Groundwater Monitoring Network in Taiwan and it's Meaning to the Earthquake Induced Hydrological Changes

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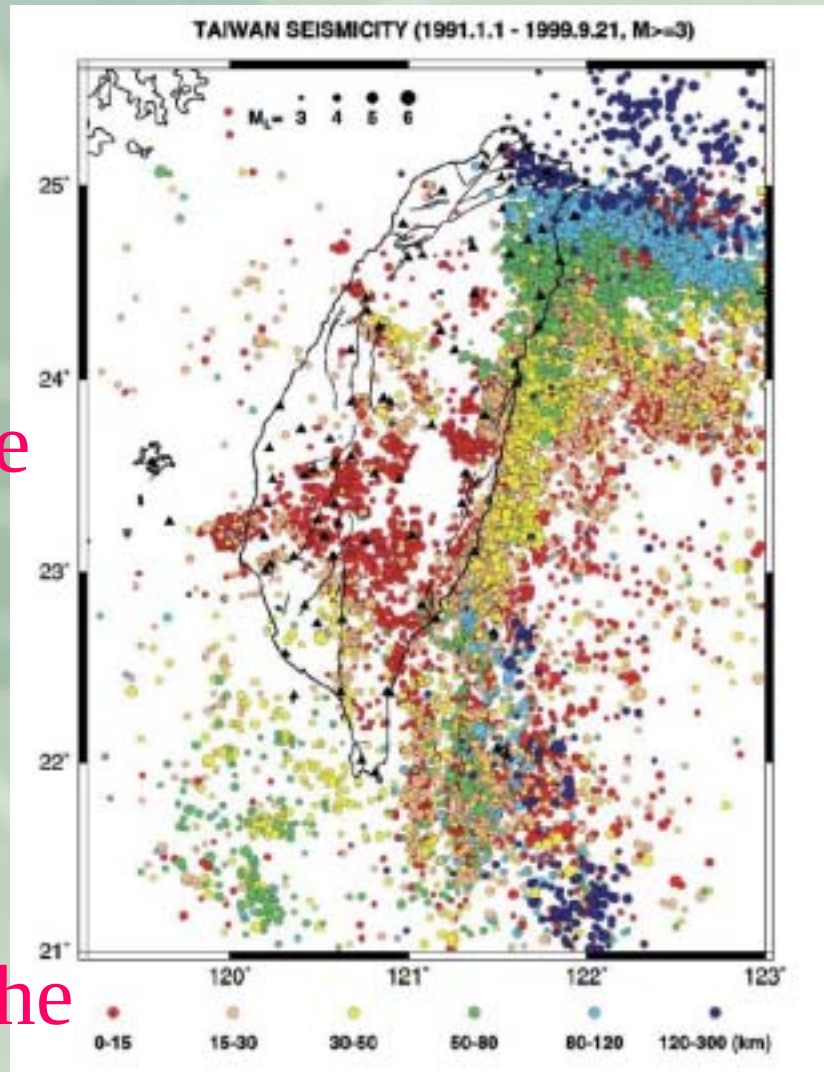
Content

- Introduction of the Groundwater Monitoring Network in Taiwan
- Update information of the study of groundwater anomalies with the earthquake
- Observation results and the future plan



I. Introduction of the Groundwater Monitoring Network in Taiwan

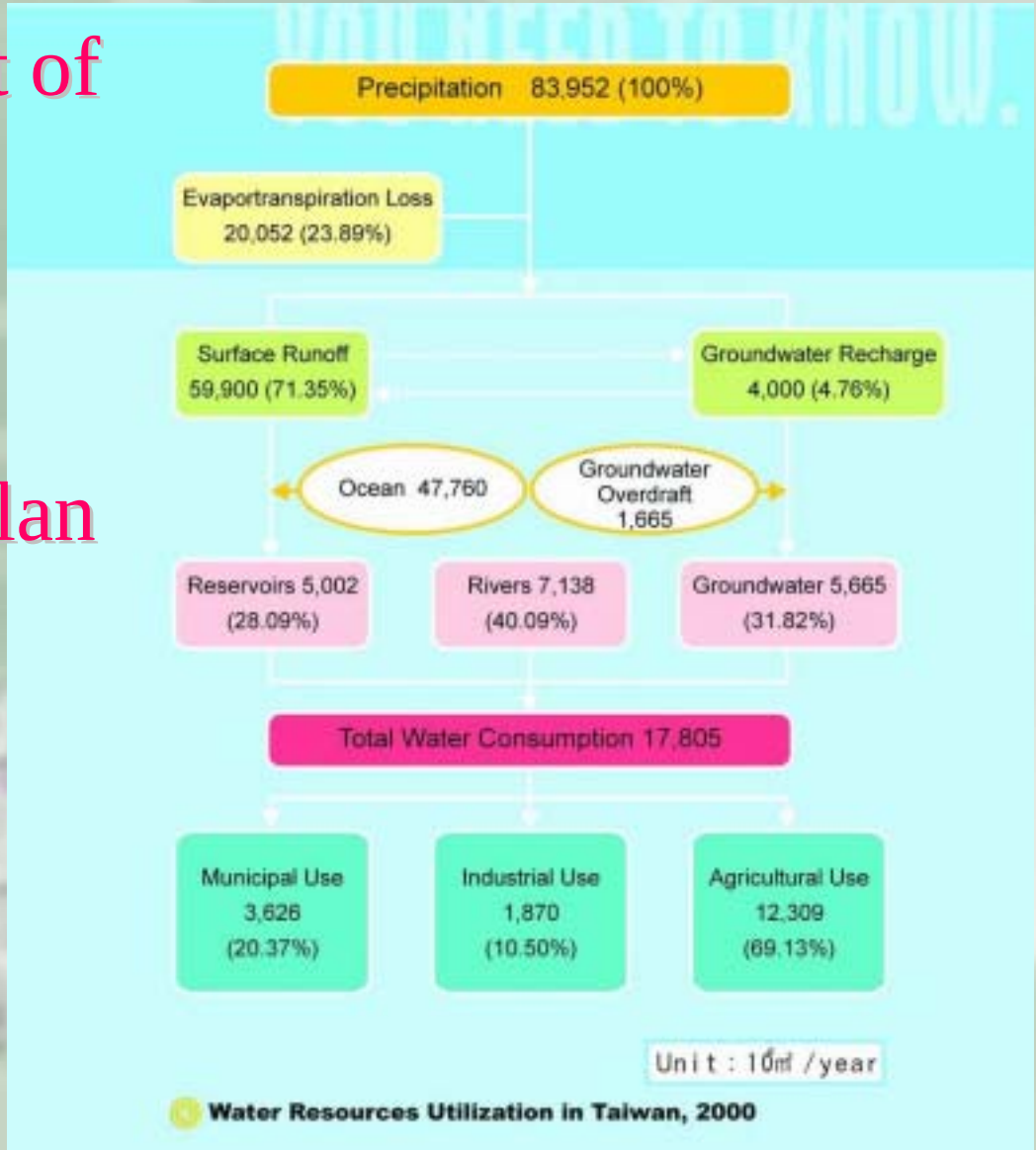



1.1 Problem Background (1/2)

- Topography of the Taiwan island
- Weather condition
- Population

1.1 Problem Background (2/2)

- The management of the groundwater resources
- The task of the plan



1.2 Goals of the Plan

Direct Goals

1. To establish the regional groundwater monitoring network system in Taiwan, to collect the long-term integrated information related to the hydrogeology, groundwater hydrology, and groundwater quality.

2. To conduct the related investigations on groundwater hydrology and hydrogeology, to fully understand the characteristics of each groundwater divisions, and to distinguish the geological and hydrological systems of each area.

3. To construct a groundwater hydrological information database and the integrated information system (including the decision-making supporting system), to facilitate the utilization and sharing of groundwater related data.

4. To enact and promulgate the principles for groundwater resources utilization and conservation.

Indirect Goals

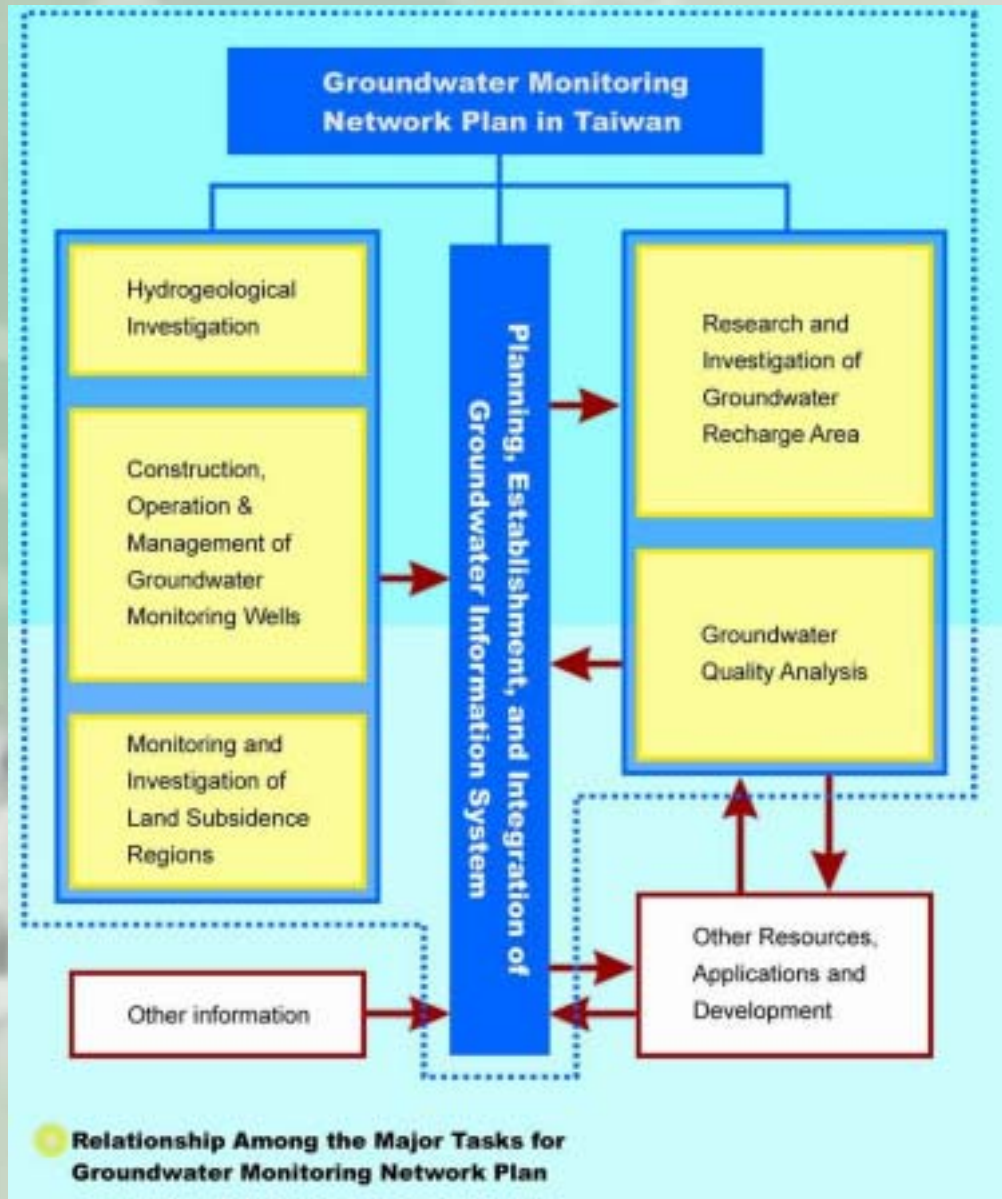
1. To regulate the courses of actions for both of the groundwater resources utilization and conservation in each area.

2. To provide a guideline for groundwater management and land subsidence mitigation plan in each area.

3. To establish the regional conjunctive operation and management projects for surface water and groundwater resources in each area.

1.3 Main Items of the Plan

1. Hydrogeological investigation
2. Construction, operation and management of the monitoring
3. Groundwater information system
4. Investigation of groundwater recharge
5. Monitoring and investigation land subsidence
6. Groundwater quality analysis



Relationship Among the Major Tasks for Groundwater Monitoring Network Plan

1.4 Phases of the Plan (1/4)

First Phase (1992 to 1998) :

1. To construct the groundwater monitoring networks and to conduct the hydrogeological surveys for Choshui River Alluvial Fan (including northern part of Chianan Plain) and Pingtung Plain where the land subsidence problems were severely occurred.

2. To complete the hydrogeological fence diagrams and to evaluate the groundwater resources potential for the aforementioned two areas.

3. To establish the groundwater information systems for the two areas.

4. To regulate the management principles of groundwater resources development and conservation practices for the two areas.

1.4 Phases of the Plan (2/4)

Second Phase (1999 to 2003) :

1. To construct the groundwater monitoring networks and to perform the hydrogeological investigations for the regions: southern part of Chianan Plain, Hsinchu-Miaoli Area, Lanyang Plain, and Penghu Island.

2. To complete the hydrogeological fence diagrams and to evaluate the groundwater resources potentials for the aforementioned four areas.

3. To regulate the management principles of groundwater resources development and conservation practices for the four areas.

4. To establish the groundwater information systems for areas being fully investigated.

5. To establish the groundwater quality database for groundwater monitoring network areas.

1.4 Phases of the Plan (3/4)

Third Phase (2004-2008) :

1. To construct the groundwater monitoring networks and to conduct the hydrogeological studies for Taipei Basin, Taoyuan-Chungli Terrace, Taichung Region, Hualien-Taitung Valley, and Hengchun Plain.

2. To complete the hydrogeological fence diagrams and to evaluate the groundwater resources potentials for the aforementioned five areas.

3. To regulate the management principles of groundwater resources development and conservation practices of the five areas.

4. To integrate the groundwater information systems for the whole country.

5. To continue establishment of the groundwater quality database for the network systems of Taiwan.

1.4 Phases of the Plan (4/4)

第一期 First phase	第二期 Second phase	第三期 Third phase	合計 Total
141 水文地質調查站 hydrogeological survey stations 332 地下水觀測井 groundwater monitoring wells 83 抽水試驗井 pumping test wells	183 水文地質調查站 hydrogeological s urvey stations 362 地下水觀測井 groundwater monitoring wells 71 抽水試驗井 pumping test wells	193 水文地質調查站 hydrogeological survey stations 296 地下水觀測井 groundwater monitoring wells 61 抽水試驗井 pumping test wells	517 水文地質調查站 hydrogeological survey stations 990 地下水觀測井 groundwater monitoring wells 215 抽水試驗井 pumping test wells
預算 44百萬美元 Total budget 44 Millions USD	預算 61百萬美元 Total budget 61 Millions USD	預算 81百萬美元 Total budget 81 Millions USD	預算 186百萬美元 Total budget 186 Millions USD

地下水分區及觀測網計畫分期分區圖

Groundwater Divisions and Monitoring Network Project Phases

1.5 Results of the Plan (1/5)

Taiwan Groundwater Monitoring Network

Sub-Province	Site	Well
Taipei Basin	2	4
Taoyuan Tableland	1	2
Hsinchu-Miaoli Area	16	35
Choshui River Alluvial Fan	70	193
Chiayi-Tainan Area	40	105
Pingtung Plain	55	132
Ilan Plain	20	39
Total	204	510

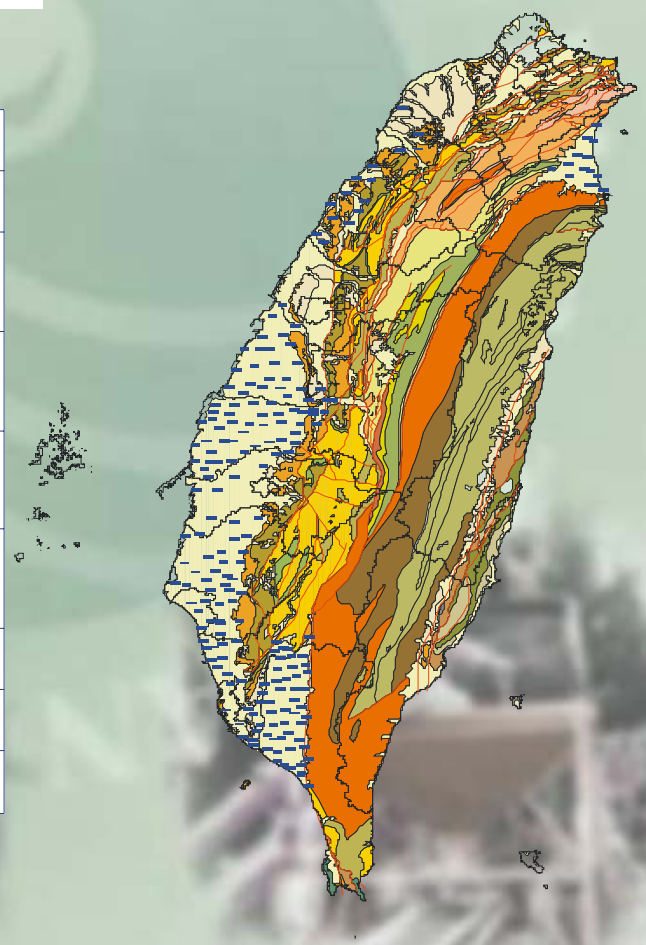
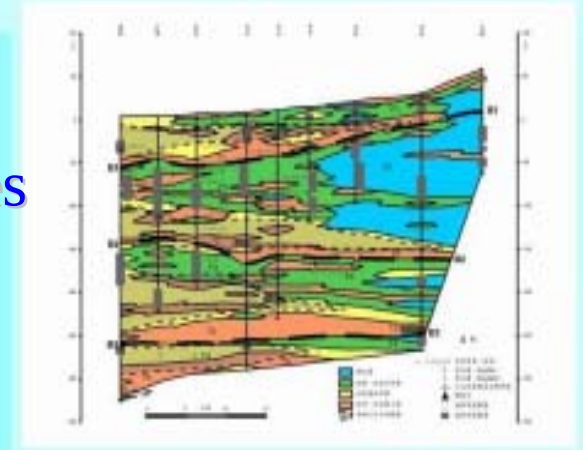


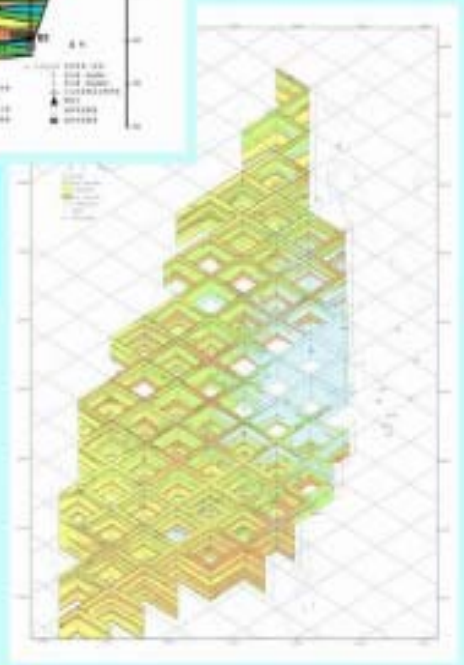
Fig.2- The Taiwan Groundwater Monitoring Network are composed by 510 observation wells distributed in the seven major groundwater division area (Hsu et al., 2000).

1.5 Results of the Plan (2/5)

- Hydrogeological Investigation
  - Drilling geological cores
  - Well logging
  - Geological dating
  - Sedimentary analysis
  - Geochemical analysis

濁水溪沖積扇之地質剖面圖
Geological Cross for Choshui River Alluvial Fan

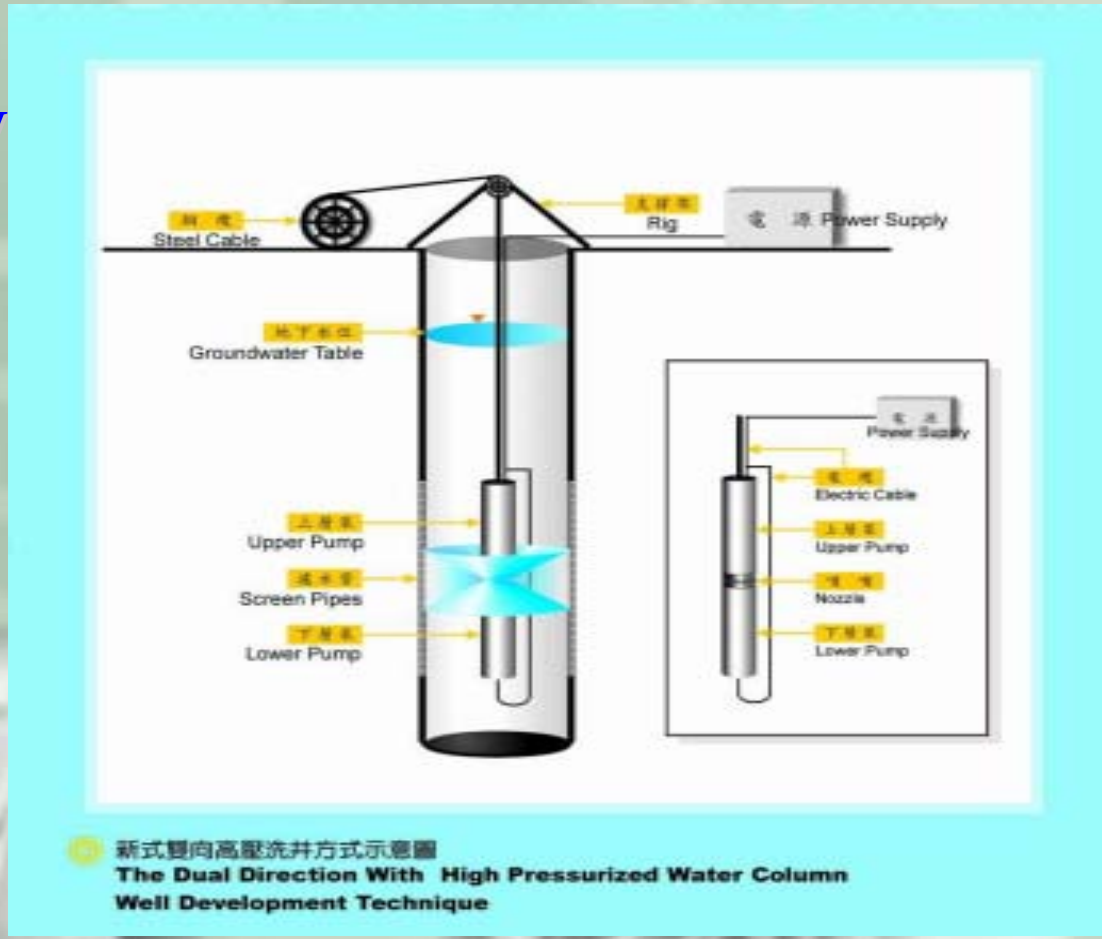




濁水溪沖積扇之水文地質屏狀圖
Geological Fence Diagram of Choshui River Alluvial Fan

1.5 Results of the Plan (3/5)

- Well maintenance
  - Examine well body and screens
  - Water quality analysis
  - Well development technique



1.5 Results of the Plan (4/5)

- Decision Support for Groundwater Resource Management
  - Increase the efficiency and quality
  - Included information retrieval and analysis, trend analysis , operation and management subsystem

資訊系統管理與展示界面
Information System Management and Display Interface

1.5 Results of the Plan (5/5)

- Regional Groundwater Resources Mapping
  - Modulus of groundwater flow
  - Coefficient of groundwater flow
  - Coefficient of river recharge

II. Introduction of the Study of Groundwater Anomalies with the Earthquake

2.1 Background of the Plan(1/4)

Tectonic Setting of Taiwan

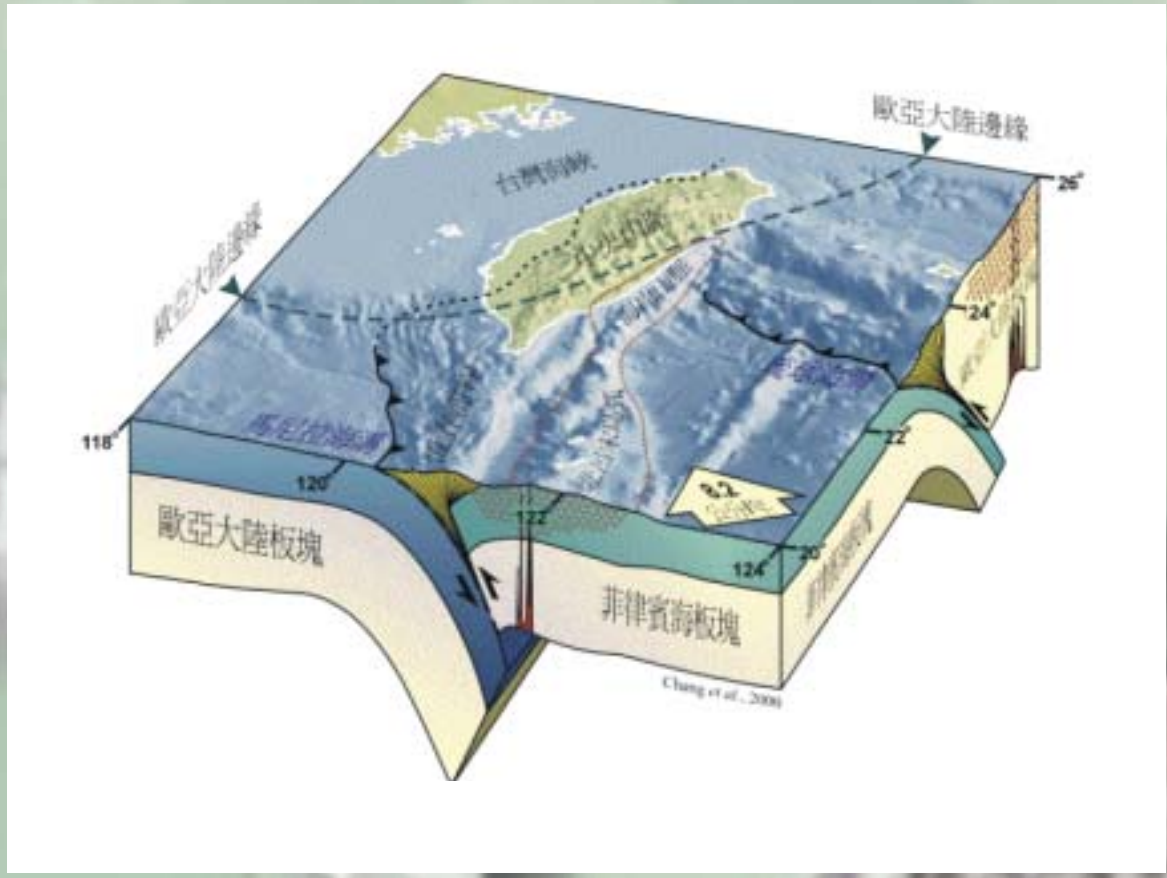
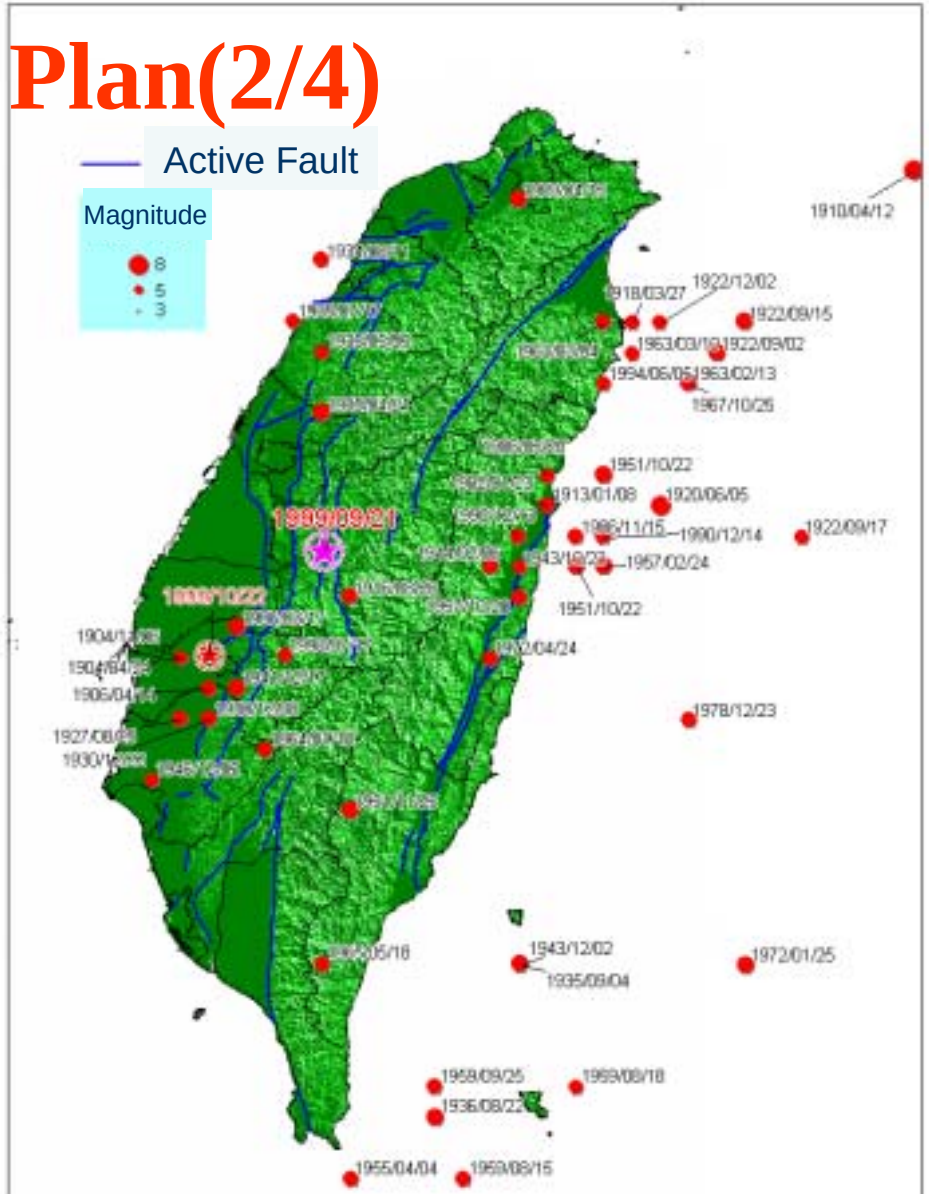


Fig.1-Tectonic framework of Taiwan are conjugate of the Eurasian plate and Philippine Sea plate (Cheng et al., 2000).

2.1 Background of the Plan(2/4)

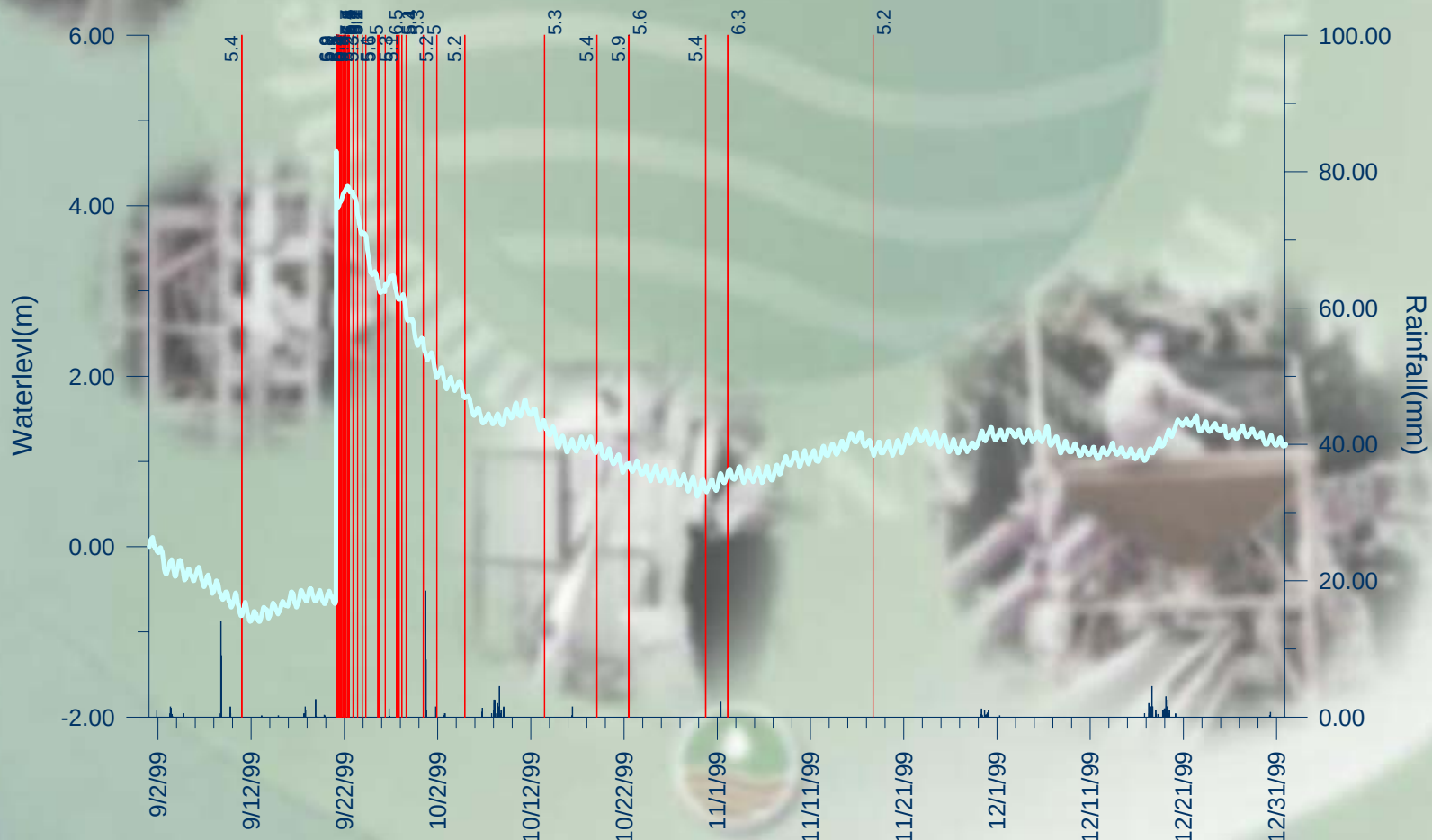
- Spatial distribution of disastrous earthquake
  - Western foothill area
  - Ilan offshore area
  - Hulien offshore area
  - Longitudinal Valley
  - Liutao-Lanyu island



Disastrous earthquake distribution during 1900-1999

2.1 Background of the Plan(3/4)

- Coseismic Groundwater Level Changes in 1999 Chi-Chi Earthquake



2.1 Background of the Plan(4/4)

Coseismic Water Level Changes Record

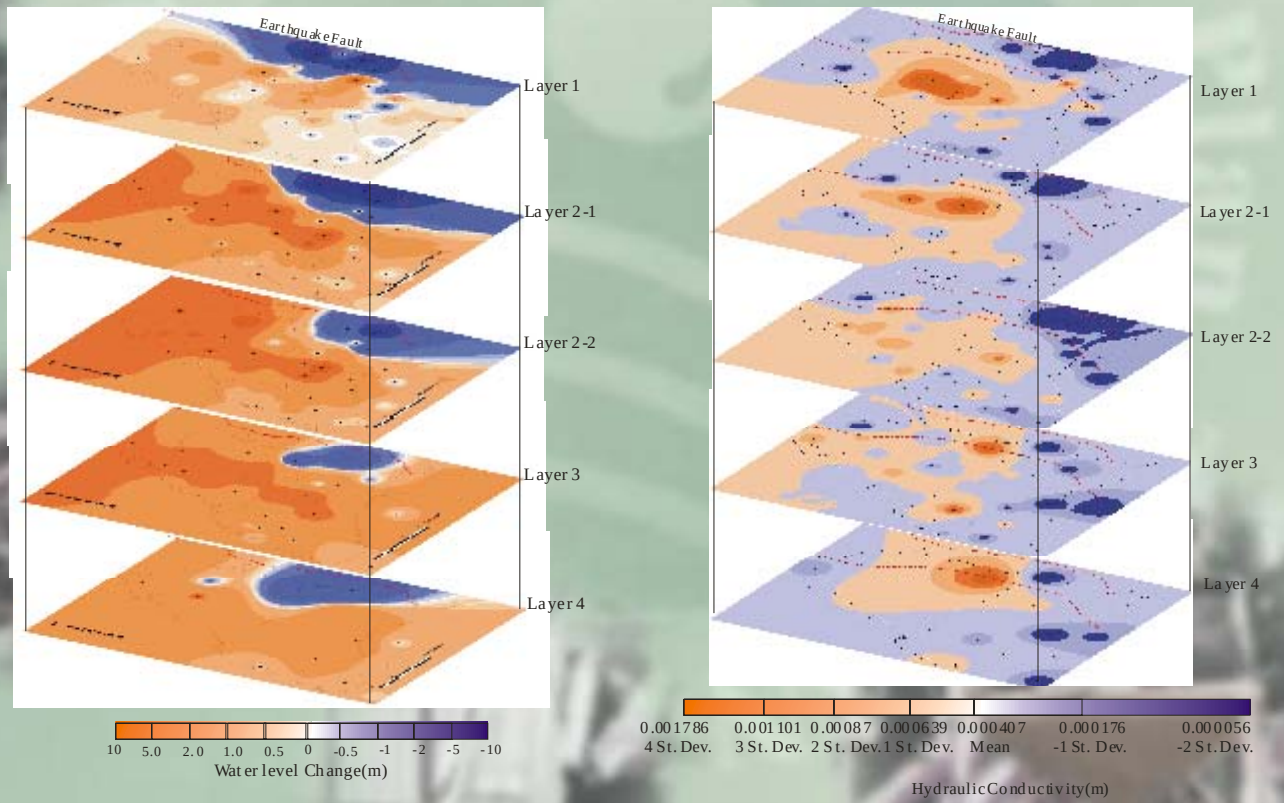


Fig4-Spatial distribution of the (a) coseismic water level changes, (b)Hydraulic conductivity, offers the detail information of coupling processes between the seismic event and the aquifer properties.

2.2 Main Items of the Study

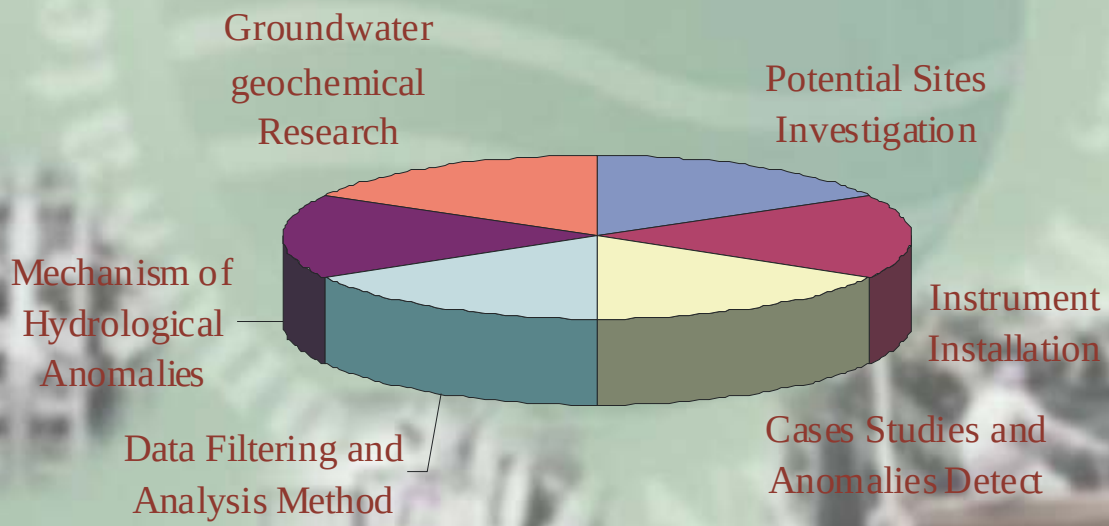


Fig.11-The research items of the study for the earthquake related groundwater changes..

2.2.1 Potential Sites Investigation

Area	Class I	Class II	Class III	Class IV	Class V
濁水溪沖積扇	2	8	12	44	100
嘉南平原區	5	7	22	18	53
宜蘭平原區	2	3	1	12	7
竹苗地區	3	2	4	12	9
桃園中壢台北	-	2	9	10	6
屏東平原	-	1	24	48	60

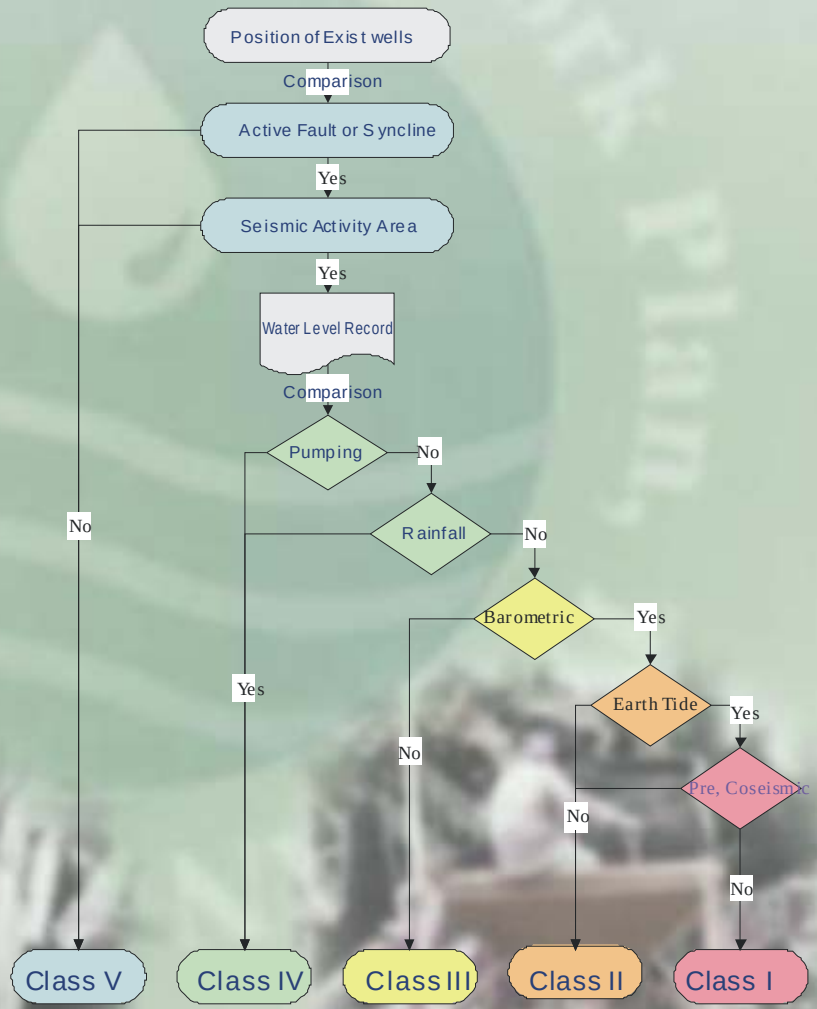


Fig.6-Standard choosing procedures of sensitive wells. The existing wells were divided into different classes by the criteria. Only Class I and II been chosen for the potential observation wells.

2.2.2 Establish of Observation Network

Fig.7-The plan of the groundwater observation network and seismic activity zone of Taiwan through the period of 2001~2004.

2.2.3 Instrument Installation (1/2)

Groundwater Observation Station

Front Side

Instruments Setting

Rear Side

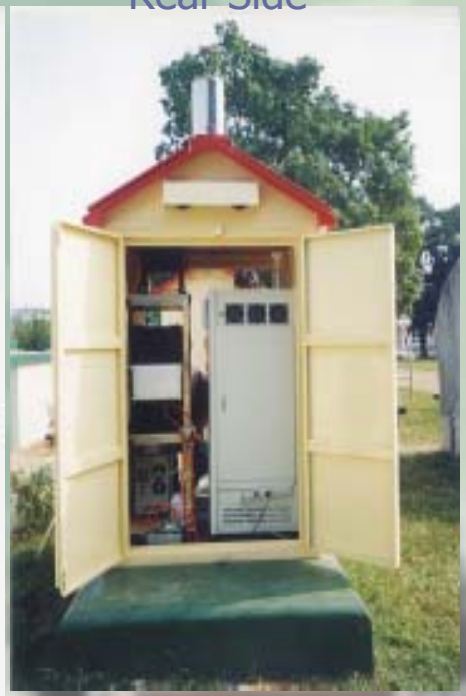


Fig.5-The appearance and instrument setup of the observation station. Observation includes groundwater level, water temperature, radon concentration and background information (air temperature, atmospheric pressure, and rainfall) record in 2 minutes sampling interval.

2.2.3 Instrument Installation (2/2)

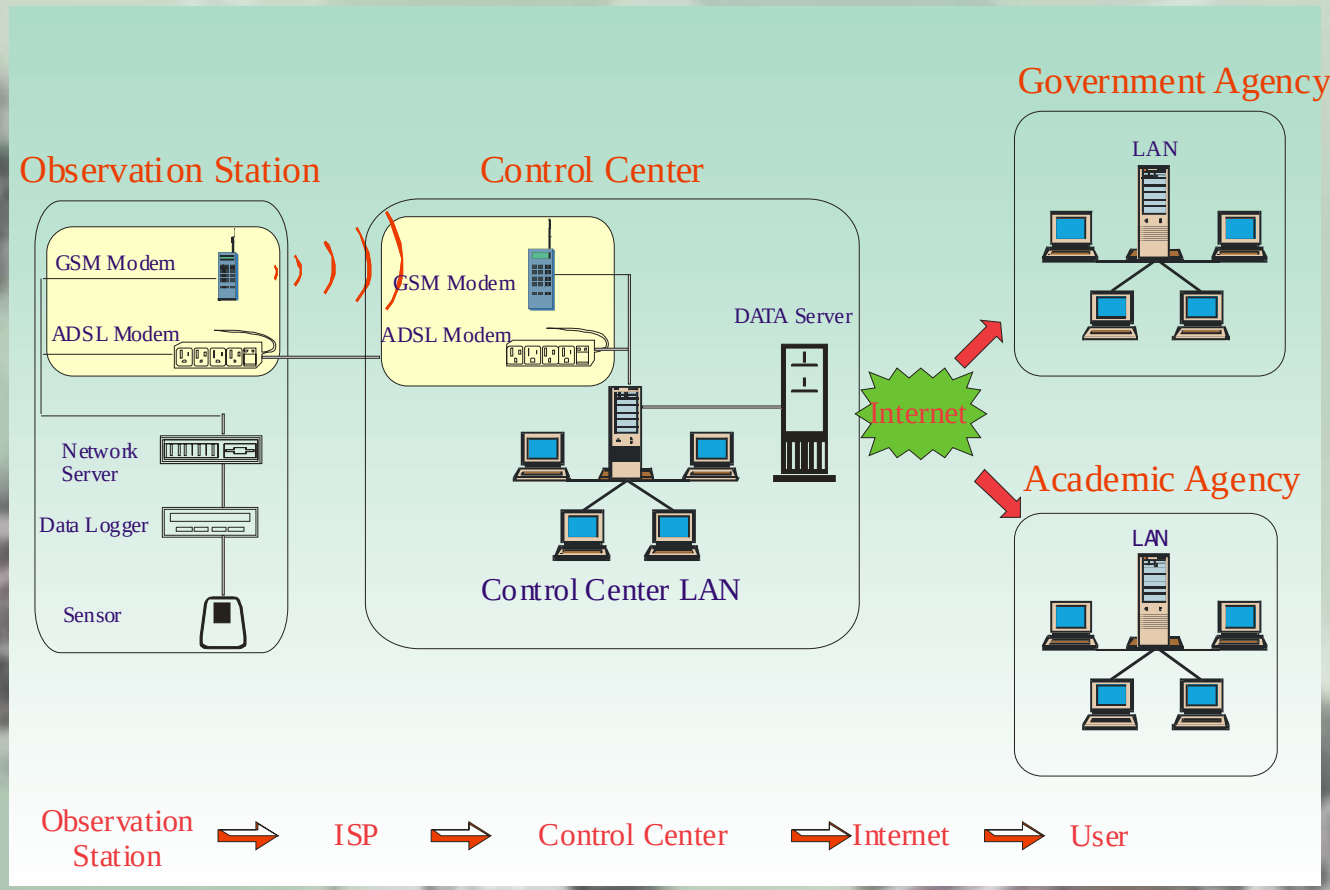


Fig.8-The framework chart of data acquisition and data transfer system. The GSM modem are use as backup system when the network failure.

2.2.4 Cases Studies and Anomalies Detect

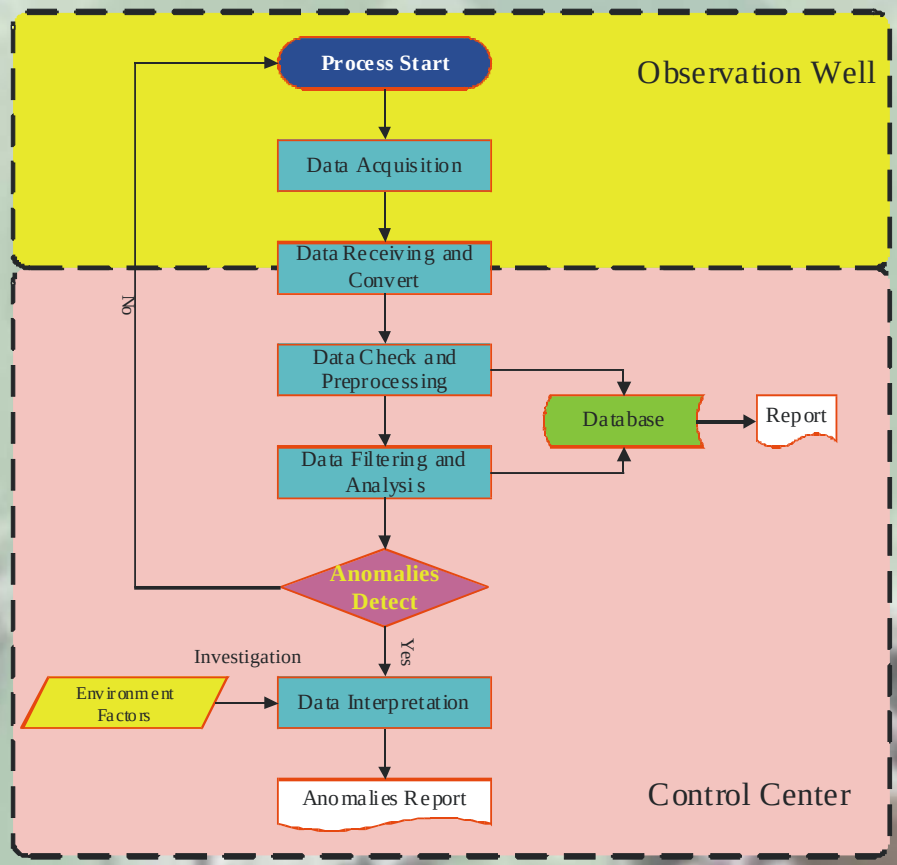
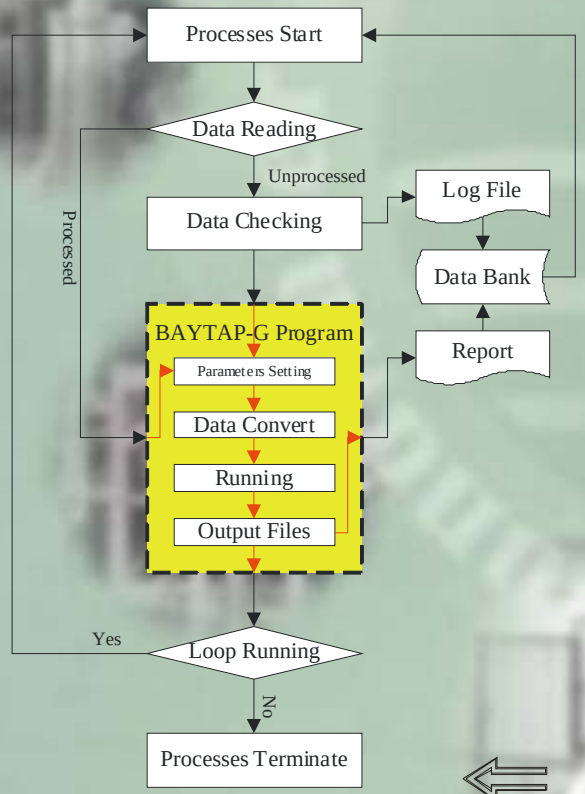


Fig.9-The flowchart of anomalies detecting system. The semi-automatic operating processes need to confirm for quality control. Both tectonic and non-tectonic anomalies been detected by the processes.

2.2.5 Data Filtering and Analysis Method (1/2)



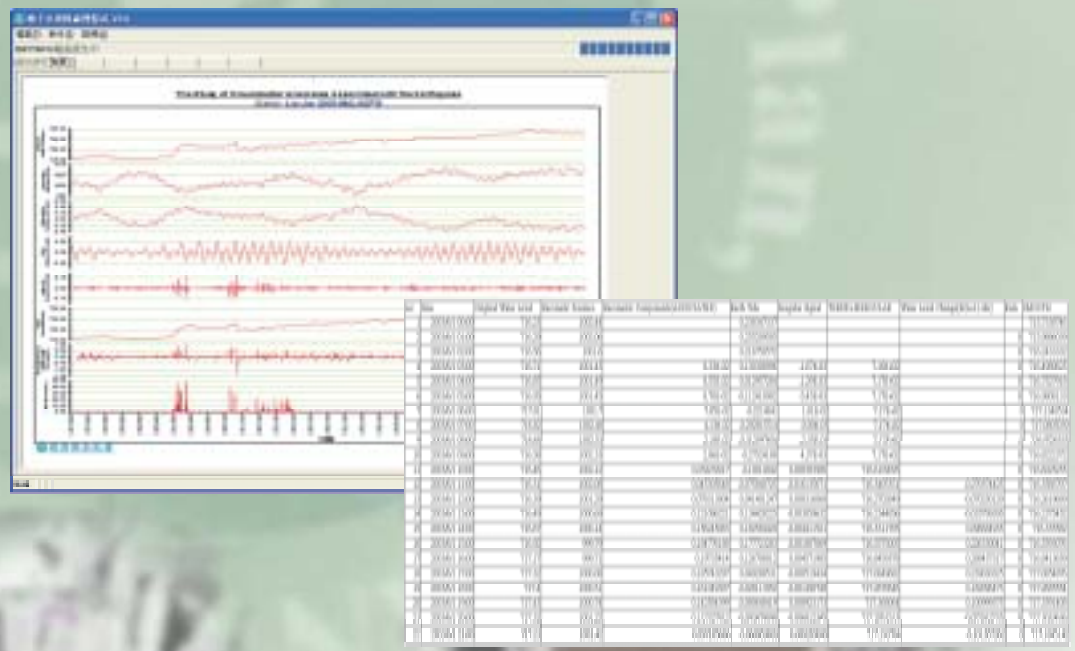
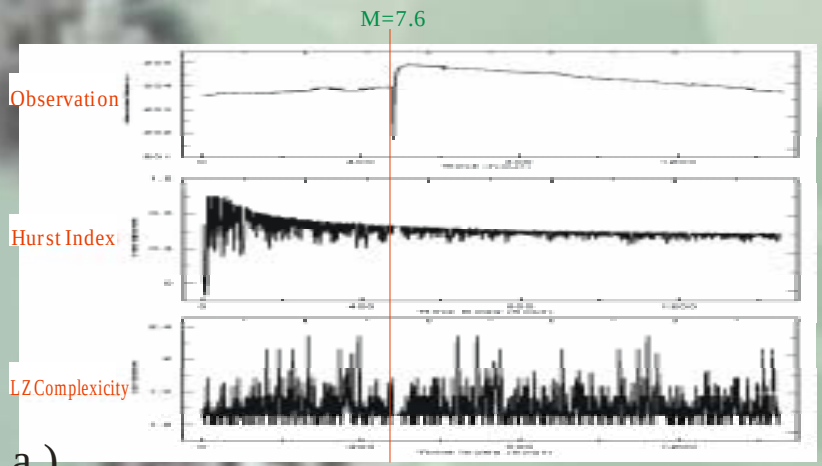


Fig.10-The Baytap-G program (Tamura et al., 1991) been used as the core program for filtering the tidal, barometric responses and irregular noises. The output signal are use for anomalies detecting.

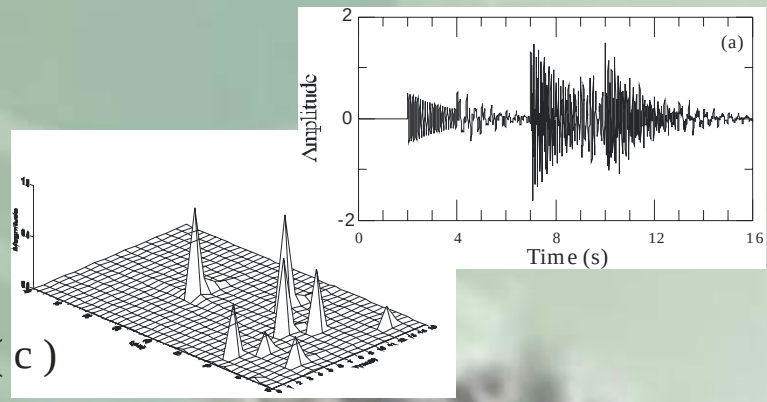
2.2.5 Data Filtering and Analysis Method (2/2)



(a)

Method	921 Earthquake		331 Earthquake
	Leap	Pulse	Leap
Moving *t* Testing	100%	43%	100%
Cramer's Method	55%	86%	28%
Yamamoto Method	100%	43%	100%
Moving *T*max Testing	76%	58%	78%
Mann-Kendall Method	69%	14%	28%
Pettitt Method	67%	14%	17%

(b)



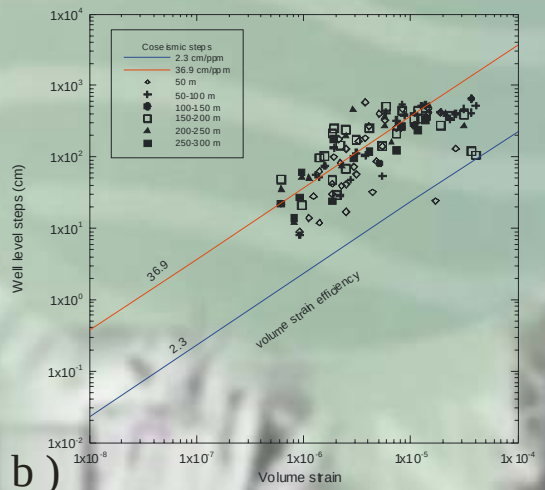
(c)

Fig.14-Intervention pattern and detection analysis for anomaly groundwater level by time series analysis. (a) Hurst Index and LZ complexity of the earthquake event. (b) Time series analysis result of Sep. 21st, 1999 and March 31st, 2002 events in the Choshuishi alluvial fan, Central Taiwan (Lee, 2002). (c)Application of spectrum analysis used Gabor transform(Tsai, et al., 2002) .

2.2.6 Mechanism of Hydrological Anomalies(1/2)

Copmressibility of soil (Cs)	10^{-7}~10^{-10} Pa^{-1}
Copmressibility of water (Cp)	$4.4*10^{-10}$ Pa^{-1}
Porosity (n)	0.15~0.25
Skempton coefficient (B)	0.73~0.99
Poisson ratio (ν)	0.15~0.35
Young's modulus (E)	69~172 MPa
Undrained Poisson ratio (ν_u)	0.38~0.49
Undrained bulk modulus (Ku)	$3.1*10^{8}$-$3.73*10^{9}$ Pa
Strain efficiency	2.3~36.9 cm/ppm

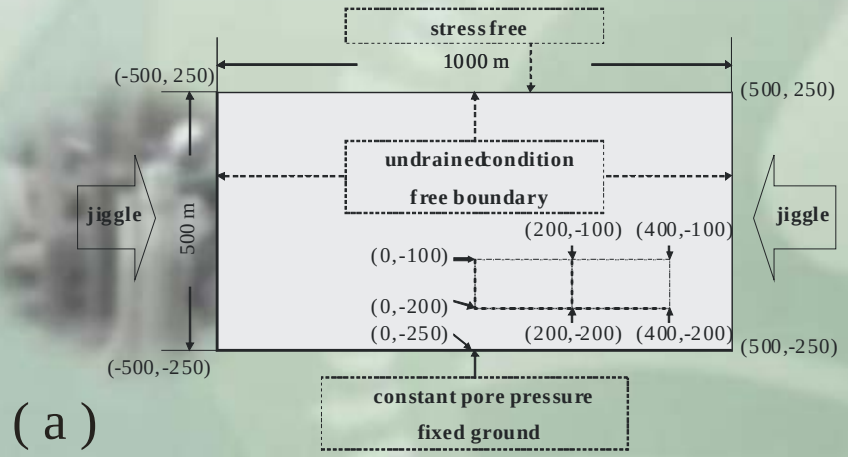
(a)



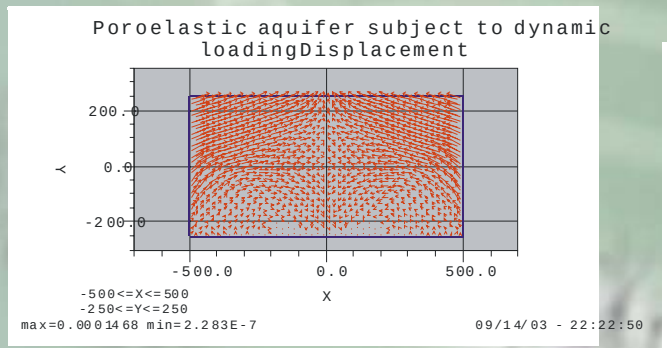
(b)

Fig.12-The application of the poroelastic theory for estimate the geo-material properties in the Choshuishi alluvial fan, central Taiwan. (a) The parameters of the alluvial deposits (b) The volumetric strain efficiency estimated from aquifer lithology (HS et al., 2003).

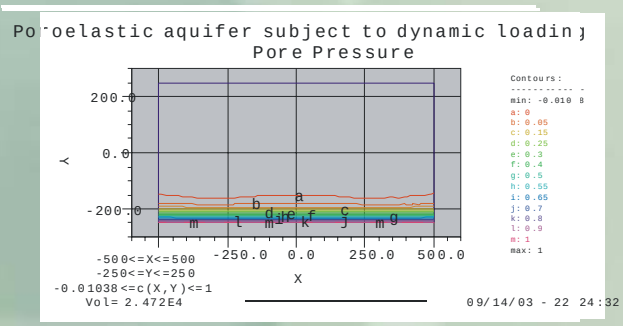
2.2.6 Mechanism of Hydrological Anomalies(2/2)



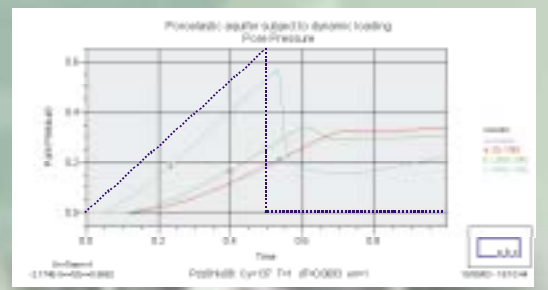
(a)



(b)



(c)

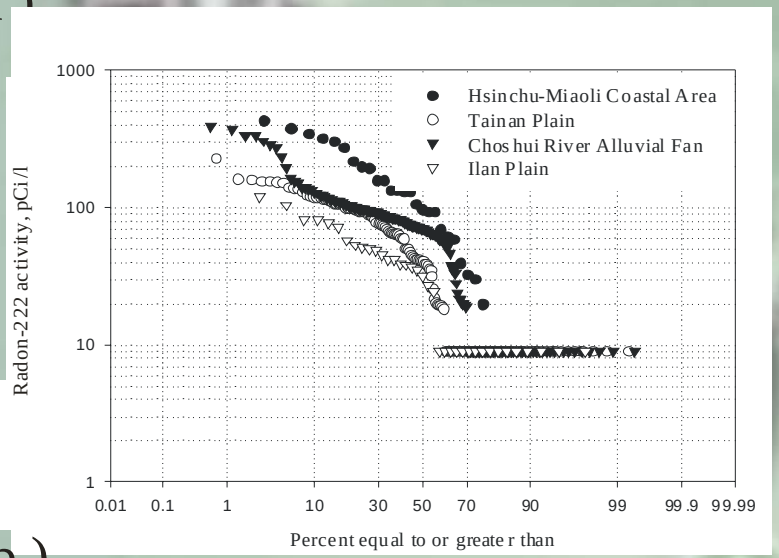


(d)

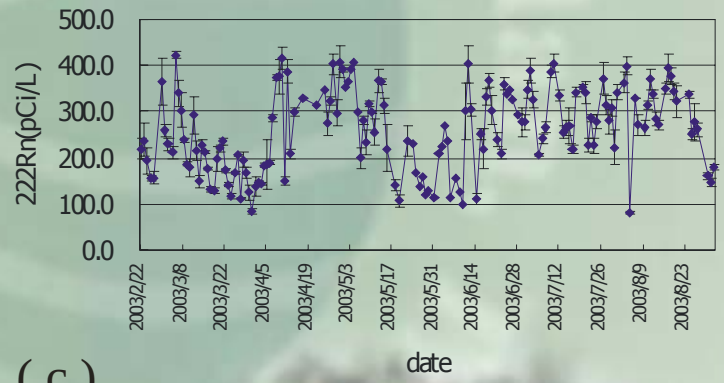
Fig.13-The numerical coupled deformation-pore pressure simulation by finite element method. (a) Problem domain (b)Displacement field (c)Pore pressure contour (d)Pore pressure changes during a "flat ramp then drop" loading (Wang et al., 2003).

2.2.7 Groundwater Geochemical Researches

(a)



(b)



(c)

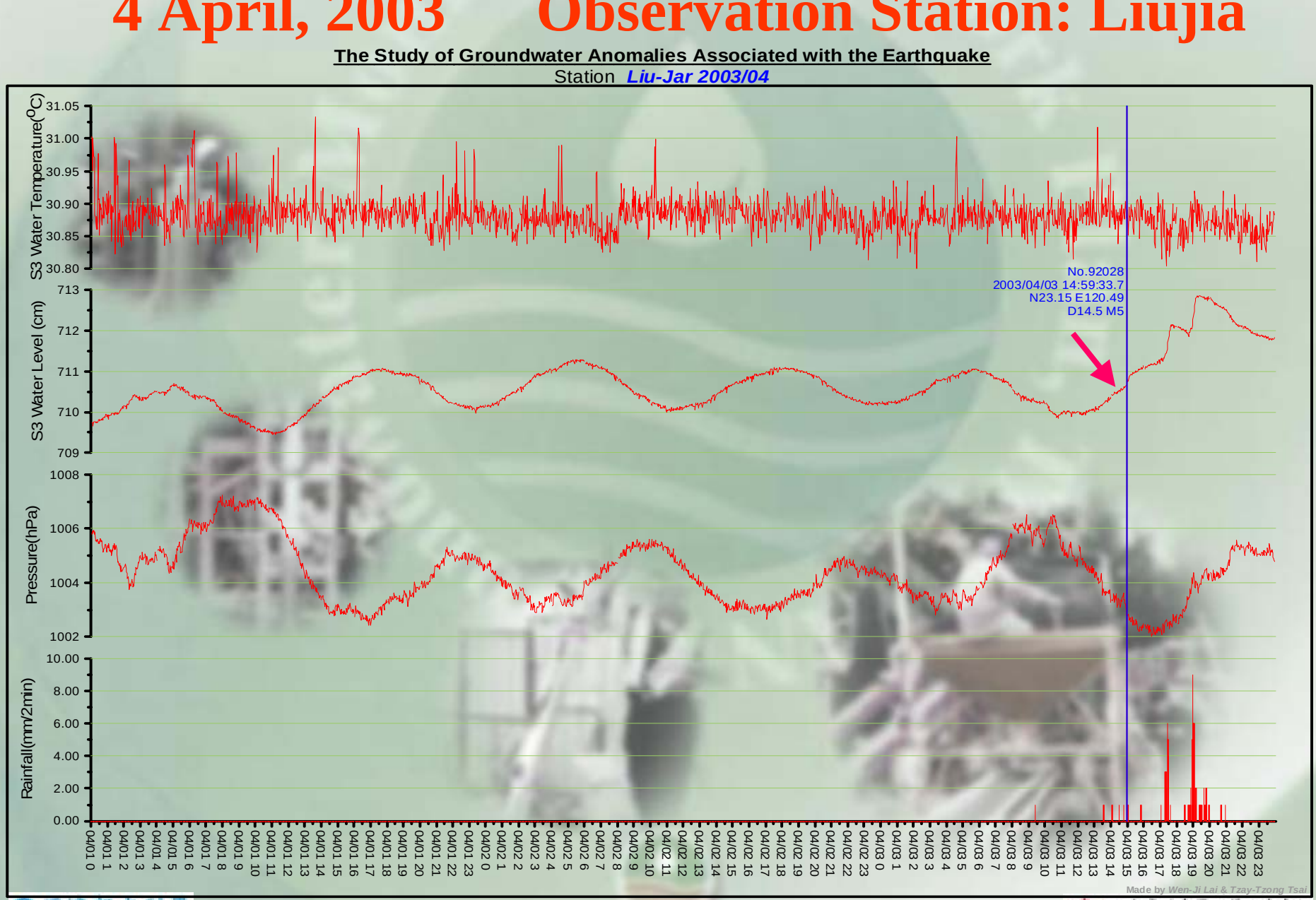
Fig.15-Measurements of Radon concentration of all groundwater observation wells. (a)sampling of pumping groundwater from well (b) The distribution of the Radon concentration of the major groundwater division areas (c)Continually measurements of Radon concentration in central Taiwan.

III. Observation Results and the Future Plan

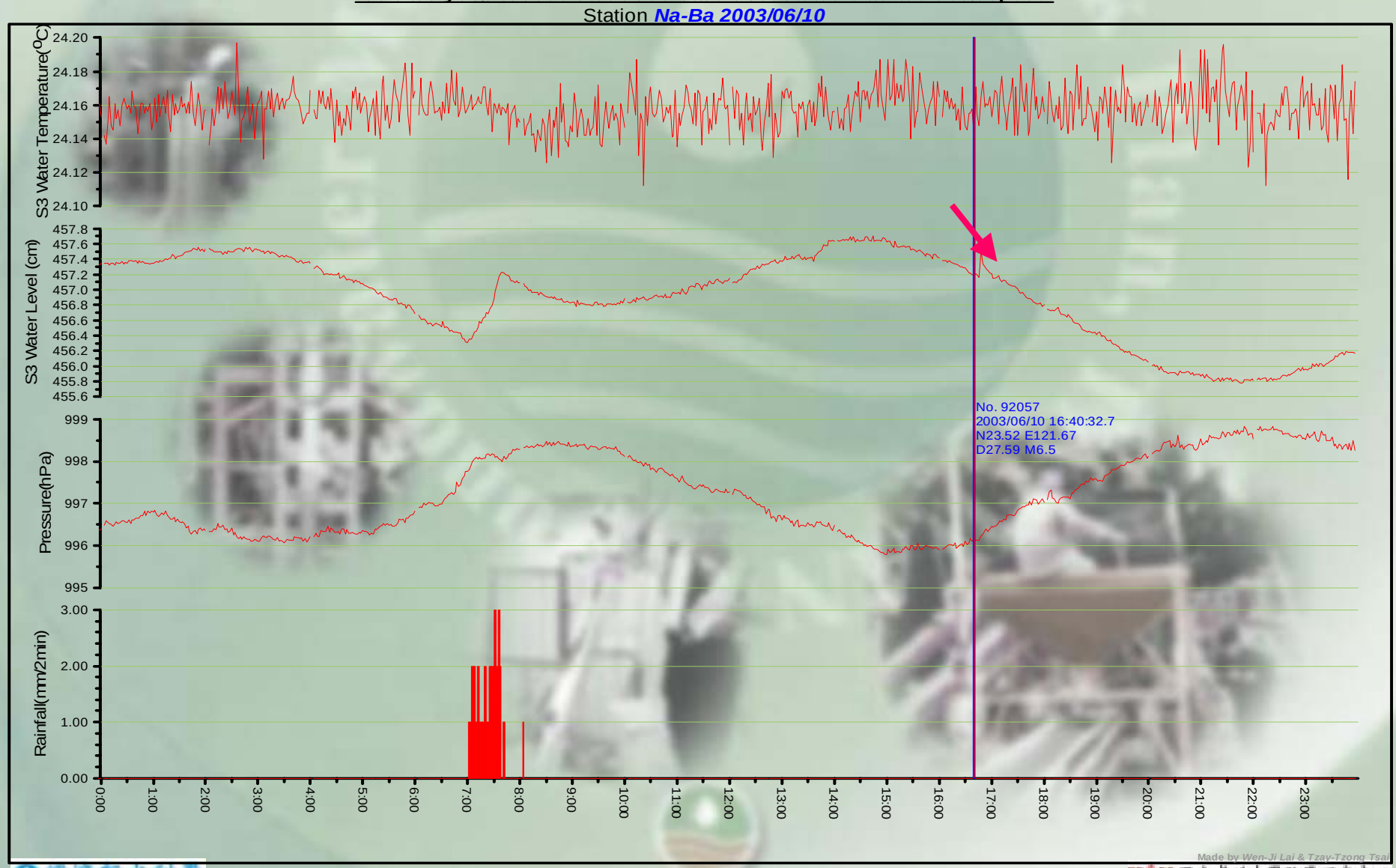
3.1 Observation Results (2003)

記錄	發震時間	震央位置	深度 (km)	規模	六甲	那拔	東和	新埔	銅鑼	壯圍	花蓮	河東
1	2003/4/3 14:59	台南.楠西	14.5	5	●	●	●					
2	2003/6/10 16:40	花東外海	27.6	6.5	●	●	●	●				
3	2003/7/16 04:27	西亞海域	10	7.6			●					
4	2003/9/26 03:50	日本.北海道	27	8.3		●	●					
5	2003/9/27 19:33	蘇聯.南西伯利亞	16	7.5		●	●	●				
6	2003/12/10 12:38	台東.成功	10	6.6	●		●		●	●	●	●

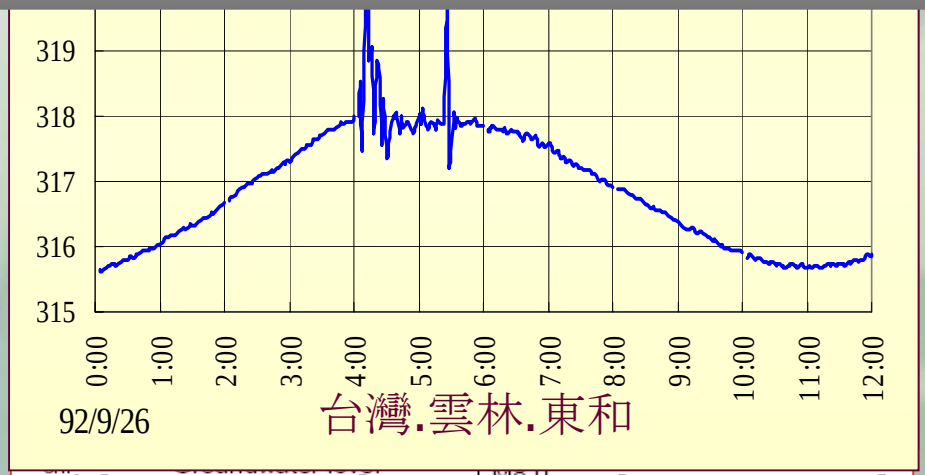
3.1.1 Local Event I: M 5.0 D 14.5 km
4 April, 2003 Observation Station: Liujia



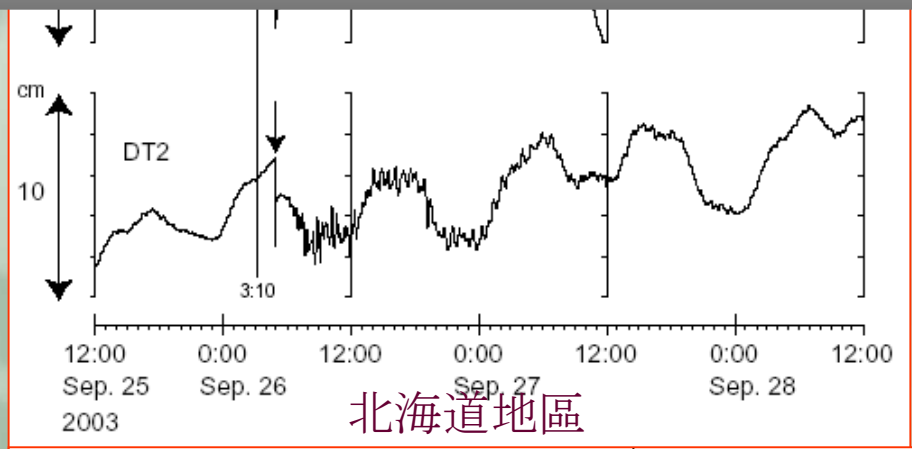
3.1.2 Local Event II: M 6.5 D 27.9 km
10 Jun, 2003 Observation Station: Naba



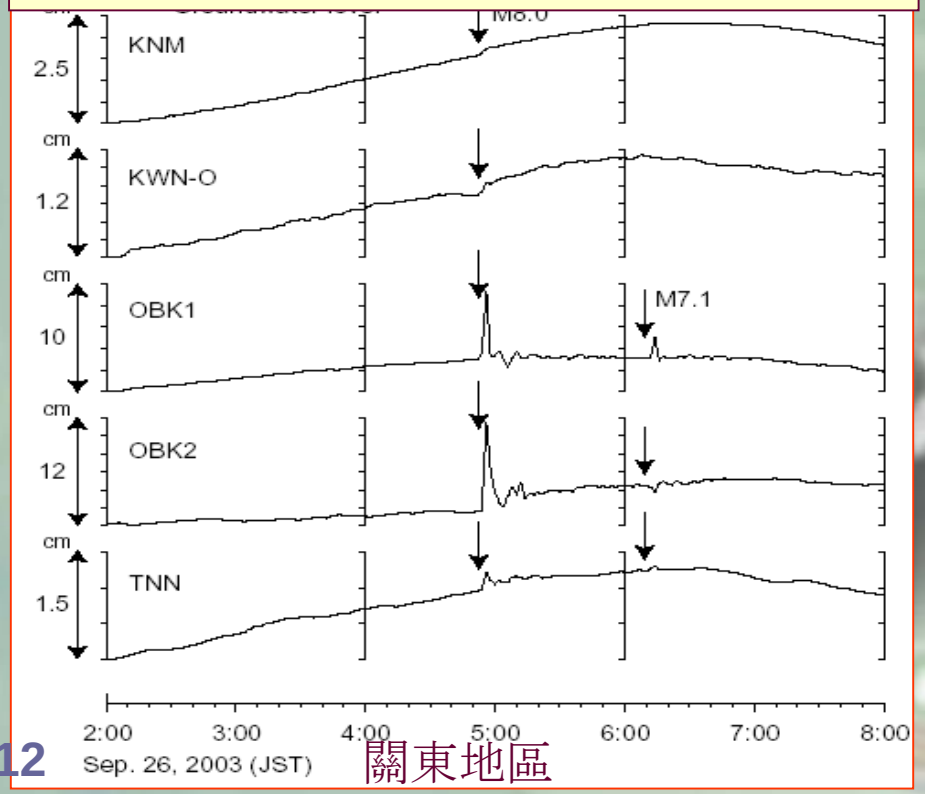
3.1.3 Distant Event: M8.1 D 27km
26 Sep. 2003,Hokaido Japan Observation: Donher



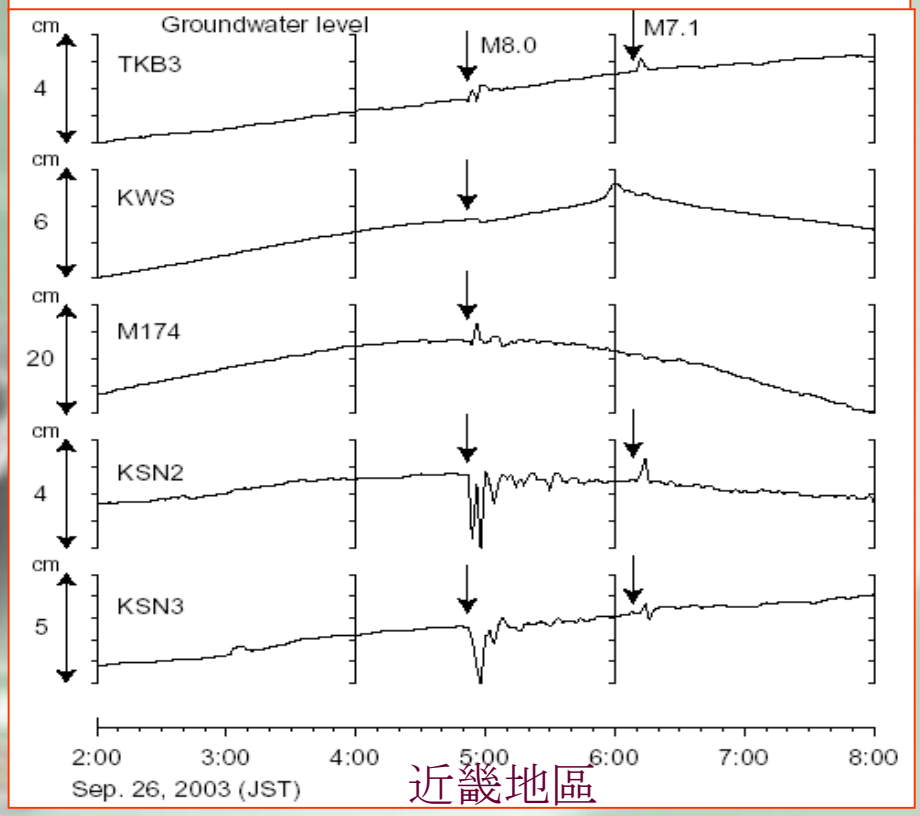
台灣.雲林.東和



北海道地區



關東地區

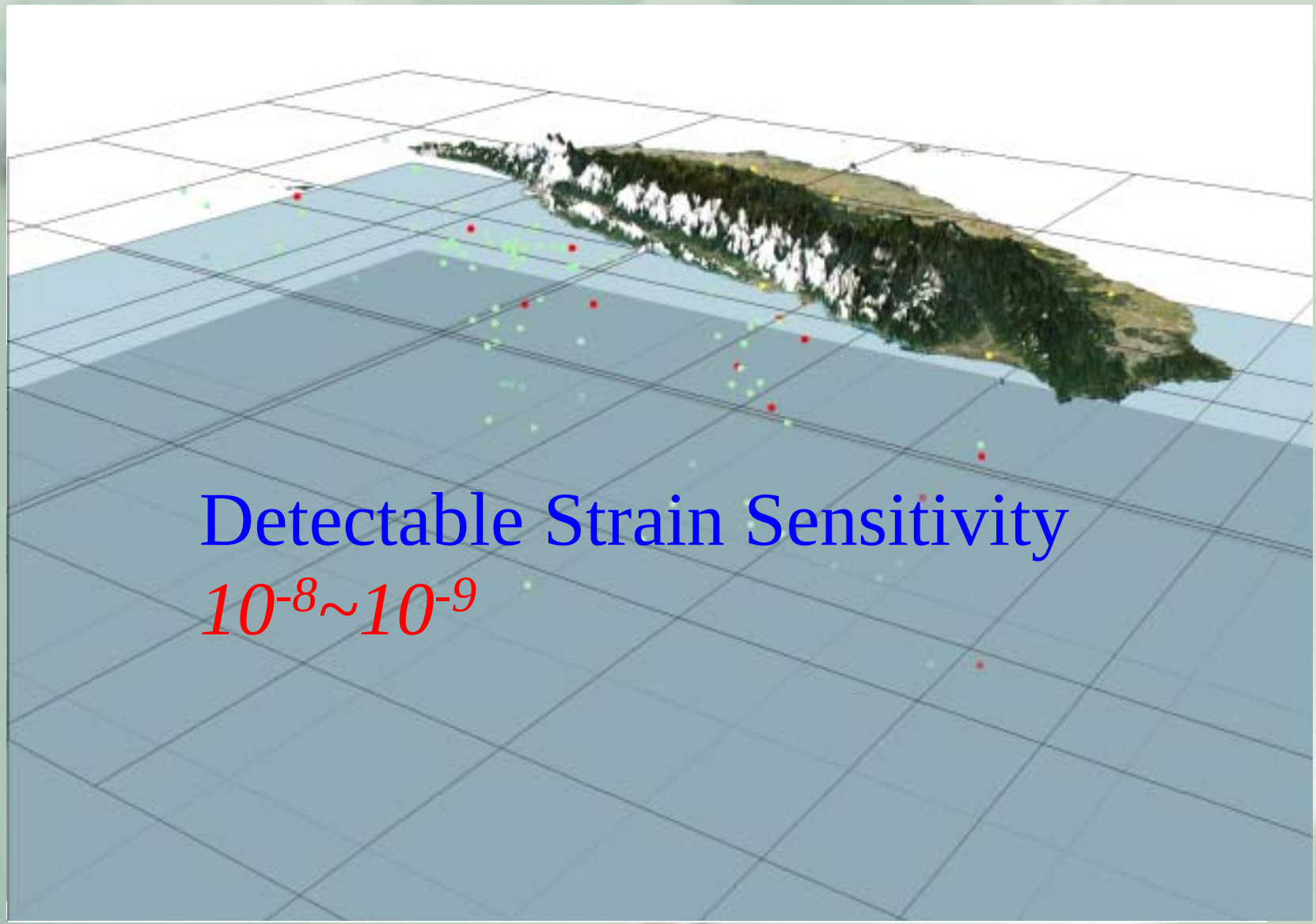


近畿地區

3.2 Observation Results (2004)

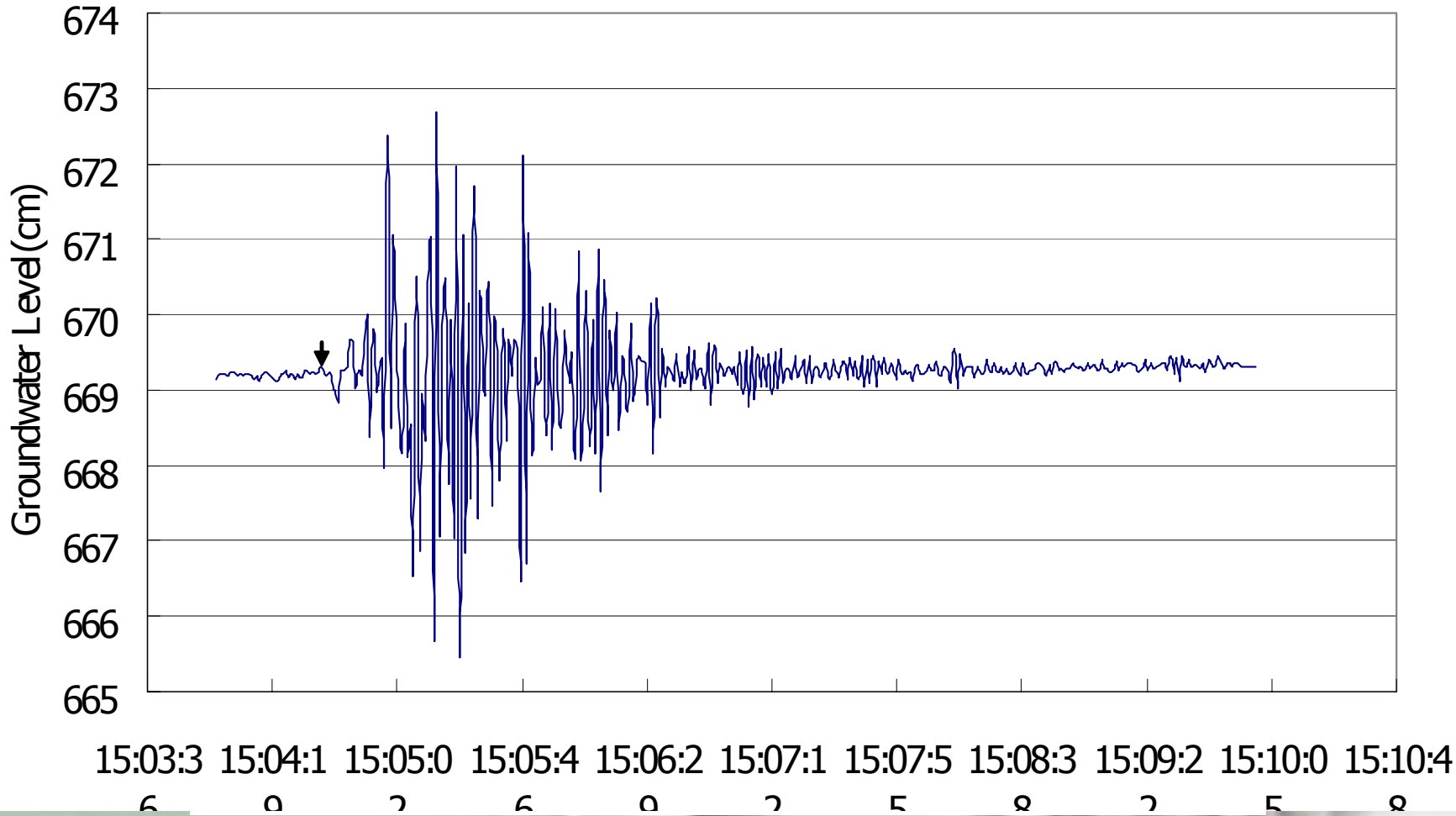
記錄	發震時間	震央位置	深度 (km)	規模	六甲	那菝	東和	新埔	銅鑼	壯圍	花蓮	河東
1	2004/1/1 11:50	花蓮.玉里	17.8	5.9							●	
2	2004/1/6 8:55	宜蘭.牛鬥	54.9	4.6						●		
3	2004/1/13 17:29	花蓮市	19.8	5.0							●	
4	2004/2/4 11:24	花蓮外海	37.8	4.3					●	●	●	
5	2004/2/9 15:13	花蓮.新城	27.6	4.3							●	
6	2004/4/25 03:26	花蓮市	15.1	4.2						●	●	
7	2004/5/1 15:36	花蓮.太魯閣	17.8	5.8	●	●	●		●	●	●	
8	2004/5/17 19:33	台東.成功	12.5	6.0					●	●	●	
9	2004/5/19 12:38	台東綠島	8.7	6.5	●	●	●	●	●	●	●	●

3.2.1 Spatial Distribution of the Seismic Activity (M>4.5)



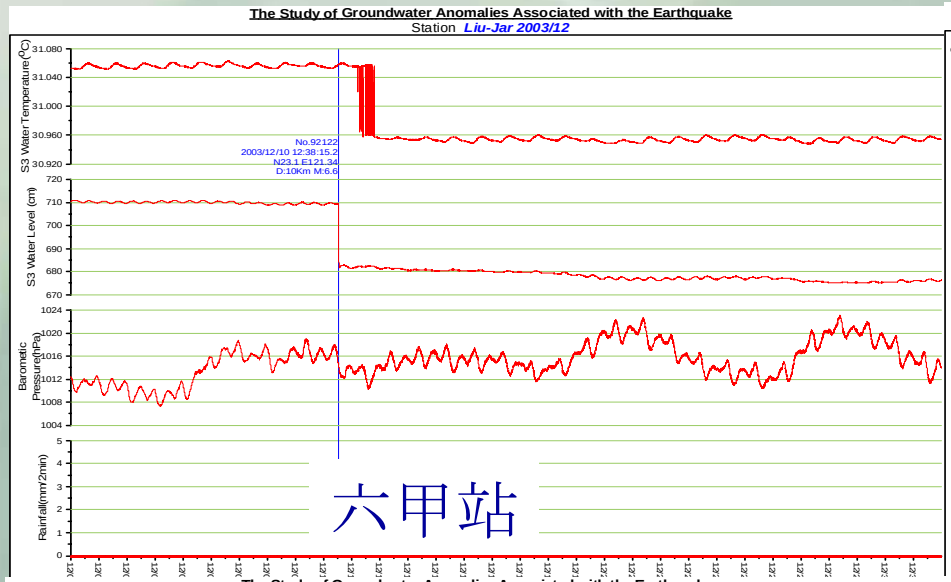
3.2.2 High Frequency Record

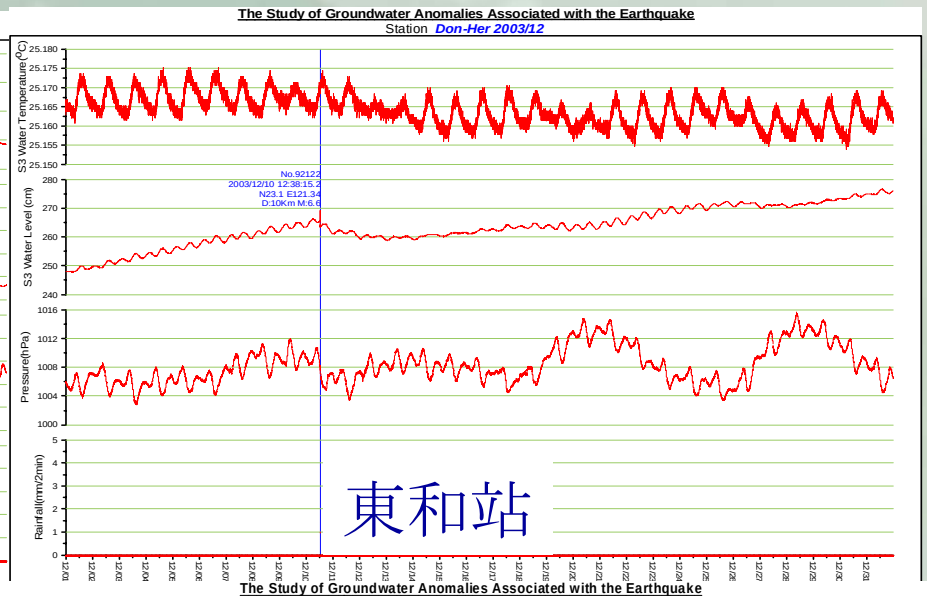
19 May,2004 M 6.5, D 8.7 km

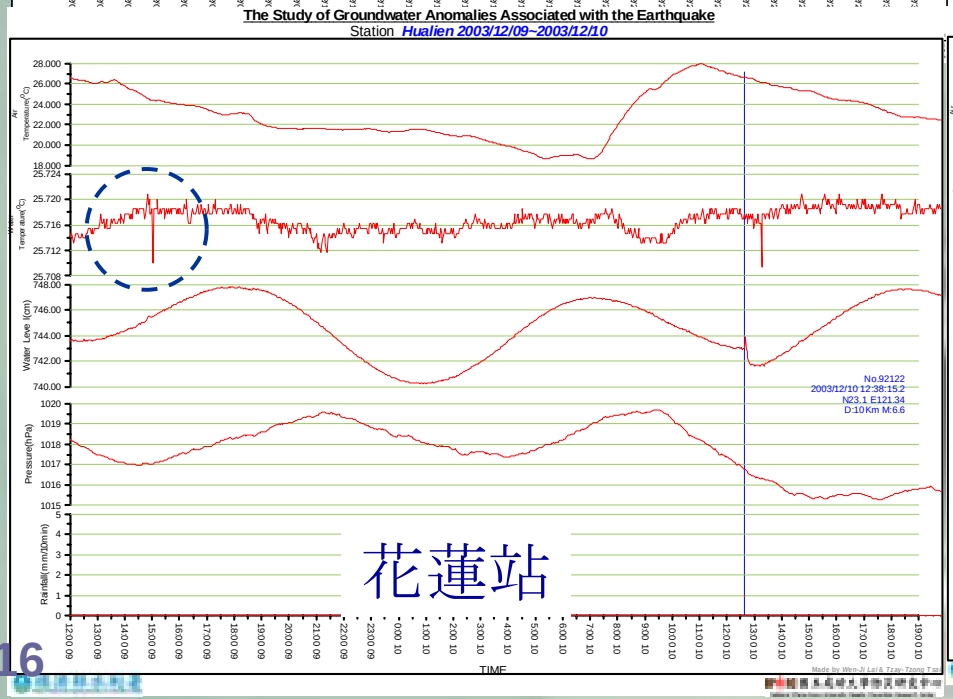


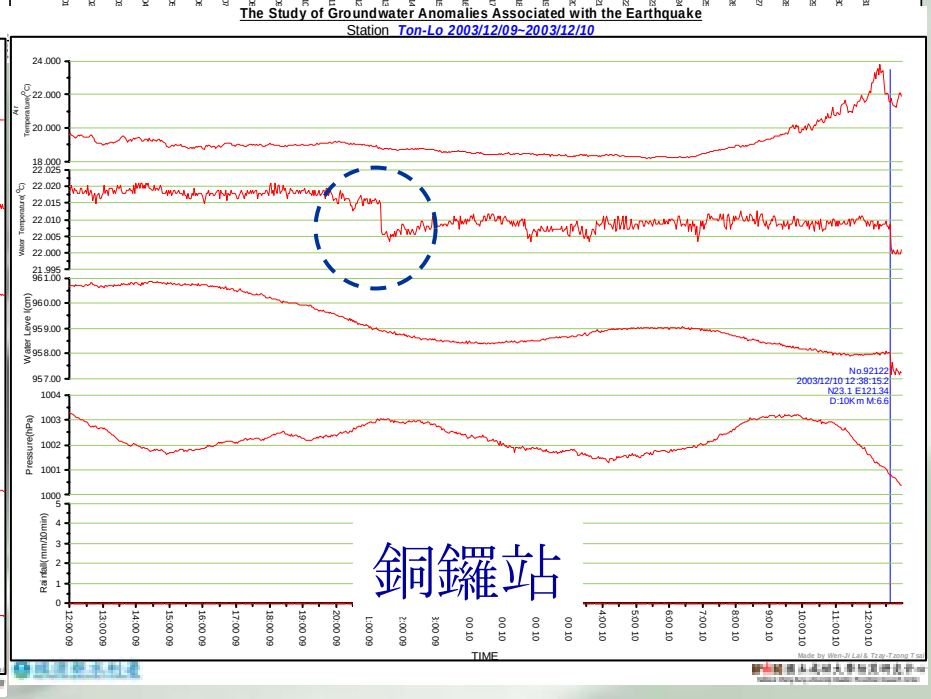
High Sampling Interval(1Hz) Groundwater Level Oscillation

3.2.3 Whole Island Event: M 6.6 D 10 km
10 Dec, 2003 Observation Station: 8 wells

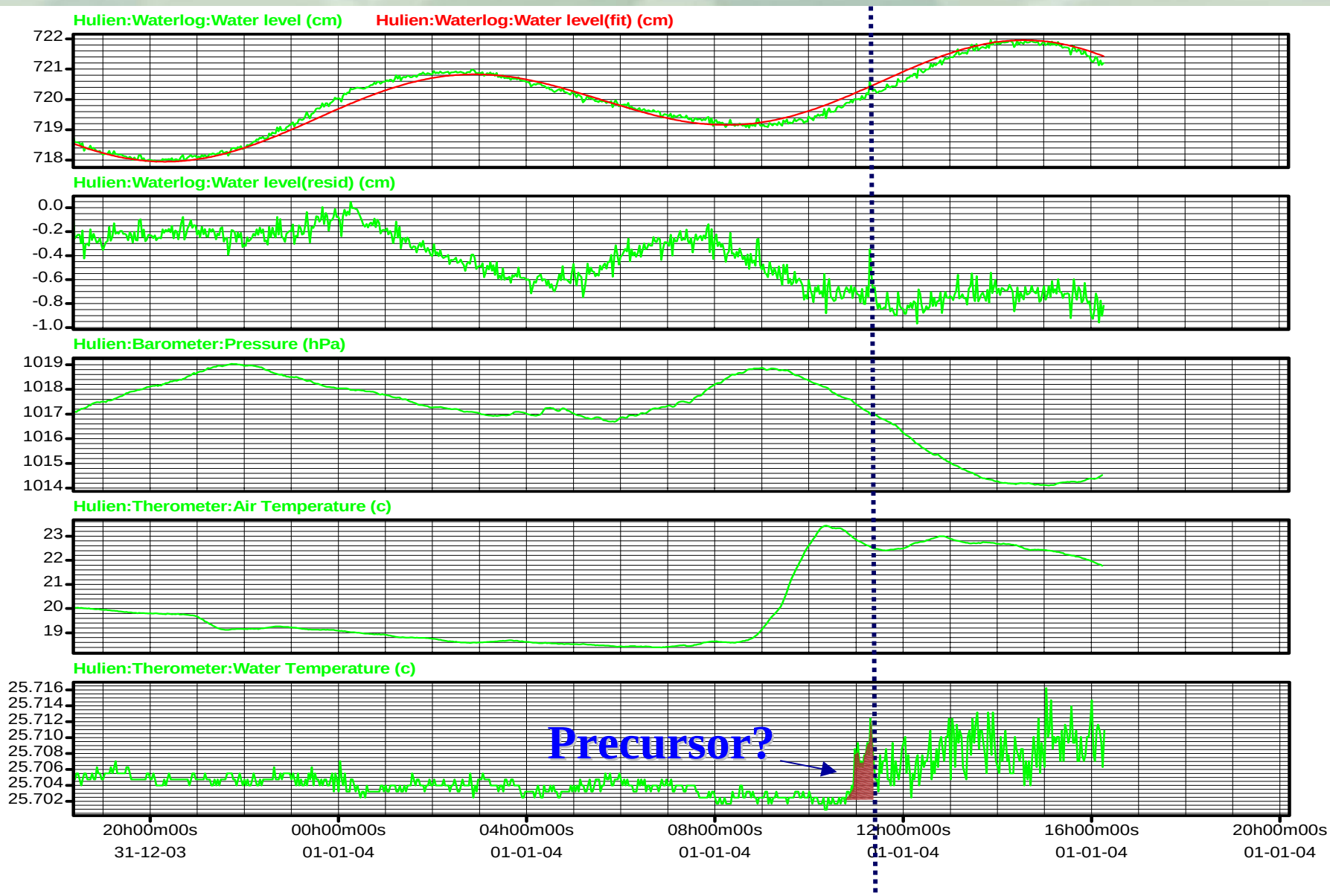








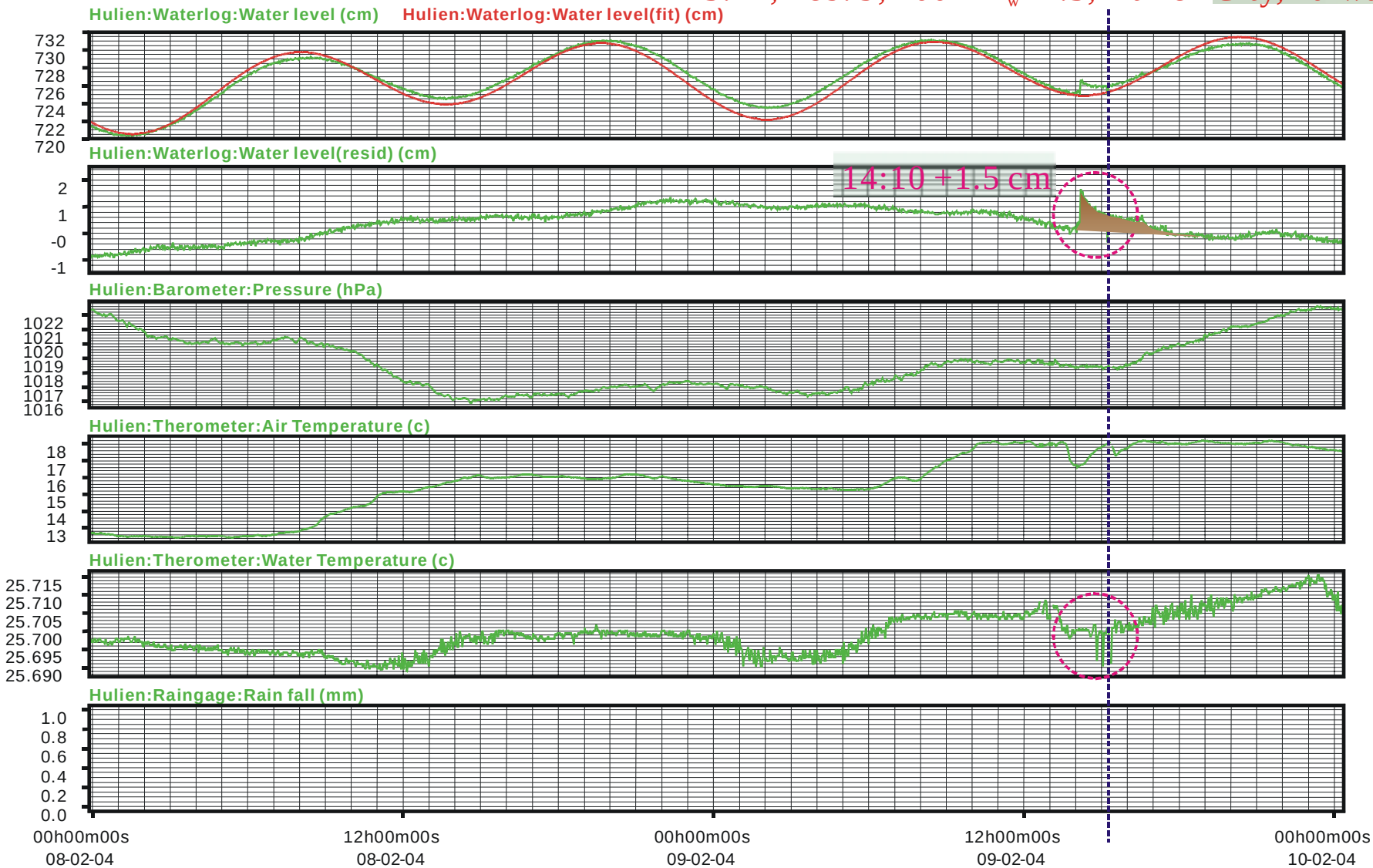
3.2.4 Preseismic Groundwater Temperature Change 93/1/1,Hulien,M 5.9, D 17.8 km



3.2.5 Preseismic Groundwater Level and Temperature Change

93/1/1,Hulien,M 5.9, D 17.8 km

15:14, Feb. 9, 2004 M_w=4.3, Hulien City, Taiwan



3.3 Summary and Future Plan

- The establishment the monitoring network of the groundwater in the whole island scale.
- Highly seismic activity make the good and frequently chances to study the problems.
- Clearly preseismic groundwater level and temperature changes offer the good opportunity to study the mechanism.
- The high resolution observation combine the dense observation network can solve the problem in the past record.
- The development of the monitoring techniques in Taiwan are very meaningful for apply in the other country of the world.