2018 UK - China Workshop on Water-Wise Cities and Smart Water Systems

Key Decision Support Technologies for River Water Pollution ‘Monitoring-Early warning-Source identification-Emergency disposal’ based on Advanced Environmental Models

先进环境模型支持下水污染“监测-预警-溯源-应急”决策管理关键技术

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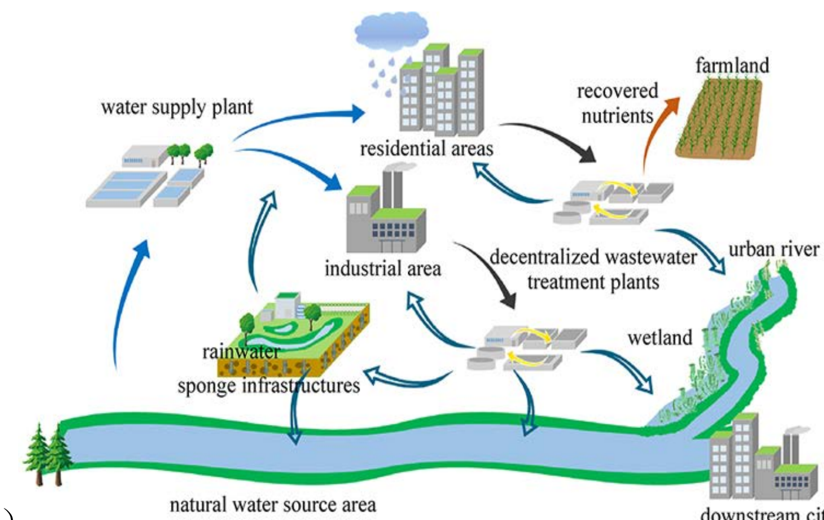
01 Background & Requirements

01 Integrated Water Pollution Control

- **River Chief Policy、Black and odorous water treatment、Sponge city reformation --** The crucial stage of comprehensive rehabilitation of water environment
- **Local governments** have implemented a large number of water control projects, including urban pollution interception, black and odor control, sponge city and Under ground Utility Tunnel.
- Construction of water control ends, sponge city pilot cities assessment.
- How to make effective operation and maintenance on river control to ensure sustainability of governance effectiveness is an important task for investor and operator, and is a technical difficulty to be solved in water quality upgrading industry.



（Nanqi Ren et al, 2017）

- **Operation company：** hope to save operation and management cost on the premise of reaching the standard.
- **Government & River Cheifs**: need timely, accurate, concise information and risk prevention and control recommendations，
- **The public** statement needs multi-sided information release.

After the remediation…

Maintain! Surveillance! Disaster Prevention!.....

Solution: At present, emerging technologies like environmental sensing, remote sensing, remote control, internet of things, big data, artificial intelligence are widely used.

02 Trends of Fusion

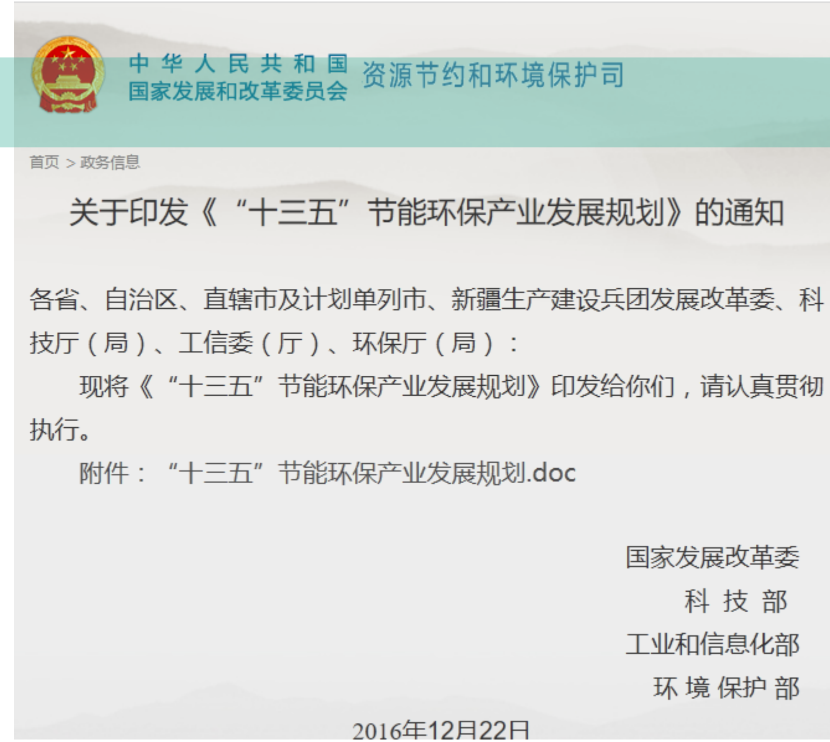
02 The Fusion of Environment Technologies

The integration of environmental governance technology and emerging information technology is a major trend in the development of the industry in the new era.

《"13th Five-Year Plan" for energy-saving environmental protection industry development》 says: "Promote the deep integration of online monitoring technology and information technology…environmental monitoring data can be modeled, refined and accurate."

《**Emerging Science and Technology trends: 2016-2045**》 published by office of the Deputy Assistant Secretary of the army puts forward that intelligent city, data analysis and water crisis response is the national strategic position.

Academician Tang Hongxiao states that environmental science and technology will then make full use of numerical information, simulation models, satellite remote sensing and other disciplines and technologies, coupled with the Internet, large data, artificial intelligence and other innovative means of integration and development.



中华人民共和国
国家发展和改革委员会 资源节约和环境保护司

首页 > 政务信息

关于印发《"十三五"节能环保产业发展规划》的通知

各省、自治区、直辖市及计划单列市、新疆生产建设兵团发展改革委、科技厅（局）、工信委（厅）、环保厅（局）：

现将《"十三五"节能环保产业发展规划》印发给你们，请认真贯彻执行。

附件："十三五"节能环保产业发展规划.doc

国家发展改革委
科 技 部
工业和信息化部
环 境 保护 部

2016年12月22日

--Science is often driven forward by the emergence of new measurements. Whenever one makes observations at a scale, precision, or frequency that was previously unattainable, one is almost guaranteed to learn something new and interesting.

By James Kirchner et al. 2004.HP.

High-frequency monitoring and surrogate monitoring

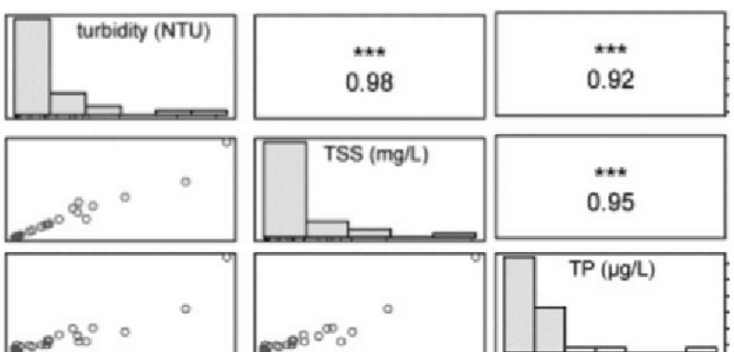
The detection and identification of specific substances in water involve the use of

- Traditional wet chemistry

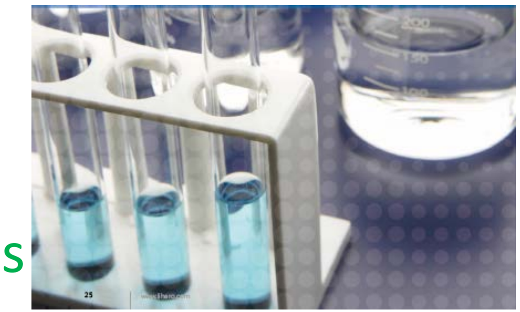
  Titrimetry, spectral analysis, mass spectrometry analysis

- Emerging data-based technologies

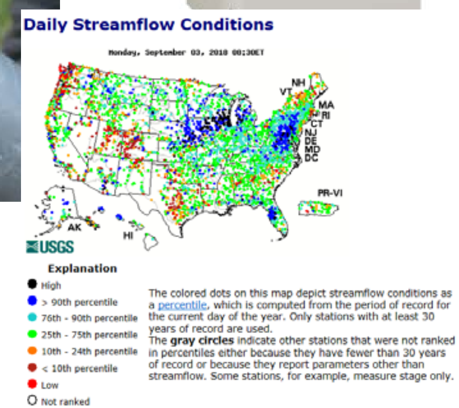
  sensor



$$y_i = mx_i + b + e_i$$



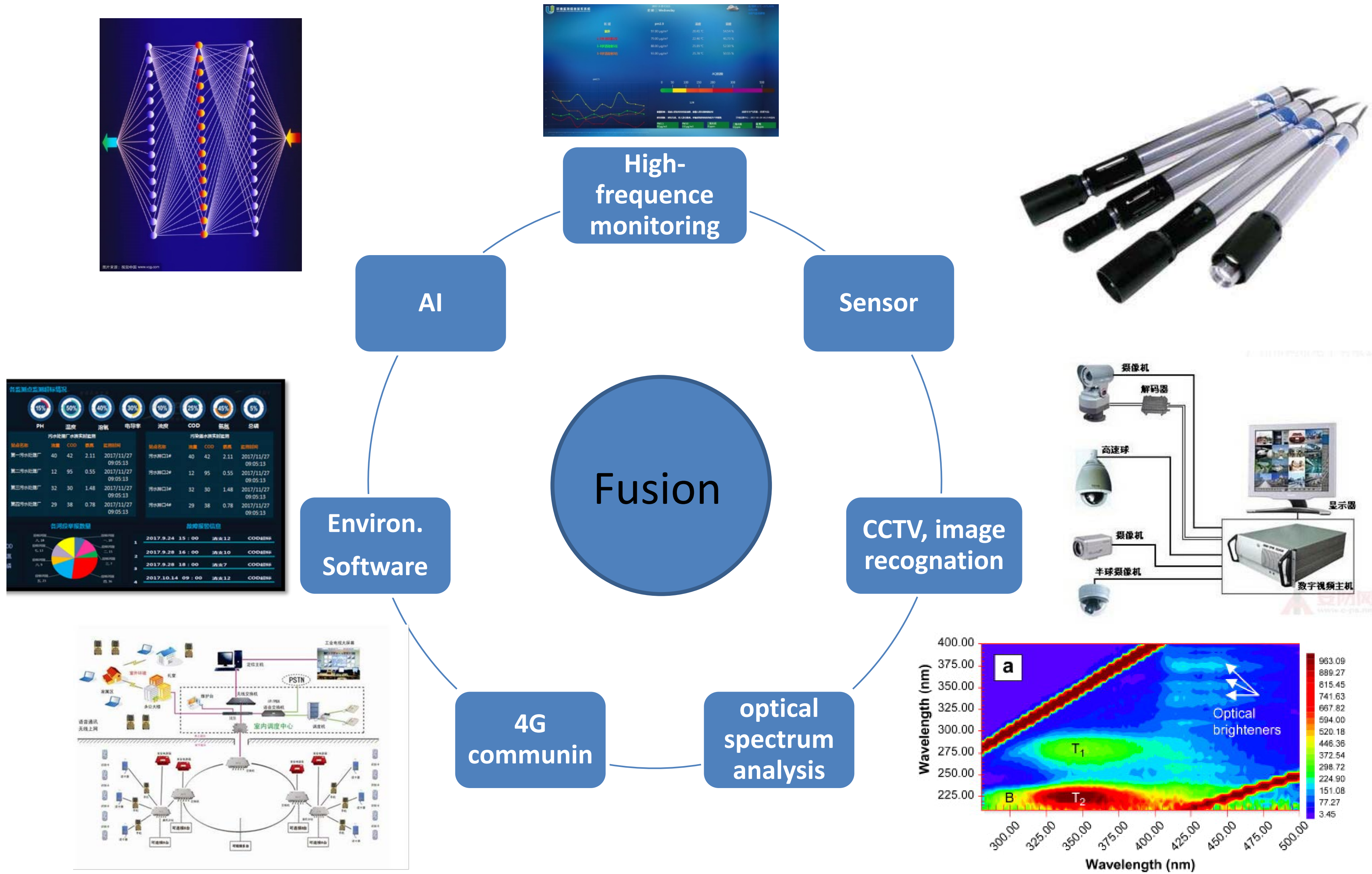
Gaetano Viviano et al. 2014



Technological challenges and scientific problems

- How to quantitatively **design online monitoring network** ?
- Successful application of river **water environment model** in water control project scale is rare, and traditional water information platform is difficult to apply to complex operation and maintenance problems;
- Chinese Water Pollution Control Campaign has its **particularity** in administration, development stage, urban infrastructure and so on. The successful experience of developed countries can not be directly used for reference;
- The existing common management platform is **difficult to meet** the **actual needs** of enterprises. The general integrated management platform for black and odorous water only considers routine business such as daily maintenance, performance appraisal, assessment and supervision, and water quality monitoring, and can not meet the production, division of powers and responsibilities, emergency response and other needs of enterprises

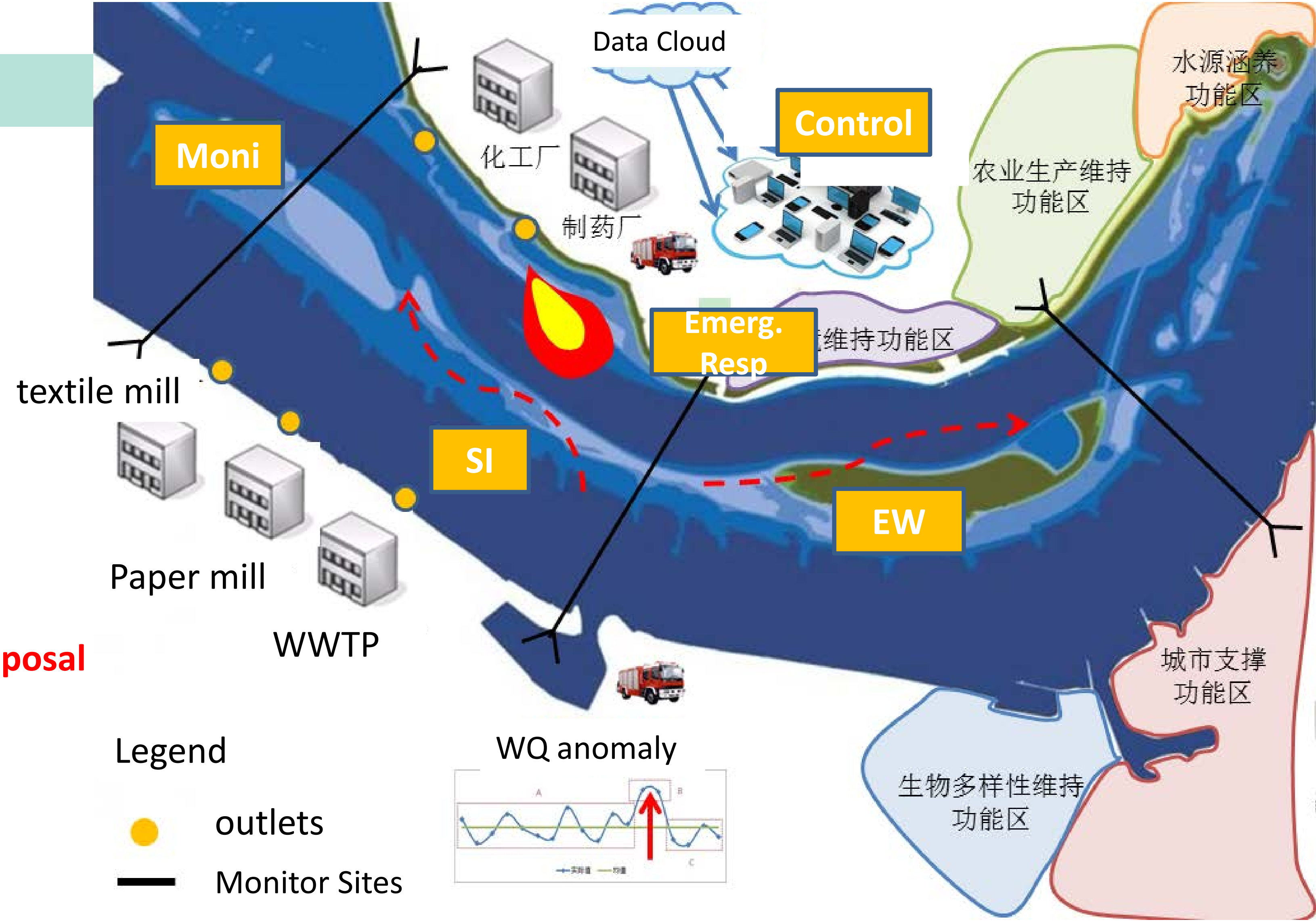
it is necessary to integrate enabling technologies, construct environmental models and technics models related to water treatment, and develop key technologies and system platforms with independent intellectual property rights。



High-frequence monitoring
AI
Sensor
Fusion
Environ. Software
CCTV, image recognation
4G communin
optical spectrum analysis
Optical brighteners
Wavelength (nm)
Wavelength (nm)

03 THADD for Pollution Defense

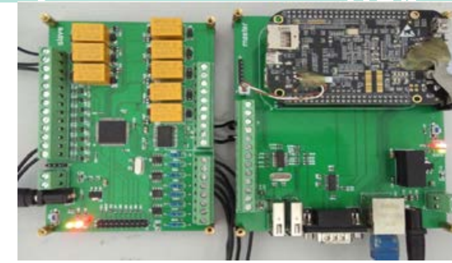
03



Monitoring-
Early warning-
Source identification-
Emergency disposal

3 The Technology framework

- Software： Algorithm、Models、 DSS
- Hardware： platform、sensor、 chip、 controller、test kits



Senor Network Design and Installation

Qualitative Identification and Quantitative Inversion of Pollution Source

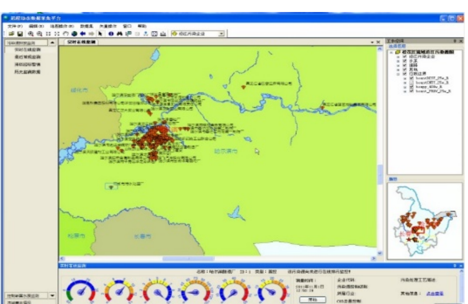
Daily Management

Precise Control and Optimization of Treatment Infrastructures

Emergency Disposal Technology and Engineering Risk Assessment

Emergency Management

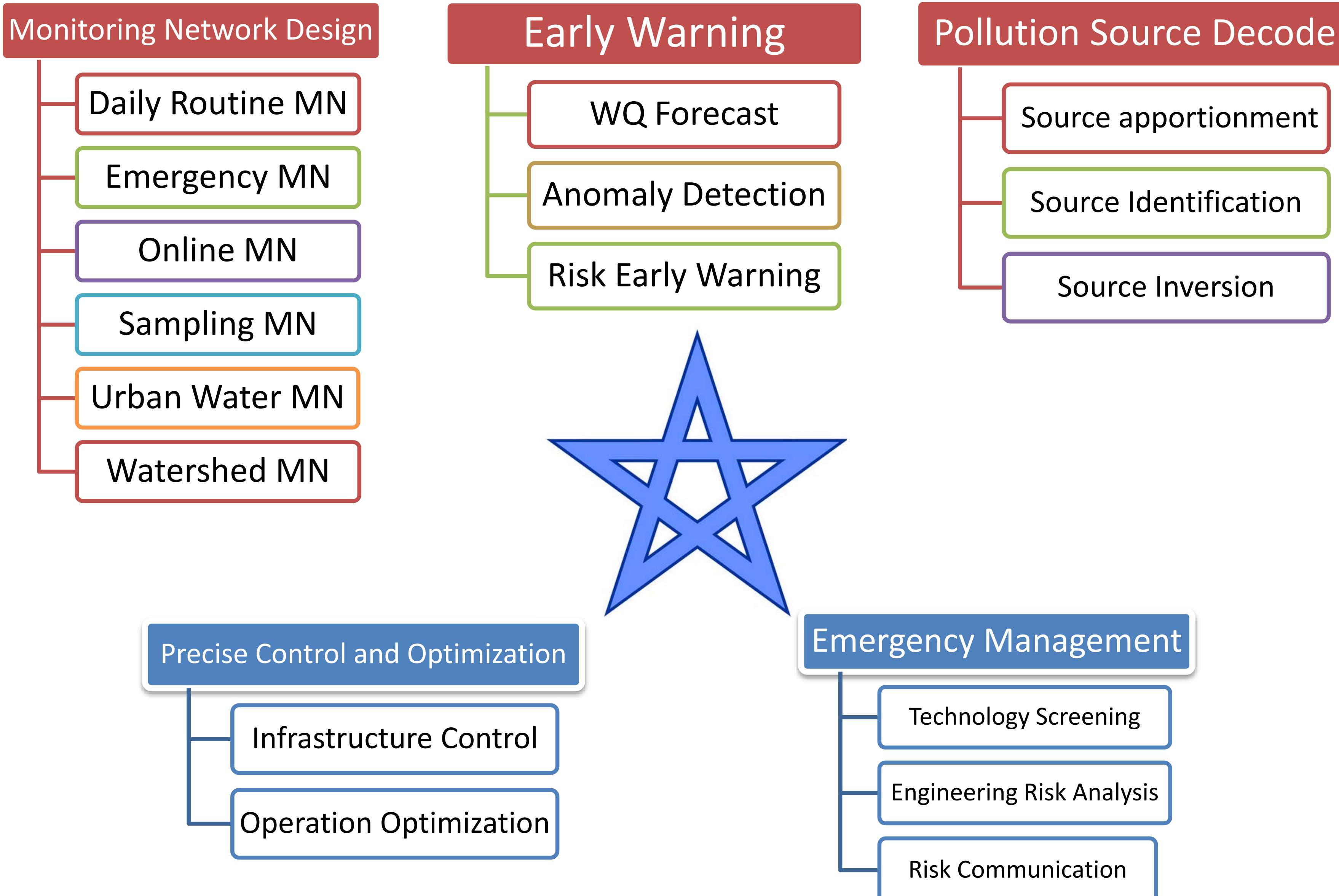
Intelligent Anomaly Alarming and Risk Early warning of water quality



THAAD: Terminal High Altitude Area Defense – Missile System

- ‘**Radar system’**——water quality sensor network based on quantitative design of monitoring network
- ‘**Early warning system**’——WQ prediction and anomaly detection based on mechanism model and data driving model
- ‘**Launch system**’——qualitative and quantitative coupling pollution source analysis；
- ‘**Combat system**’——emission control, emergency disposal, Fine control and optimization operation of engineering facilities

04 Key Decision Support Technologies with Advanced Environmental Models



Monitoring Network Design
Daily Routine MN
Emergency MN
Online MN
Sampling MN
Urban Water MN
Watershed MN
Early Warning
WQ Forecast
Anomaly Detection
Risk Early Warning
Pollution Source Decode
Source apportionment
Source Identification
Source Inversion
Precise Control and Optimization
Infrastructure Control
Operation Optimization
Emergency Management
Technology Screening
Engineering Risk Analysis
Risk Communication

core technology： optimization design of sensor and sampling network

Problems and needs：

- Online monitoring sites are expensive
- Meet control needs
- Limited funds
- Use a few sites to represent the water quality change of target river
- Normal management、 Emergency management

Solution： Quantitative design method

- Matter element analysis（Chen et al., 2012）, Information theory（Harmancigolu et al., 1992）,
- Genetic algorithm optimization（Telci et al.2009）
- Complex network method（yangxue Xiang，2016）,
- Cluster analysis （Tanos et al., 2016）

Water quality model + Information entropy + Optimization

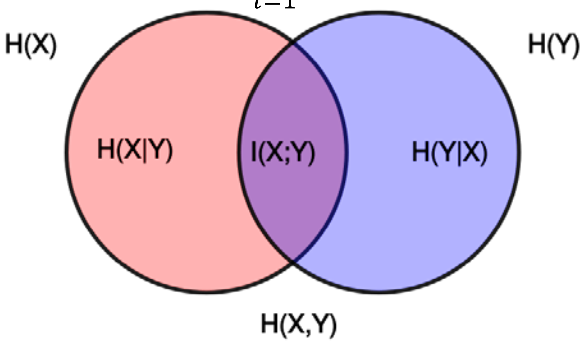
Complex network analysis

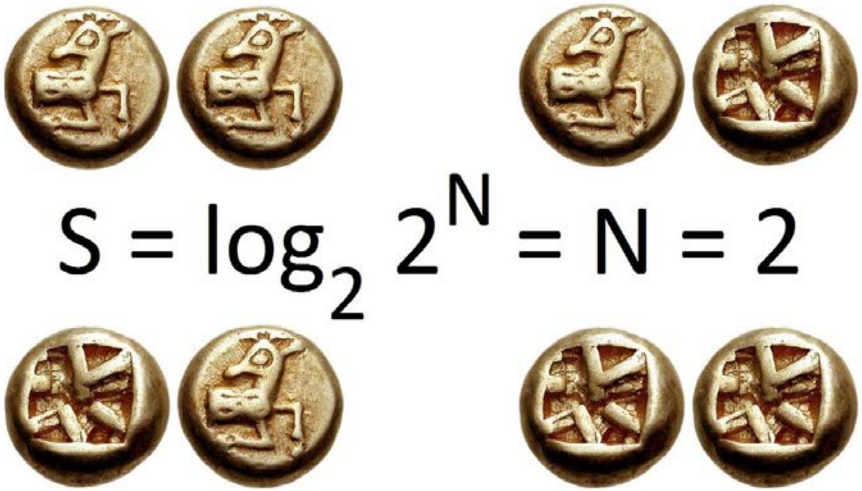
Function of water quality model： （1）expand monitoring data； （2）take the simulation performance of the model as the optimization objective

Information entropy theory

- Entropy is a parameter that describes the disorder of an object.
- Shannon(1948) described information as 'a decrease of uncertainty', and gave the definition of information entropy.
- A random variable X follows the distribution $P(X=x_i)=p_i$, i=1,2,…,n. Then the uncertainty or information entropy of X is defined as

$$H(X) = -\sum_{i=1}^{n} p_i \log p_i$$

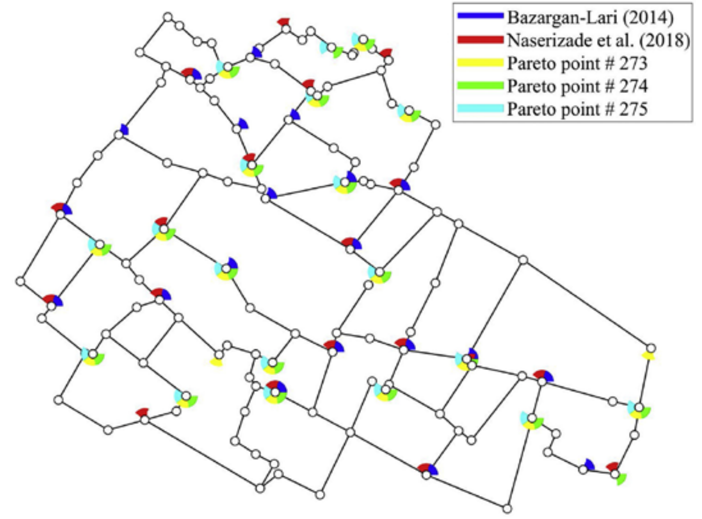


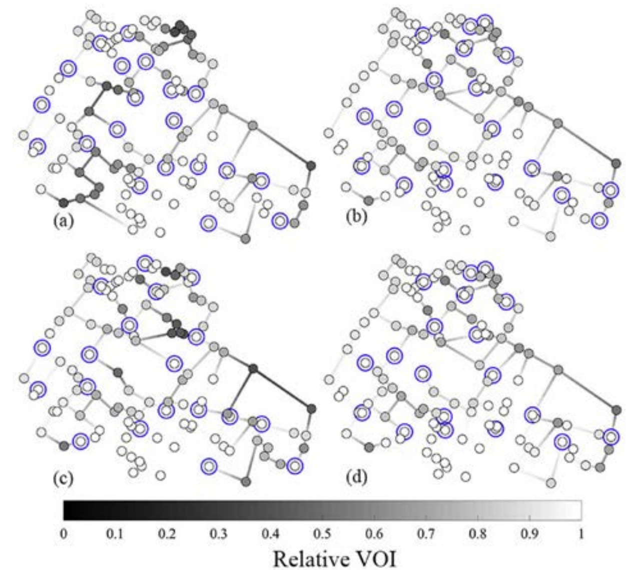


Optimal placement of sensors in distribution systems ensures safety of drinking water.

- Value of Information (VOI) can be used for accurate and robust placement of sensors.
- VOI enhances the decision space and enables exploring the entire feasible space.
- Transinformation Entropy (TE) minimizes redundant information from multiple sensors.
- TE maximizes probability of detecting contamination events.

$$VOI_i(j) = \sum_{M} P(m)\left[\max_{a}\left(\sum_{S} C(a,s)P(s|m)\right) - \max_{a}\left(\sum_{S} C(a,s)P(s)\right)\right],$$





Khorshidi, et al. 2018, Water Research

Quantitatively Design of Emergency Monitoring Network

Rules:

Maximize the information which can be captured by the network
Minimizes redundant information from monitoring section

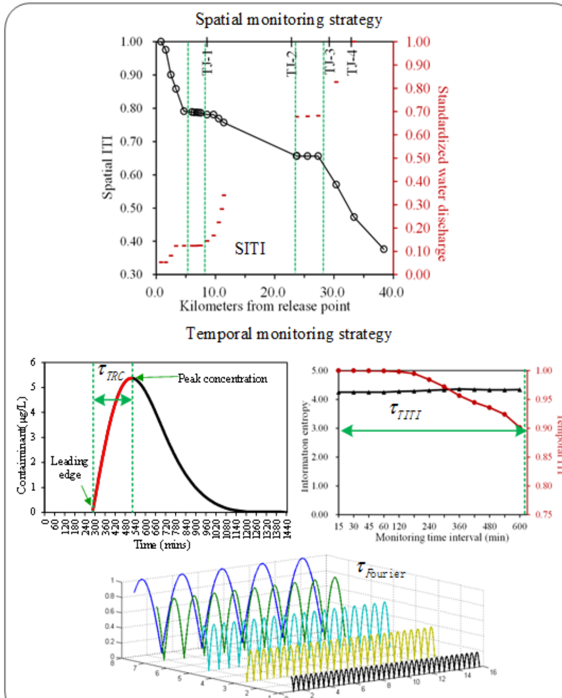
Emergency Contaminant Spills in River

The novel framework for emergency monitoring strategy

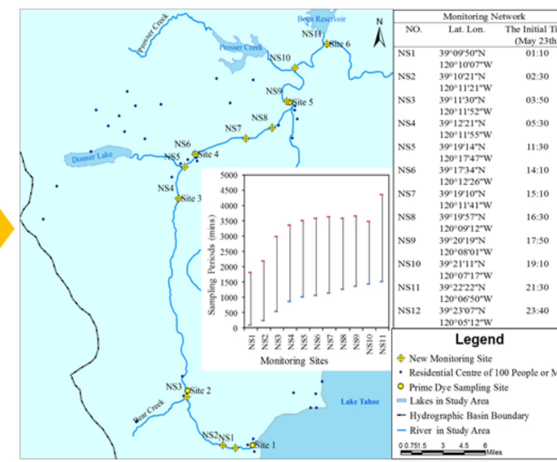
$$\frac{\partial AC}{\partial t} + \frac{\partial QC}{\partial x} - \frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right) = -AKC + C_2 q$$

$$SITI_d = (SITI_0 - SITI_{min})e^{-kd} + SITI_{min}$$

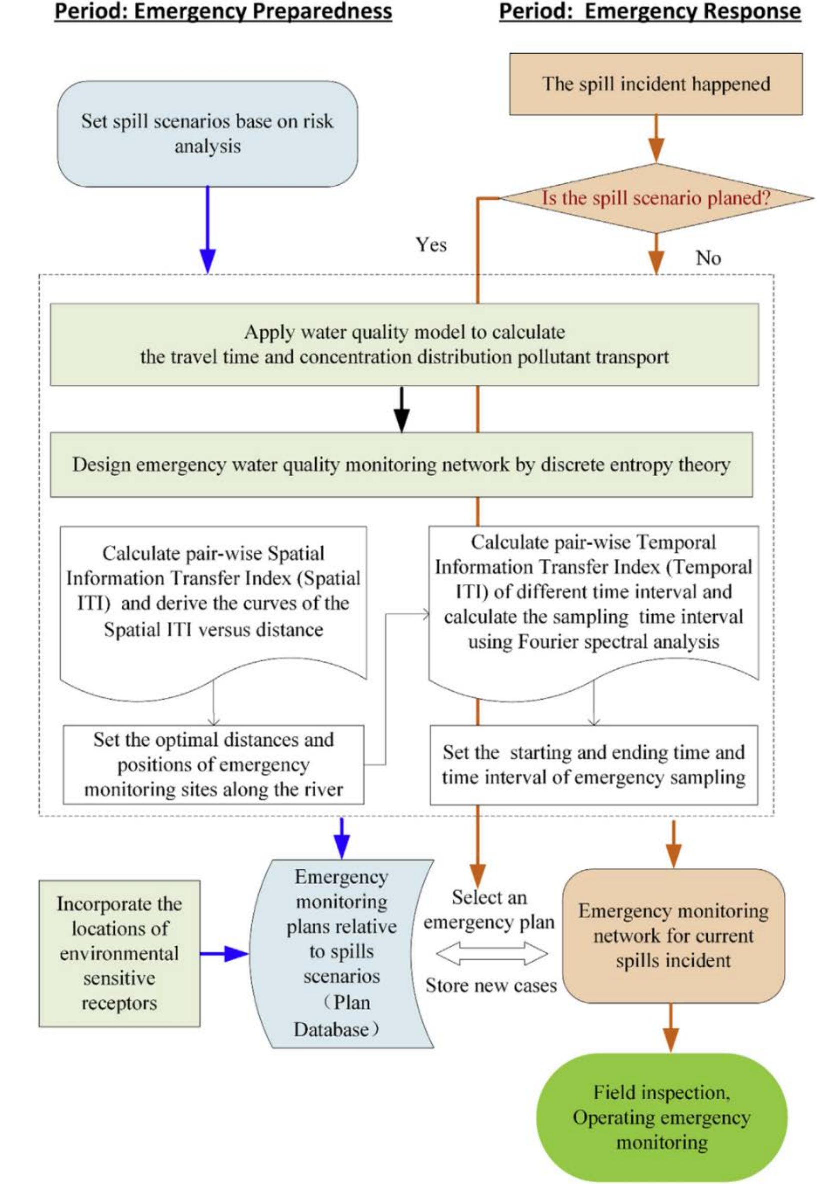
$$\tau = \min(\tau_{TITI}, \tau_{TRC}, \tau_{Fourier})$$



The Monitoring Networks



Jiping Jiang*, et al.
2018. *Water Research*



Step 1: Initialization

A: Empirically set the first monitoring site S_0 at location L_0 and the furthest location L_m downstream of concern.

B: Assign m potential monitoring locations L downstream S_0 with distance interval Δd, where $L_i = L_0 + i*\Delta d$ (i=1,2,…,m)

C: Extract containment breakthrough curves (BTC_S) at each location L_i from containment transport model outputs

D: Divide each BTC into n segments, i.e. there are n+1 concentration values

E: Calculate the discrete entropy H(X) at each BTC according to Eq.(1)

Step 2: Design emergency monitoring sites S based on Spatial ITIs

A: Calculate SITI(L_i) between the i^{th} location L_i and initial location L_0 according to Eq. (2-4)

B: Find optimal monitoring sites S_k from potential locations L

```
    Set k=1
    For i=1 to m
  set j=i+1
        while (SITI (L_i)-SITI (L_j) < 10% AND j ≤ m)
            j=j+1;
        end while
        if j ≠ m+1
            set the k^th monitoring sites S_k=L_j
            i=j; k=k+1;
        end if
   End for
```

C: Assemble [L_0, S_1,…,S_K, L_m] for the emergency monitoring sites S

Step 3: Design sampling time interval τ at sites S based on Temporal ITIs and Fourier analysis

A: Extract travel time of leading edge, peak concentration and tail end of contaminant plume ,T_l ,T_p, and T_t respectively, from containment transport model outputs for each site S

B. Extract discrete BTCs in [T_l , T_t] by different potential sampling time interval ΔT_r , r=1,…,R

C: Calculate TITIs between each BTCs by ΔT_r and BTCs by minimum time interval ΔT_0, e.g. 5mins

D: Calculate optimal sampling time interval based on TITIs, τ_{TITI}

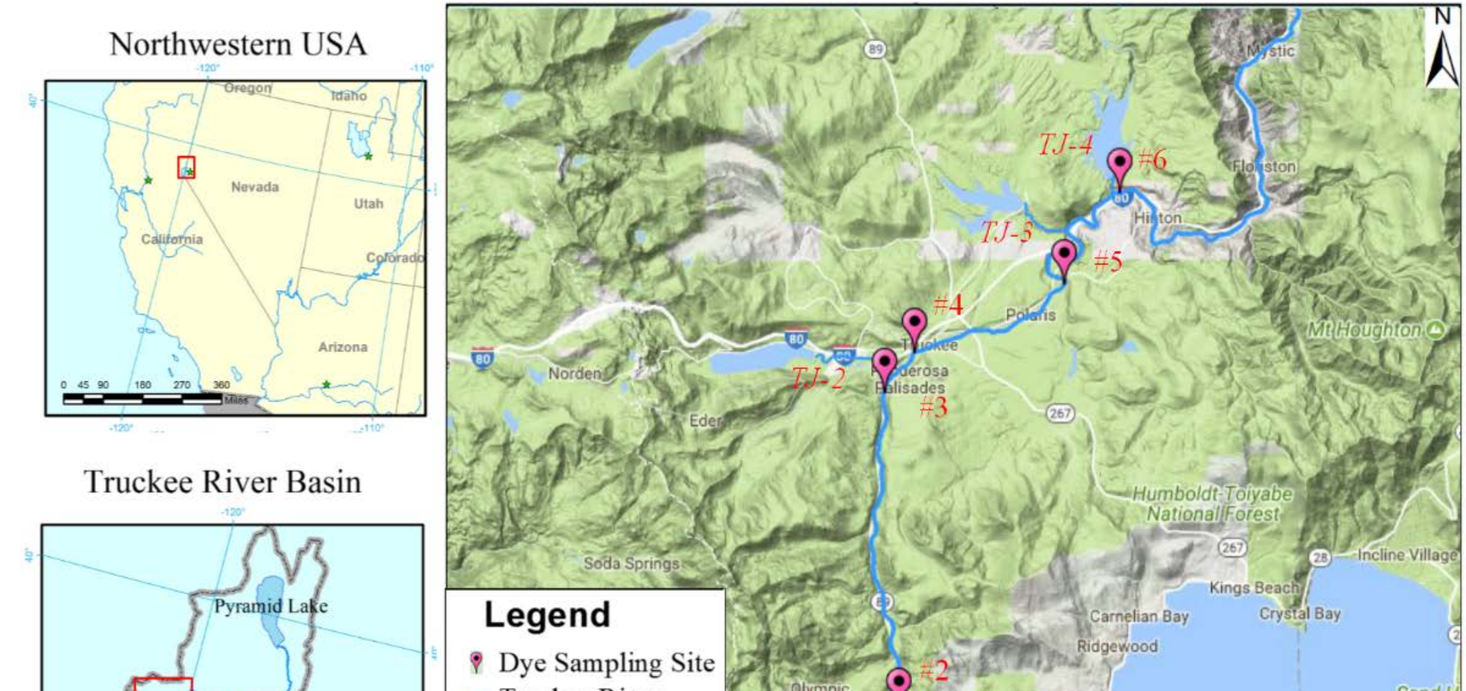
```
    Set r=1
    while (TITI (ΔT_0)-TITI(ΔT_r) < 5% AND r≤R)
        r=r+1;
    end while
    Set τ_TITI = ΔT_r
```

E: Calculate optimal sampling time interval based on BTC characteristics, τ_{BTC}, which is defined by T_l and T_p and able to estimate by Eq. (8)

F: Calculate optimal sampling time interval based on Fourier analysis, $\tau_{Fourier}$, estimated by Eq. (10)

G: Set $\tau = \min(\tau_{TITI}, \tau_{BTC}, \tau_{Fourier})$

Step 4: Assemble emergency monitoring plan by sampling at sites S with time interval τ during the period [T_l , T_t]



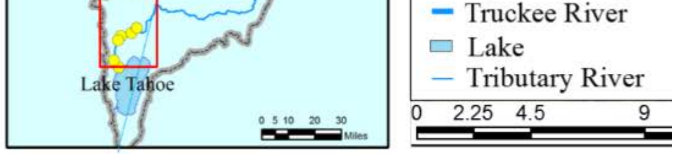


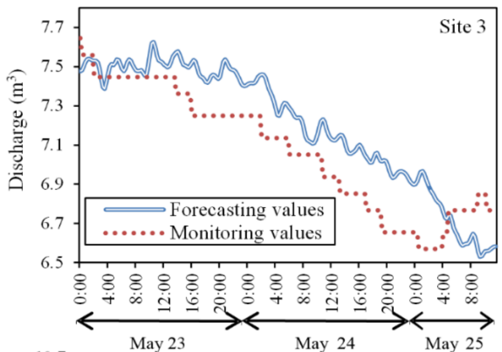
Fig. 2 The study area of Truckee River and sampling sites for dye tracing experiment

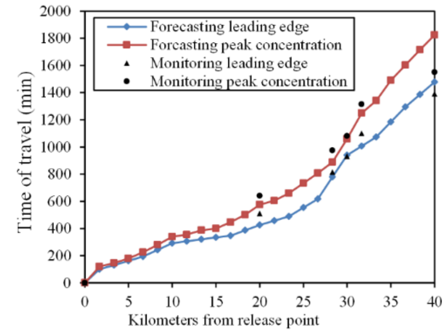
The description of injection location, sampling stations and tributaries.

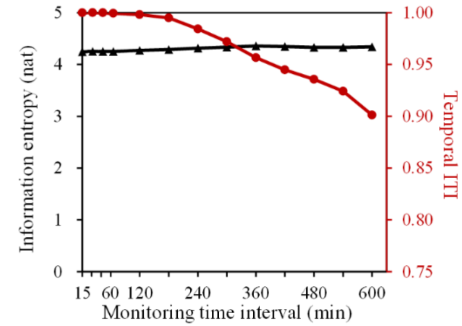
Site No.	USGS Station No.	USGS Station Name	Distance (*m*)	Latitude Longitude	Monitoring Type	Notes
#1	10337500	Truckee River at Tahoe City, Calif	0(injection)	39°09′59″ N 120°08′36″ W	Hydro[b]	Downstream side of State Route 89 bridge (lake side)
#2		Truckee River below Squaw Creek near Tahoe City, Calif	9897.47	39°12′42″ N 120°11′54″ W	WQ[c]	Under private bridge below Squaw Creek.
#3	10338000	Truckee River near Truckee, Calif.	20326.01	39°19′14″ N 120°17′47″ W	Hydro + WQ	Near center of channel at gaging station.
#4	10339010	Truckee River at Brockway Road at Truckee, Calif	24767.80	39°19′36″ N 120°11′00″ W	WQ	Near right bank under bridge
#5		Truckee River at Glenshire Drive near Truckee, Calif	32363.90	39°21′11″ N 120°07′17″ W	WQ	Center of channel under bridge
#6	10344505	Truckee River at Boca Bridge near Truckee, Calif	40249.69	39°23′07″ N 120°05′12″ W	Hydro + WQ	30 feet downstream from new Boca Bridge
TJ-1[a]		Olympic valley (lake cushing)	9859.43	39°12′43″ N 120°11′57″ W	Hydro	Squaw creek, close to Site2
TJ-2		Donner Creek at Hwy 89 Near Truckee Ca	23813.57	39°19′16″N 120°12′25″W	Hydro	Donner Creek, between Site3 & 4
TJ-3	10339419	Truckee-Carson Martis Creek Near Truckee Calif.	34139.04	39°19′44″N 120°07′00″W	Hydro	Martis Creek, close to Site5
TJ-4	10340500	Prosser Creek Dam Near Truckee, Calif	36965.00	39°22′24″N 120°07′50″W	Hydro	Prosser Creek, Between Site5 & 6

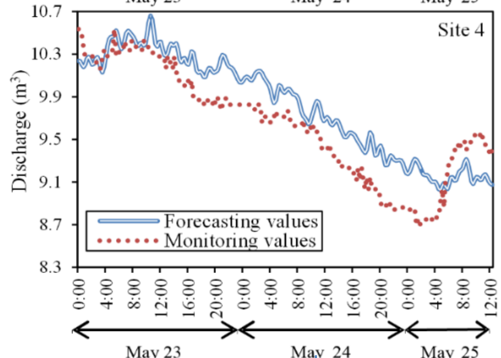
a. tributary junction, b. monitoring hydrological parameters, c. monitoring water quality parameters.

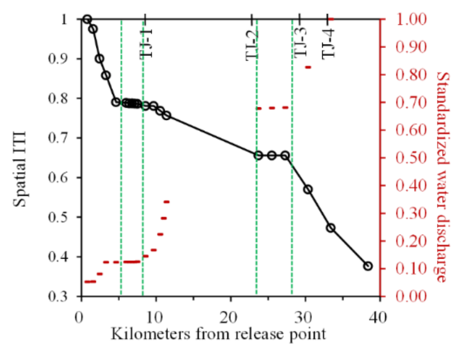
Validation Case : Truckee River, Southeast USA

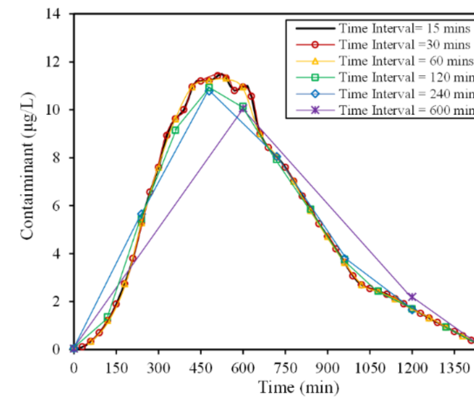






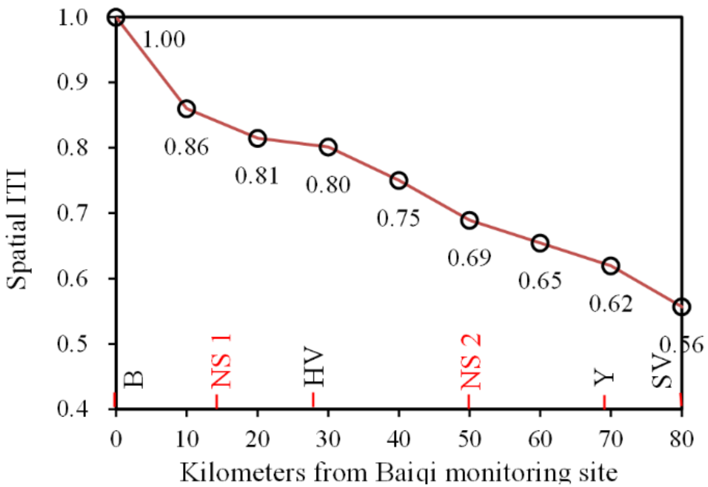






Discharge site 3	PeakC	TITI
Discharge site 4	SITI	BTCs

Validation Case : Songhua River, Northeast China



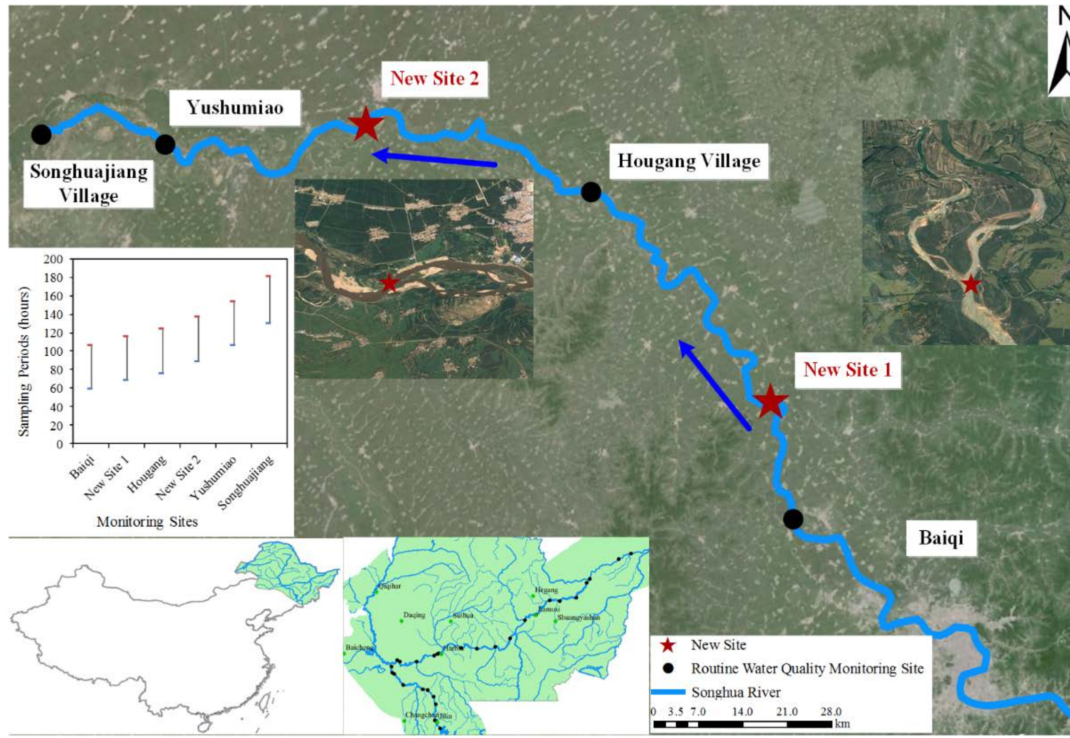
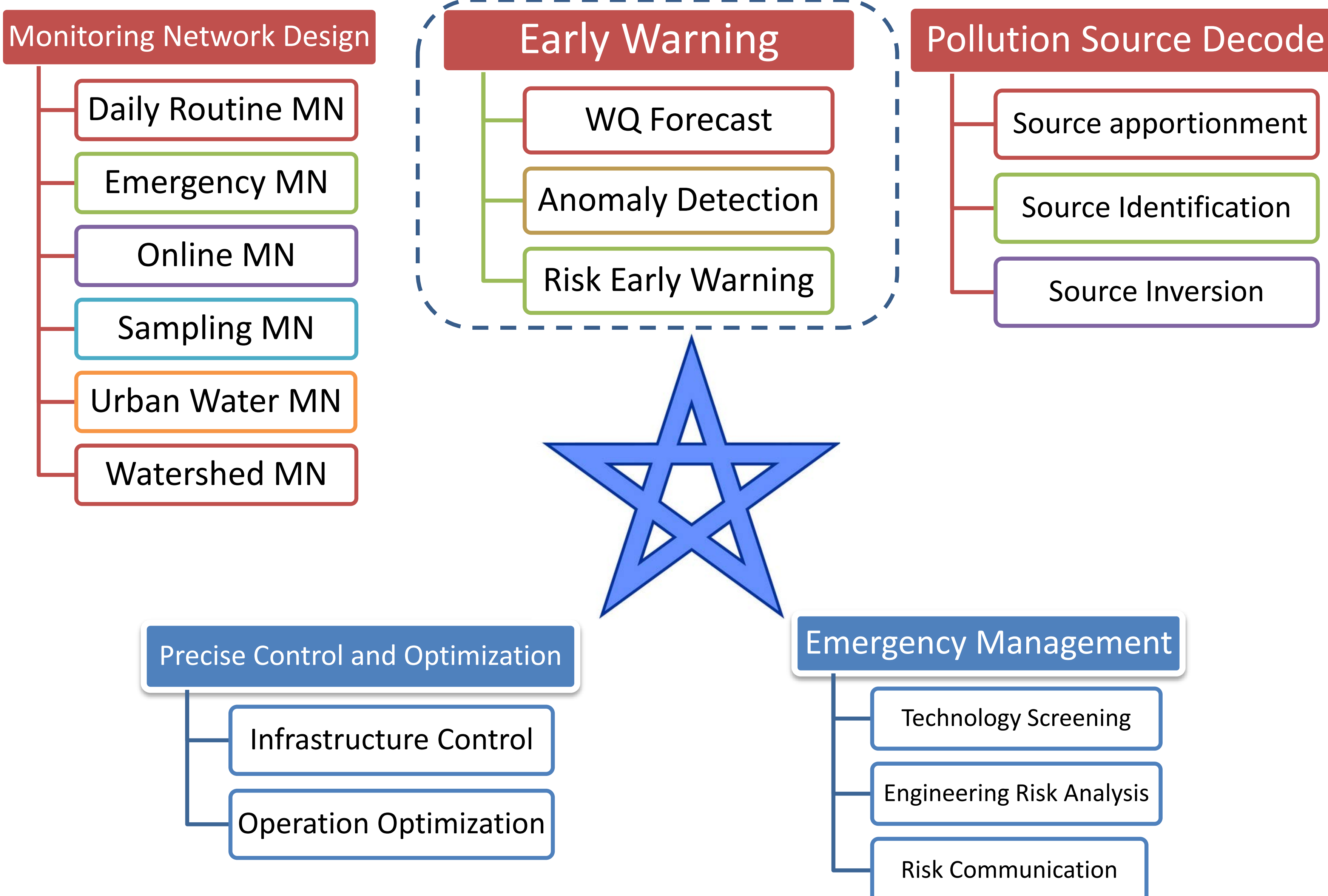


Fig. 10 Spatial ITI decrases downstream in Songhua River nitrobenzen spill case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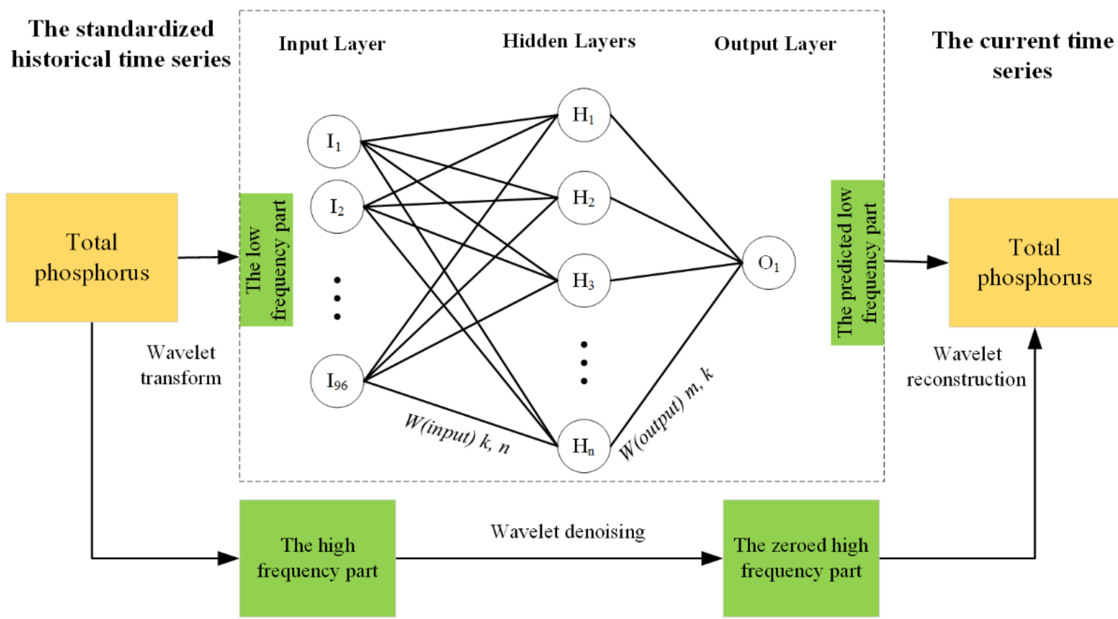
Source Inversion
Precise Control and Optimization
Infrastructure Control
Operation Optimization
Emergency Management
Technology Screening
Engineering Risk Analysis
Risk Communication

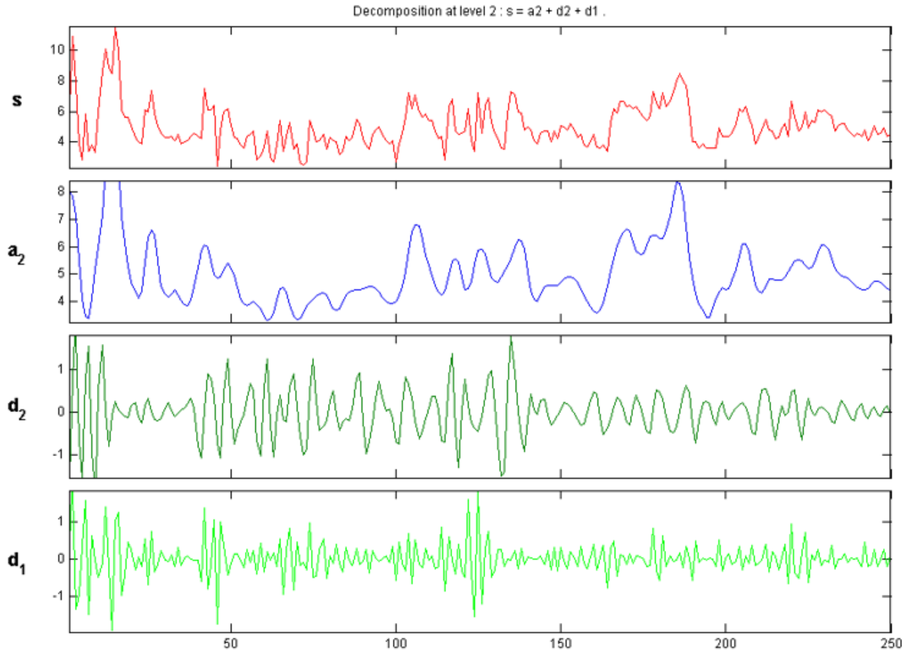
- Data-driven water quality forecast-水质预测
- Abnormal detection -异常预报
- Risk early warning-风险预警

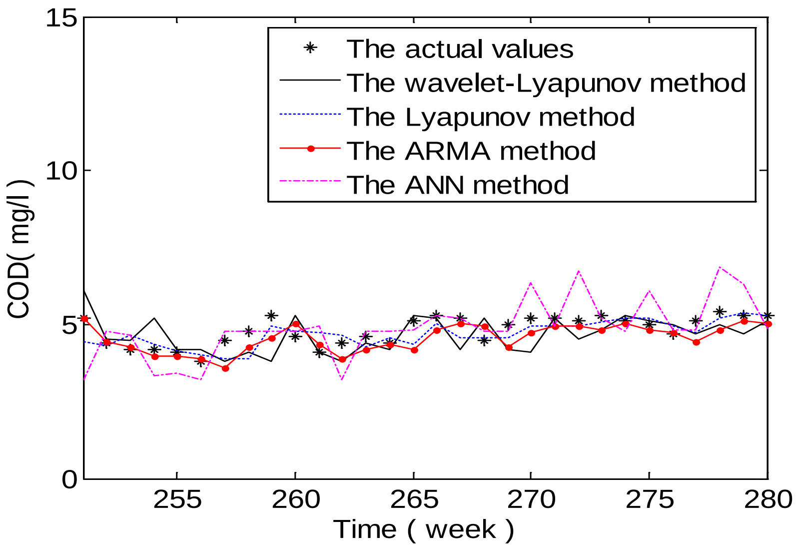
Data-driven models such as artificial neural networks (ANN), wavelet artificial neural networks (Wavelet-ANN), SVM, etc. can be used to predict time series



Babovic, 2005. Data mining in hydrology.

1. Water quality forecast: "Wavelet-Chaos" Hybrid model





Huaihe, Potomac River

Jiping Jiang, et al. 2018.
J. Hydrology. submitted.

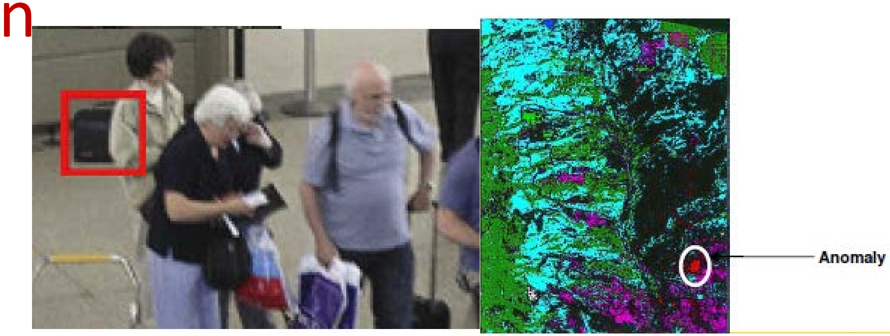
2. Anomaly Detection

What are anomalies?

- Anomaly is a pattern in the data that does not conform to the expected behavior
- Also referred to as **outliers**, **exceptions**, **peculiarities**, surprise, etc.

Application of Anomaly detection

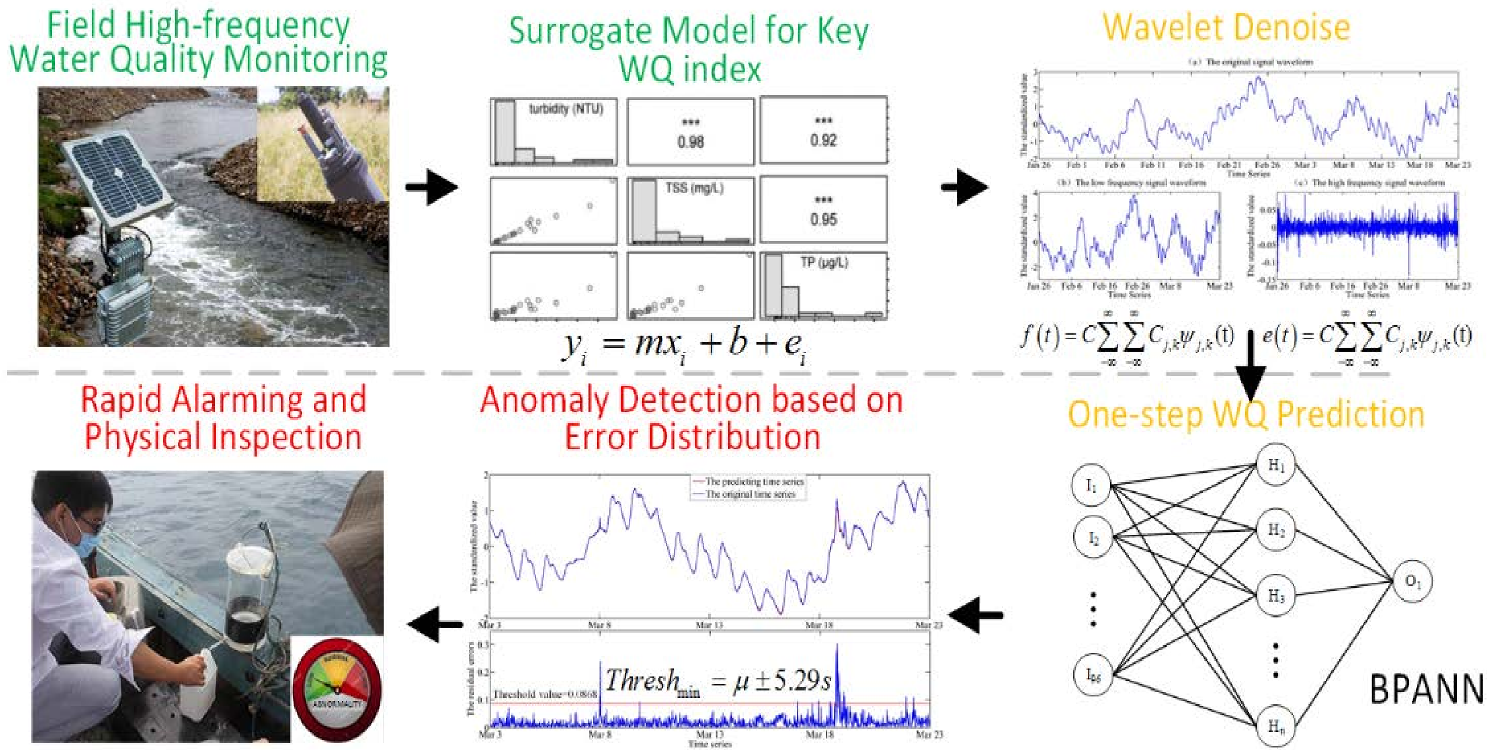
- Network intrusion detection
- Insurance / Credit card fraud detection
- Healthcare Informatics / Medical diagnostics
- Industrial Damage Detection
- Image Processing / Video surveillance
- Novel Topic Detection in Text Mining
- Environmental management



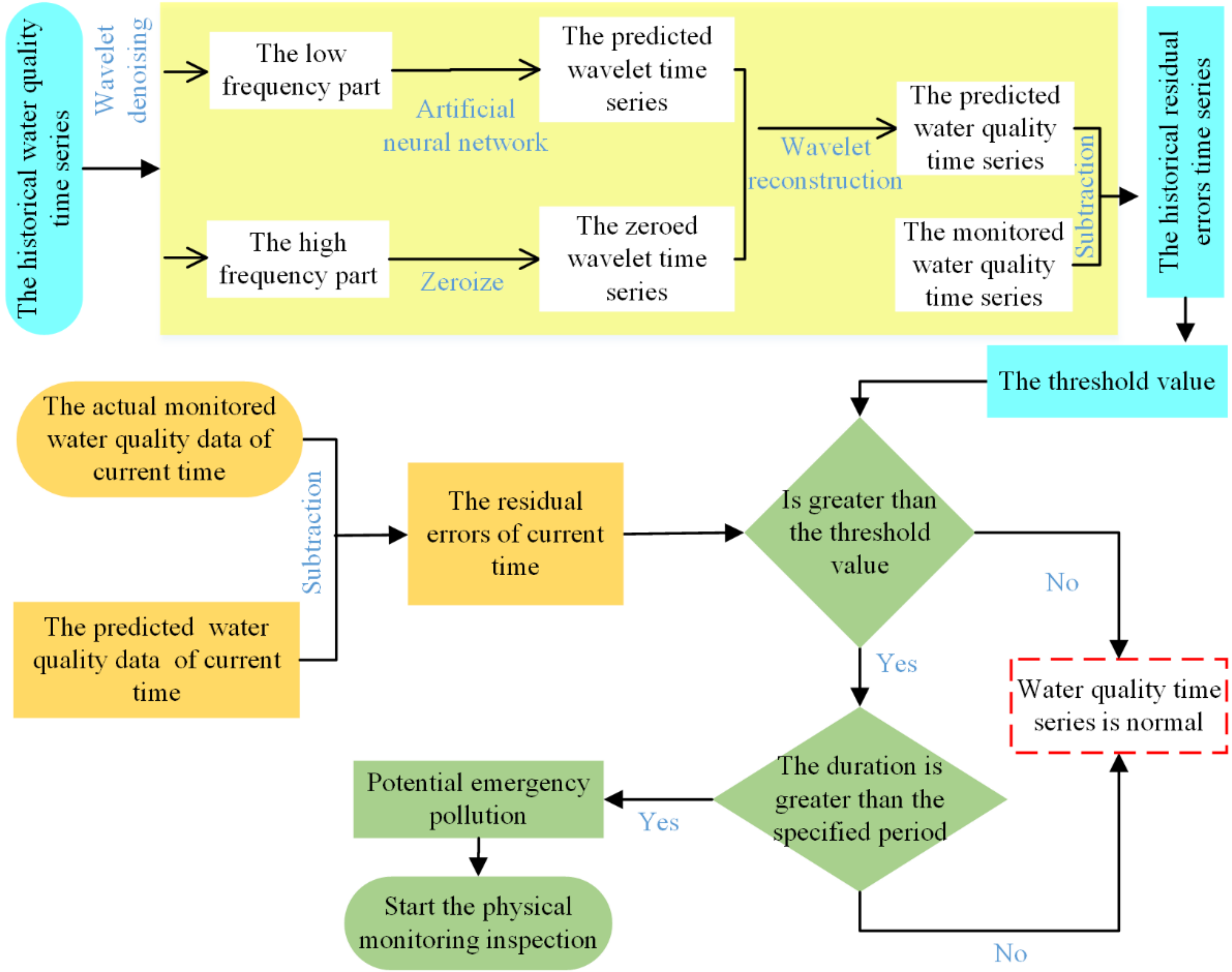
(Aleksandar Lazarevic et al, 2008. Data Mining for Anomaly Detection)

2. Anomaly Detection

Combined with Surrogate model and data-driven model to alarm water quality anomaly



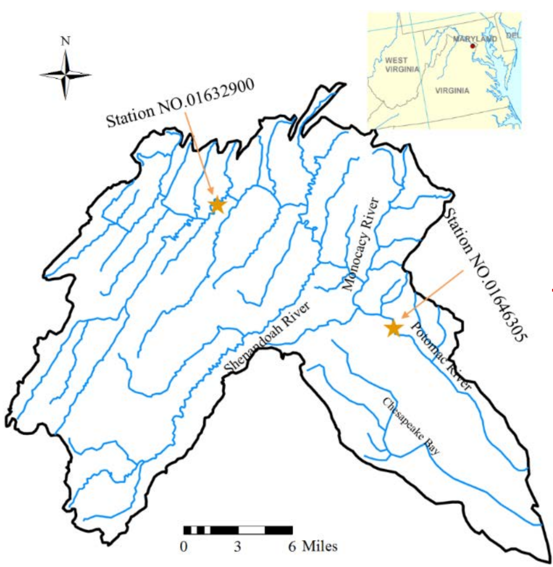
Binshi, Peng Wang, **Jiping Jiang***, et al. 2017. *Sci. Total Environ.*



Binshi, Peng Wang, Jiping Jiang*, et al. 2017. *Sci. Total Environ.*

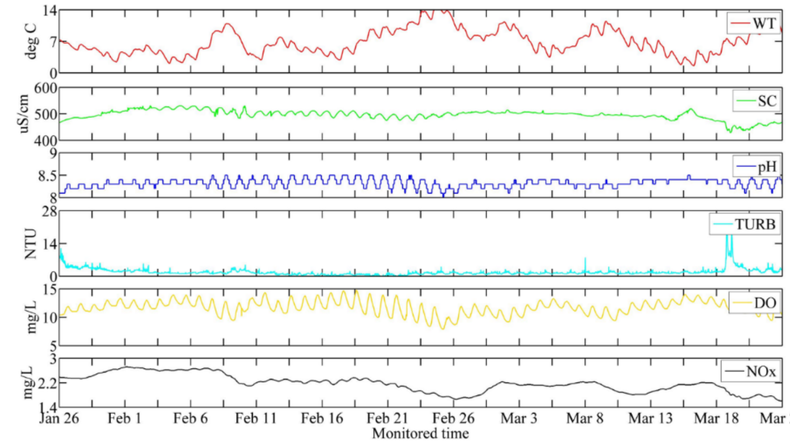
Study area and monitoring data

- The Potomac River is located along the United States coast of the mid-Atlantic Ocean and flows into the Chesapeake Bay.



Two monitoring stations in the upstream and downstream

The time interval is 15 mins

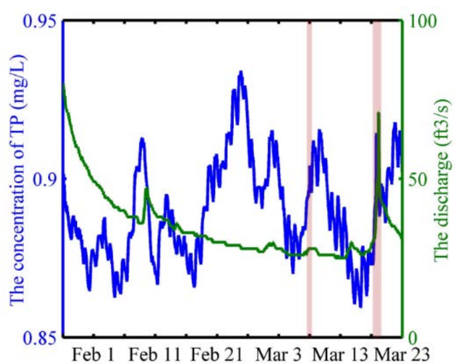


https://waterdata.usgs.gov/nwis/sw

TP time series and anomaly events

- The concentrations of TP was measured by surrogate relationships in high-frequency (time interval is 15 mins)

$$TP = 0.00103TURB + 0.00570WT - 0.227\log_{10}SC + 0.776$$

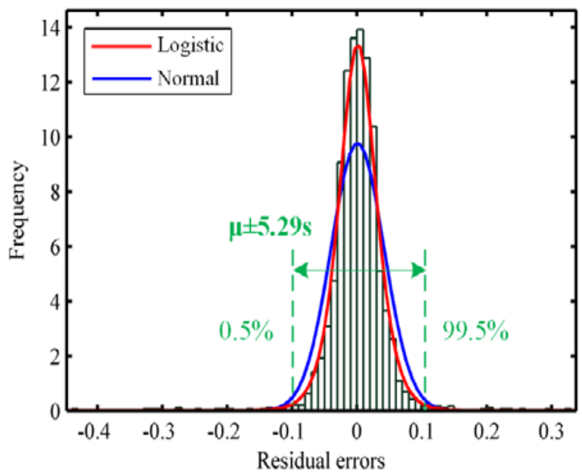


Concentration time series of TP and discharge

Two anomaly events were observed from the time series:
March 8 and March 18-19

Baseline construction for water quality prediction

- The threshold value is determined by the error distribution function of the baseline time series.



Distribution of the residual errors of prediction for the baseline (station no.01632900)

Normal, logistic functions or other distribution function were used to fit the error distribution.

The 0.5% and 99.5% quantiles of the cumulative distribution are used to identify outliers

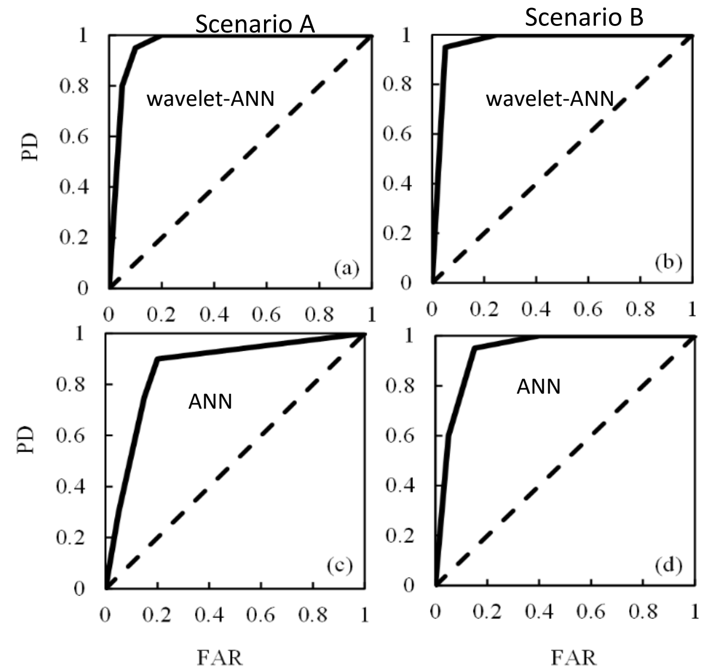
$$f(x;\mu,s)=\frac{e^{-\frac{x-\mu}{s}}}{s(1+e^{-\frac{x-\mu}{s}})}$$

$$Thresh_{\mathrm{inf}}=\mu+\ln\left(\frac{p_{\mathrm{inf}}}{1-p_{\mathrm{inf}}}\right)s=\mu-5.29s$$

$$Thresh_{\mathrm{sup}}=\mu+\ln\left(\frac{p_{\mathrm{sup}}}{1-p_{\mathrm{sup}}}\right)s=\mu+5.29s$$

Reliability analysis of anomaly detection results

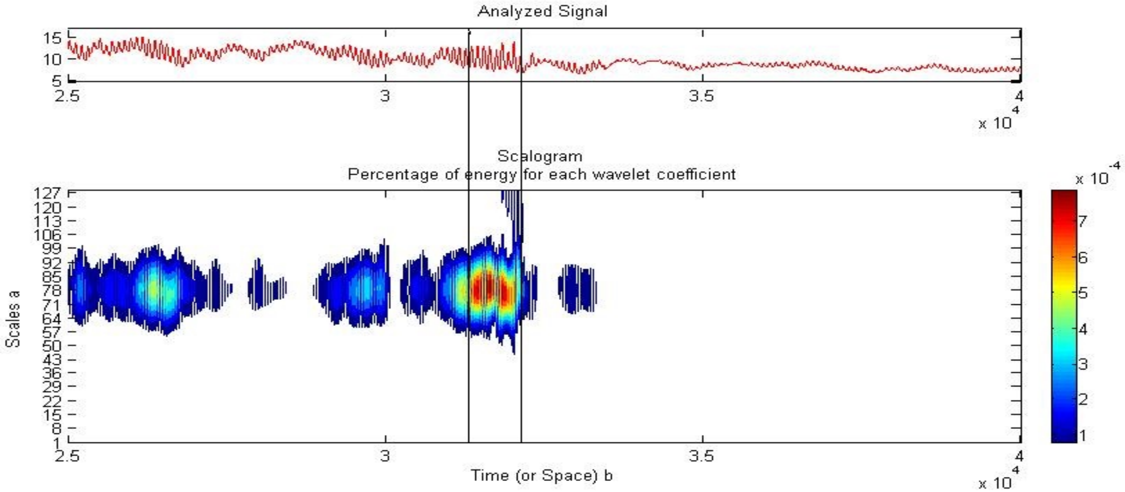
- The receiver operating characteristic (ROC) curve can be used to assess the quality of decision making and the accuracy of detection information (He et al., 2013).

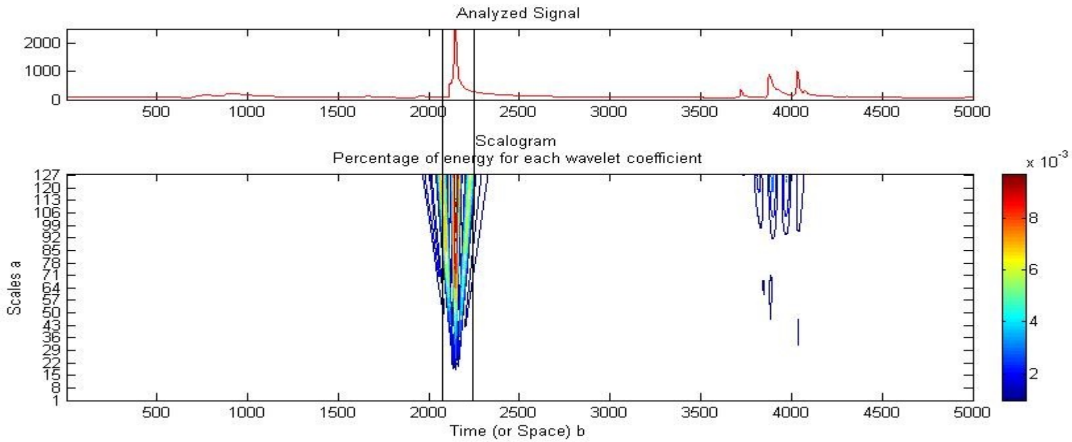


Two hypothetic scenarios were established. We established an abnormal event that occurred each day from March 3 to March 23 at 10:00 am and 12:00 am.

- 2 times of original time series in scenario A
- 3 times in scenario B

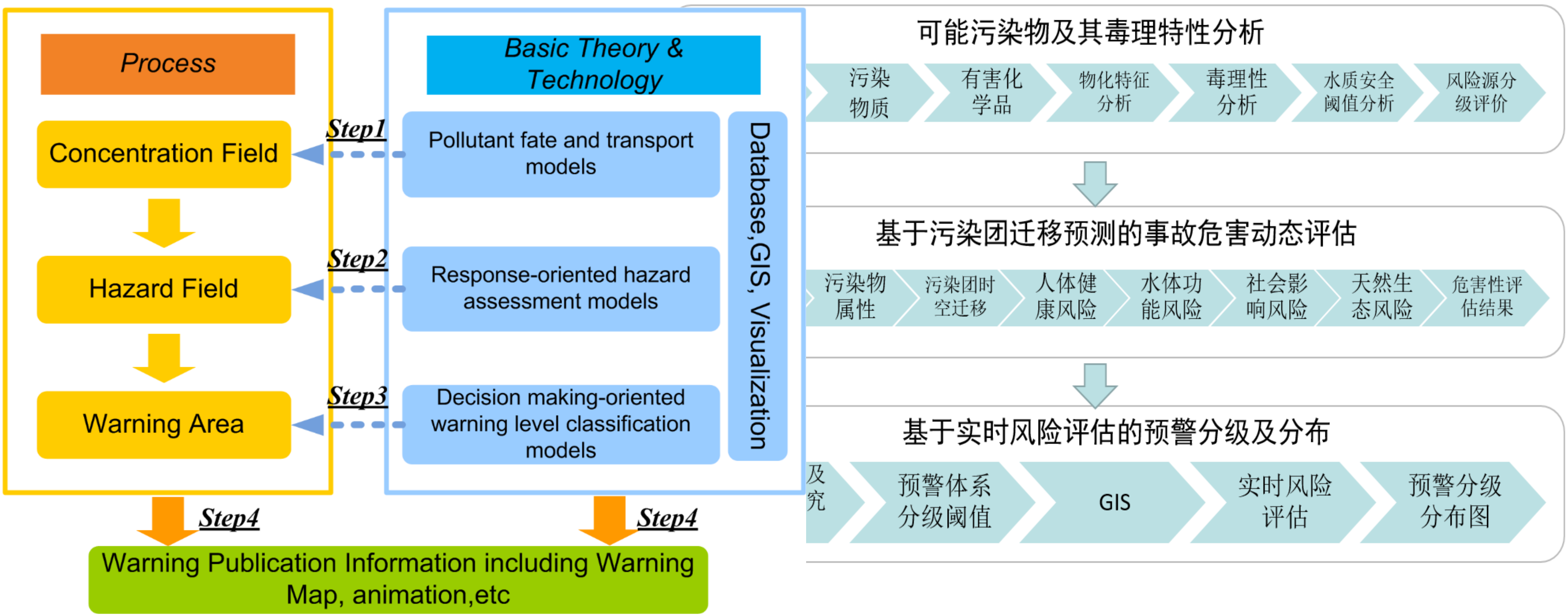
2. Anomaly Detection : spectral analysis



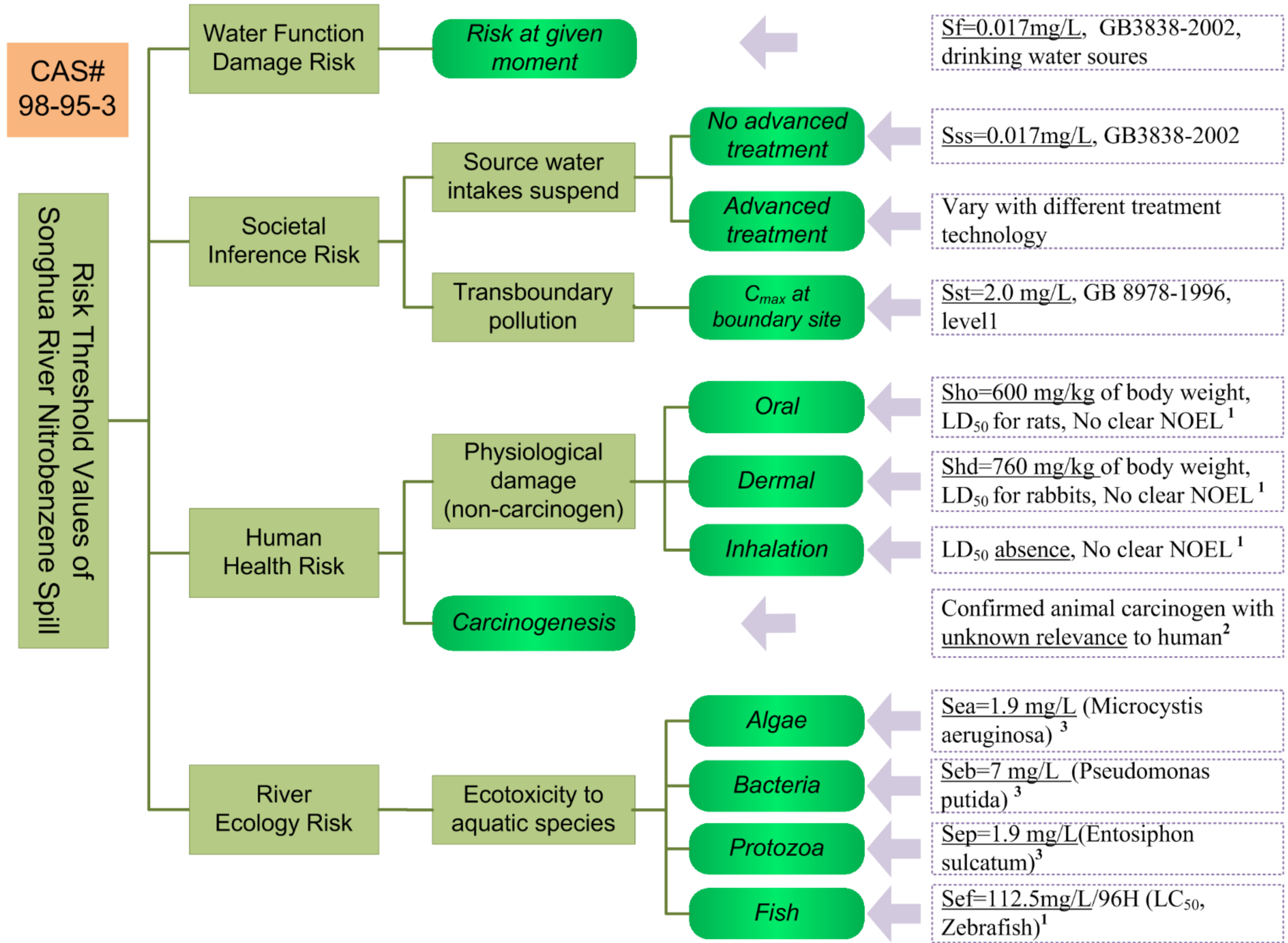


Jiping Jiang, et al. 2018.
J. Hydrol. Under review

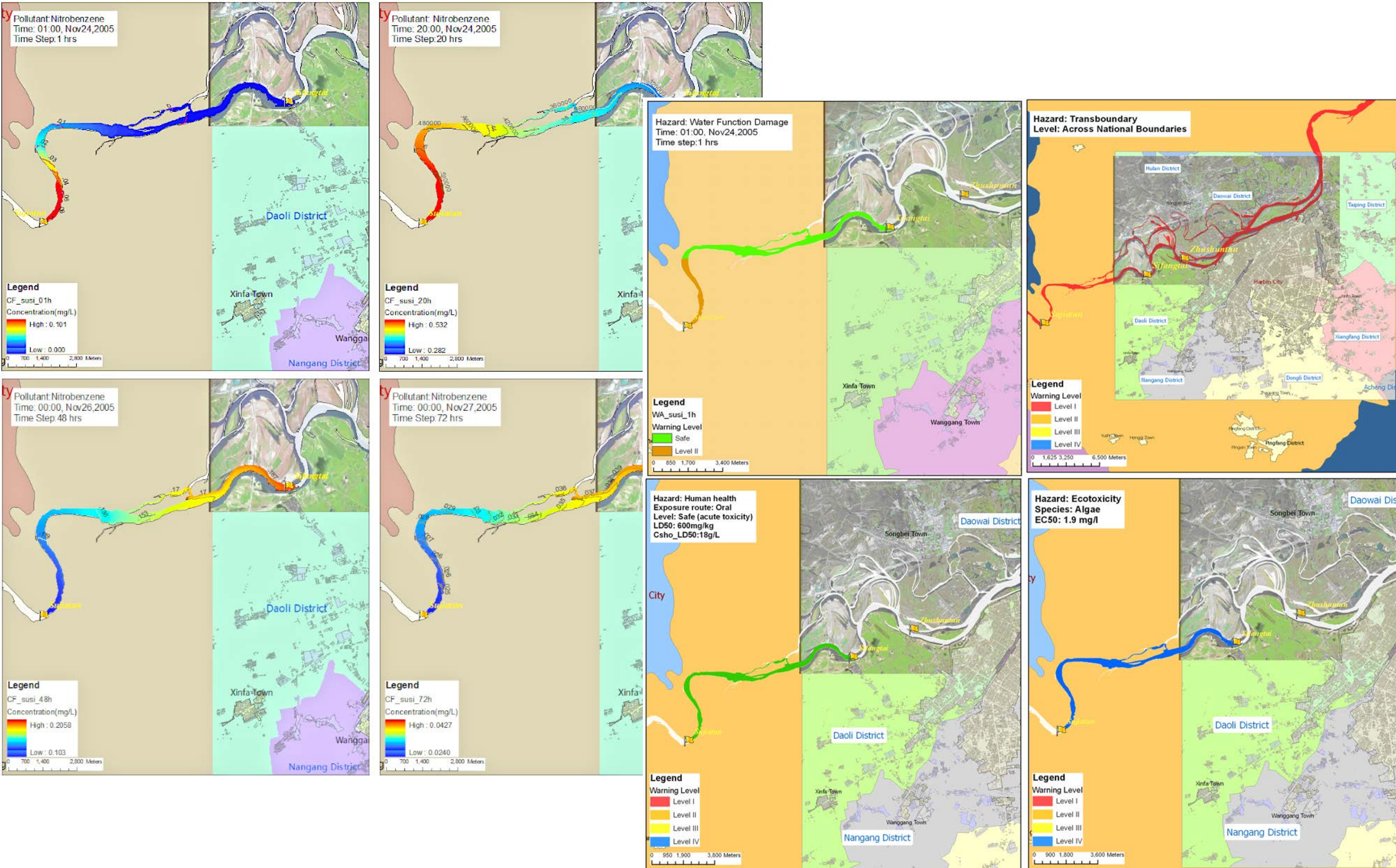
3. A GIS-based Generic Real-time Risk Assessment Framework for Pollution Incident

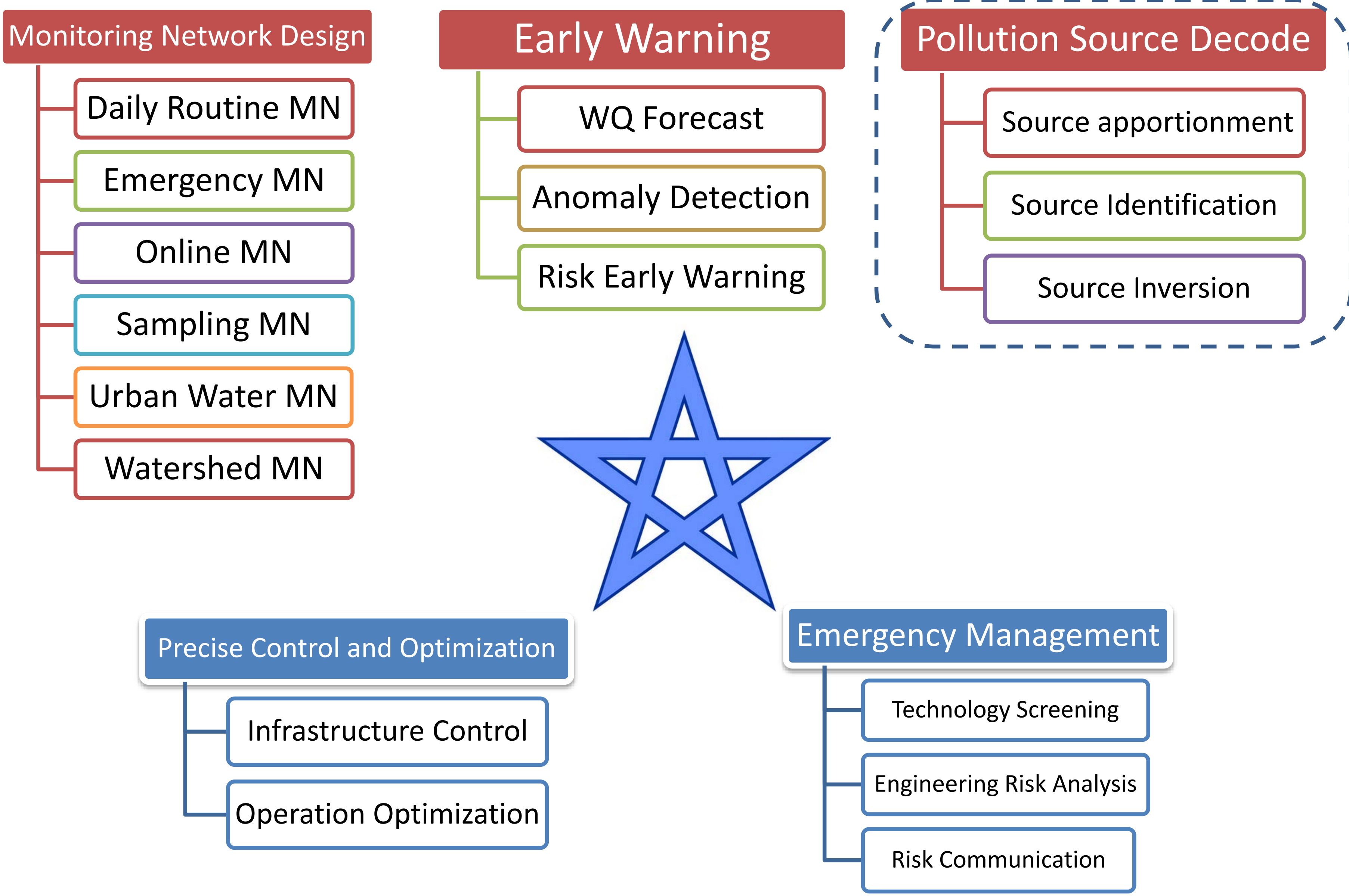


Jiping Jiang, et al. 2012. *J.Hazard.Mater.*



CAS# 98-95-3
Risk Threshold Values of Songhua River Nitrobenzene Spill
Water Function Damage Risk
Risk at given moment
Sf=0.017mg/L, GB3838-2002, drinking water soures
Societal Inference Risk
Source water intakes suspend
No advanced treatment
Sss=0.017mg/L, GB3838-2002
Advanced treatment
Vary with different treatment technology
Transboundary pollution
C_{max} at boundary site
Sst=2.0 mg/L, GB 8978-1996, level1
Human Health Risk
Physiological damage (non-carcinogen)
Oral
Sho=600 mg/kg of body weight, LD_{50} for rats, No clear NOEL [1]
Dermal
Shd=760 mg/kg of body weight, LD_{50} for rabbits, No clear NOEL [1]
Inhalation
LD_{50} absence, No clear NOEL [1]
Carcinogenesis
Confirmed animal carcinogen with unknown relevance to human[2]
River Ecology Risk
Ecotoxicity to aquatic species
Algae
Sea=1.9 mg/L (Microcystis aeruginosa) [3]
Bacteria
Seb=7 mg/L (Pseudomonas putida) [3]
Protozoa
Sep=1.9 mg/L(Entosiphon sulcatum)[3]
Fish
Sef=112.5mg/L/96H (LC_{50}, Zebrafish)[1]


Pollutant:Nitrobenzene
Time: 01:00, Nov24,2005
Time Step:1 hrs
Daoli District
Xinfa Town
Nangang District
Legend
CF_susi_01h
Concentration(mg/L)
High : 0.101
Low : 0.000
0 700 1,400 2,800 Meters
Pollutant: Nitrobenzene
Time: 20:00, Nov24,2005
Time Step:20 hrs
Legend
CF_susi_20h
Concentration(mg/L)
High : 0.532
Low : 0.282
0 700 1,400 2,800 Meters
Pollutant:Nitrobenzene
Time: 00:00, Nov26,2005
Time Step:48 hrs
Daoli District
Xinfa Town
Nangang District
Legend
CF_susi_48h
Concentration(mg/L)
High : 0.2058
Low : 0.103
0 700 1,400 2,800 Meters
Pollutant:Nitrobenzene
Time: 00:00, Nov27,2005
Time Step:72 hrs
Legend
CF_susi_72h
Concentration(mg/L)
High : 0.0427
Low : 0.0240
0 700 1,400 2,800 Meters
Hazard: Water Function Damage
Time: 01:00, Nov24,2005
Time step:1 hrs
Xinfa Town
Wanggang Town
Legend
WA_susi_1h
Warning Level
Safe
Level II
0 850 1,700 3,400 Meters
Hazard: Transboundary
Level: Across National Boundaries
Hulan District
Daowai District
Taiping District
Harbin City
Daoli District
Xiangfang District
Nangang District
Dongli District
Acheng Dis
Pingfang District
Legend
Warning Level
Level I
Level II
Level III
Level IV
0 1,625 3,250 6,500 Meters
Hazard: Human health
Exposure route: Oral
Level: Safe (acute toxicity)
LD50: 600mg/kg
Csho_LD50:18g/L
City
Daowai District
Songbei Town
Daoli District
Nangang District
Legend
Warning Level
Level I
Level II
Level III
Level IV
0 950 1,900 3,800 Meters
Hazard: Ecotoxicity
Species: Algae
EC50: 1.9 mg/l
Songbei Town
Daoli District
Xinfa Town
Wanggang Town
Nangang District
Legend
Warning Level
Level I
Level II
Level III
Level IV
0 900 1,800 3,600 Meters


Monitoring Network Design
Daily Routine MN
Emergency MN
Online MN
Sampling MN
Urban Water MN
Watershed MN
Early Warning
WQ Forecast
Anomaly Detection
Risk Early Warning
Pollution Source Decode
Source apportionment
Source Identification
Source Inversion
Precise Control and Optimization
Infrastructure Control
Operation Optimization
Emergency Management
Technology Screening
Engineering Risk Analysis
Risk Communication

- **Statistic data analysis**

Analysis of pollution source types based on positive definite matrix decomposition

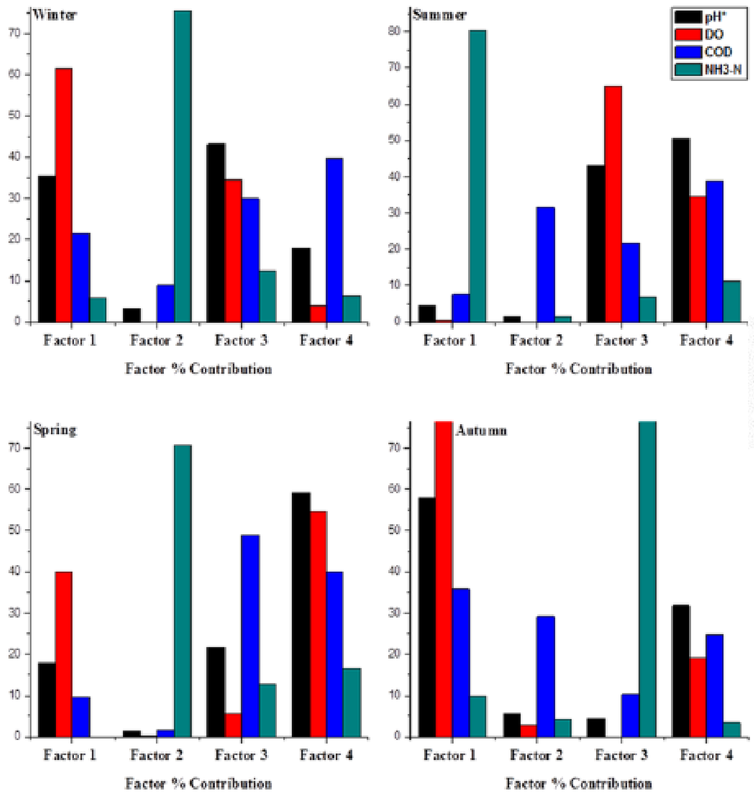
- **Qualitative tracing-Spectral source apportionment**

Fingerprint source analysis based on Raman spectra、fluorescence、and deep-UV

- **Quantitative tracing**

Pollution source inversion technology based on MCMC Bayesian inference

Source apportionment



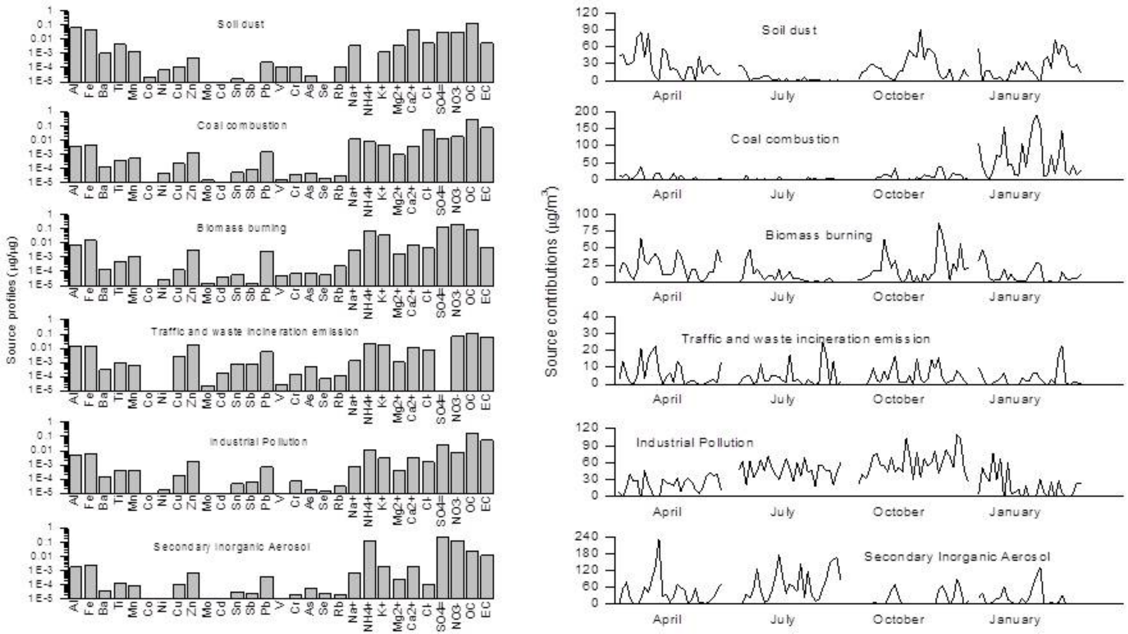


Fig. 4. Temporal factor loadings obtained from PMF analysis of water quality parameters of Huaihe River basin. Factors along with its corresponding NPS are given.

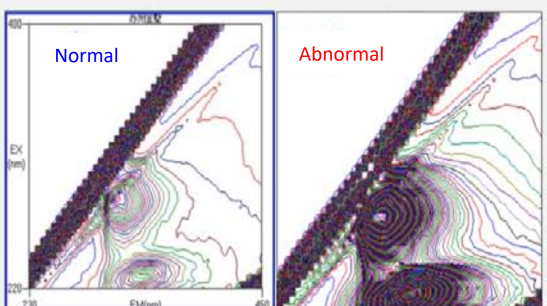
Afed Khan, Jiping Jiang*,et al. Applied Water Science (under review).

Source Identification

Early warning

- Long-period online monitoring and automatic warning
- Warning of primary pollution source
- Two orders of magnitude higher than visible ultraviolet light

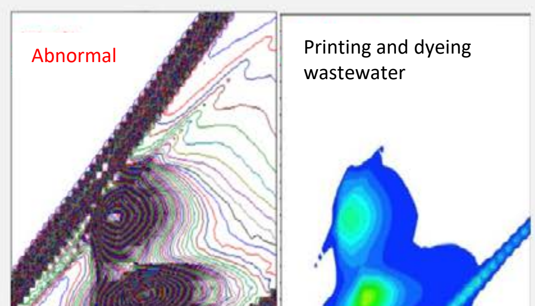
Sensitive to water quality



Pollution tracing

- Tracing time within 20-30 minutes
- Extensive to industry, precision to enterprise
- Multi process enterprises can collect multiple fingerprints

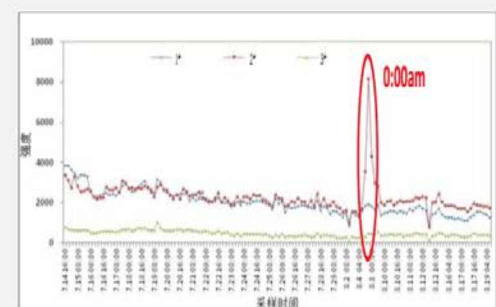
Identify the source quickly



Obtain evidence

- Saving the digital spectrogram of water automatically
- Saving the data for 20 years
- Providing the rank of Contribution rate of pollution

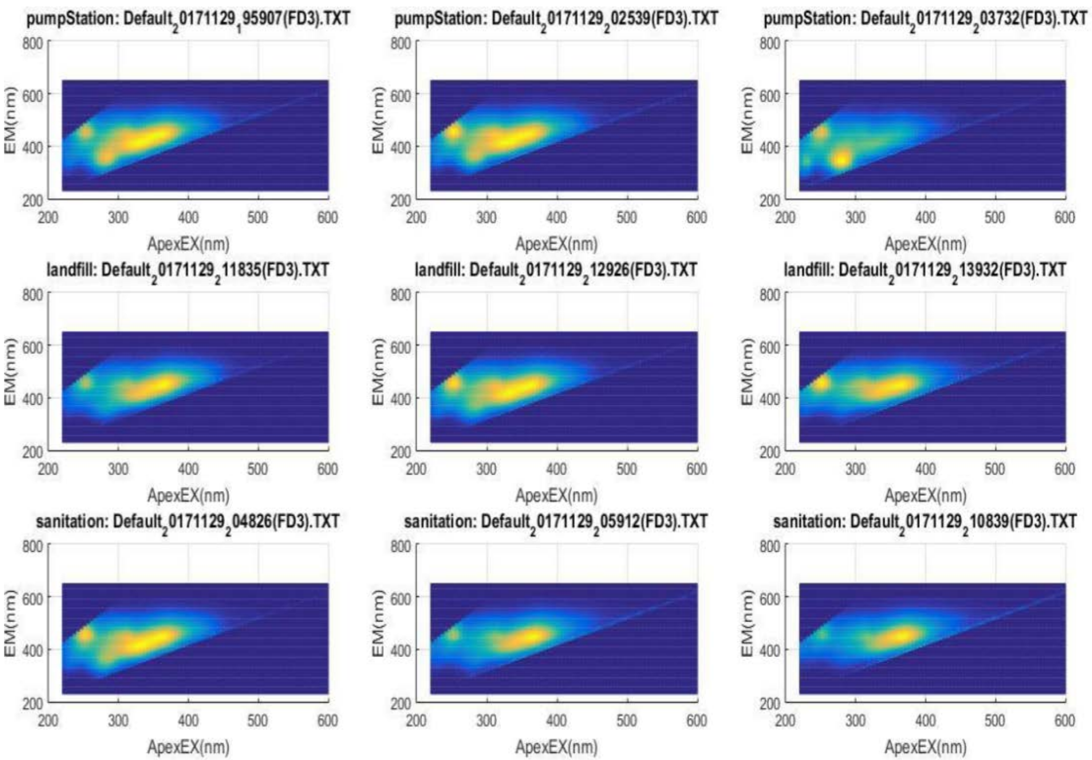
Collect data for all time



Source： Shenzhen environmental monitoring station

Buji WWTP, Shenzhen

Water quality fingerprint and similarity degree(SE)

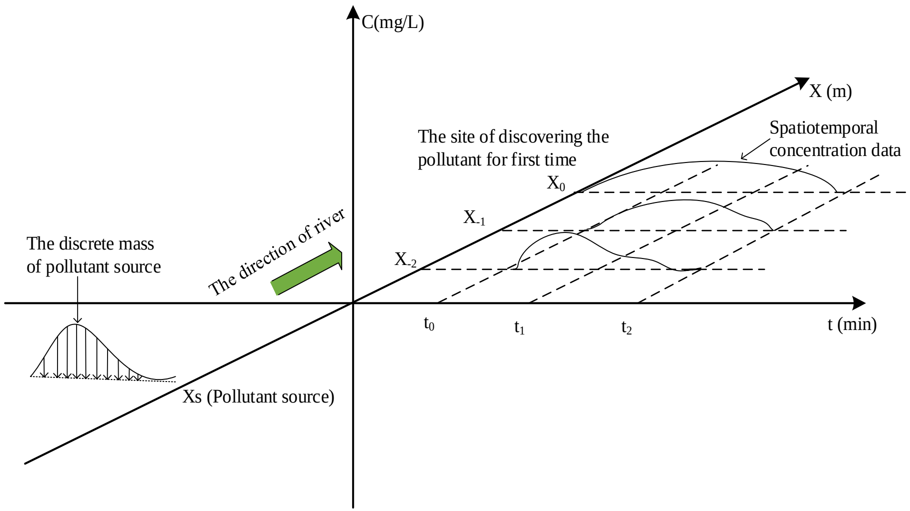


Site 1-Site2	SE
Pump Station-Landfill site 11:00	95-98%
Pump Station-Landfill site 12:00	97-100%
Stormwater well-Landfill site 11:00	98-99%
Stormwater well--Landfill site 12:00	94-100%
Stormwater well--Landfill site 11:00	91-99%
Stormwater well--pump 12:00	92-100%

Results:

- ✓ **Main pollution type： NH3-N，from landfill site leakage**
- ✓ **Landfill Site Renovation，WWTP outlet back to normal**

Source Inversion



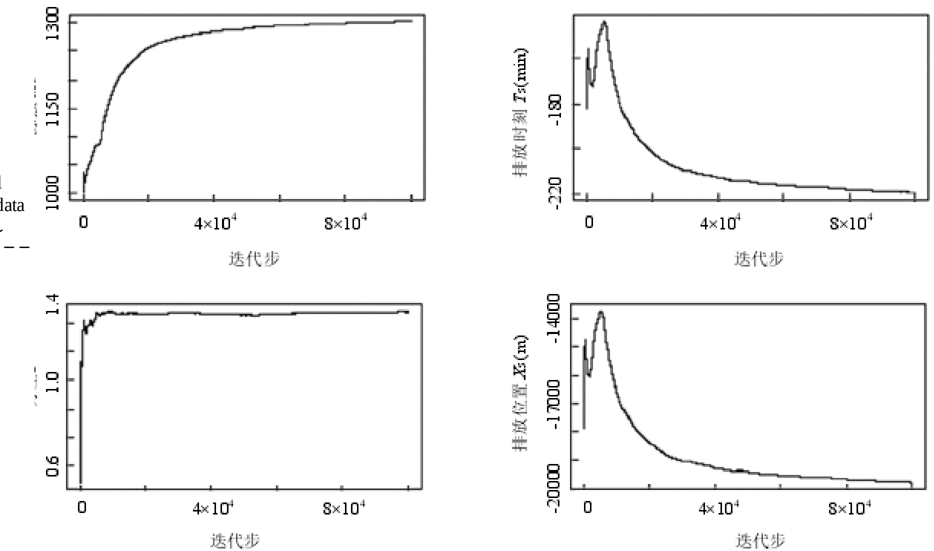


图 4　源项参数和方差 σ^2 在 MCMC 采样过程的均值变化

Fig.4　Running mean of source parameters and σ^2

表 3　Case-T1(Truckee River)反演结果的概要统计量

Table 3　Summary statistics of inverse results at Case-T1(Truckee River)

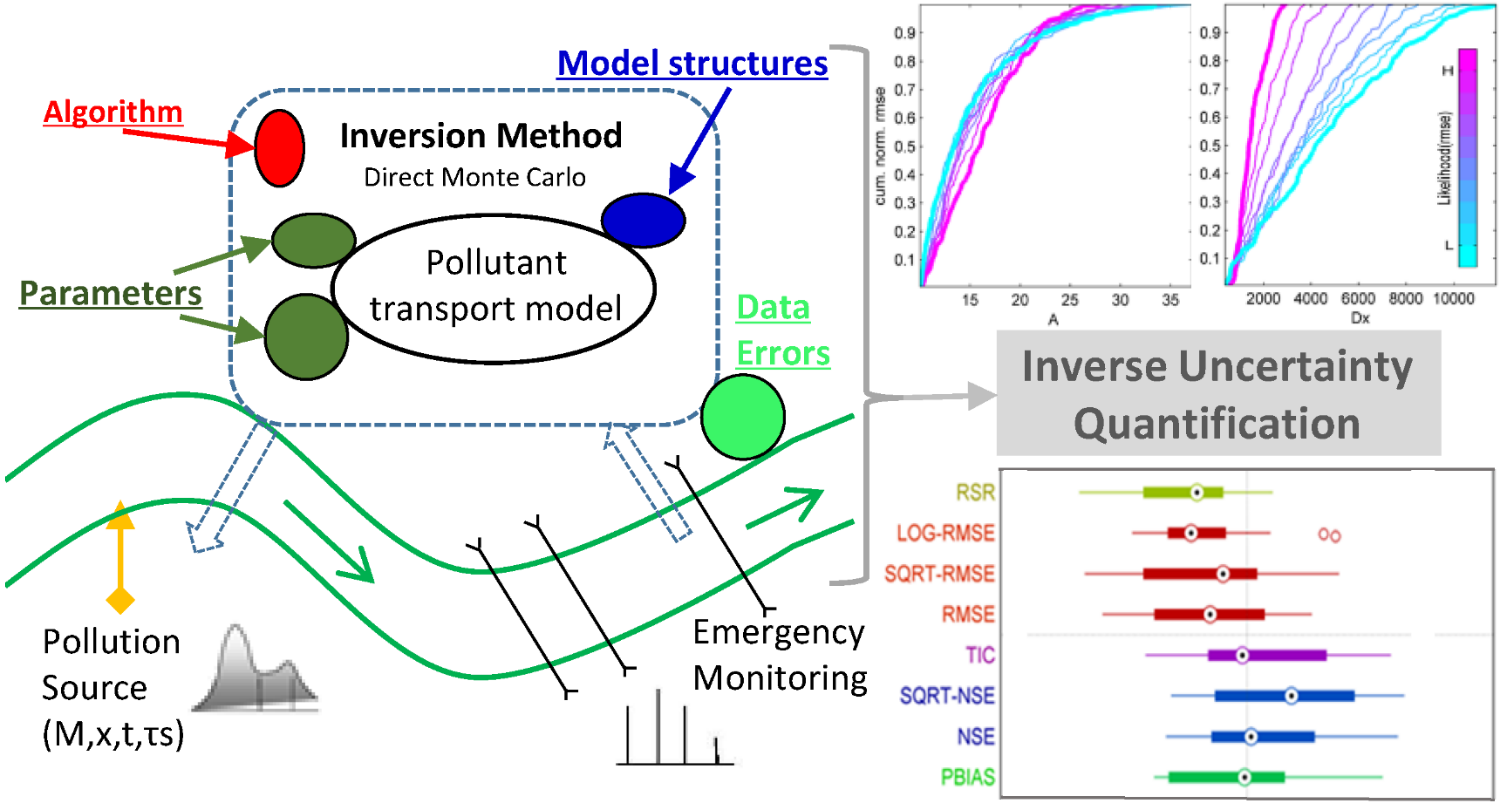
指标	真实值	Mean	SD	Skewness	$P_{0.025}$	$P_{0.5}$	$P_{0.975}$	Bayes 区间*(α=0.05)
似然函数采用均方差误差假定								
M_s(g)	1300	1303	100	-0.062	1081	1309	1484	[1091, 1486]
X_s(m)	-22108	-19813	3424	0.137	-25731	-19947	-12591	[-26345,-13837]
T_s(min)	-215	-219	42.7	0.135	-293	-220	-129	[-300, -145]
σ^2($\mu g^2/L^2$)		1.68	0.389	0.909	1.07	1.63	2.58	[1.00, 2.45]
似然函数采用异方差误差假定								
M_s(g)	1300	1366	172	0.462	1066	1351	1737	[1050,1714]
X_s(m)	-22108	-23969	1966	1.284	-26222	-24482	-19046	[-26456,-19999]
T_s(min)	-215	-271	24.5	1.283	-299	-278	-210	[-300,-222]
σ^2($\mu g^2/L^2$)		0.375	0.096	1.303	0.23	0.36	0.63	[0.216,0.565]

$$p(s|C,I) \propto p(s|I)\,l(C|s,I)$$

$$\propto I(s \in \mathrm{Real})\exp\left[-\frac{1}{2}\sum_i \frac{(C_j - R_j(s))^2}{\sigma_{\mathrm{meas}}^2 + \sigma_{\mathrm{model}}^2}\right]$$

Jiping Jiang* et al, *China Environ. Sci.* 2018.

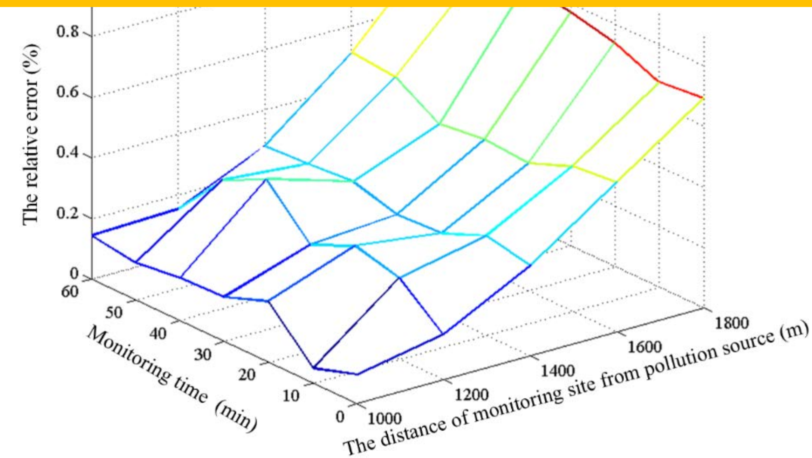
Source Inverse Uncertainty Quantification

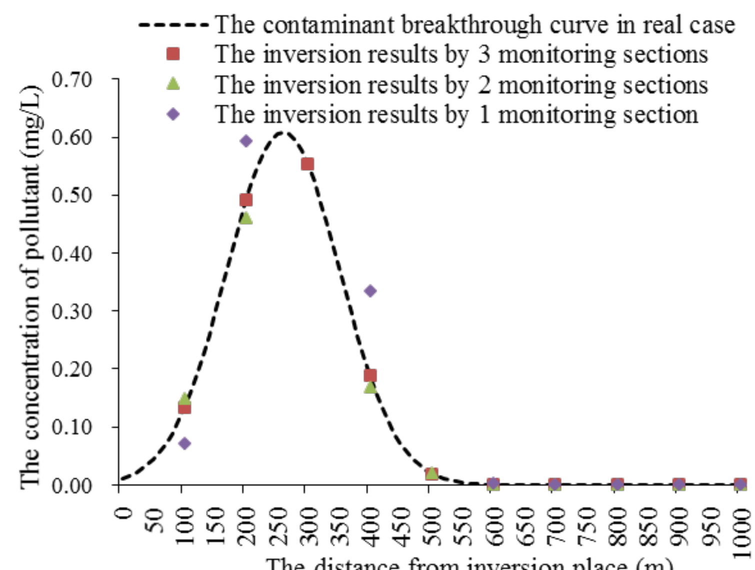


Jiping Jiang*, et al. Frontiers ESE. 2018.

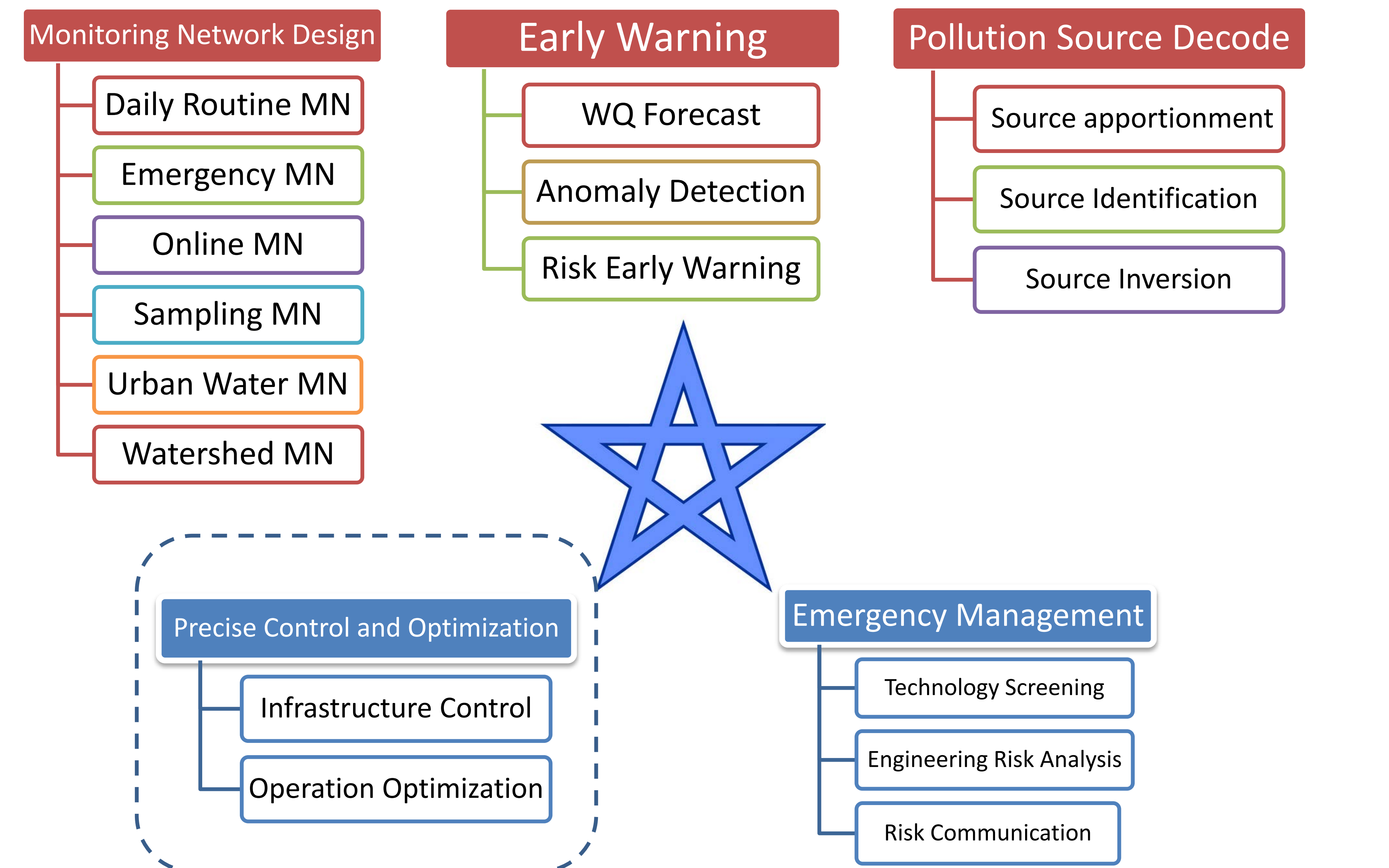
Monitoring Section Design for Emergency Source Inversion

Inversion methods	The location of monitoring sections	Sampling time interval	Notes
Correlation coefficient	All sections be set in same distance interval	All sections be sampled in the same time	Compared with other method, the distribution of monitoring sections more concentrated
Direct optimization	The first monitoring section should be as close as possible to the pollution source	Increase the amount of sampling and monitoring sections as the increasing of assumed sources	This method will be useful only in the condition that the characteristics of pollution sources is known
Backward probability density	The monitoring sections should be set in the location that can capture the full information of pollution plume	--	The number of monitoring sections is related to the release types
Bayesian inference	The distance interval of monitoring sections should be approximate to the value of	The sampling time interval of monitoring sections is the smaller value between and degradation characteristics time	The location and time interval of monitoring sections be set according to the Shannon sampling theorem





Jiang et al. 2018. Environ. Monit. & Assess. in prepare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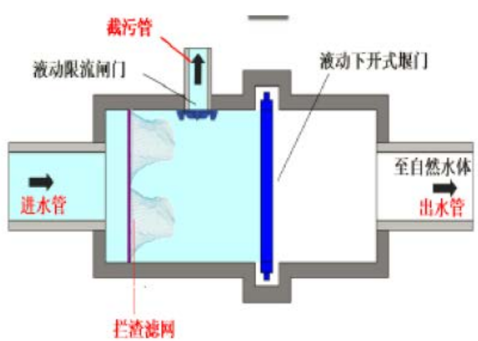
Risk Early Warning
Pollution Source Decode
Source apportionment
Source Identification
Source Inversion
Precise Control and Optimization
Infrastructure Control
Operation Optimization
Emergency Management
Technology Screening
Engineering Risk Analysis
Risk Communication

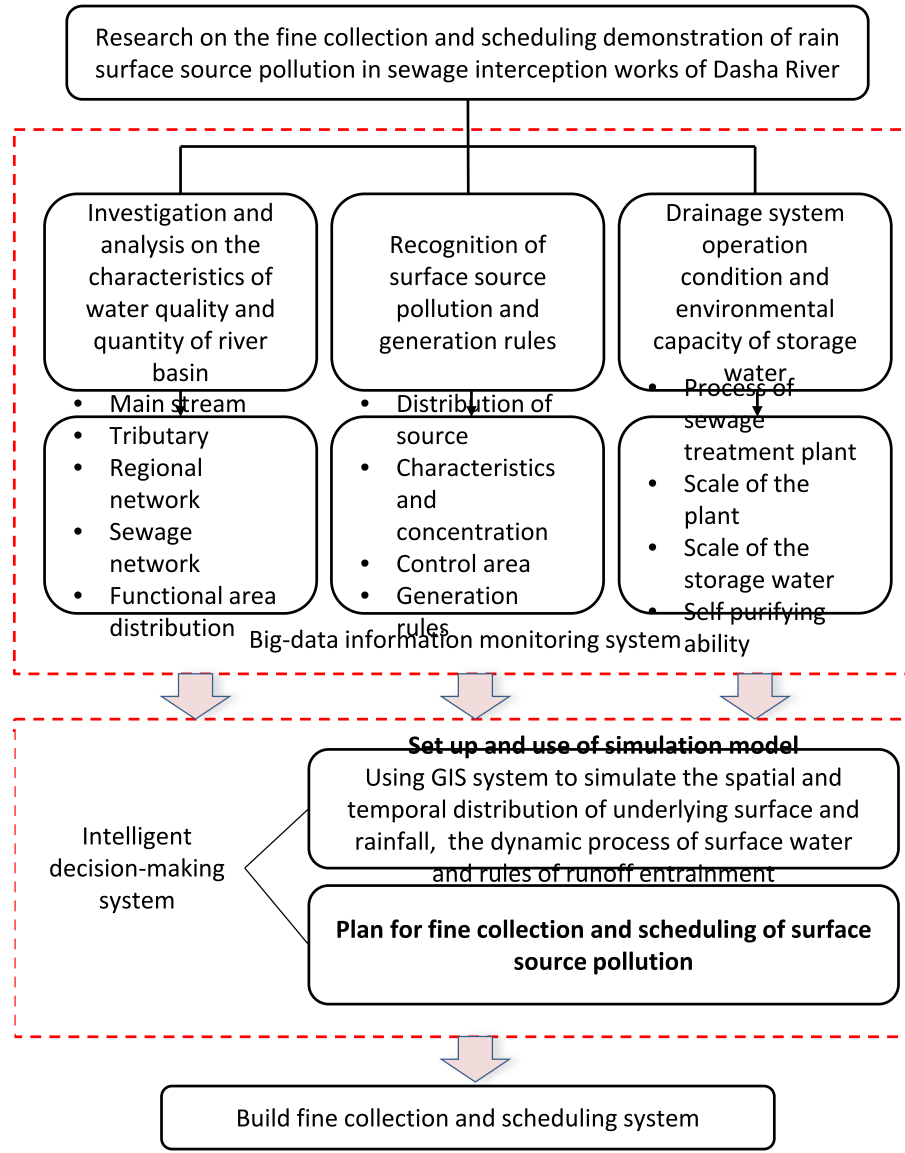
Fine collection and scheduling of surface non-point source pollution

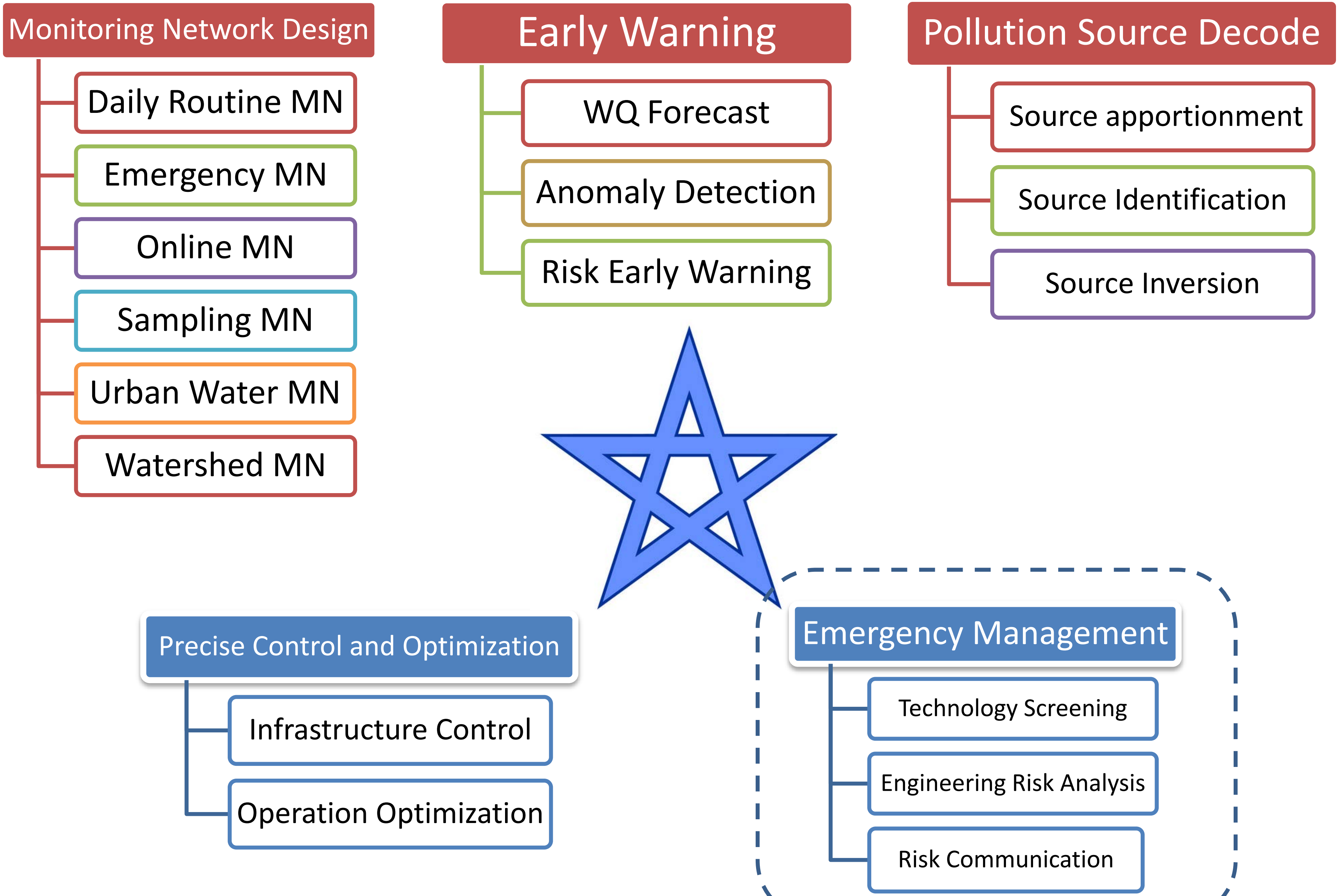
Set model for typical water control engineering measures (such as dosing system, dredging system, water oxygen enrichment system, source control and sewage interception system, rainwater treatment system, etc.), then parameterize and model the physical process.

The objective function is built based on the operational efficiency and the coupled water quality environment model to optimize the operation.



Source： Zijun Dong’s proposal

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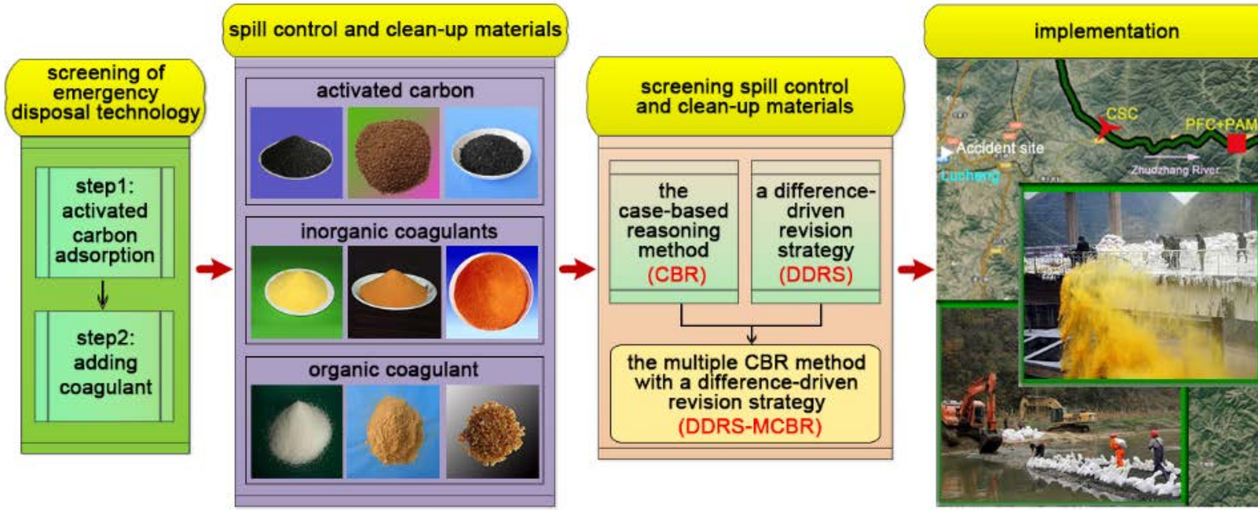
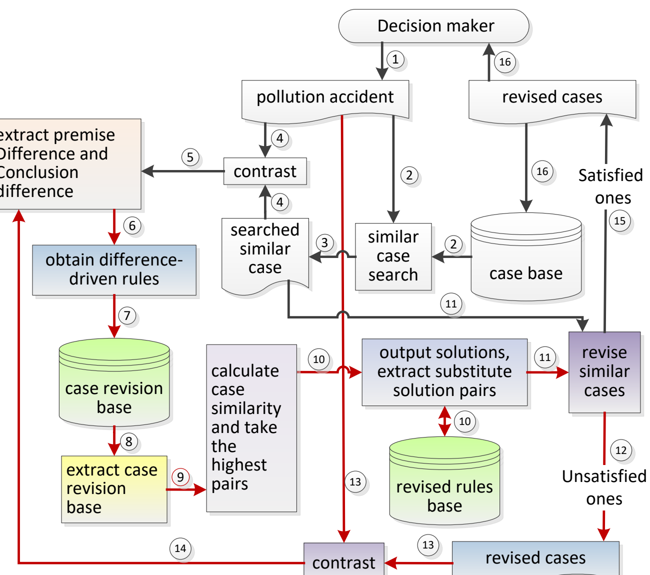
Anomaly Detection
Risk Early Warning
Pollution Source Decode
Source apportionment
Source Identification
Source Inversion
Precise Control and Optimization
Infrastructure Control
Operation Optimization
Emergency Management
Technology Screening
Engineering Risk Analysis
Risk Communication

Screening of pollution control technology and materials

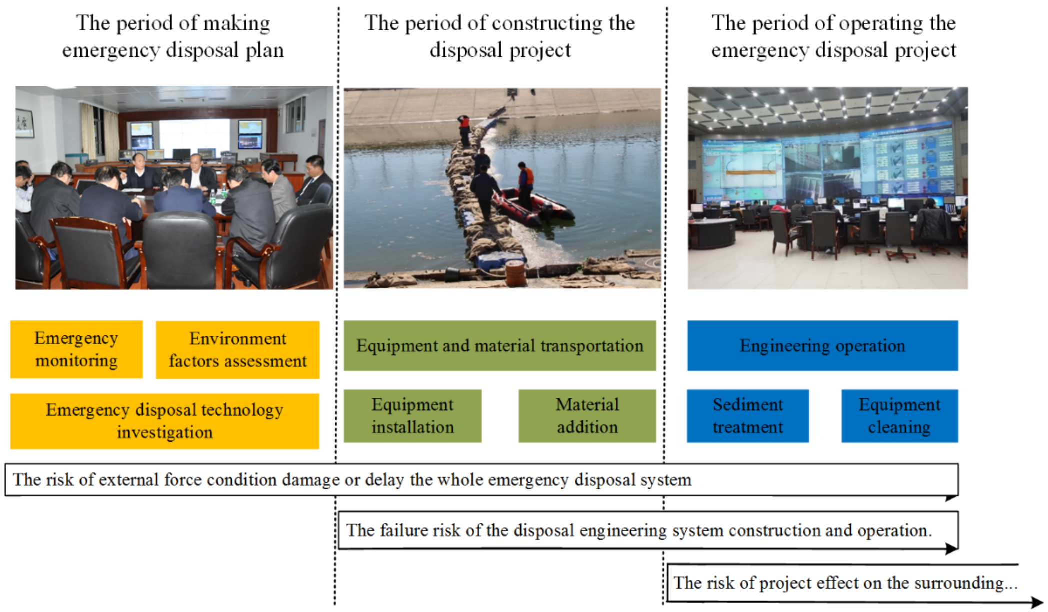
Screening of pollution control an
clean-up materials for river
chemical spills using the multiple
case-based reasoning method
with a difference-driven revision
strategy

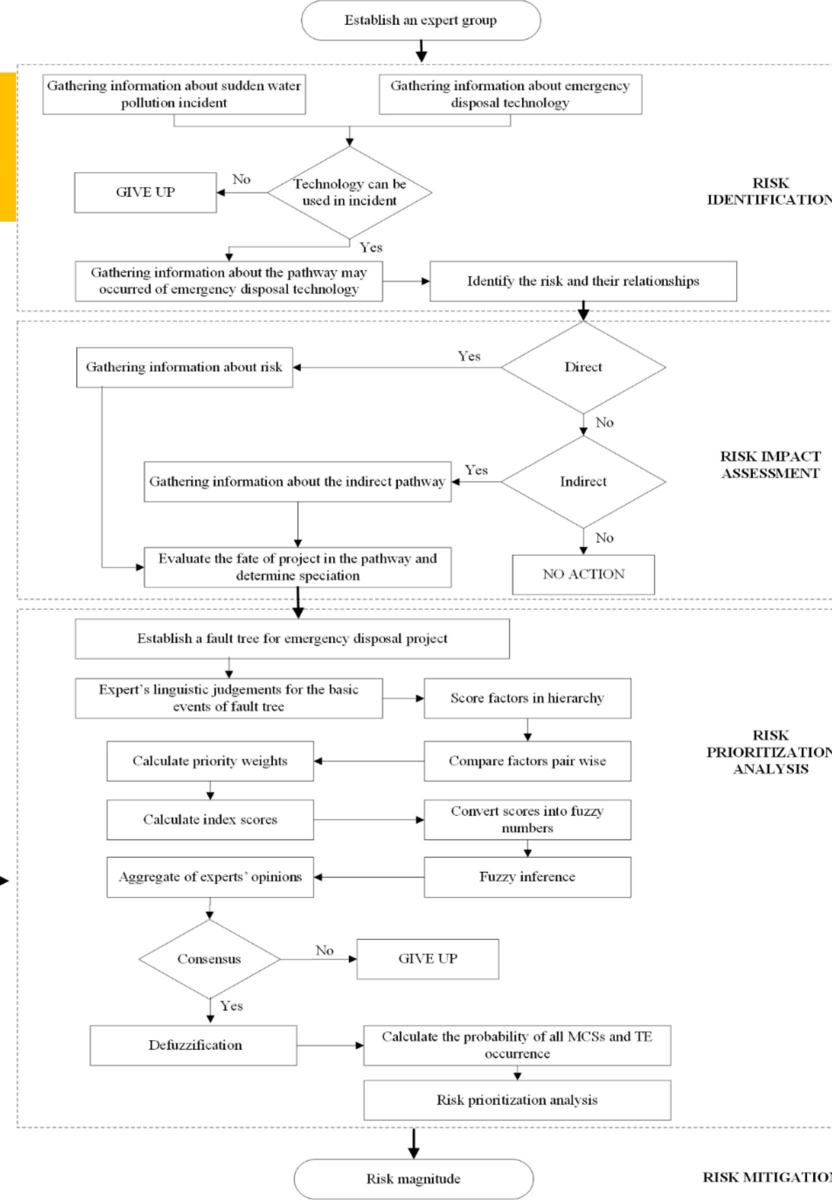




Rentao Liu, Jiping Jiang*, et al. 2016. Environ.Sci.Pollut.Res.
Rentao Liu, Jiping Jiang*, et al. 2017. Acta Scientiae Circumstantiae

Engineering Risk Assessment for Emergency Disposal Projects of Sudden Water Pollution





Binshi, Jiping Jiang*, et al. 2016.
Environ.Sci.Pollut. Res.

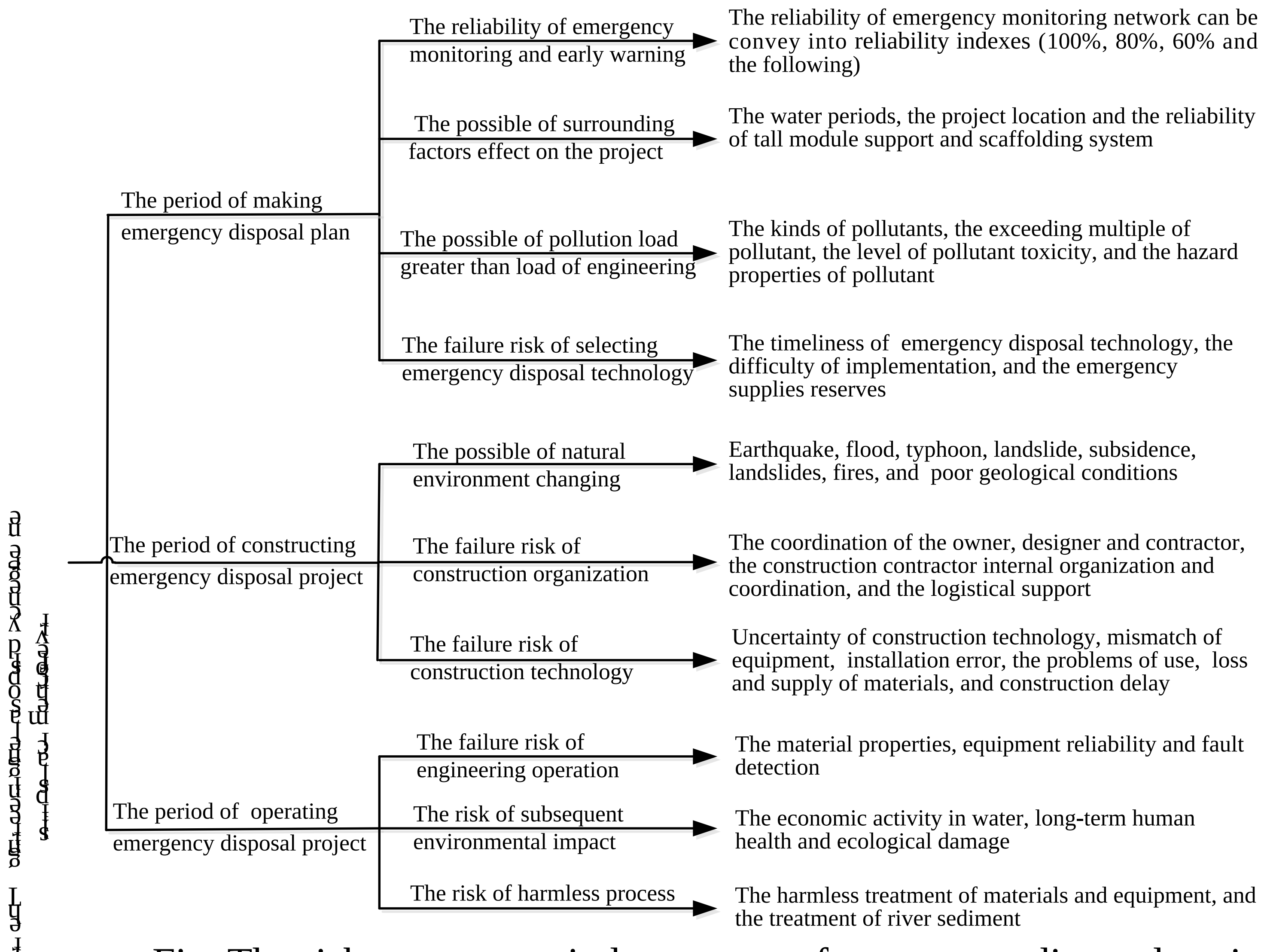
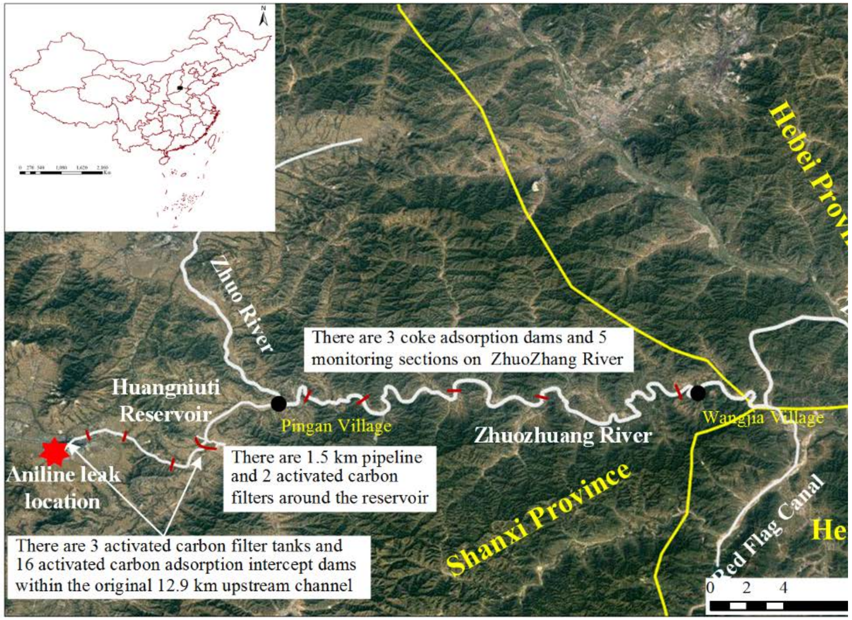


Fig. The risk assessment index system of emergency disposal projects



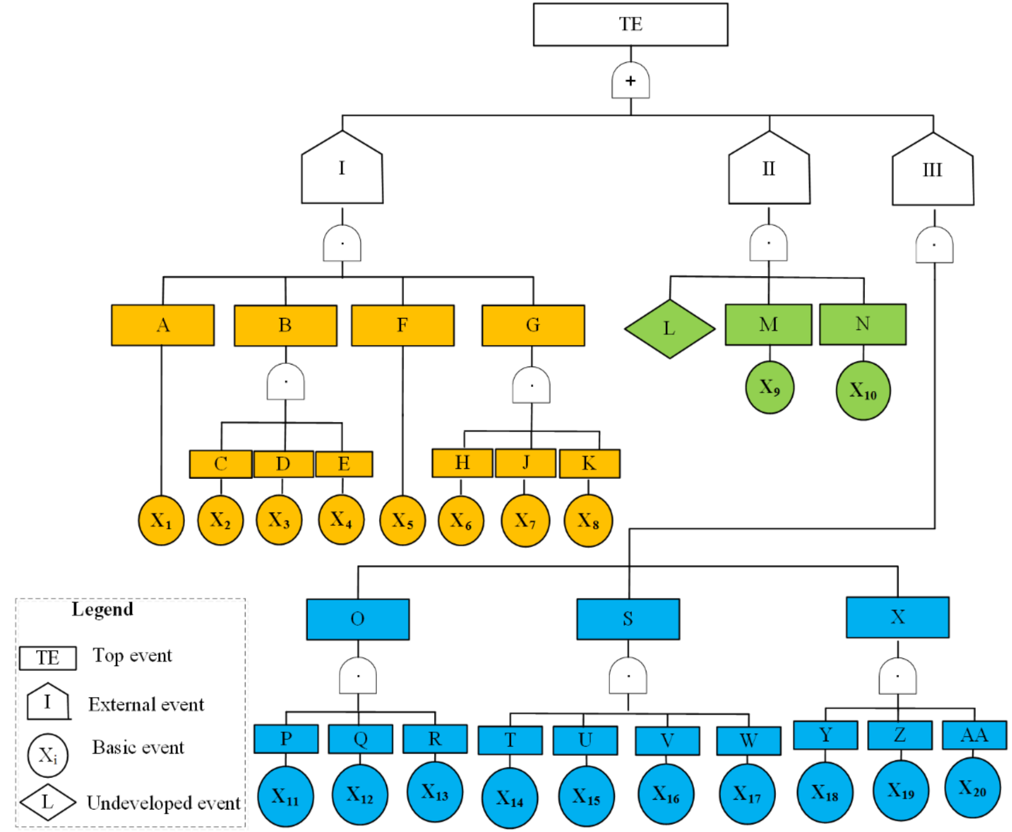
The fault tree analysis

↓

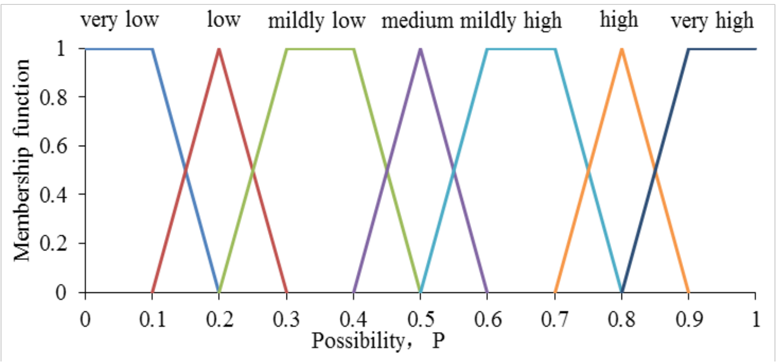
Fuzzy assessment of expert judgment

↓

Order of importance and probability



TE-Top event; I-the period of making the emergency disposal plan; II-the period of constructing emergency disposal project; III-the period of operating emergency disposal project; A-emergency monitoring and early waring; B-surrounding factors; C-water period; D-the location of project; E-tall module support and scaffolding system; F-pollution load; G-emergency disposal technology; H-the timeliness of emergency disposal technology; J-the difficulty of implementation; K-emergency supplies reserves; L-natural environment changing; M-the constructing organization; N-the construction technology; O- the operation of project; P----the material properties; Q-the equipment reliability; R-the fault detection; S-subsequent environmental impact; T-water function damage; U-the affected to the contact people; V-the transboundary pollution; W-the secondary pollution; X-the harmless process of emergency waste; Y-the treatment of adsorbent; Z-the treatment of river sediment; AA-the clean of equipment used in project.



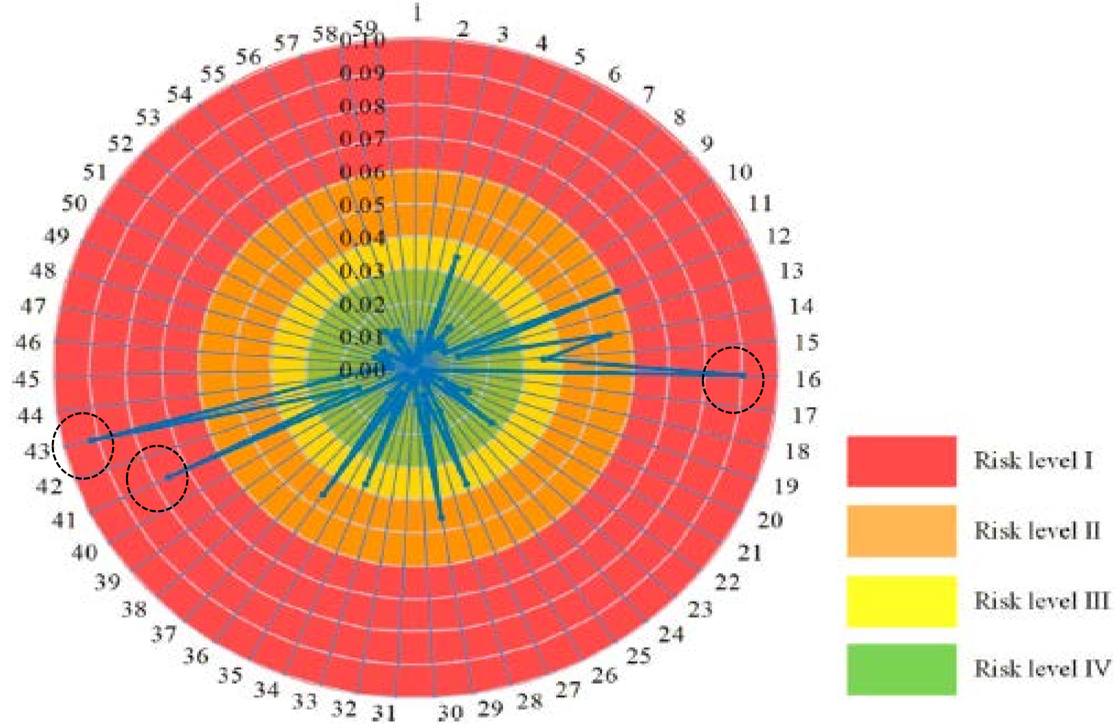


Fig. The contribution of MCSs to TE probability and their risk sensitive analysis

the decision makers can select effective preventive measures using limited emergency resources

监测网络设计

- □ 常规监测网络
- □ 应急监测网络
- □ 在线监测网络
- □ 采样断面监测网络
- □ 城市水体
- □ 流域

预警

- □ 水质预测
- □ 异常预报/检测
- □ 风险预警

溯源

- □ 统计/专家系统源解析
- □ 定性化学溯源
- □ 定量反演

优化控制

- □ 工程设施精细控制
- □ 工程设施优化运行

应急管理

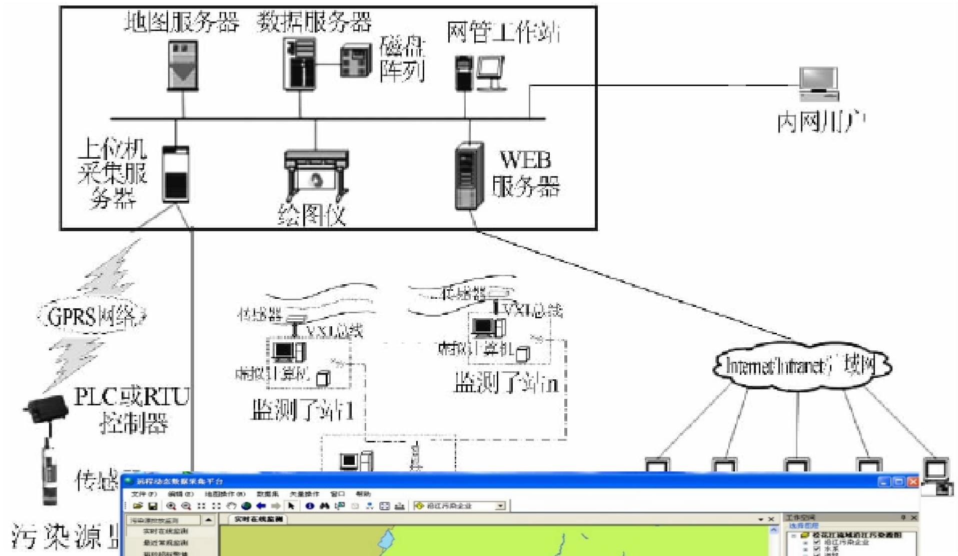
- □ 应急技术筛选
- □ 工程风险分析
- □ 风险交流

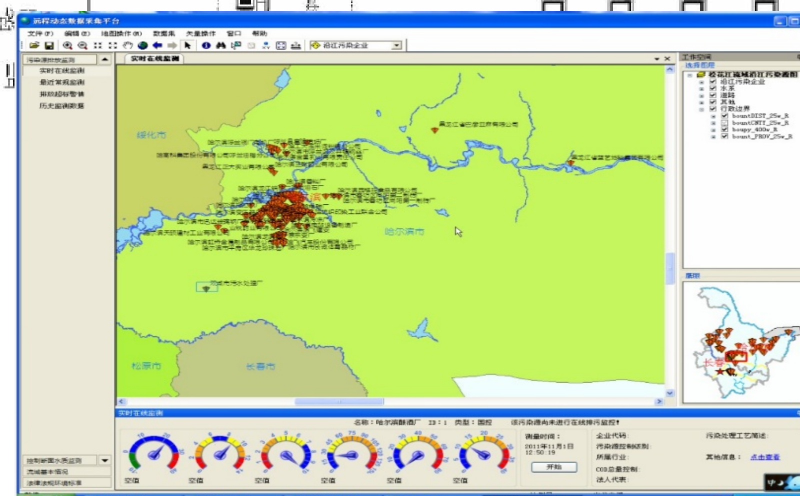
05 Demonstration Projects

05 Demonstration projects

- Songhua River
- South-to-North Water Division Project
- Maozhou River, Houhai River in Shenzhen

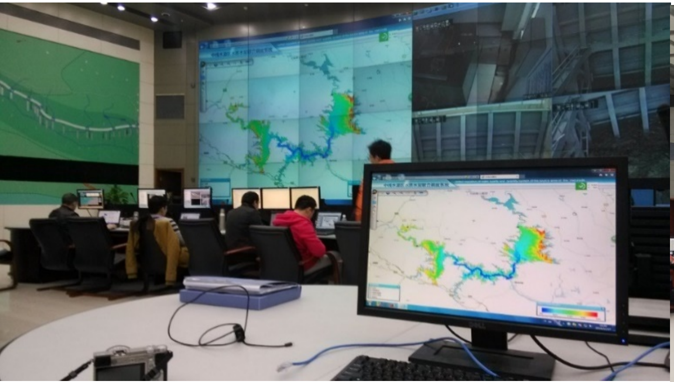
EWERS for Songhua River Point Pollution control





EWERS for South-to-North Water division projects

Water Source Area of the Middle Route



Main Chanel of Middle route

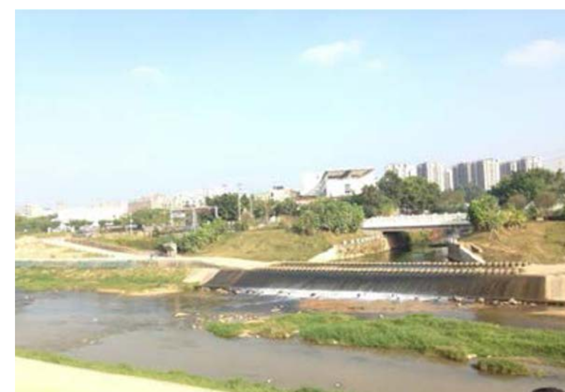
East Route

光明段-典型箱涵入河口

光明段-茅洲河支流-光明污水厂排口入河口

光明段-光明污水厂排口-进入茅洲河支流

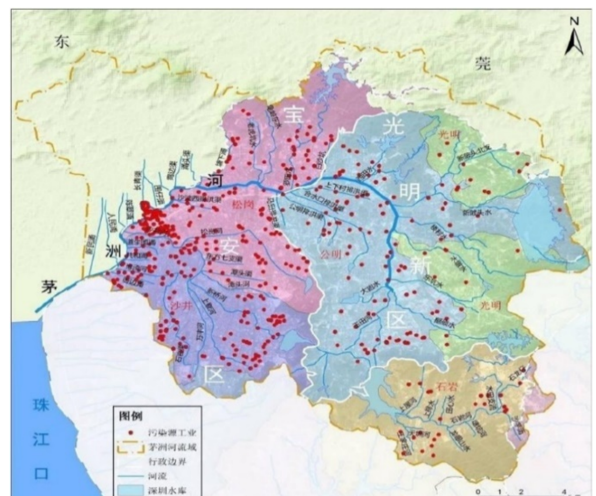
界河段典型箱涵排口



Maozhou River： Clean water, close to CBD

茅洲河现状

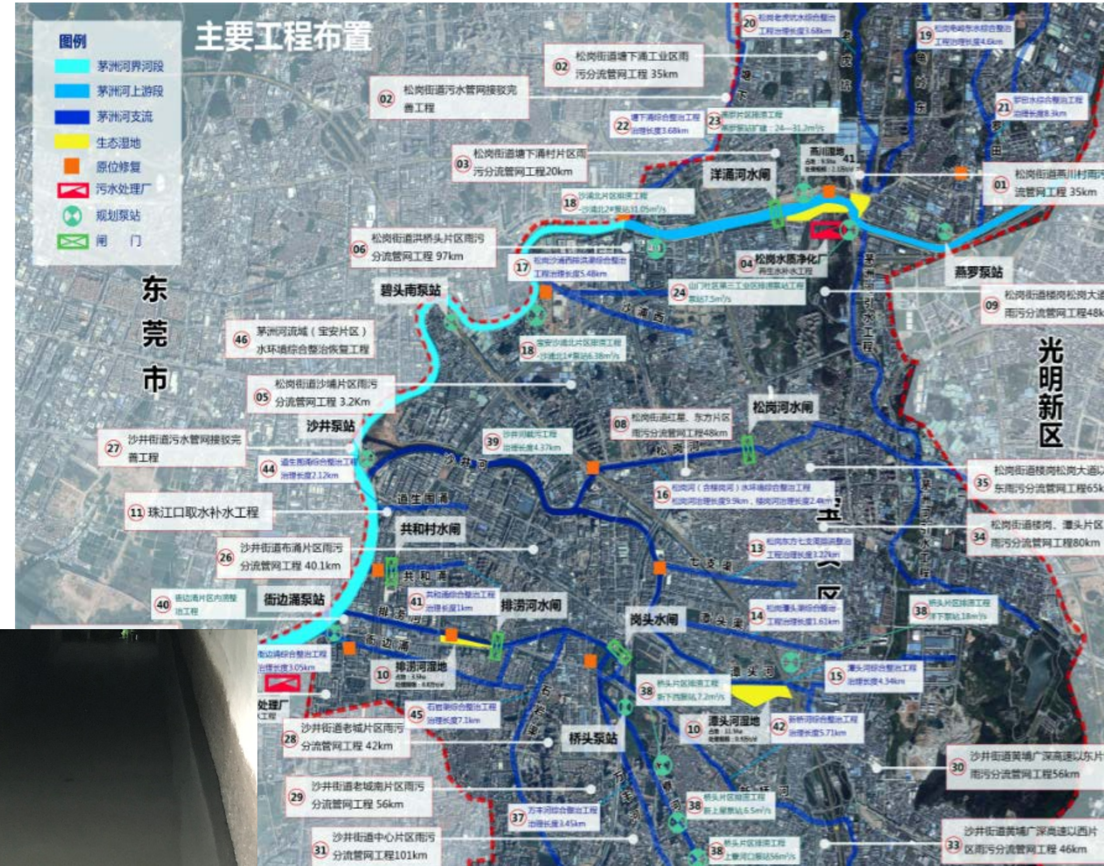
- 工业废水污染和生活污水污染问题突出
- 地势低洼，河道断面狭窄，防洪能力低；
- 支流多，排水口数量大，分布复杂；
- 企业偷排乱排现象屡禁不止，人工走访为主的环保督查工作效率低下，环境监管面临巨大挑战



industrial pollution sources， 2015

Drainage Outlets monitoring and management

Maozhou River, Shenzhen



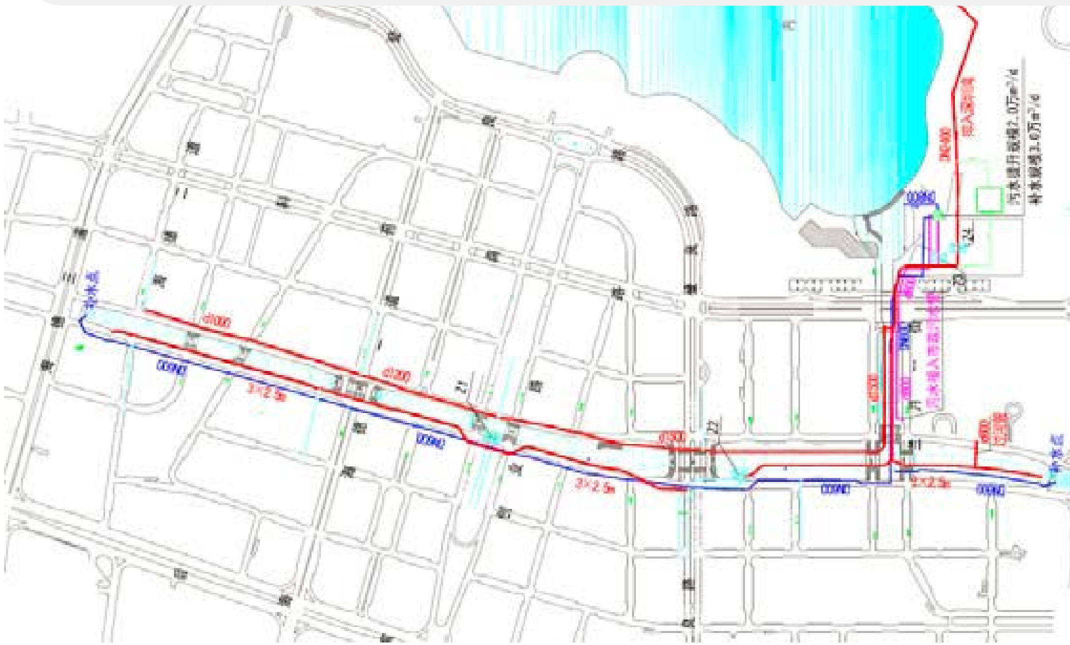
深圳市科创委应用示范项目

Houhai River： Clean water, close to CBD

后海河位于南山区后海中心路，是南山区重要水务设施，该河以东滨路为界分为后海南河与后海北河，全长约4公里，主要功能为排洪和截污，兼顾景观。南河于2011年建成，北河于2013年建成。

后海河段作为特区内改造完成的典型河段，黑臭治理完成后的运维监管有着重要意义。

南山区环境保护和水务局对后海河后续的改善水质措施强调工程措施和强化运维管理措施两大类



Houhai River Drainage System

Concluding Remarks

In order to set local and advance environment model based on the environmental science knowledge, we need support of basic **facilities of Information & Communication Technology**（ICT）, **integrate with other enabling technology**, then establish the operation platform.

Now we are living in **the era of big data**, it is more and more important to set up **intelligent and precise** environmental management. The data-driven model come back into fashion, integrated with other technologies, can provide technical support in water quality guarantee, city water environment management and surface or dot source pollution control.

On the basis of the research above, comprehensive operation and maintenance of enterprise needs, management processes, stakeholder information exchange, develop corresponding system modules to integrate the intelligent management and control system platform of water body comprehensive operation and maintenance platform, including functions like public APP, government decision, etc., for daily optimal operation scheduling and emergency decision support for operation and maintenance of water bodies。

Environmental Science & Technology

Comment

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Disruptive Environmental Research

Speculation about technologies that may never succeed will not solve the world's environmental problems. Nonetheless, we need to create more space for risk-taking and disruptive innovation if we hope to attract the brightest people, obtain the necessary funding and develop the fresh ideas needed to succeed in the coming decades. After all, rapid advances in biotechnology, materials science, and computing mean that ideas that once seemed like science fiction are becoming reality in the blink of a bionic eye.

Disruptive Innovation on Water-Wise Cities or Future Water City ?

David L. Sedlak,* Editor-in-Chief


Command-Control- Communication-Computer-Intelligence-Surveillance-Reconnaissance

Thanks