** (reuse)
The Netherlands	National	Hard	Regulation (under review)	1993	X	SAT-MAR, dunes, ASR
Israel (Shafdan)	Local-National[1]	Hard	Operator rules	From 1966	X	SAT-MAR, basins
Torreele (Belgium)	Local	Hard	Operator rules	2012	X	SAT-MAR, dunes
USA	National	Soft	Regulation	1974 & 2019	X	ASR, multiple
WFD	International	Soft	Regulation	2000		Basins, ASR
WHO guidelines*	-	Soft	Guidelines	2001		SAT-MAR (reuse)
Windhoek (Namibia)	National	-	Guidelines. Regulation proposal	2004		Interdune basins, ASR

ASR* Aquifer Storage and Recovery - RBF** River Bank Filtration
SAT-MAR*** Soil & Aquifer Treatment for Managed Aquifer Recharge - [1]Mekorot applies Shafdan's standards to National level
MACs: Maximum Allowable Concentrations - * Legal regulations have a reference framework (international/national etc.). The framework of guidelines is often based on regional characteristics or settings or is a general outline of common knowledge.

- *American Society of Civil Engineers (ASCE) "Standard Guidelines for Artificial Recharge of Groundwater*
- *Australia Guidelines for water recycling:managing health and environmental risk(phase2) MAR*

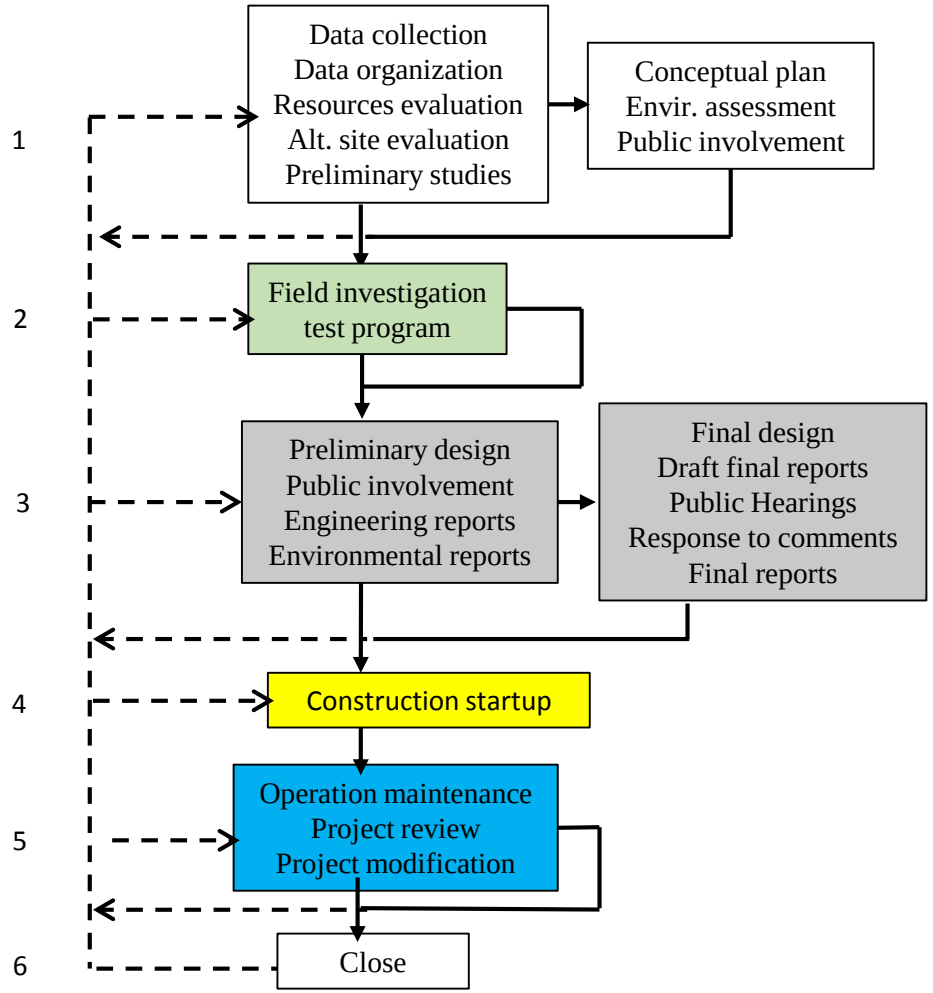




EWRI/ASCE 34-01
Standard Guidelines for Artificial Recharge of Ground Water

- ***Objective:*** *to provide a standardized system guide to standardize the establishment, operation and maintenance of groundwater recharge projects.*
- ***Scope:*** *It standardizes the planning, design, construction, maintenance, operation and shutdown of the non natural groundwater recharge system, so as to strengthen the natural recharge of groundwater. Economic, environmental and legal considerations (water rights, laws, regulations), as well as site investigation and testing procedures that can be applied to all steps are taken into account.*

The recharge method can be through the surface infiltration of water, or directly into the aquifer through the well.



Establishment of artificial recharge project for groundwater aquifer
EWRI/ASCE 34-01 Standard Guidelines for Artificial Recharge of Ground Water

Managed aquifer recharge in Western Australia

MAR： *MAR is the intentional recharge of water to aquifers for subsequent recovery or environmental benefit; the managed process assures adequate protection of human health and the environment. Aquifers may be recharged by diversion of water into wells or infiltration of water through the floor of basins, galleries or rivers.*

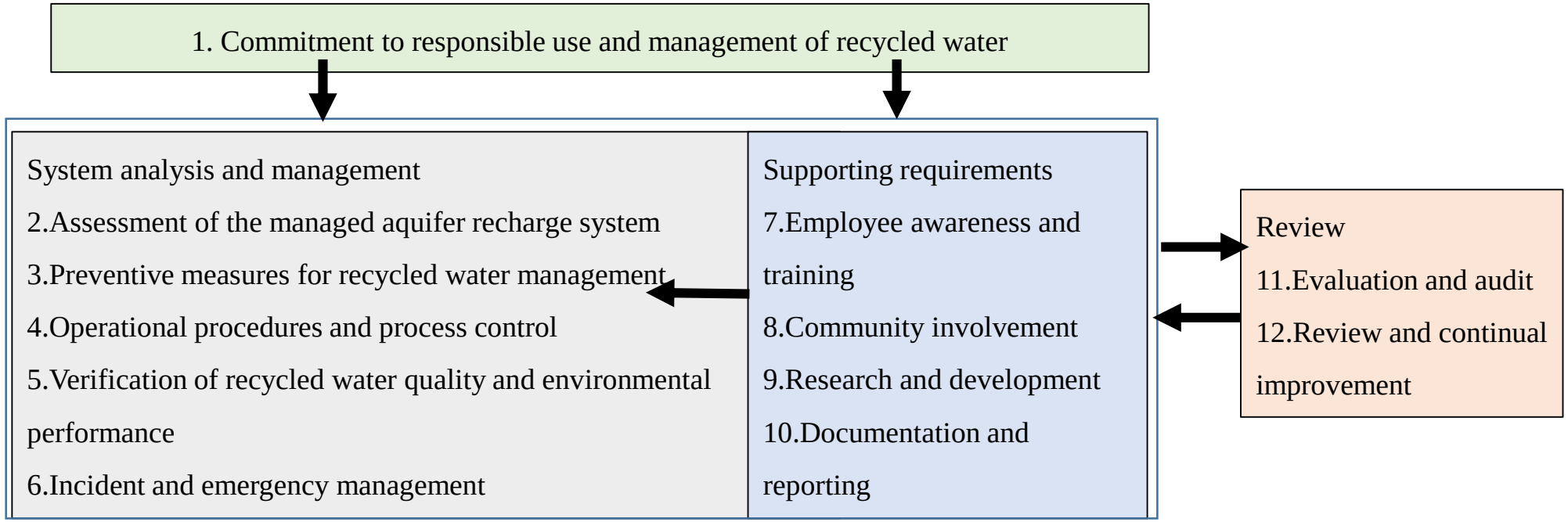
Types of groundwater recharge

Unintentional	Unmanaged	Managed
•Clearing deep-rooted vegetation or soil tillage •Leakage from water pipes and sewers •Irrigation deep seepage •Infiltration of runoff from impervious areas •Spraying defoliants	•Stormwater drainage wells and sumps •Septic tank leach fields •Mining and industrial water disposal to sumps •Floodplain water harvesting	•Injection and recovery wells •Infiltration basins and recovery wells

Australian Guidelines for Water Recycling :MANAGING HEALTH AND ENVIRONMENTAL RISKS (PHASE 2)
Managed Aquifer Recharge

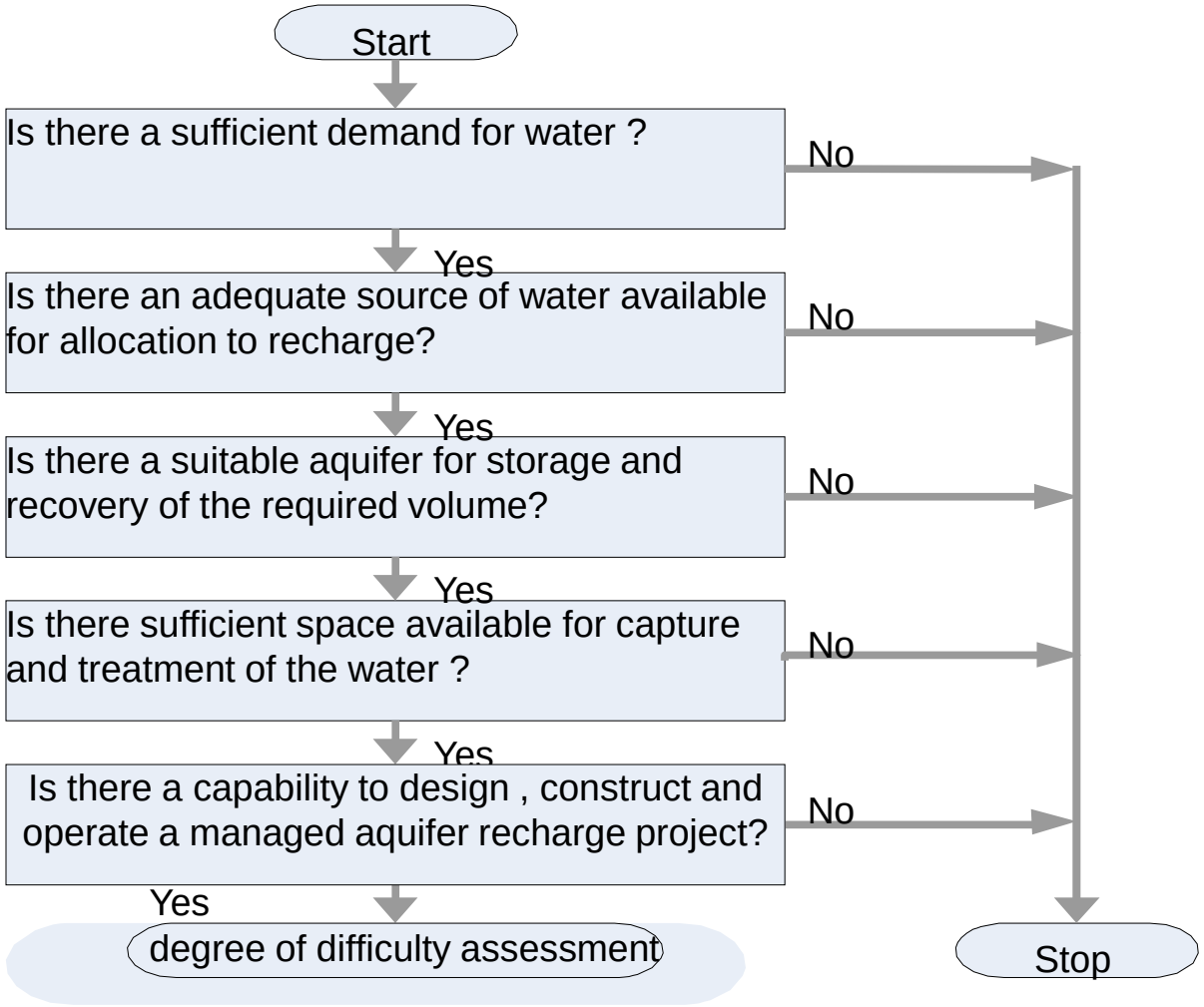
Framework for MAR

- *The risk management plan is the record document of MAR.*
- *Australian drinking water guidelines（NHMRC–NRMMC 2004）and basic concepts of water cycle guidelines——**It is better to prevent the occurrence of danger than to clean up the dangerous influence afterwards.***

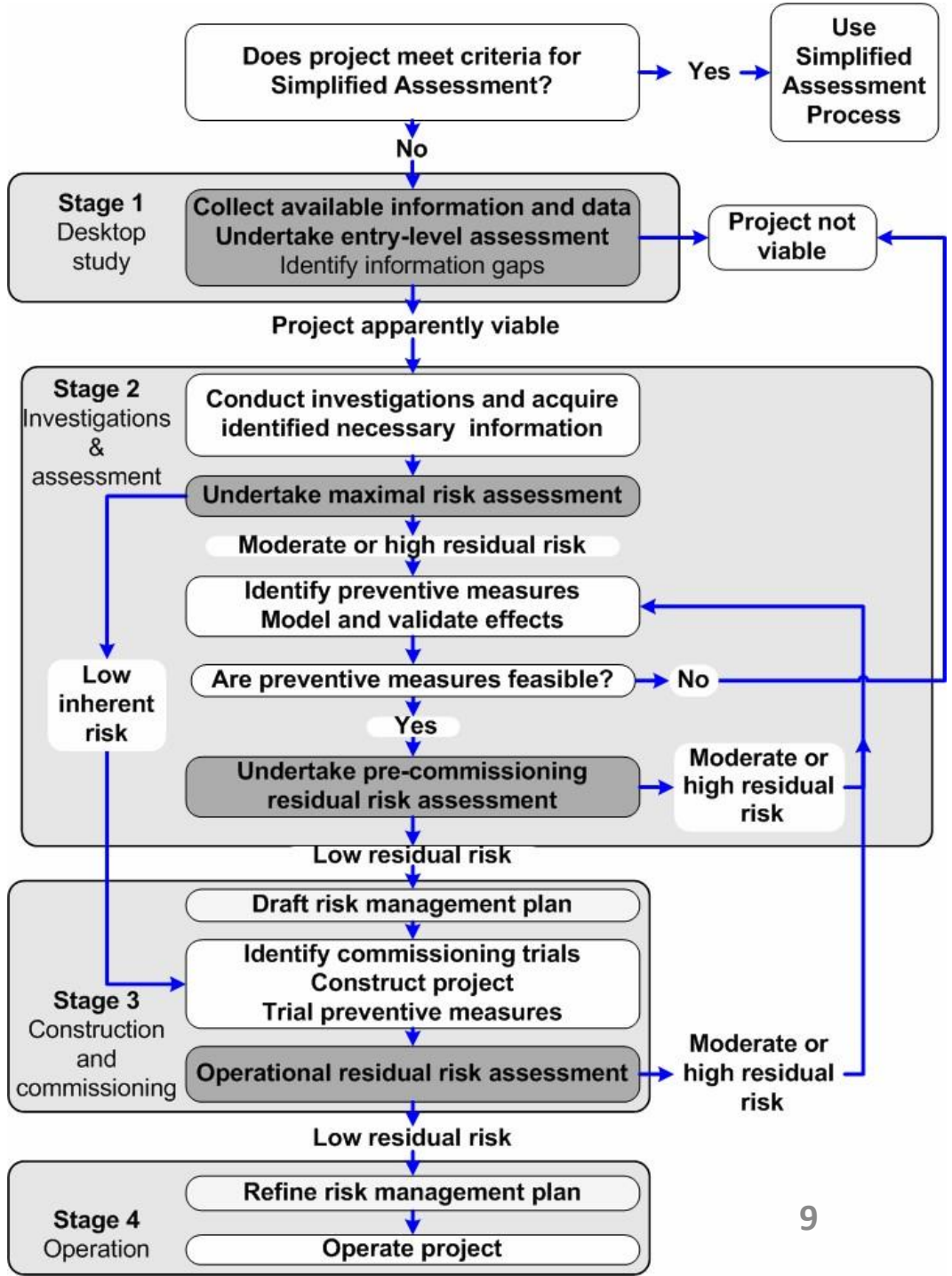


Aquifer recharge risk management——**Multiple barrier method**. Australia (NHMRC-NRMMC 2004) and internationally (WHO 2006) recognized this as a means to protect the quality of drinking water. The multiple barrier method shall cover every component of the managed aquifer recharge system and be submitted to the regulatory agency of the project jurisdiction for approval.

Australia "Aquifer Replenishment Guidelines" assessment procedures



Simple evaluation procedure



The Australian Guidelines for Water Recycling: Managing Health and Environmental Risks provides a stepwise method for assessing risks to human health and the environment

Assess the risks to human health

Identify possible hazards in water sources and their impact on human health.

Find out the possibility of human exposure (dose) and disease (reaction).

Consider the potential impact of the hazard or hazardous event, the severity of the potential impact, and the size of the population that may be affected.

Integrate the information from step 1 to step 3 to assess the risks of various potential hazards.

Step 1 Identify hazards and hazardous events

↓

Step 2 Estimate the likelihood

↓

Step 3 Assess the impact

↓

Step 4 Describe the risk

Assess environmental risks

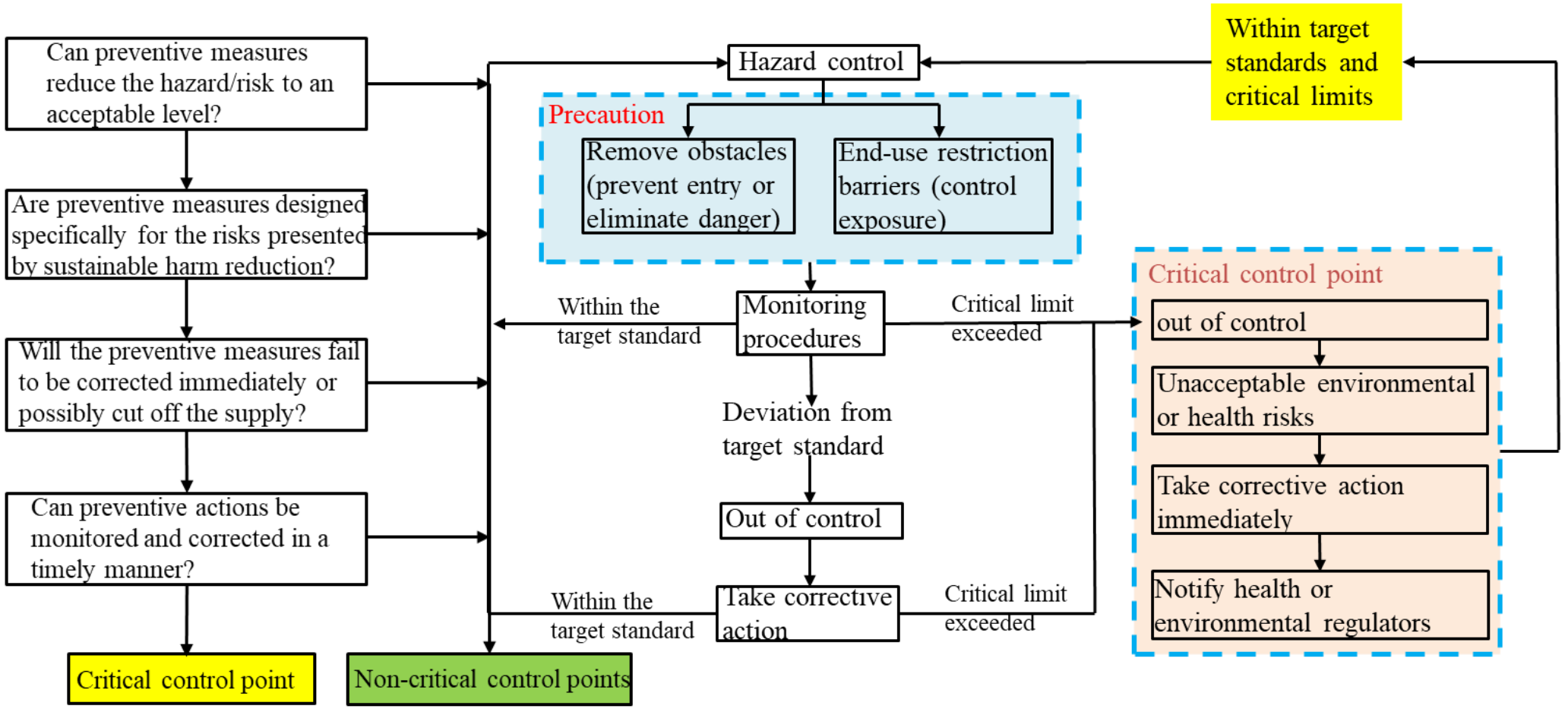
Identify the hazards that may exist in the water source or the hazards that may occur and their possible impact on the environment.

Find out how likely it is that a dangerous event (such as an increase in salinity in an emergency) will occur.

Consider the possible impact of hazards or hazardous events, including where the reclaimed water is used first and where it may eventually go.

Integrate the information from step 1 to step 3 to assess the risks of various potential hazards.

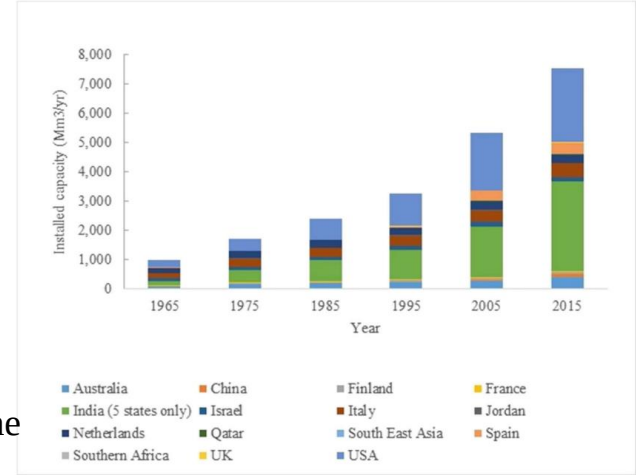
The relationship between preventive measures and critical control points and target standards and critical limits

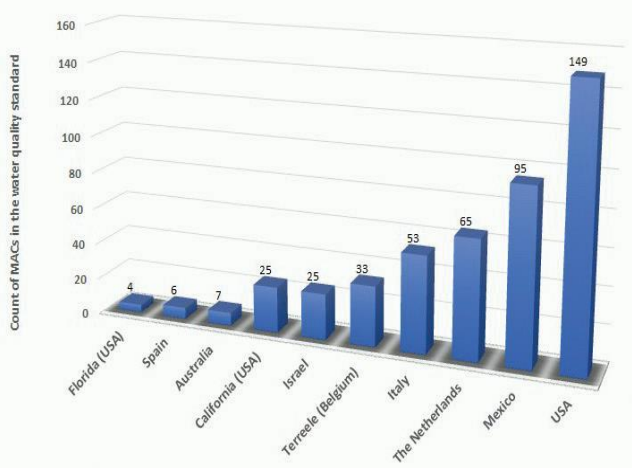


Critical control point decision tree

Suggestions on the list of parameters that should be determined for MAR water samples in the laboratory and on-site

1. **E. Escherichia coli:** aspects of ecotoxicology. Most regulatory requirements（SAT-MAR）
2. **Nematodes:** aspects of ecotoxicology. Most regulatory requirements（SAT-MAR）
3. **pH：** Influence of redox conditions
4. **Temperature:** environmental conditions, solubility, stoichiometric product
5. **Conductivity:** parameters related to salinization and total compound
6. **COD：** Specific parameters for water reuse, removed in the case of natural water sources（SAT-MAR）
7. **COD_5：** In the case of natural water sources, water reuse with specific parameters removed（SAT-MAR）
8. **Total dissolved oxygen（TDO）：** Potential super-oxidation conditions and generation of gas blockage in the receiving medium
9. **Total organic carbon（TOC）：** Biological clogging potential and chemical reaction buffer index
10. **Total nitrogen（N）：** Residual products after the decomposition of nitrogen molecules, such as the decomposition of diffusion pollution products
11. **Total phosphorus（P）：** Indicators of biological clogging potential and chemical reaction buffer
12. **Total suspended matter（TSS）：** Parameters are related to turbidity and are required in most regulations
13. **Total dissolved solids（TDS）：** Parameters related to turbidity are required in most regulations
14. Turbidity: turbidity parameter required by most regulations
15. **Ammonium（NH_4）：** Residual products after the decomposition of nitrogen molecules
16. **Nitrate（NO_3^-）：** Molecules trapped in receptors in the MAR project





17.Sulfate（SO_4）： Large components, chemical attack on materials

18.Chloride: chemical attack on materials, salinity indicator

19.Bicarbonate: The parameter is not required in the specification, but it is the basic parameter for water chemistry calculatic

20.Sodium (Na): chemical attack on materials, salinity indicator

21.Potassium (K): There is no requirement in the regulations, but the basic parameter of water chemistry calculation

22.Calcium (Ca): Not required by regulations, but it is the basis for water stoichiometry, hardness, **etc.**

23.Magnesium (Mg): Not required in some regulations, but is the basis for water stoichiometry, hardness, etc.

24.Boron (B): Phytotoxic ion

25.Silica (Si): Determines the geochemical environment and biological/chemical reactions. Potential quartz precipitation

26.Arsenic (As): Eco-toxicity ion

27.Iron (Fe): Metal, has a high impact on physical, chemical and biological clogging

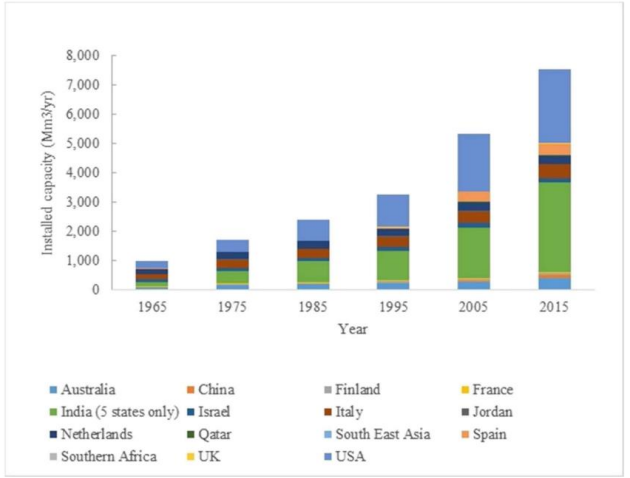
28.Manganese (Mn): physical, chemical, and biological clogging determining parameters

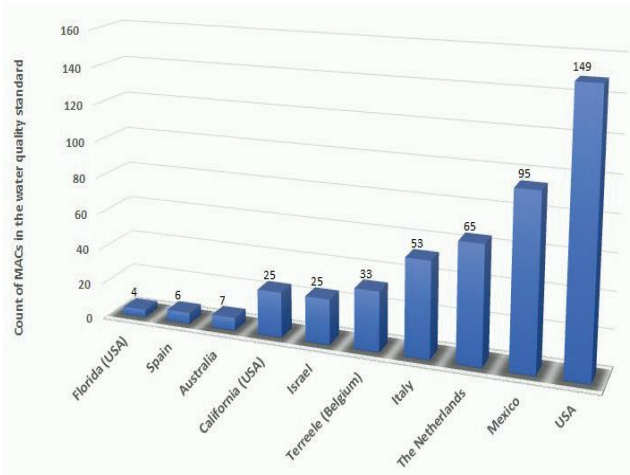
29.Chromium (Cr): The determining parameter of physical, chemical, and biological clogging. Most regulations require

30.Copper (Cu): Special effects on crops. Common leaks from agricultural industrial activities

31.Zinc (Zn): special effects on crops

32.Grease: runoff in urban areas and dedicated for SAT-MAR (natural river/rainwater can be removed)





MAR in China

- ***Research status:*** *China has carried out a variety of groundwater recharge methods research and practice, but the impact and risk of groundwater recharge engineering on the ecological environment are not clear, and there is a lack of groundwater safety recharge standards and safety control policies.*
- ***China's current relevant standards for groundwater recharge are:*** *technical specification of urban wastewater reuse for farmland (GB/T 22103-2008) and quality of urban wastewater reuse for groundwater recharge (GB/T 19772-2005).*
- ***Regulations on groundwater recharge in China:*** *Regulations on groundwater management (Draft)*

Law of the people's Republic of China on the prevention and control of water pollution (revised for the second time on June 27, 2017)

Groundwater recharge, various pollution sources and human activities are restricted, including

- ***Article 43:*** *"Artificial recharge to replenish groundwater without deterioration of groundwater quality“*
- ***Article 58:*** *"Farmland irrigation water shall meet the corresponding water quality standards to prevent contamination of soil, groundwater and agricultural products"*

Groundwater Management Regulations (Draft for Solicitation of Comments)

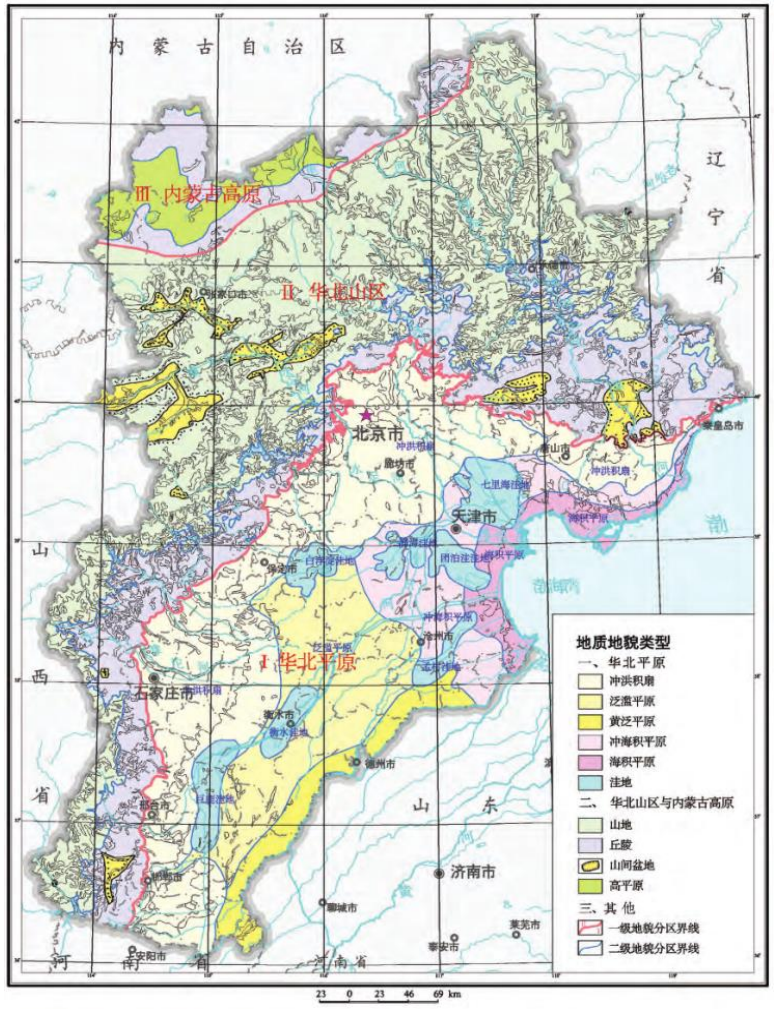
- ***Article 28** (**Management and Protection of Groundwater and Drinking Water Source Sites**) The State implements a system of approval and safety assessment for groundwater and drinking water sources.*

- ***Article 29** (**Conservation of Groundwater Sources**) Local people's governments at or above the county level shall strengthen the protection of groundwater source replenishment areas, make full use of natural conditions to supplement groundwater, and effectively conserve groundwater sources.*

- ***Article 43** (**Groundwater Replenishment**) The State encourages the use of scientific and reasonable methods to replenish groundwater in areas with conditions for overexploitation of groundwater, increase groundwater replenishment, and conserve groundwater sources.*

02 Demand and Risk of MAR in Beijing-Tianjin-Hebei

Groundwater replenishment demand in Beijing-Tianjin-Hebei

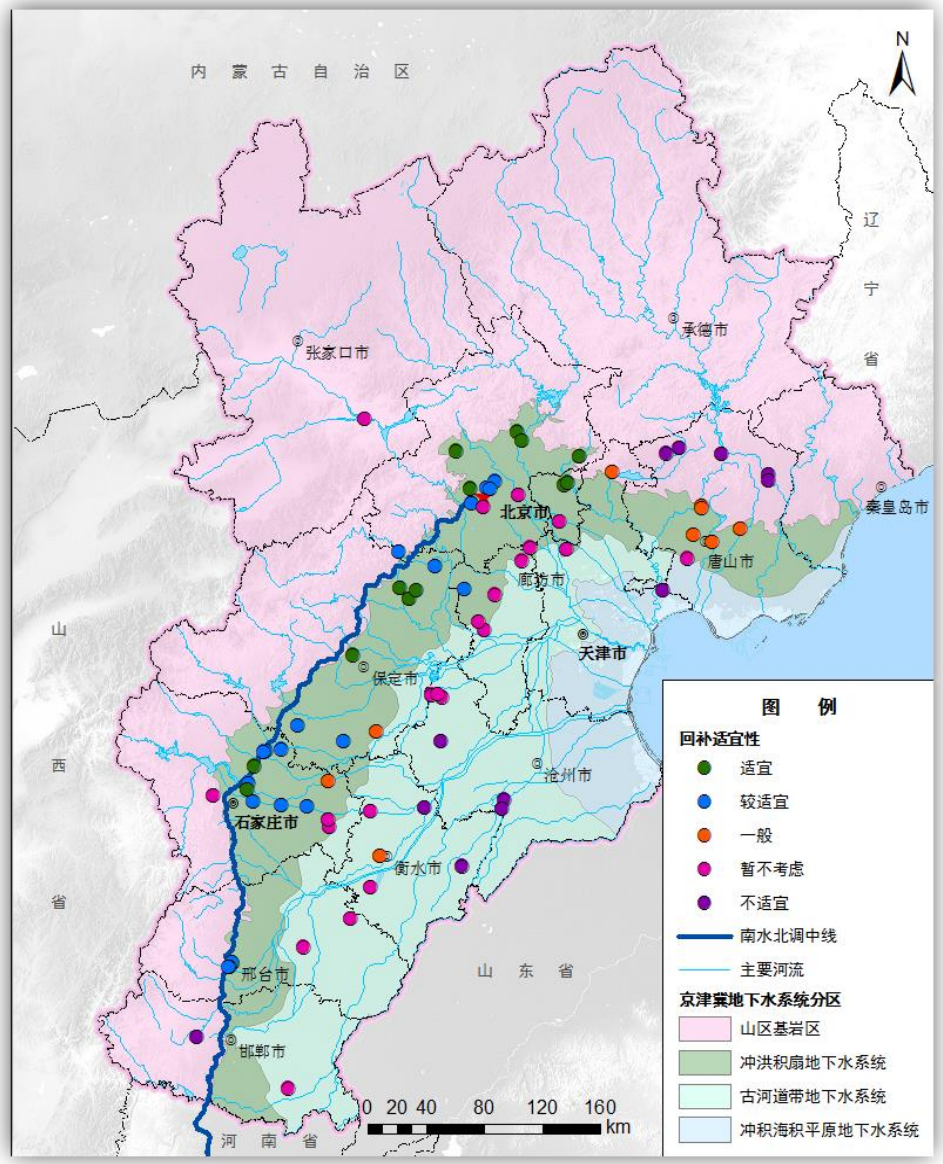


Geological and geomorphological map of Beijing-Tianjin-Hebei (quoted from: Ma Zhen, etc.: Analysis of land resources and environmental geological conditions in Beijing-Tianjin-Hebei area)

- Water resources are scarce. The average amount of water resources for many years is only $3.70\times10^{10}m^3$, which is less than 1.3% of the country's total, but it carries about 10% of the country's population.
- Due to water shortage and long-term over-exploitation (an average annual over-exploitation of 7.2 billion cubic meters), groundwater reserves have accumulated a loss of 150 billion cubic meters, and the world’s largest "North China Plain-Bohai Rim Compound Funnel" has been formed.

Groundwater replenishment is an effective measure to systematically solve the water supply safety of the Beijing-Tianjin-Hebei region, restore the extraction capacity of the water source, and improve the water ecological environment.

Suitability of Groundwater Replenishment in Beijing-Tianjin-Hebei Region



Grade	Suitability index	Suitability situation
suitable	0.8-1.0	It has good replenishment potential, low replenishment risk, and high replenishment benefit
Relatively suitable	0.6-0.8	It has relatively good replenishment potential, and the replenishment risk is small, and the replenishment benefit is higher
Commonly	0.4-0.6	With general replenishment potential, lower replenishment risk, higher replenishment benefit
Relatively unsuitable	0.2-0.4	The replenishment potential is small or the replenishment risk is greater or the replenishment benefit is low
Not suitable	0.0-0.2	Almost no replenishment potential or high replenishment risk, or low replenishment benefit

Groundwater source with replenishment potential—It is distributed in shallow groundwater source areas such as Chaobai River and Hutuo River, where the alluvial proluvial fan is beaded

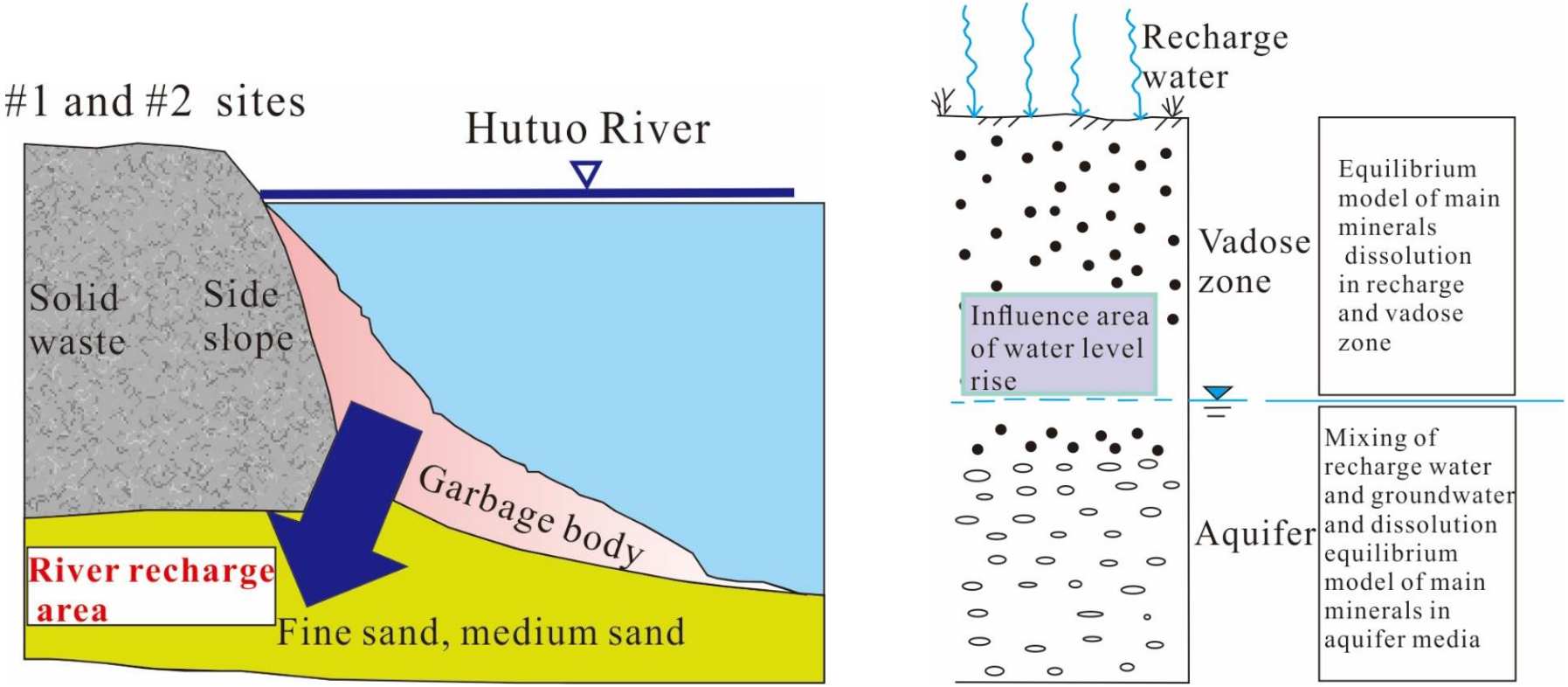
Risk for MAR in the Beijing-Tianjin-Hebei region

- *The Beijing-Tianjin-Hebei region belongs to the Haihe River Basin. According to the 2015 Environmental Statistics Bulletin, the Haihe River Basin discharged a total of 8.47 billion tons of wastewater, 2.517 million tons of COD, and 218,000 tons of ammonia nitrogen.*

- *In 2015, the top four industries in Haihe River Basin were chemical raw materials and chemical products manufacturing industry, paper and paper products industry, agricultural and sideline food processing industry, coal mining and washing industry, and their wastewater discharge accounted for 49.1% of the total wastewater discharge of the key investigated industrial enterprises.*

- *The pollution components of groundwater in are mainly nitrogen, lead, chromium, cadmium, mercury and other heavy metals, as well as organochlorine solvents, polycyclic aromatic hydrocarbons, pesticides and other toxic and harmful organic compounds, which are scattered in large and medium-sized cities, around industrial and mining enterprises, on both sides of sewage river and some farmland areas. Nitrogen pollution tends to be planar in some areas.*

The pollution problem left over by history and the environmental background become the hidden danger of secondary pollution risk of groundwater recharge



Causes of water quality change after recharge

Groundwater level rise caused by groundwater recharge may threaten the safety of existing underground facilities and structures

- *The Beijing-Tianjin-Hebei region, especially the underground space in Beijing, mainly uses the space above the shallow level, mainly in the central city, urban fringe groups and some satellite towns.*
- *Underground gas station, underground storage tanks and sporadic landfills are scattered underground.*
- *Excessive rise of the water level after groundwater recharge will threaten the safety of existing underground facilities and underground structures, as well as easily cause solid waste to contact groundwater.*
- *Municipal solid waste includes construction waste, industrial waste and domestic waste. The composition of construction waste is relatively simple, while the composition of industrial and domestic waste is complex, and often contains a large number of toxic and harmful components, which will cause great pollution to soil and groundwater.*

Different water sources and different types of groundwater recharge affect the groundwater quality in the recharge area

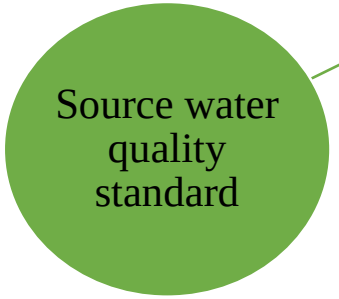
- *Groundwater replenishment includes artificial replenishment using externally transferred water, rain floods or water from reservoirs, natural replenishment such as surface runoff and rainfall, and unintentional replenishment such as infiltration/leakage of water pipes and sewers and deep irrigation.*
- *The analysis and testing results of 258 trace organics in groundwater, reclaimed water and transferred water in the study area show that trace organics such as antibiotics in the reclaimed water are far more species than groundwater and transferred water, and the concentration is also higher.*
- *In the initial stage, the rainwater dissolved a large amount of acid gas, automobile exhaust and factory exhaust gas in the air. After landing on the ground, it scoured the asphalt oil chain roof, asphalt concrete road, construction site, etc., containing a large number of organic matter, pathogens, heavy metals, grease, suspended solids and other pollutants, and the pollution degree may exceed that of ordinary urban sewage.*

03 Policy and Guideline for MAR in Beijing-Tianjin-Hebei

Policy for MAR

- Planning project management
- Replenishment water management
- Replenishment process management (design, start-up, operation and maintenance, shutdown)
- Replenishment area management
- Replenishment monitoring and effect evaluation

Risk control policy



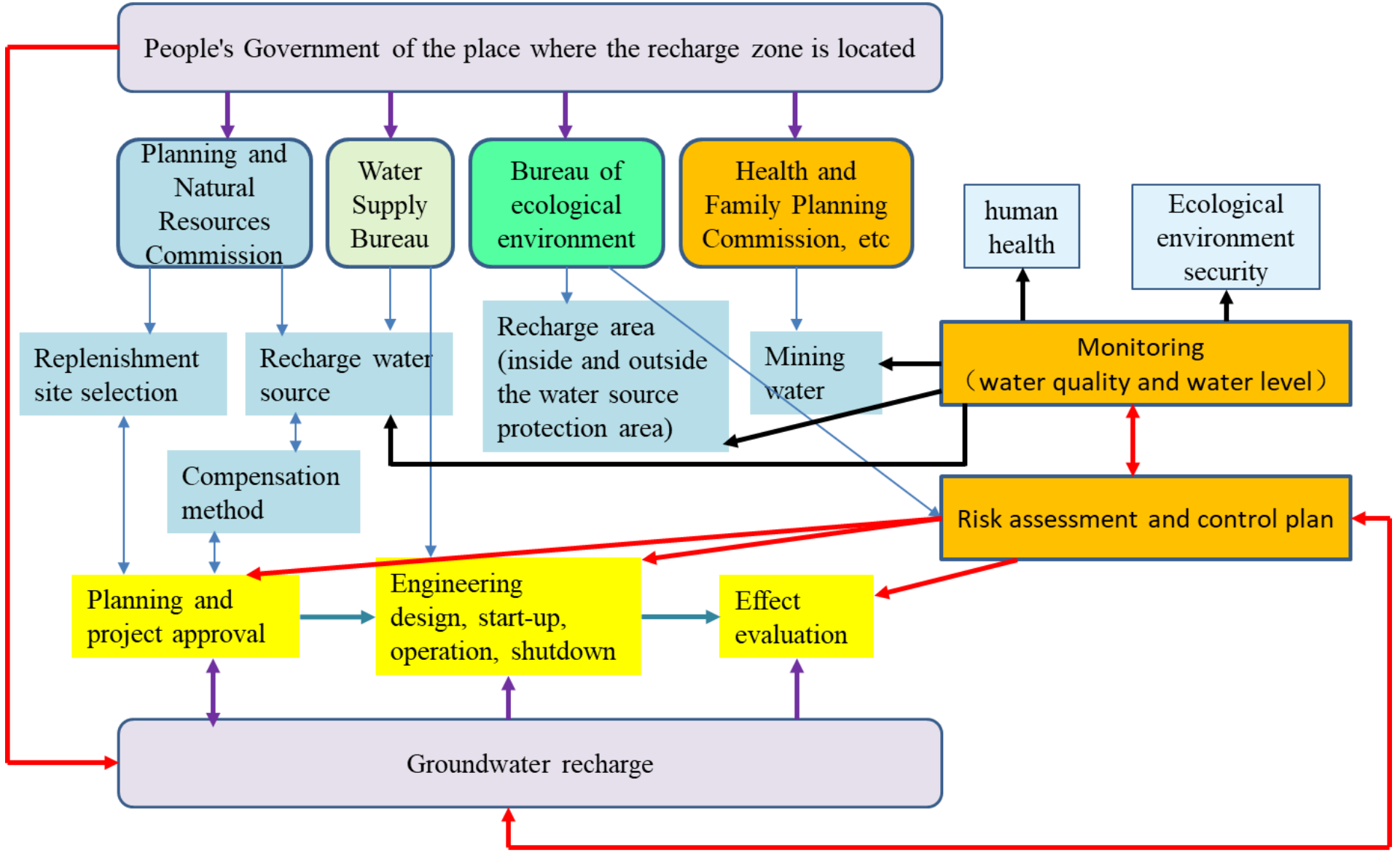
- Replenishing drinking water source water quality standards
- Replenishing non-drinking water source water quality standards

- Replenishment suitability evaluation technology
- Covering risk assessment technology
- Safe clamshell technology screening
- Joint monitoring of surface and underground
- Accident risk reduction technology
- Joint regulation of water resources

Risk Identification and Evaluation Index of MAR

Risk Factor	Risk point	Risk indicators
Replenish water source water quality	External transfer of surface water	Silt, alien organisms, algae
	Rain and flood	Contaminants and water carried by mixed surface runoff
	Reclaimed water	Micro-polluted organic matter: personal care products, antibiotics; pathogenic microorganisms
Replenishment area	Surface	Land use type, soil medium, terrain slope, rainfall infiltration and replenishment, surface runoff
	Vadose zone	Aerated zone media, aerated zone thickness, and aerated zone pollution-medium background
	Aquifer	Groundwater depth, aquifer medium, structure, thickness, pollution
Sensitive target	Pollution sources	Pollution source type, distance, pollution load, hydrogeological conditions
	Water source	Level of water source, water supply population, distance
Replenishment method	River lake infiltration	Length and area of replenishment river
	Dakoujing	Excavation depth, well diameter, gravel
	Tube well	Well depth, well diameter, gravel
	Tunnel infiltration	Tunnel shape, gravel at the bottom of the pit
Replenishment process	Replenishment intensity	Water volume and water level
	Replenishment cycle	Continuous, intermittent, occasional
	Retention time	Replenishment water retention time

Clarify the rights and responsibilities of relevant departments for MAR



Risk Control System

Guideline for the risk management and control of natural infiltration and replenishment of groundwater by River in the Beijing-Tianjin-Hebei

- Including 6 Chapters and 34 Articles

Chapter 1. General

Chapter 2. Approval of river canal infiltration and replenishment of groundwater projects

Chapter 3. Risk management of groundwater recharge project with river channel infiltration

Chapter 4. Pollution risk management of groundwater recharge area by river channel infiltration

Chapter 5. Emergency monitoring, early warning and emergency treatment

Chapter 6. legal responsibility

Acknowledgement

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