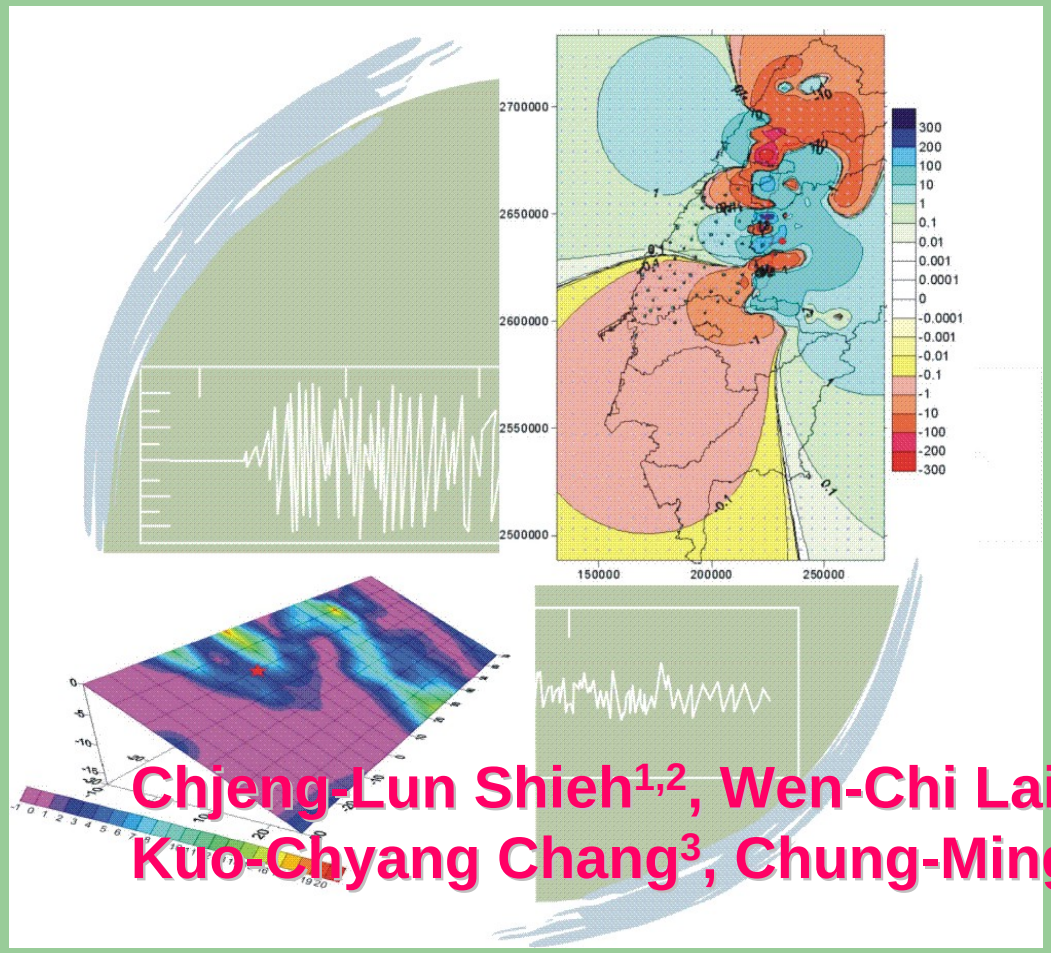
The Study of Groundwater Anomalies Associated with the Earthquake in Taiwan: An update in 2003



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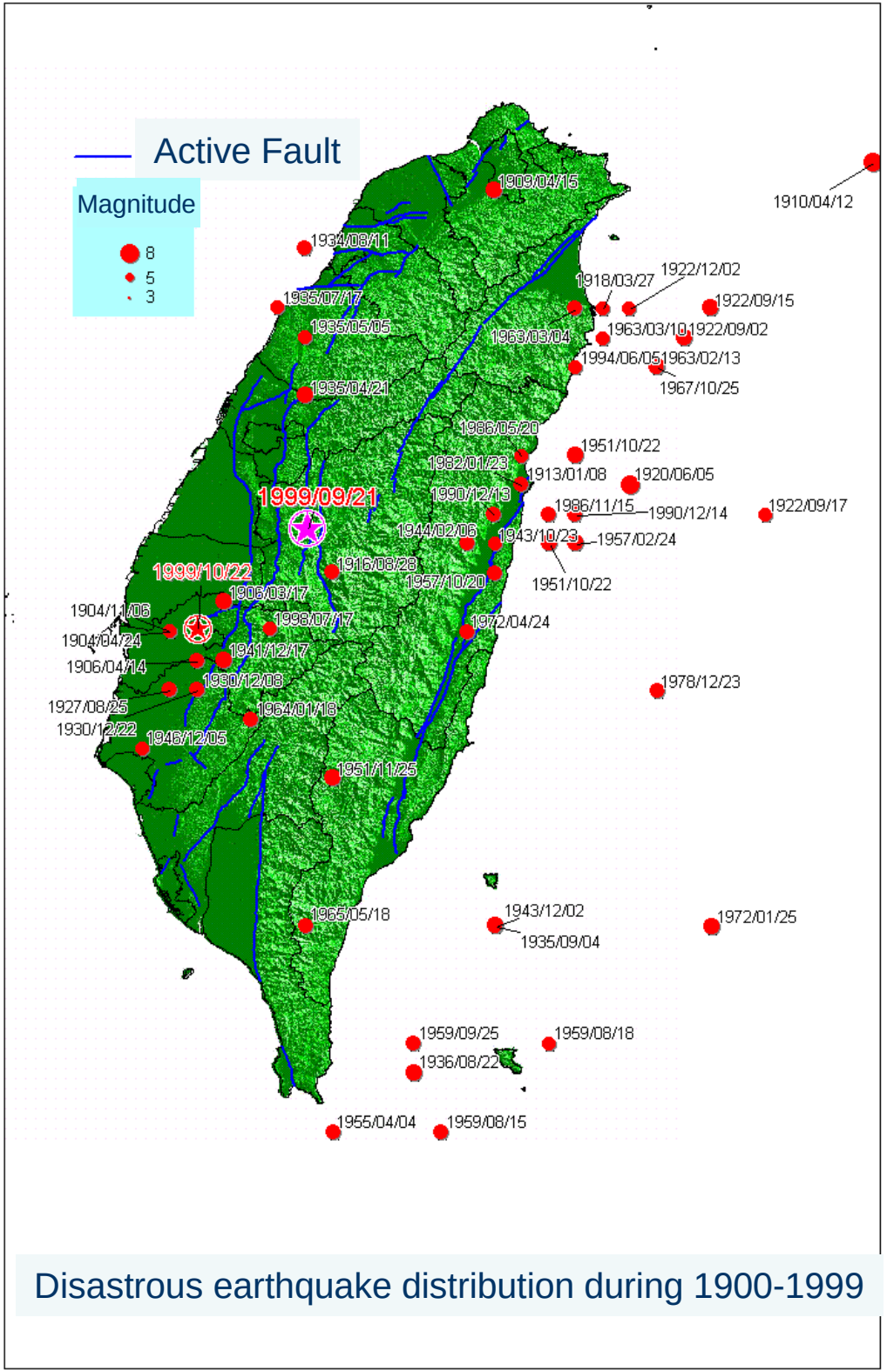
3. Water Resource Agency, Ministry of Economic Affair, Taiwan R.O.C.

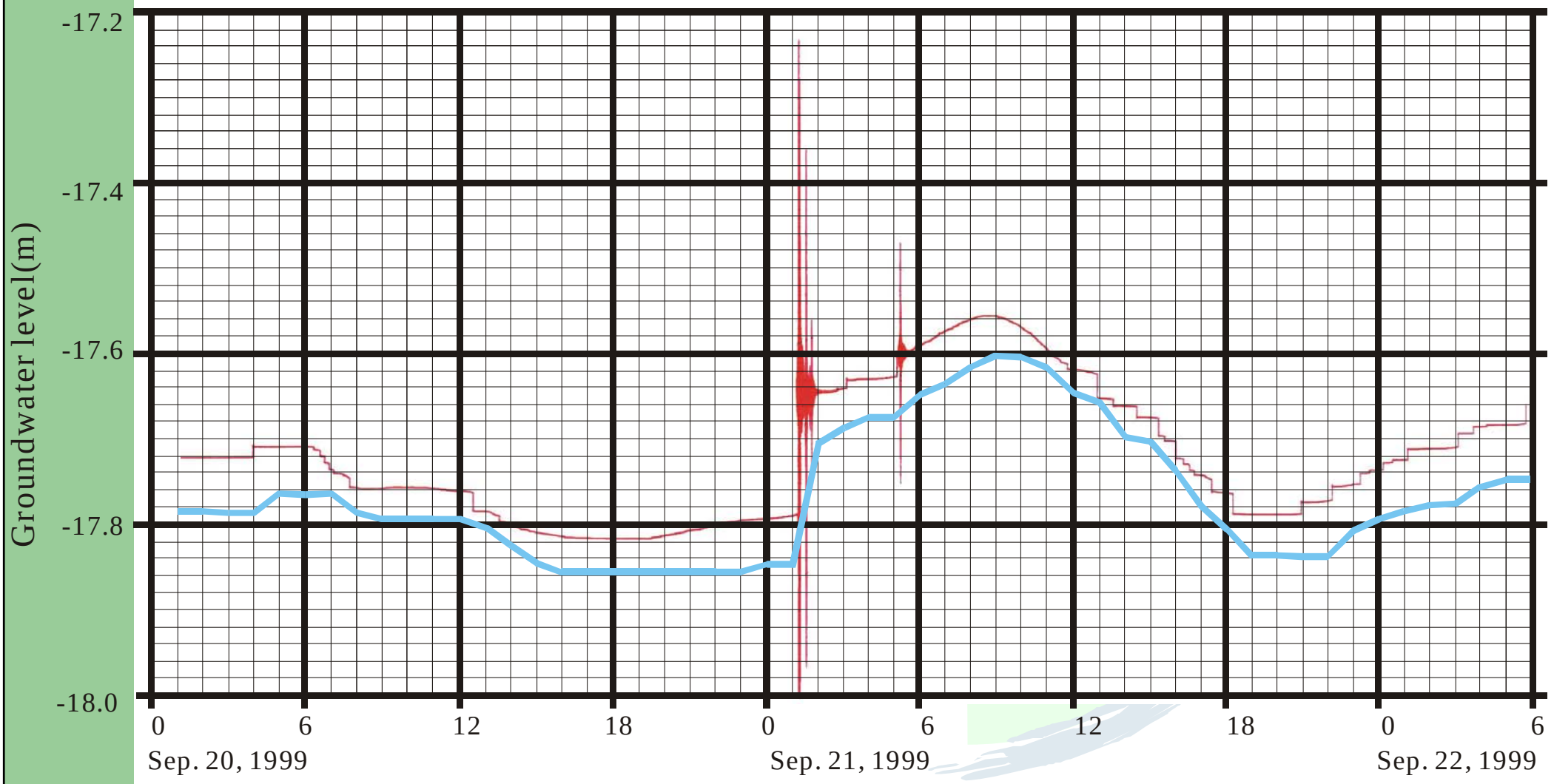
Spatial Distribution of Disastrous Earthquake

- Western foothill area
- Ilan offshore area
- Hulien offshore area
- Longitudinal Valley
- Liutao-Lanyu island



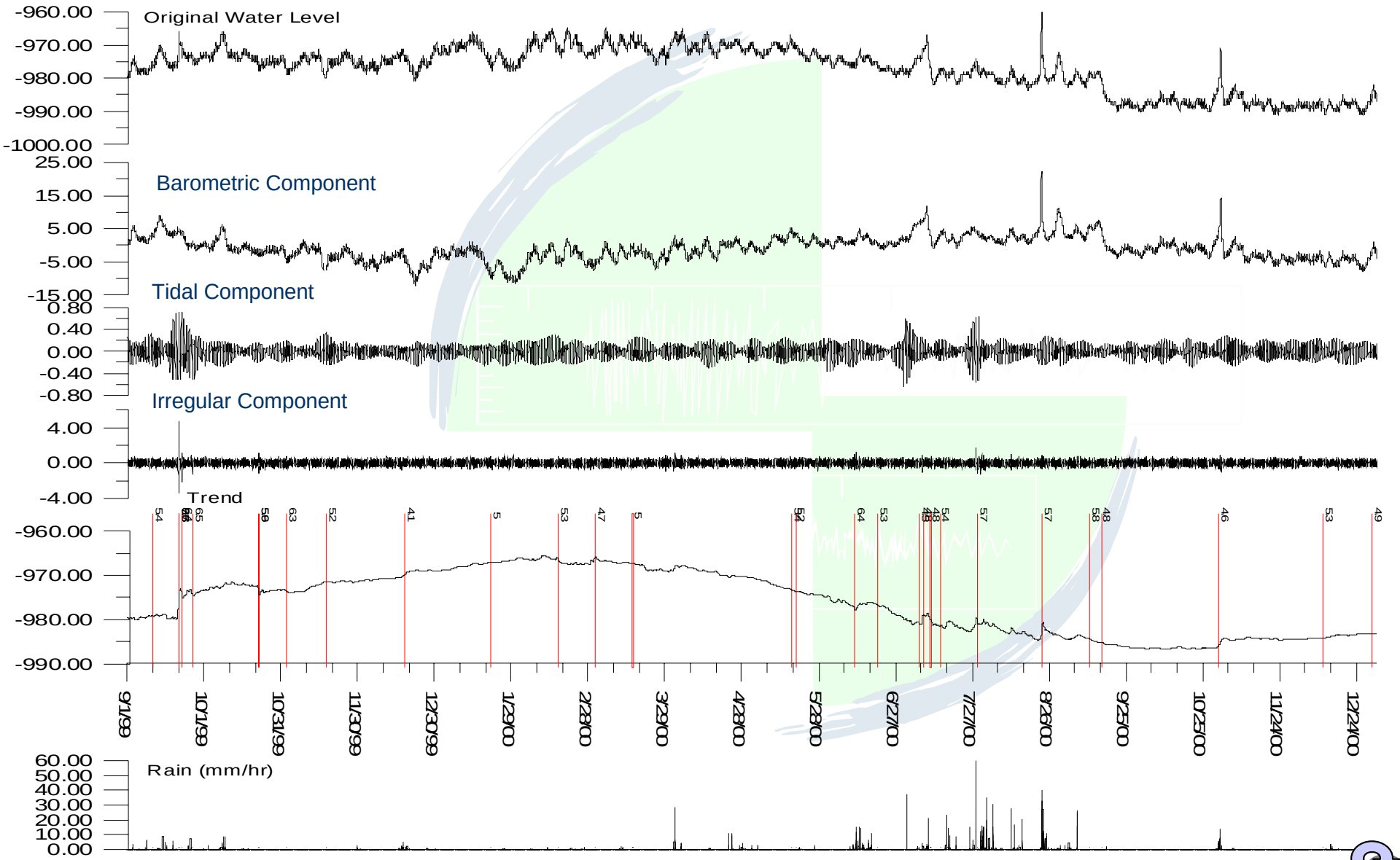
Disastrous earthquake distribution during 1900-1999

Coseismic Water Level Changes of the Chi-Chi Taiwan Earthquake, 1999



Components of Groundwater Level Fluctuation

(Derived from the analysis result of Baytap-G Program for Tunye (2) observation well:1999/9/1~2000/12/31)

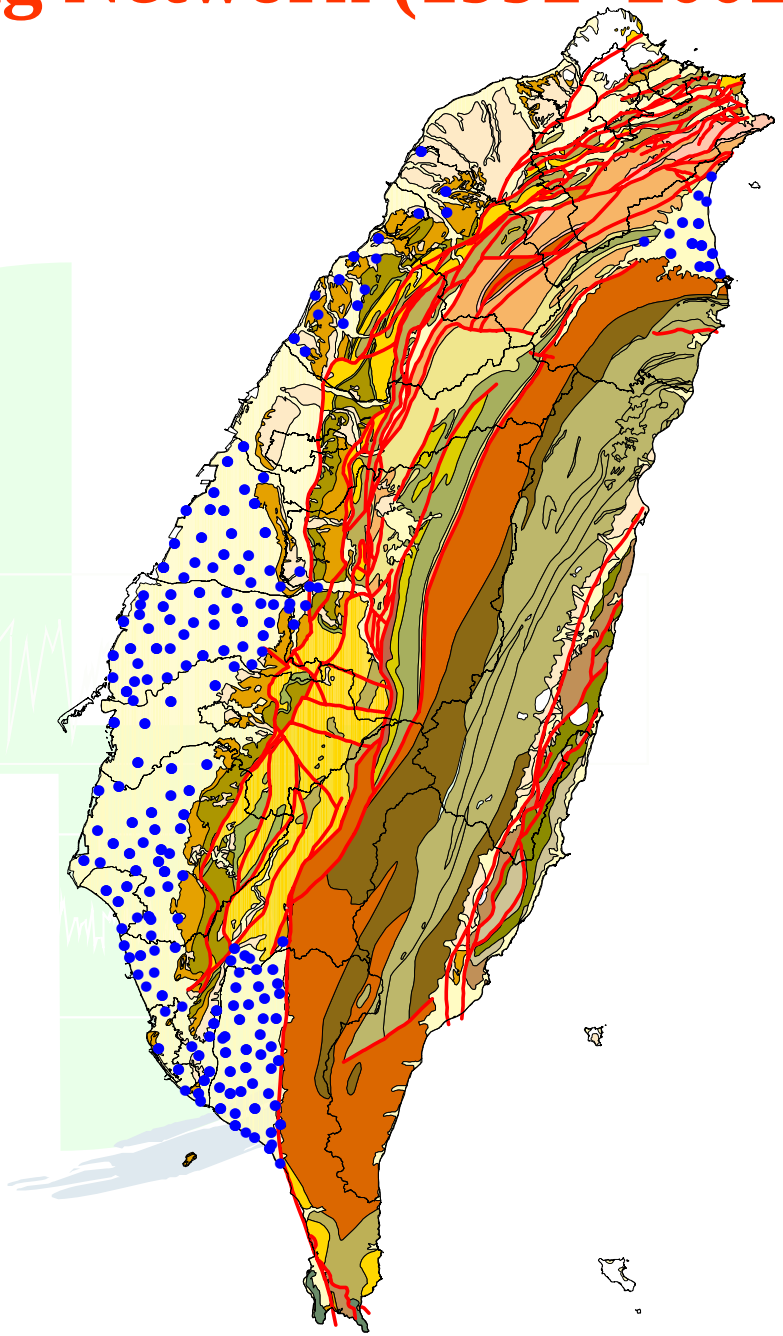


Goals of Our Work

- **Final Goals**
  - Application for earthquake hazard mitigation
  - Cross-Linkage with related projects
- **Directly Goals**
  - Provide good quality observation data
  - Development of needed techniques and researches for long-term monitoring
  - Evaluate the relationship between groundwater changes and earthquake occurrences
  - Extend the functions of “Groundwater Monitoring Networks of Taiwan”

Taiwan Groundwater Monitoring Network (1992~2002)

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

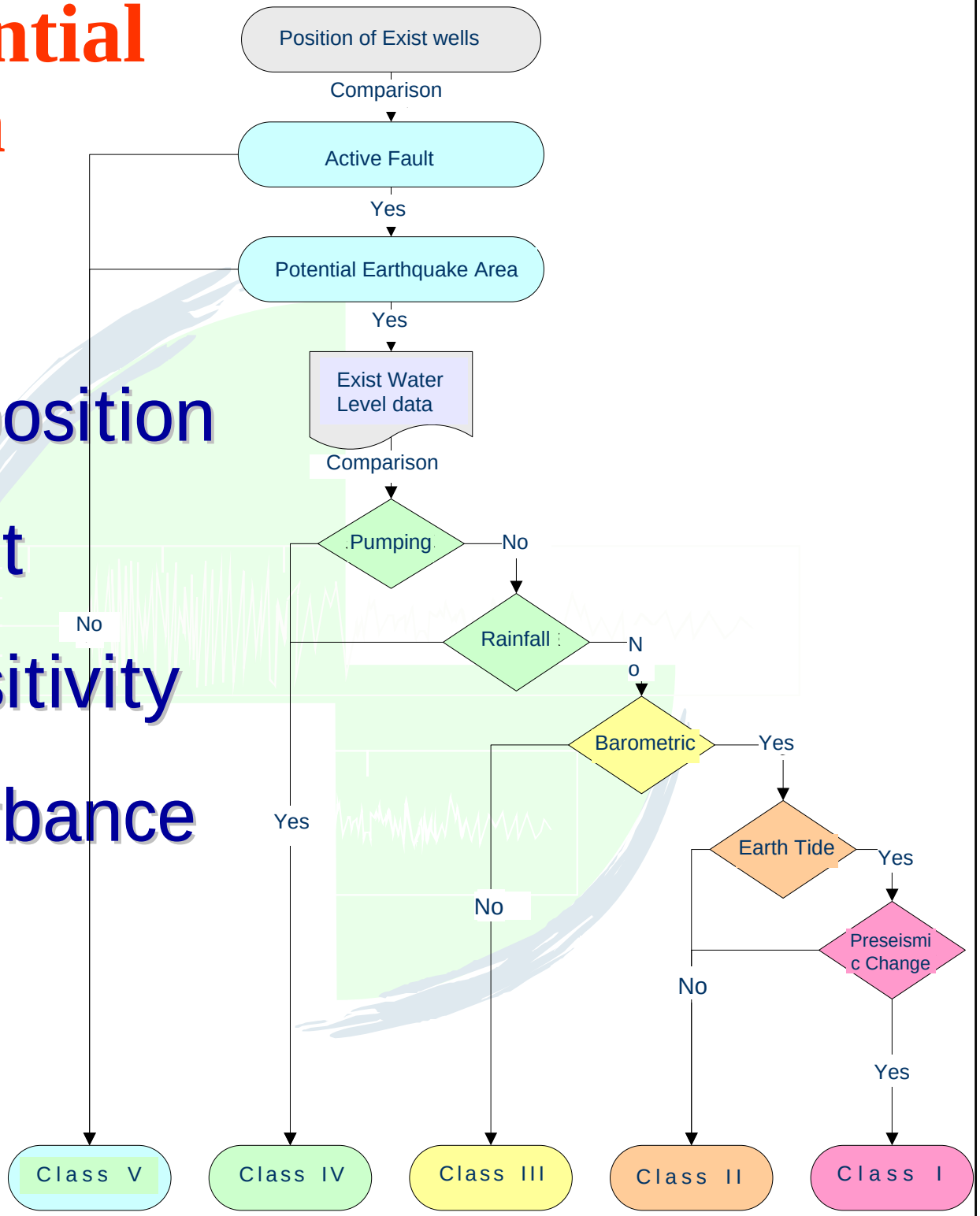


Previously Work(2001~2002)

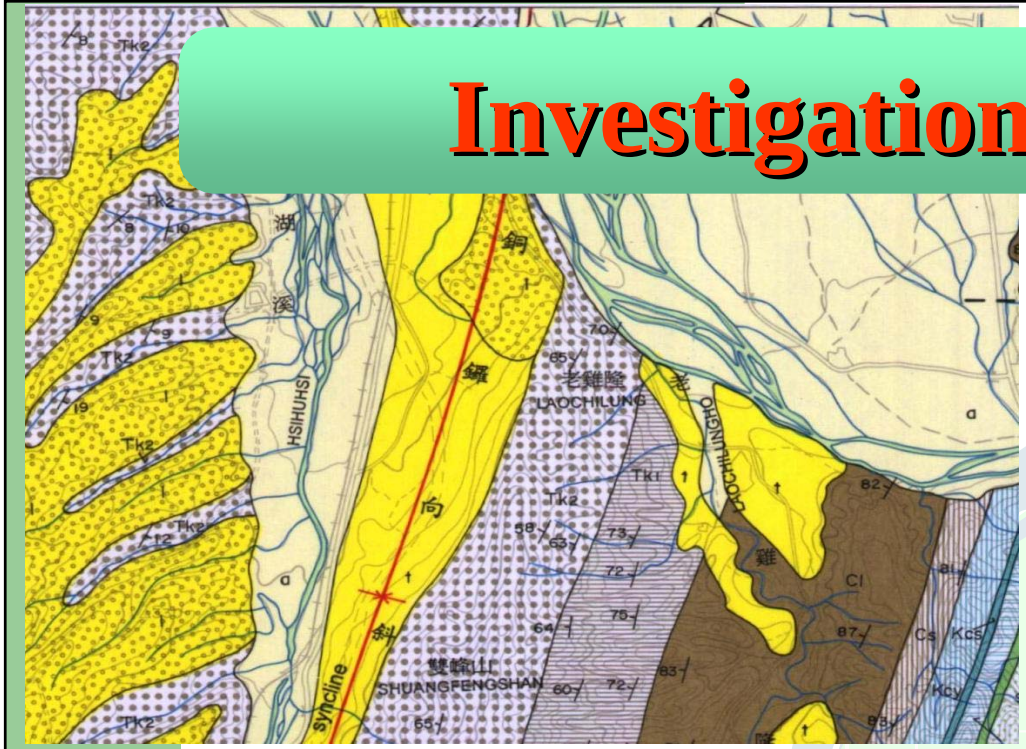
- Investigation of potential sites
- Establishment of the monitoring system
- Observation data acquisition and transfer
- Data analysis and interpretation
- Development and establish of the procedures of monitoring
- Evaluate the relationship between groundwater changes and earthquake occurrences: 1999 ChiChi Earthquake, Recent examples

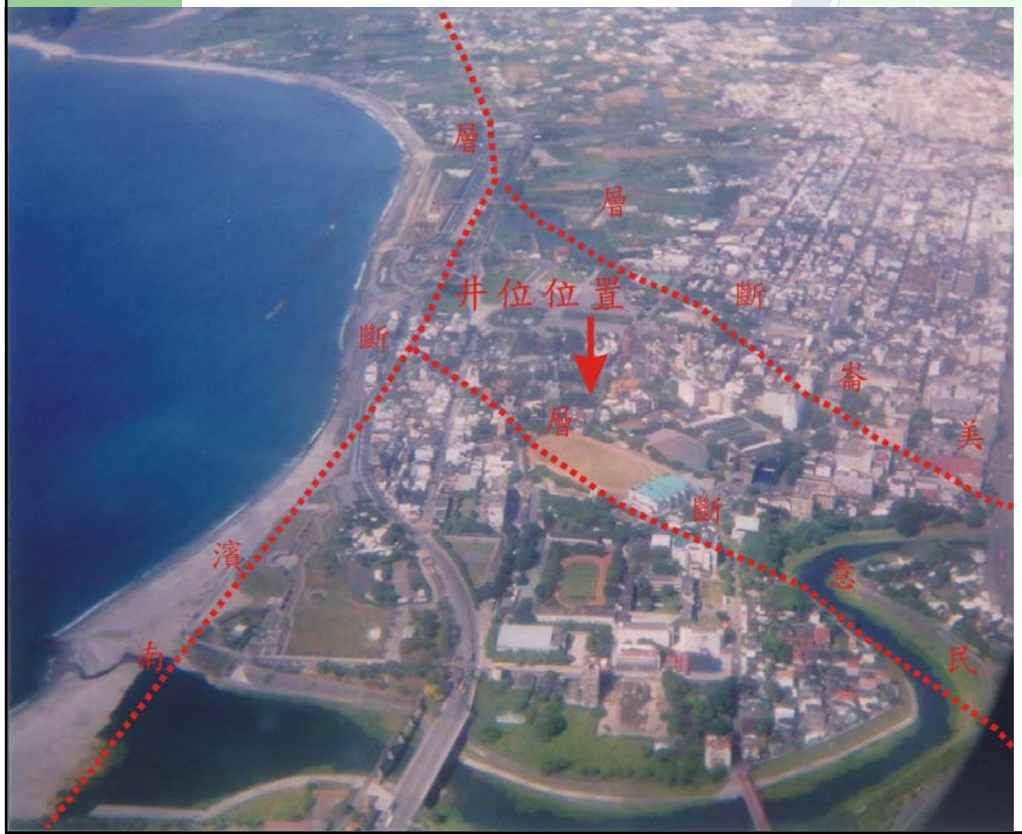
Criteria for Potential Site Selection

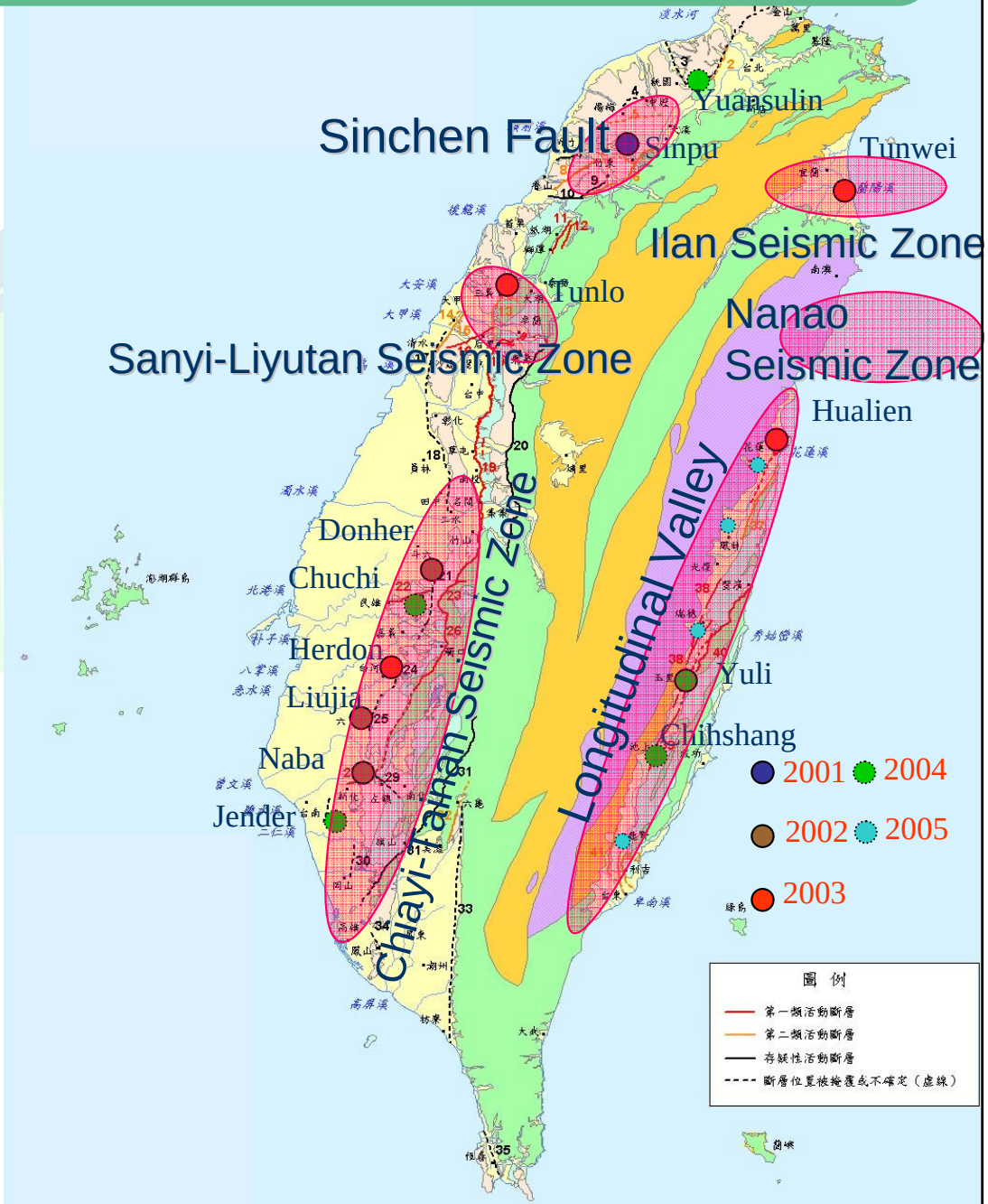
- Good Structural position
- Good confinement
- Highly strain sensitivity
- No artificial disturbance



Investigation of potential sites

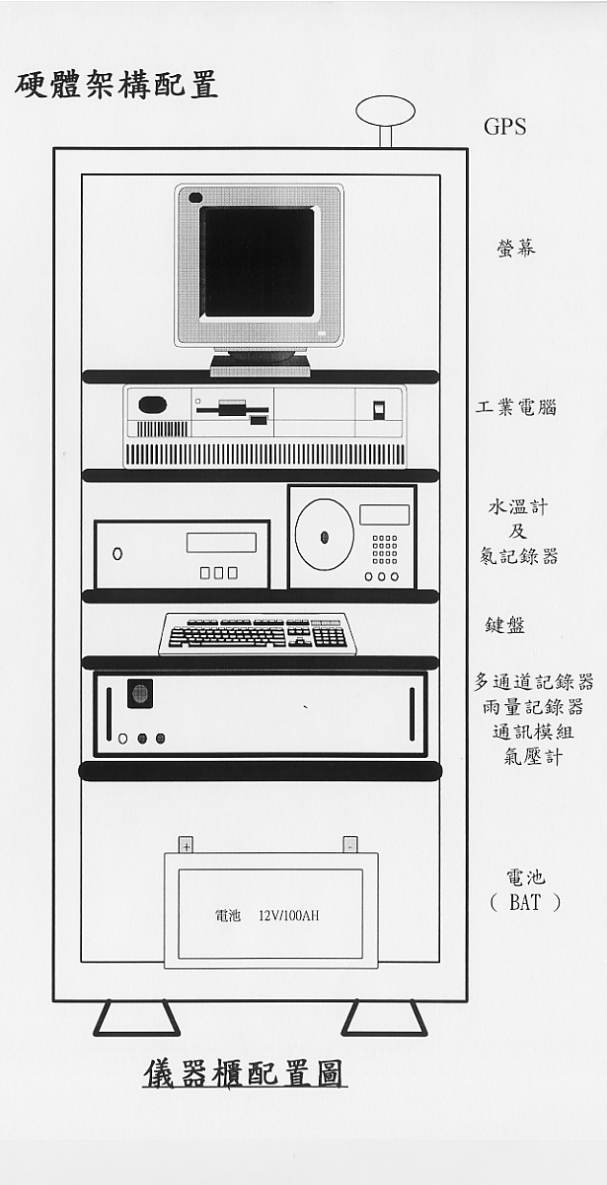






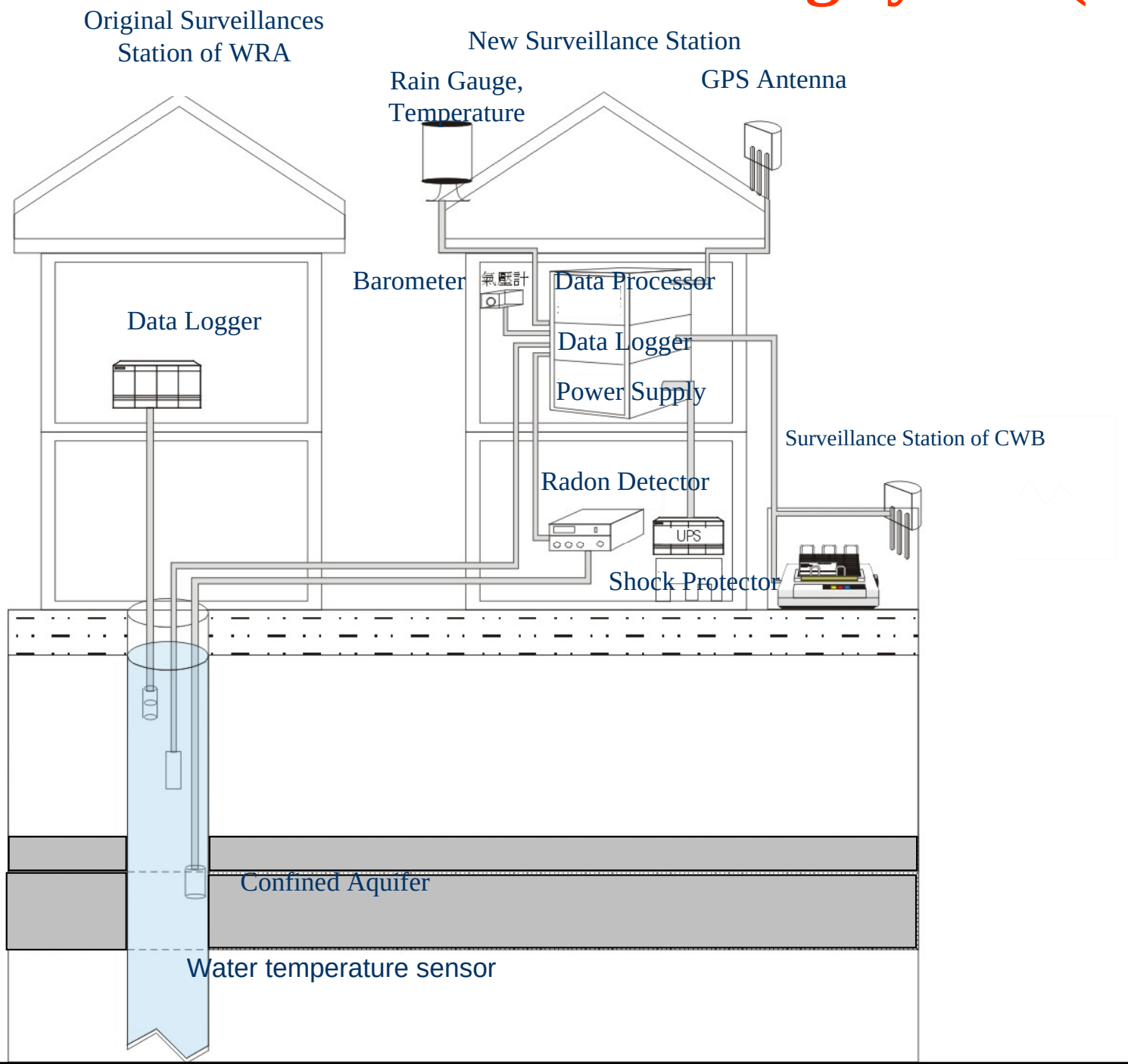
Establishment of the monitoring system(1/2)

Front Side

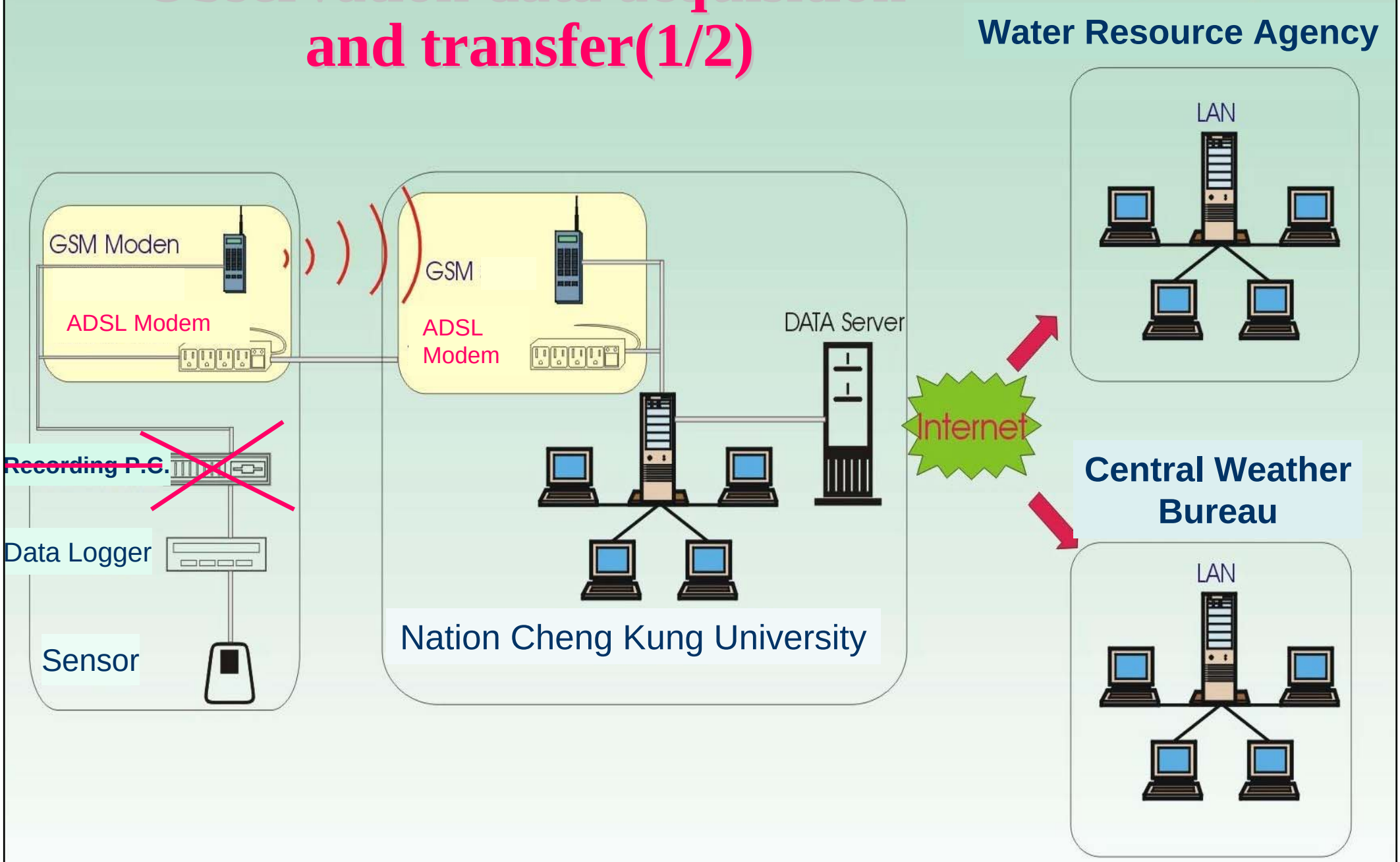


Rear Side

Establishment of the monitoring system(2/2)



Observation data acquisition and transfer(1/2)

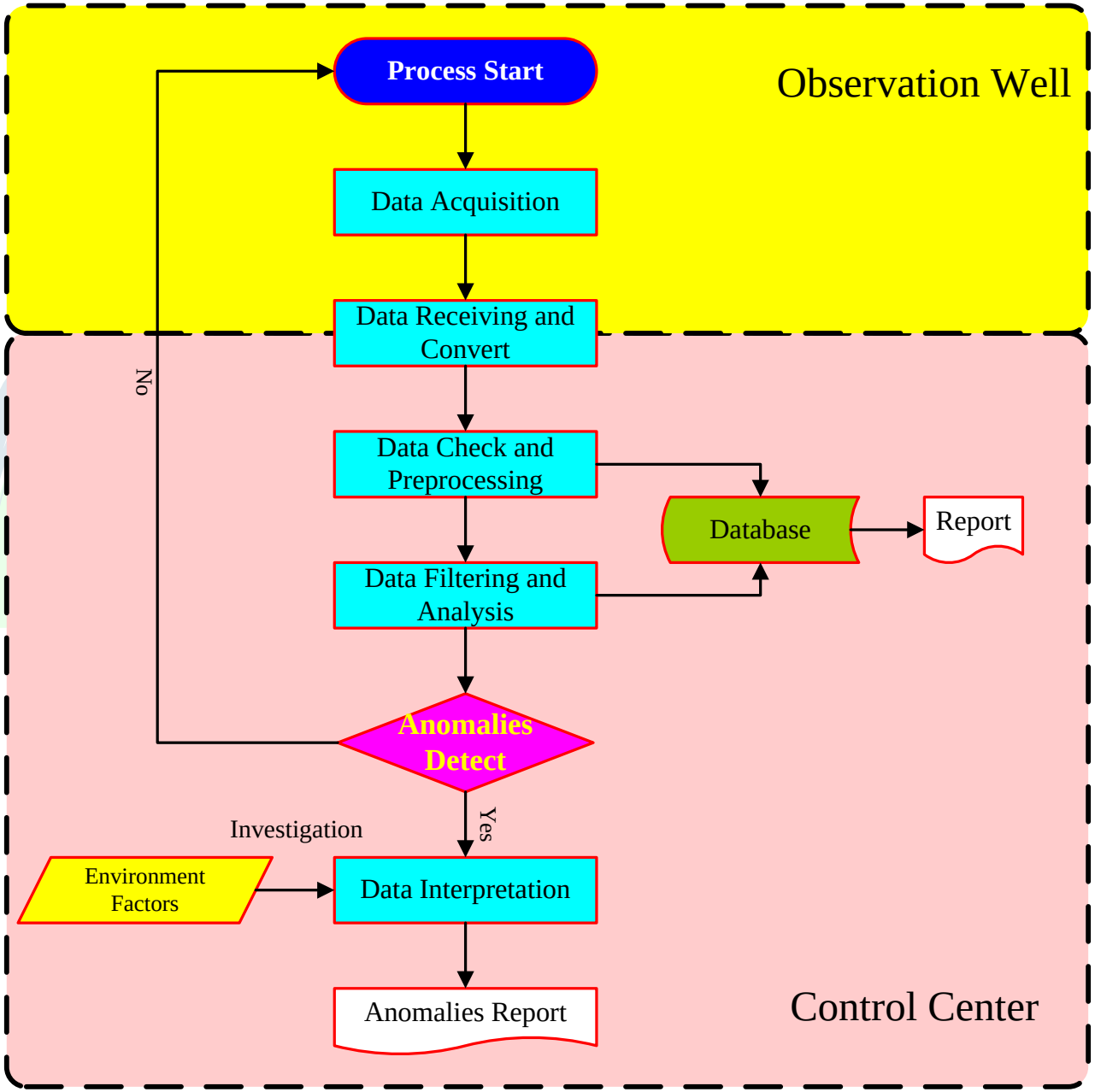


Observation Well → ADSL Internet → Monitoring Center → Internet → Government Agency

Development and establish of the procedures of monitoring

- Instruments Condition Check
- Data Receive
- Data Preprocess
- Data Filtering
- Anomalies Detect
- Data Interpretation
- Report Printing

- Automation Processing
  - More Wells
  - Highly Sampling Rate

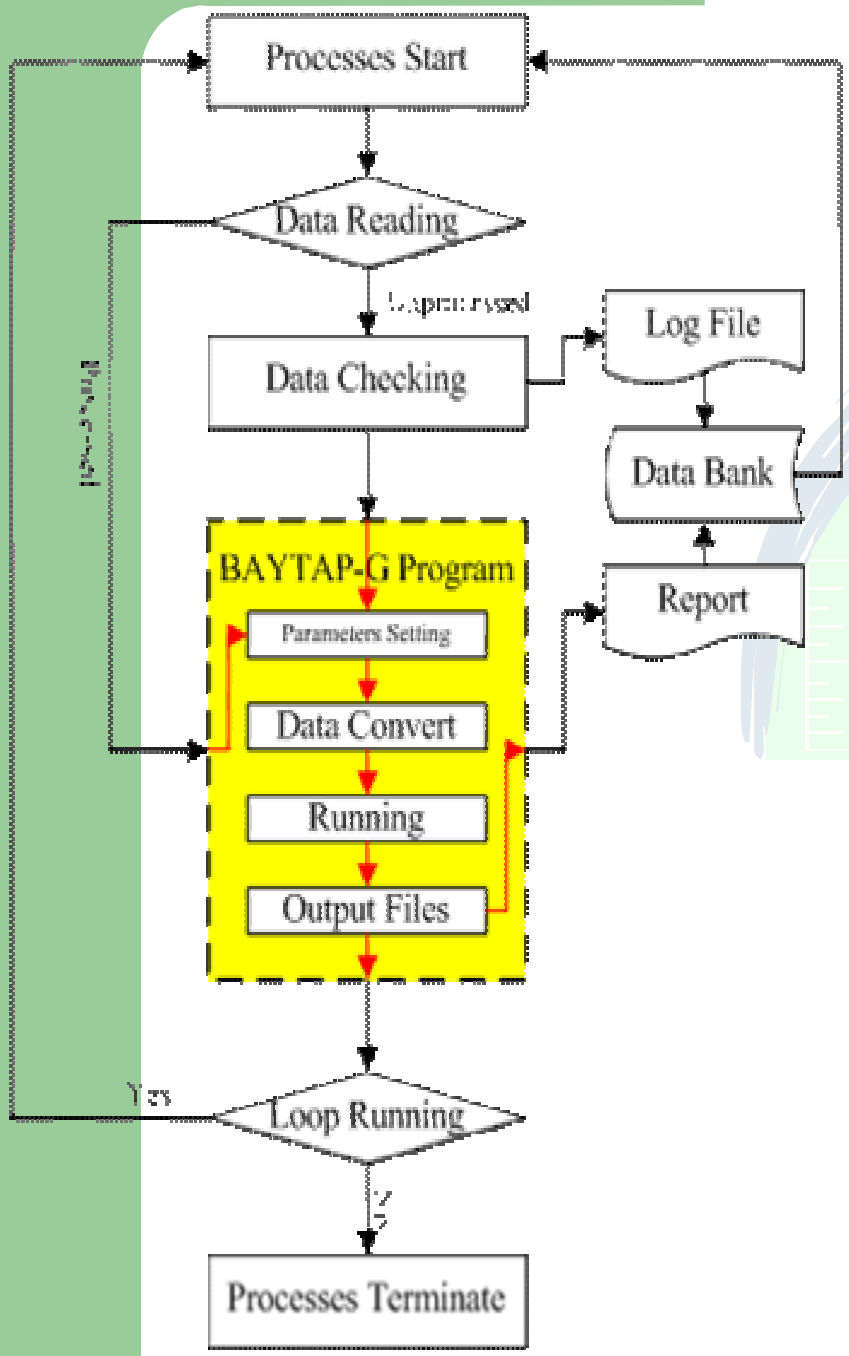


Data Receiving and Instruments Management

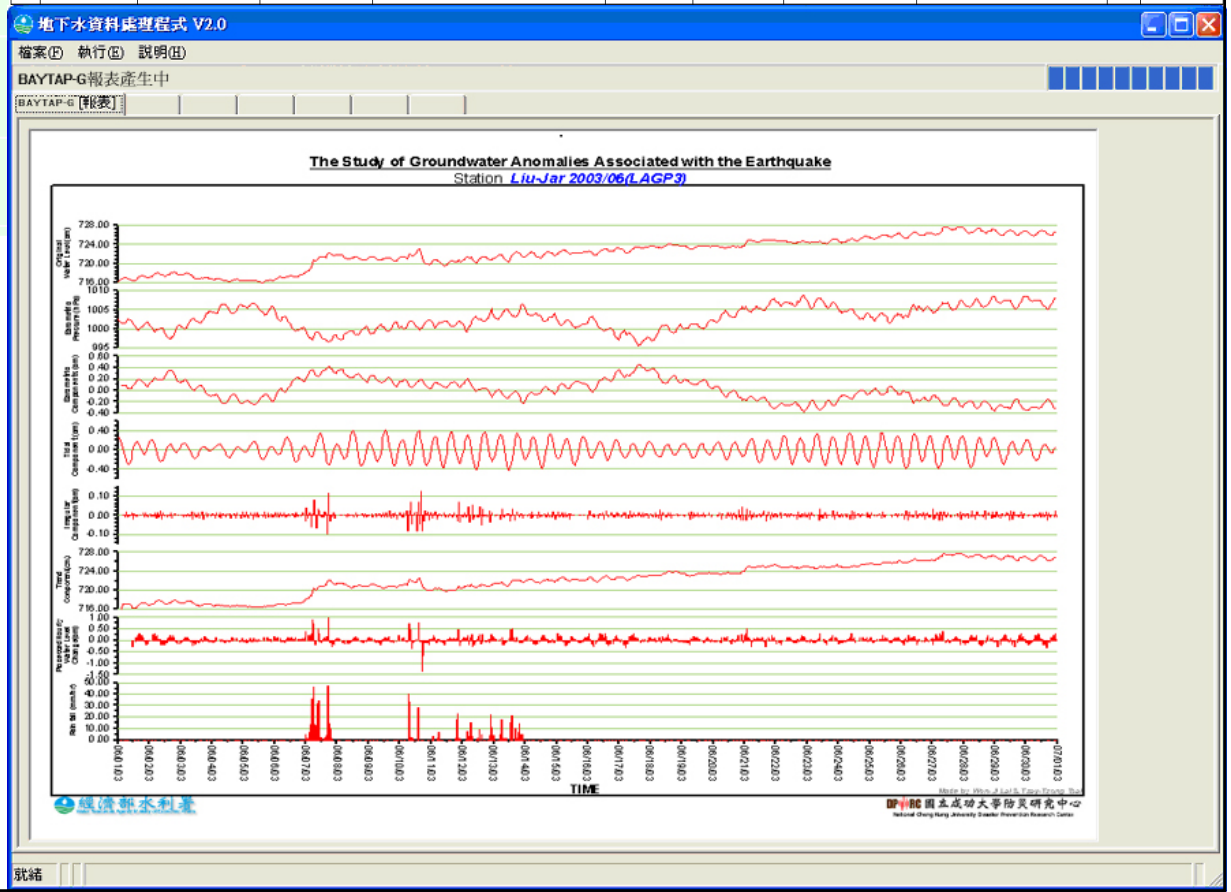
- Instruments Condition Check
- Data Receive
- Data Preprocess
- Data Filtering
- Anomalies Detect
- Data Interpretation
- Report Preparation

- Automation Processing
  - More Wells
  - Highly Sampling Rate

Observation Data Filtering

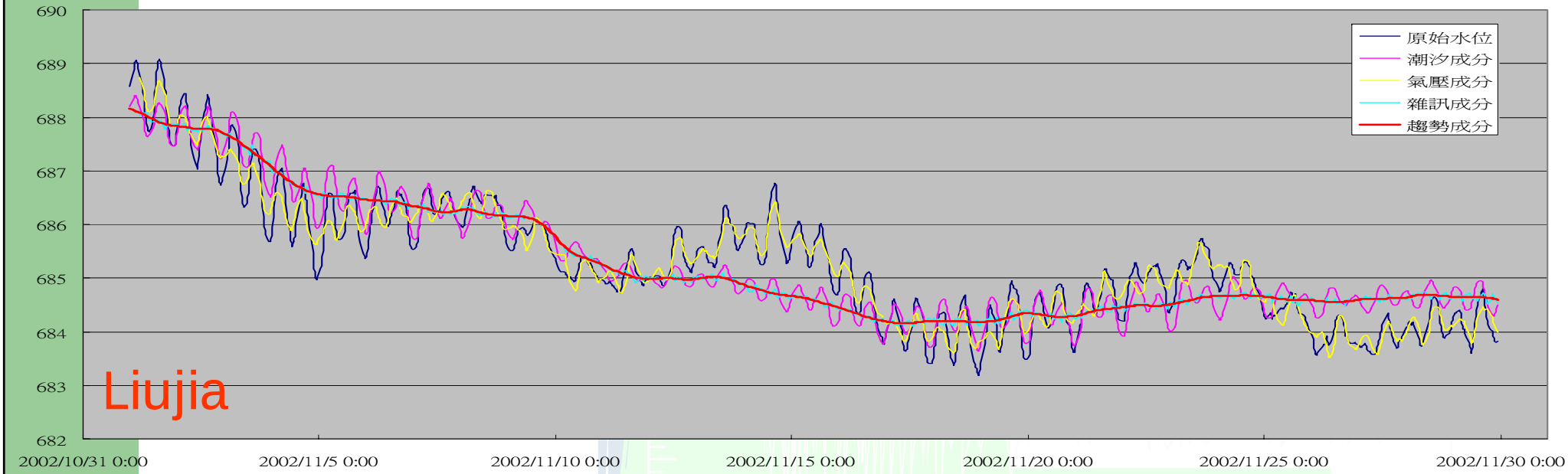


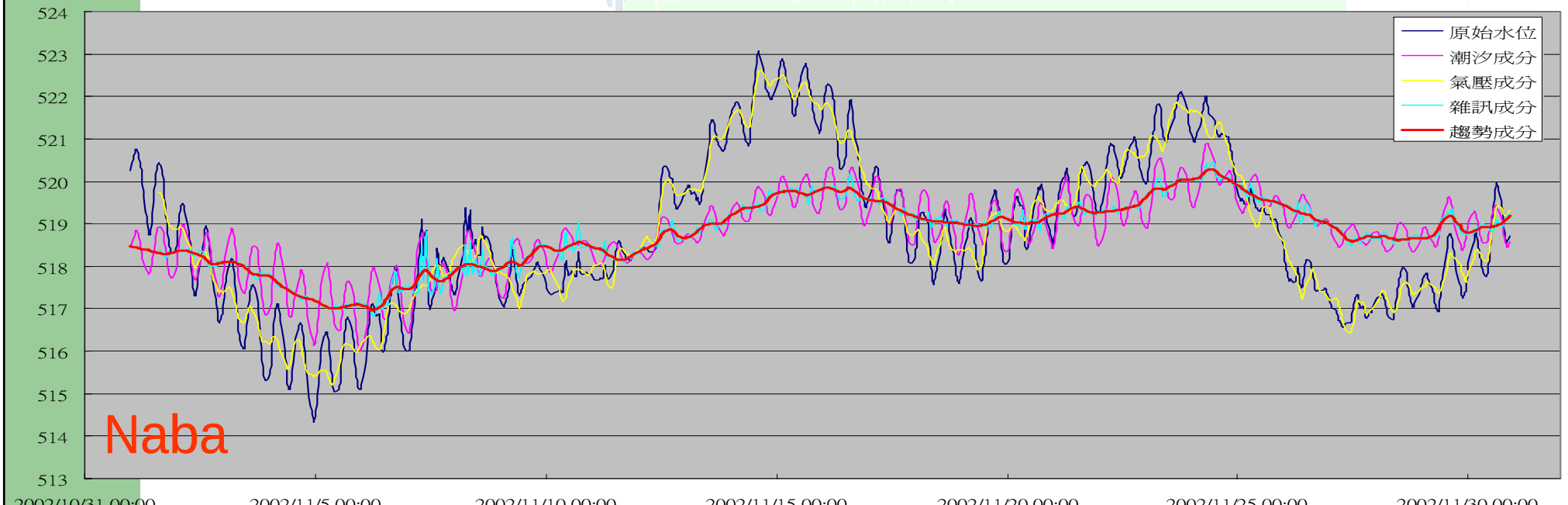
rec	time	Original Water Level	Barometic Pressure	Barometric Components(ASSOCIATED)	Earth Tide	Irregular Signal	TREND+IRREGULAR	Water Level Change[H(n+1)-Hn]	Rain	SMOOTH
1	2003/6/1 00:00	716.23	1002.44		0.238347337					715.7338746
2	2003/6/1 01:00	716.29	1002.06		0.255209505				0	715.9886039
3	2003/6/1 02:00	716.56	1001.6		0.216750572				0	716.2433332
4	2003/6/1 03:00	716.71	1001.43	8.33E-02	0.130308996	-1.67E-03	7.16E+02		0	716.4980625
5	2003/6/1 04:00	716.85	1001.49	8.55E-02	0.012957284	-1.29E-03	7.17E+02		0	716.7527918
6	2003/6/1 05:00	716.95	1001.45	8.70E-02	-0.112410902	-5.45E-03	7.17E+02		0	716.9808133
7	2003/6/1 06:00	717.01	1001.7	7.85E-02	-0.2214641	1.81E-02	7.17E+02		0	717.1348534
8	2003/6/1 07:00	716.82	1002.48	4.13E-02	-0.292815514	-9.00E-03	7.17E+02		0	717.0805039
9	2003/6/1 08:00	716.68	1002.53	2.18E-02	-0.312097654	-2.35E-03	7.17E+02		0	716.9726535
10	2003/6/1 09:00	716.58	1002.33	2.86E-02	-0.27524188	4.37E-03	7.17E+02		0	716.8222372
11	2003/6/1 10:00	716.46	1002.12	0.039239917	-0.19014942	0.008383986	716.6109095		0	716.6025255
12	2003/6/1 11:00	716.31	1002.08	0.045305648	-0.075840725	-0.016135671	716.3405351	-0.270374425	0	716.3566707
13	2003/6/1 12:00	716.39	1001.29	0.078313804	0.041401247	0.008316068	716.2702849	-0.070250129	0	716.2619689
14	2003/6/1 13:00	716.49	1000.69	0.121086221	0.134428225	-0.003059632	716.2344856	-0.035799395	0	716.2375452
15	2003/6/1 14:00	716.67	1000.14	0.156245083	0.182584429	-0.004411521	716.3311705	0.096684935	0	716.335582
16	2003/6/1 15:00	716.92	999.79	0.184776188	0.177723283	-0.001807069	716.5575005	0.226330041	0	716.5593076
17	2003/6/1 16:00	717.17	999.71	0.19735414	0.126708012	0.004571985	716.8459378	0.288437317	0	716.8413659
18	2003/6/1 17:00	717.32	1000.08	0.185743297	0.049288531	-0.000519434	717.0849682	0.239030325	0	717.0854876



Data analysis and interpretation(1/2)

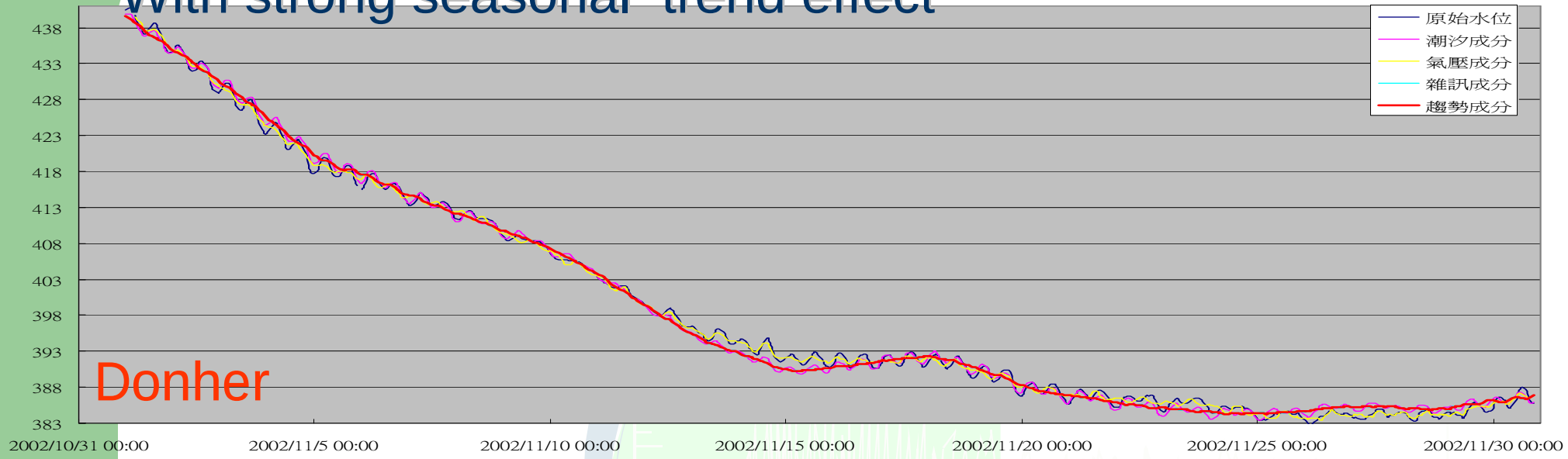
With weakly seasonal trend effect

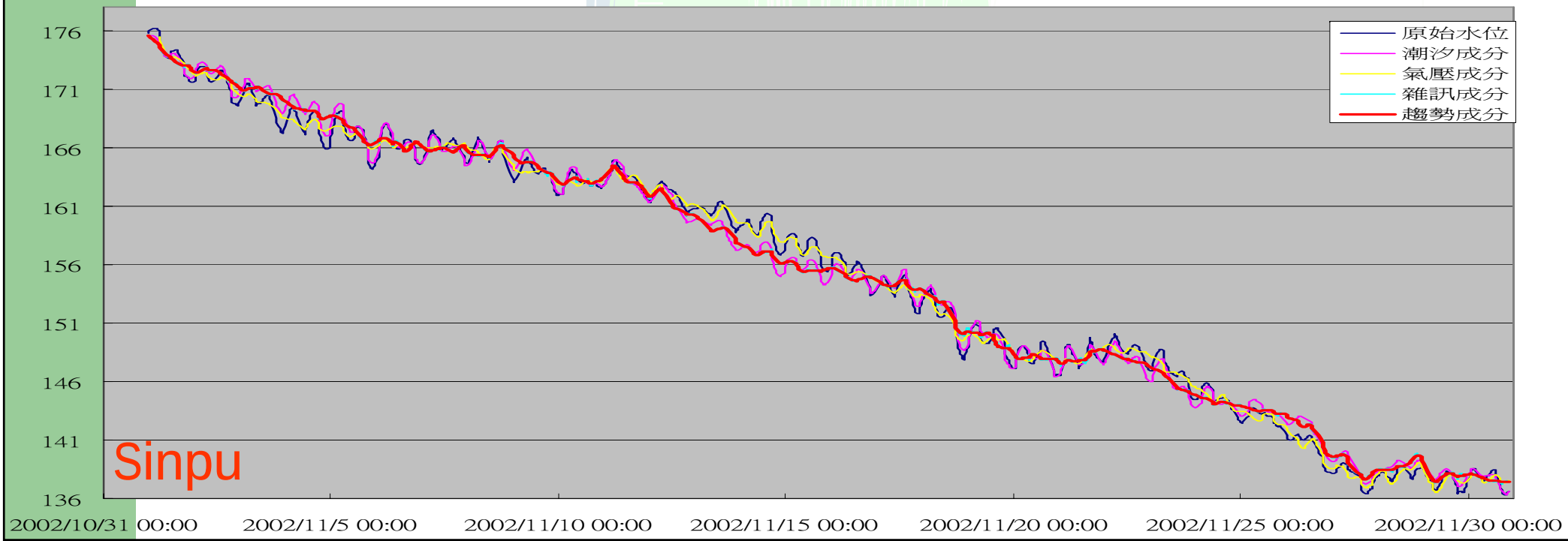




Data analysis and interpretation(2/2)

With strong seasonal trend effect

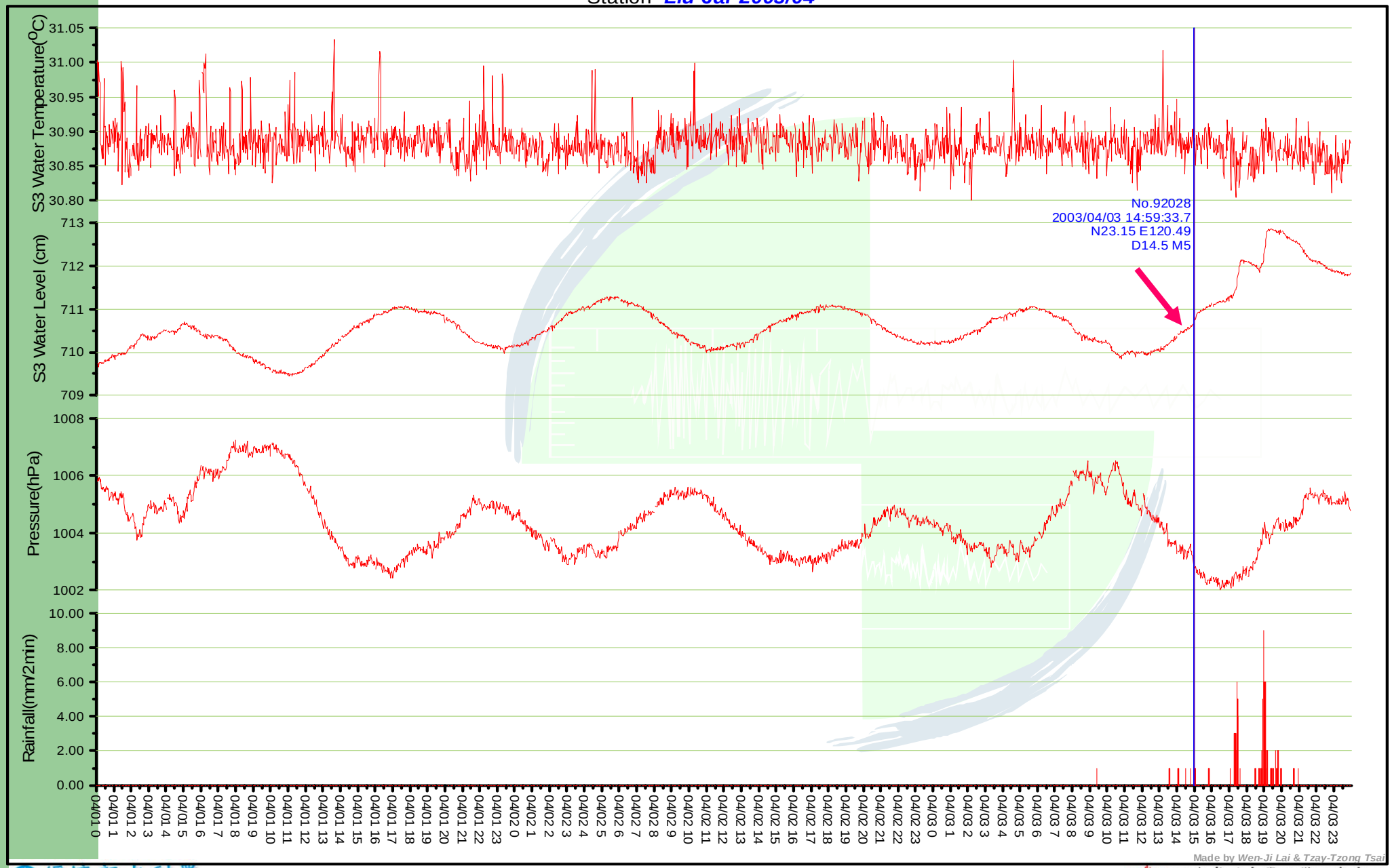




Apr. 3rd, 2003 Eq. Coseismic Response

The Study of Groundwater Anomalies Associated with the Earthquake

Station ***Liu-Jar 2003/04***

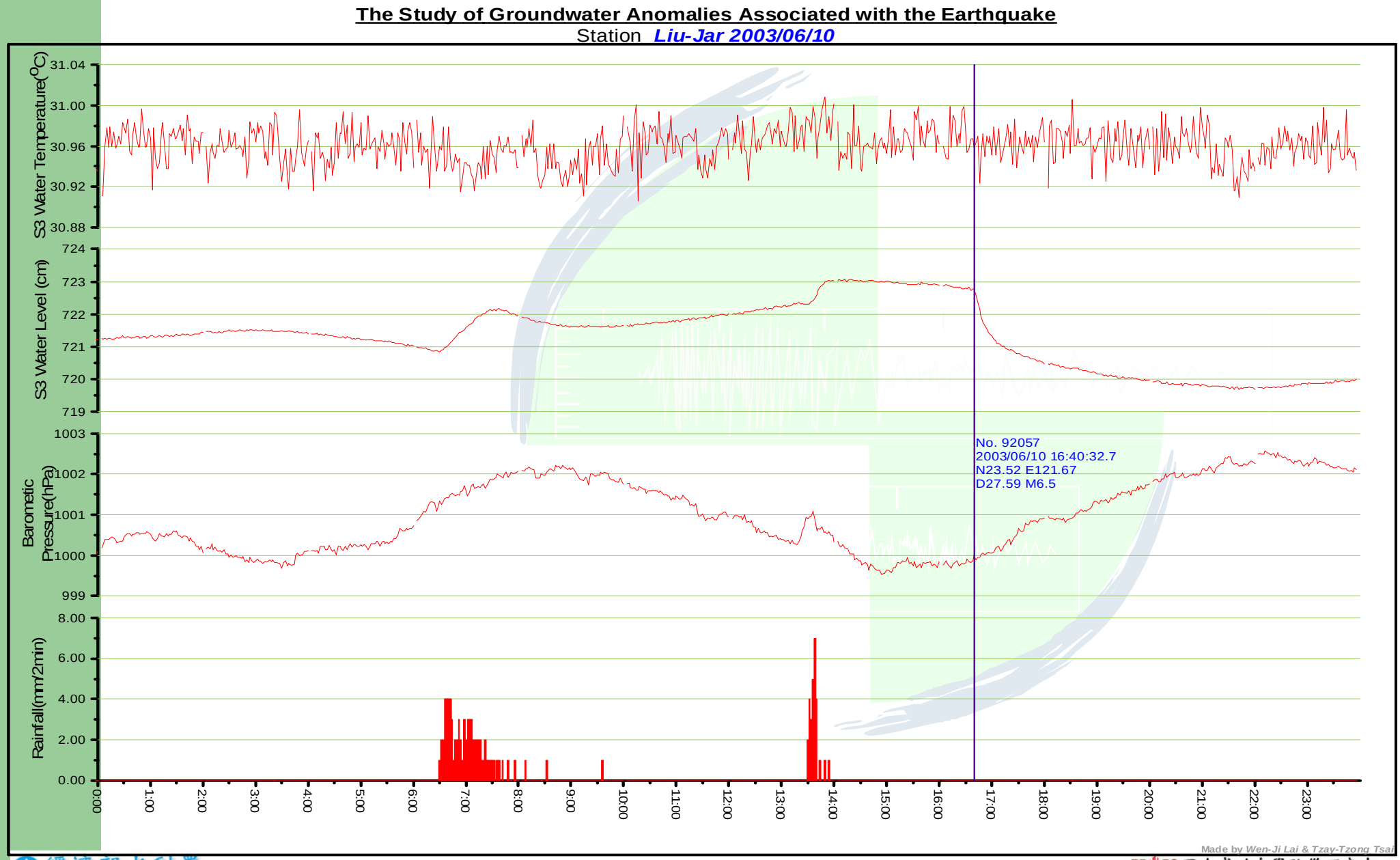


Made by *Wen-Ji Lai & Tzay-Tzong Tsai*

經濟部水利署 Water Resources Agency, Ministry of Economic Affairs

DPRC 國立成功大學防災研究中心 National Cheng Kung University Disaster Prevention Research Center

Jun. 10th, 2003 Eq. Coseismic Response



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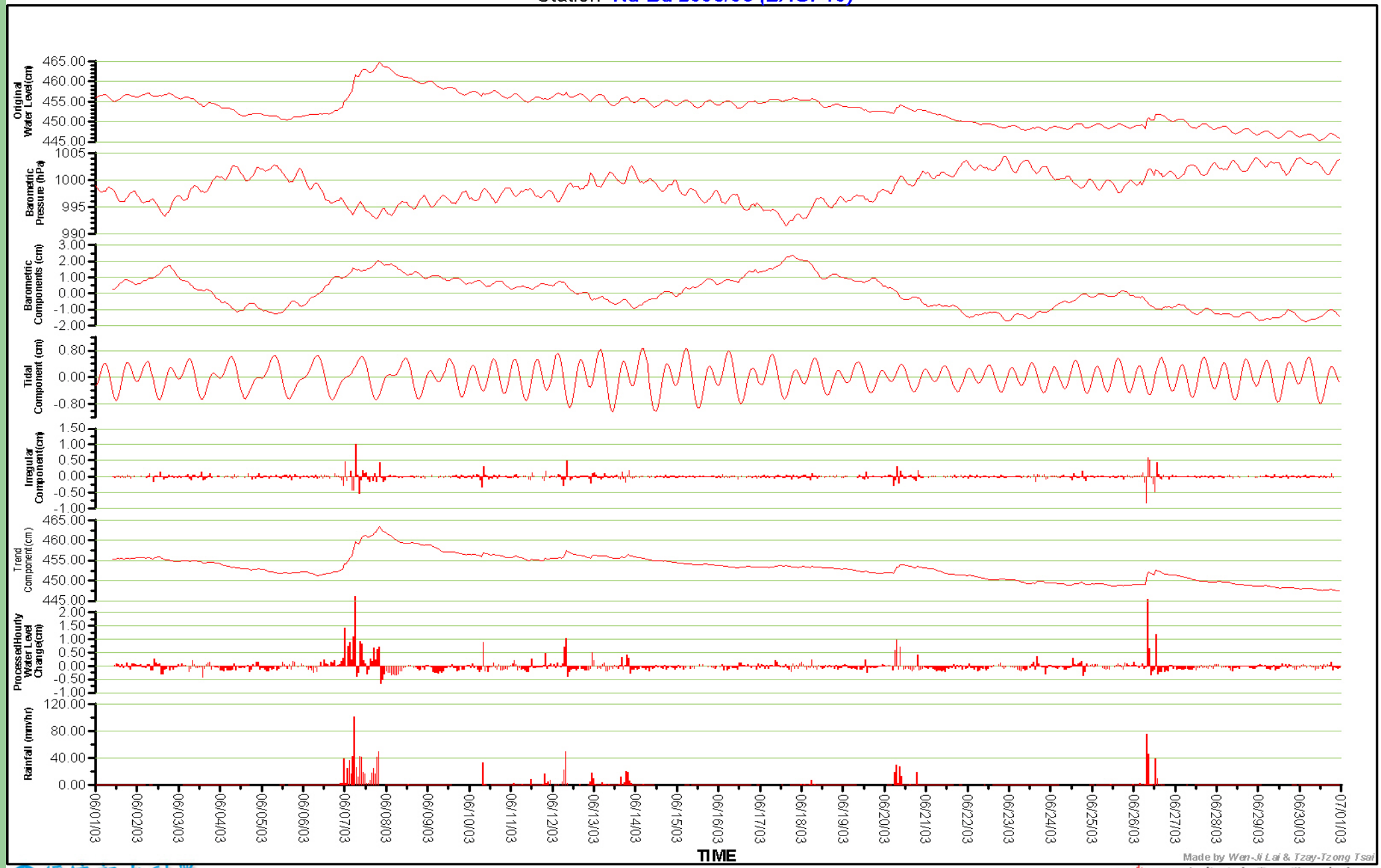
經濟部水利署 Water Resources Agency, Ministry of Economic Affairs

DPRC 國立成功大學防災研究中心 National Cheng Kung University Disaster Prevention Research Center

Rainfall Effect

The Study of Groundwater Anomalies Associated with the Earthquake

Station ***Na-Ba 2003/06 (LAGP10)***

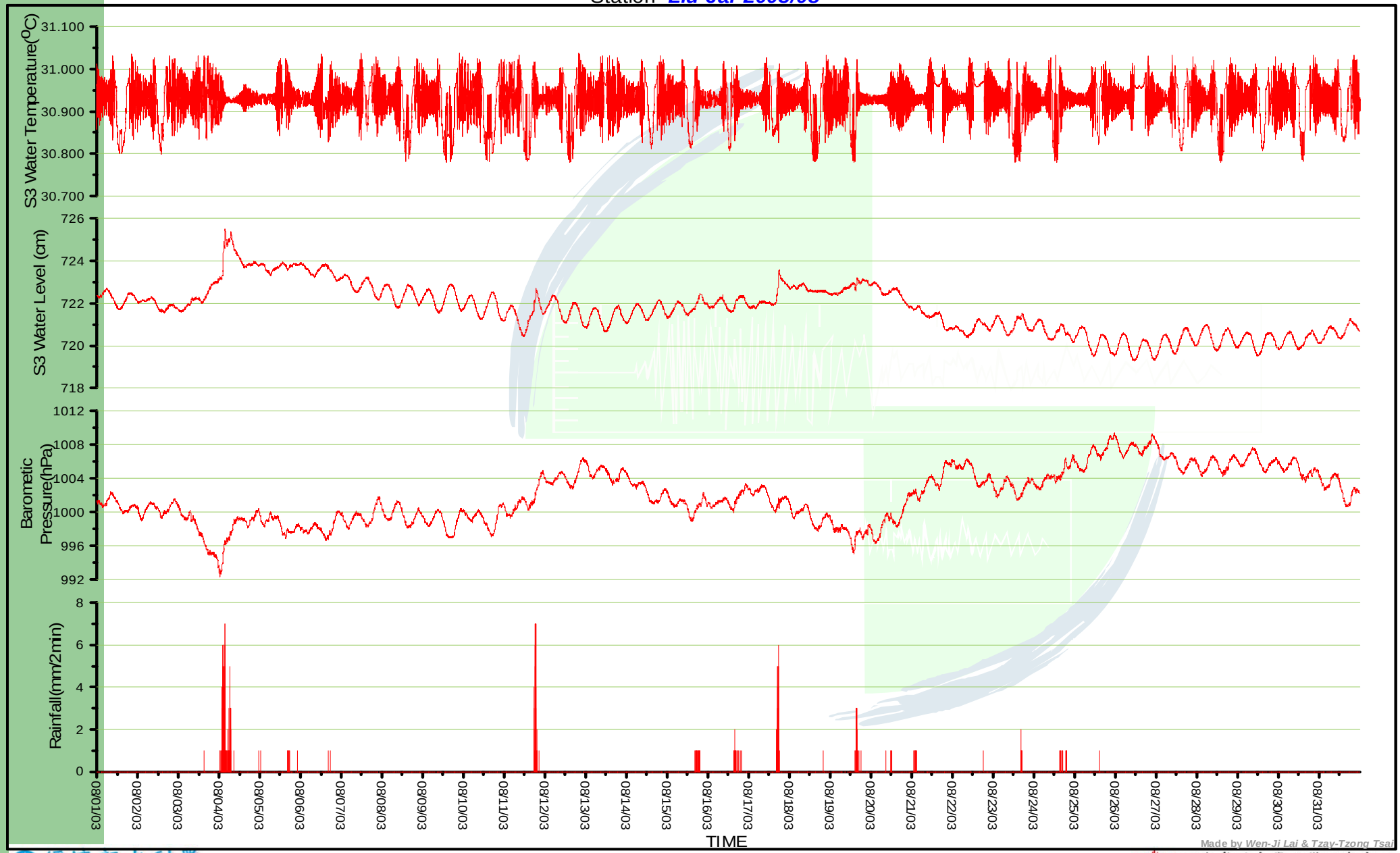


Made by Wen-Ji Lai & Tzay-Tzong Tsai

Fluctuation of the water temperature(1/2)

The Study of Groundwater Anomalies Associated with the Earthquake

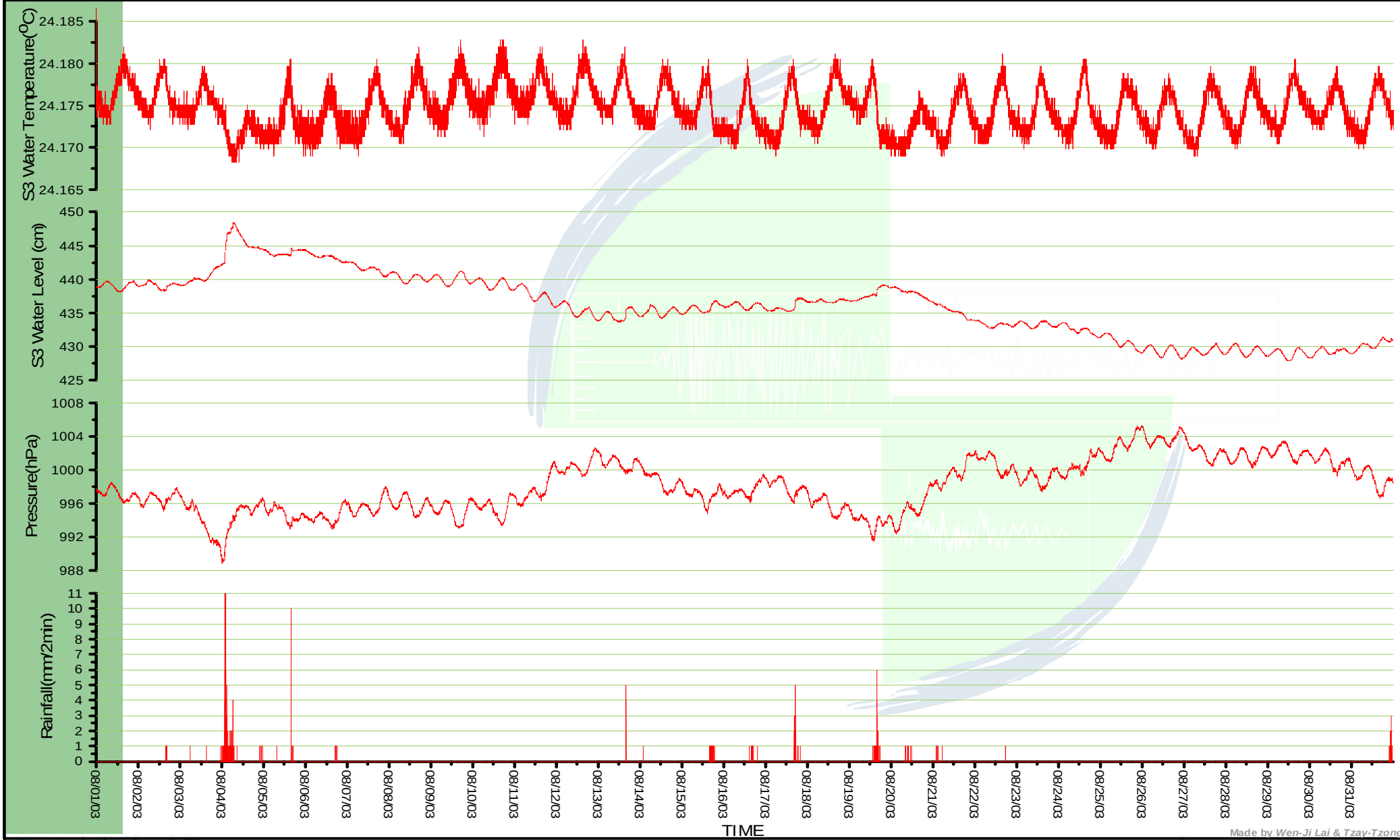
Station *Liu-Jar 2003/08*



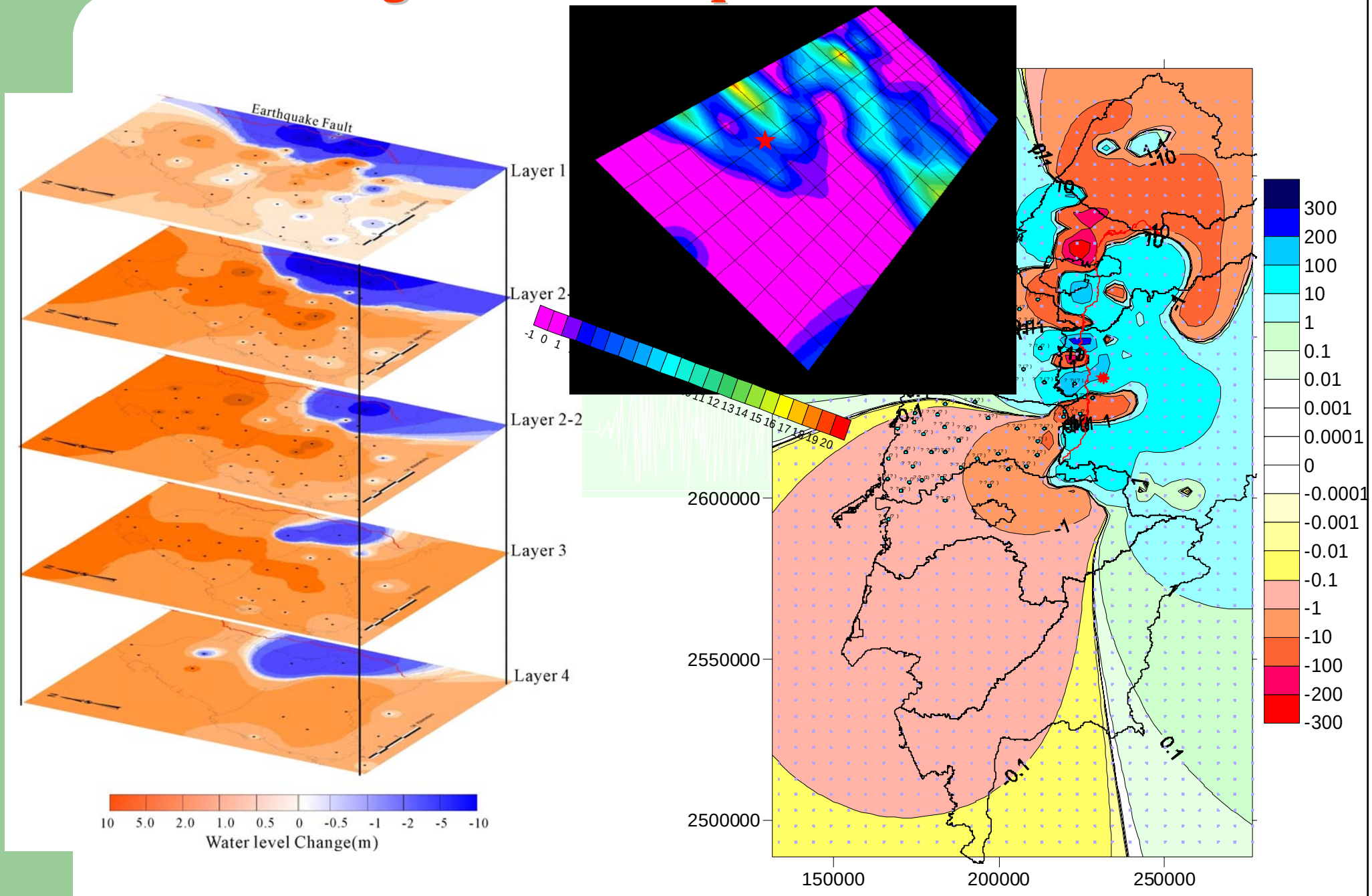
Fluctuation of the water temperature(2/2)

The Study of Groundwater Anomalies Associated with the Earthquake

Station ***Na-Ba 2003/08***



Evaluate the relationship between groundwater changes and earthquake occurrences



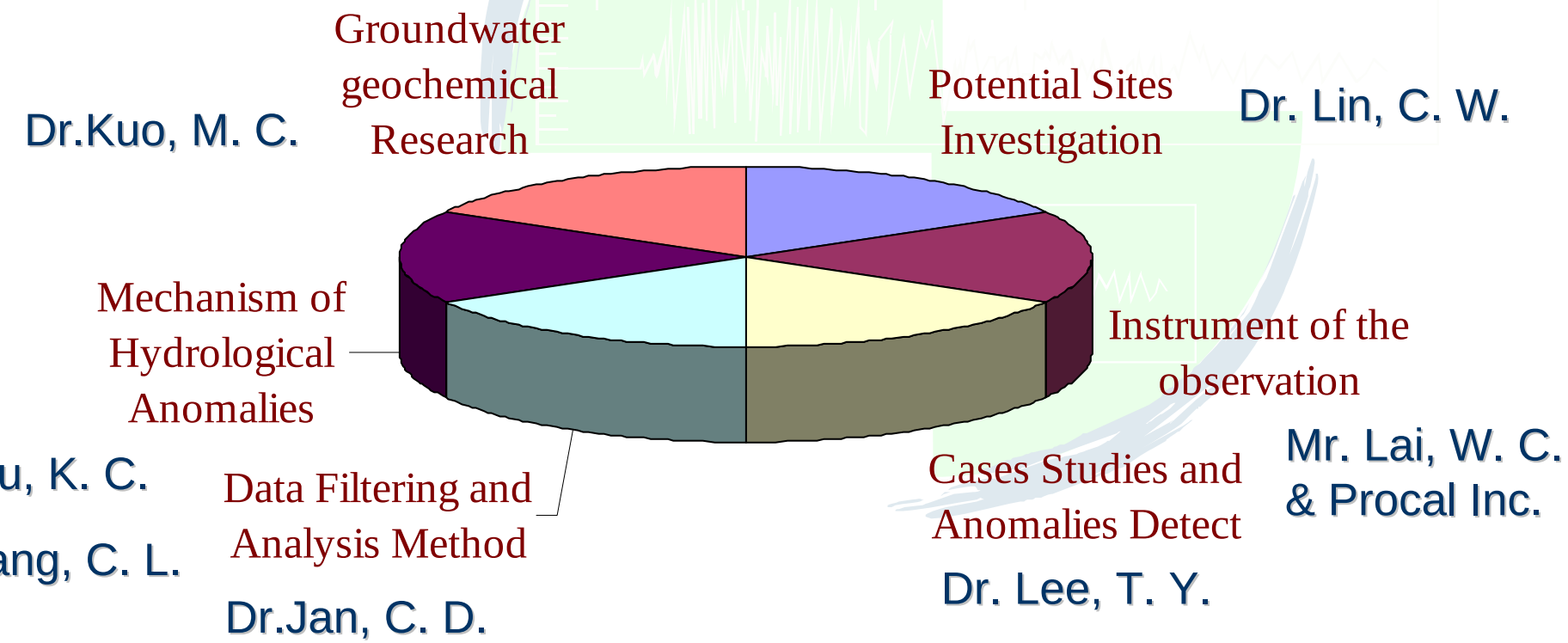
Database of the Coseismic Groundwater Level Changes of the 1999 Taiwan ChiChi Earthquake

- Coseismic Responses of 368 wells around Taiwan
  - Well Parameters: location, geological setting, height, depth, screened depth
  - Aquifer Parameters : Thickness, Hydraulic Conductivity, Hydrogeological setting
  - Water Level Records: Time series of the water level changes (Original record sheets, and digitized data)
  - Seismic Parameters : Interpolate intensity, ground motion 3 components
  - Earthquake Fault Parameters: Distances from earthquake fault to well, distances from epicenter from well, surface rupture
  - Crust deformation Parameters: Strain derived from fault slip data, GPS survey in vertical and horizontal

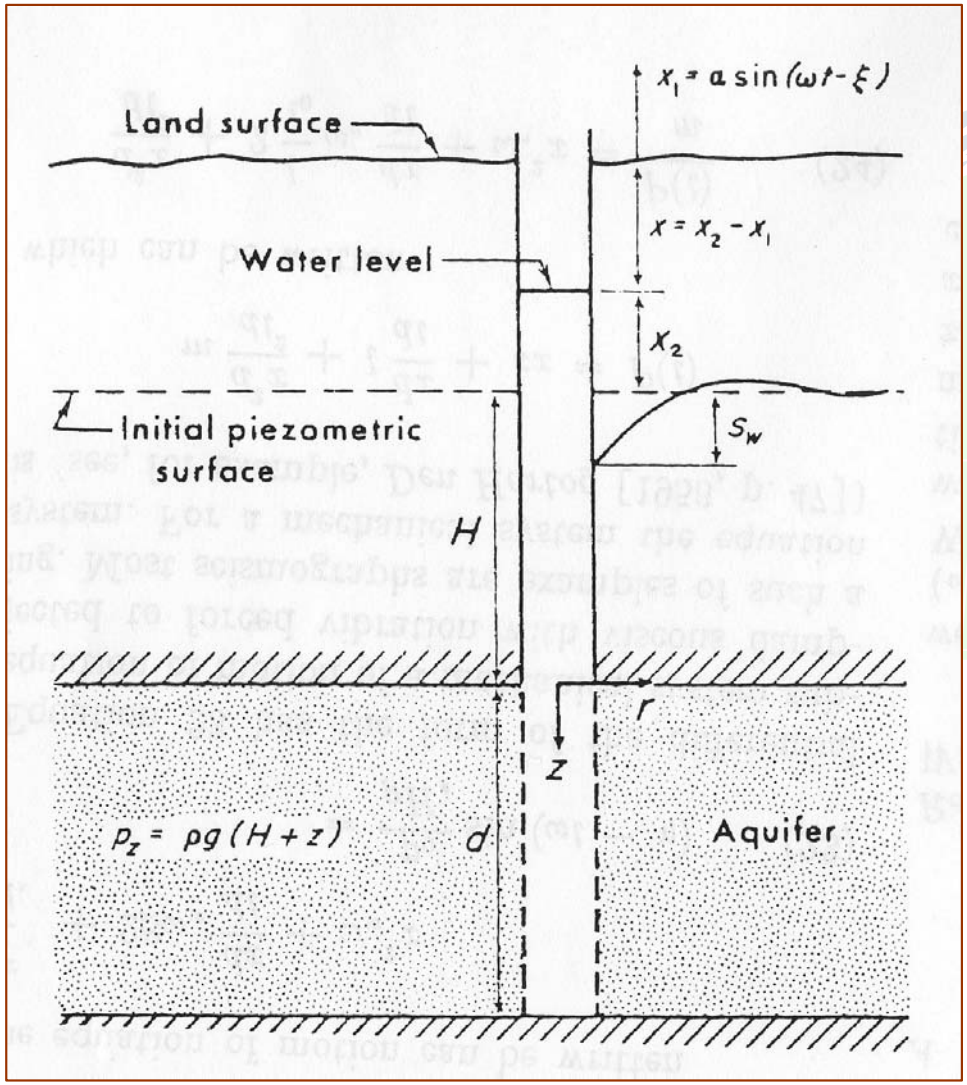
號	井名	目前高程(	震央距	震度	垂直加速	東西向加速	南北向加速	水文地質分	斷層距	GPS_Ver	GPS_Hor	coseismic	濾管起點	濾管終點
7010111	國 聖(一)	21.25	31435	5	118	154	143	扇央	13571	-0.063	0.549	0.38	8	30
7010121	國 聖(二)	21.35	31435	5	118	154	143	扇央	13571	-0.063	0.549	5.21	120	126
7010131	國 聖(三)	21.86	31435	5	118	154	143	扇央	13571	-0.063	0.549	1.05	185	197
7010211	東 芳(一)	10.9	32740	5	100	144	136	扇央	18147	-0.055	0.405	3.38	101	125
7010221	東 芳(二)	10.9	32740	5	100	144	136	扇央	18147	-0.055	0.405	3.73	162	174
7020111	洛 津(一)	4.55	39235	4.1	68	83	72	扇尾	26816	-0.058	0.276	0.62	25	34
7020121	洛 津(二)	4.46	39235	4.1	68	83	72	扇尾	26816	-0.058	0.276	5.22	108	120
7020131	洛 津(三)	4.41	39235	4.1	68	83	72	扇尾	26816	-0.058	0.276	3.47	180	198
7040111	線 西(一)	5.39	41574	4.9	89	124	114	扇尾	24774	-0.064	0.431	0.23	10	28
7040121	線 西(二)	5.26	41574	4.9	89	124	114	扇尾	24774	-0.064	0.431	4.2	55	71
7040131	線 西(三)	5.28	41574	4.9	89	124	114	扇尾	24774	-0.064	0.431	4.28	105	117
7040141	線 西(四)	5.39	41574	4.9	89	124	114	扇尾	24774	-0.064	0.431	2.75	158	194
7050111	全 興(一)	6.52	41920	5	90	160	138	扇尾	21983	-0.063	0.574	0.19	8	17
7050121	全 興(二)	6.42	41920	5	90	160	138	扇尾	21983	-0.063	0.574	4.66	102	120
7050131	全 興(三)	6.5	41920	5	90	160	138	扇尾	21983	-0.063	0.574	3.86	183	192
7050141	全 興(四)	6.41	41920	5	90	160	138	扇尾	21983	-0.063	0.574	2.7	240	252
7060111	文 昌(一)	7.63	37790	4.8	93	111	92	扇尾	27449	-0.044	0.239	0.13	5	17
7060121	文 昌(二)	7.63	37790	4.8	93	111	92	扇尾	27449	-0.044	0.239	2.76	48	60
7060131	文 昌(三)	7.63	37790	4.8	93	111	92	扇尾	27449	-0.044	0.239	4.09	108	120
7060141	文 昌(四)	7.64	37790	4.8	93	111	92	扇尾	27449	-0.044	0.239	3.38	186	204
7080111	花 壇(一)	15.03	28034	5	95	153	139	扇央	15207	-0.068	0.455	1.25	8	20
7080121	花 壇(二)	15.51	28034	5	95	153	139	扇央	15207	-0.068	0.455	1.31	44	65
7080131	花 壇(三)	15.06	28034	5	95	153	139	扇央	15207	-0.068	0.455	3.98	112	130
7080141	花 壇(四)	15.83	28034	5	95	153	139	扇央	15207	-0.068	0.455	-0.26	264	294
7100111	員 林(一)	26.84	20836	5.1	121	188	190	扇央	11453	-0.109	0.532	6.55	51	69
7100121	員 林(二)	26.73	20836	5.1	121	188	190	扇央	11453	-0.109	0.532	6.46	91	121
7100131	員 林(三)	26.73	20836	5.1	121	188	190	扇央	11453	-0.109	0.532	4.12	134	140
7100141	員 林(四)	26.74	20836	5.1	121	188	190	扇央	11453	-0.109	0.532	1.2	180	198
7110111	溪湖(一)	18.92	29837	4.9	81	100	116	扇央	21189	-0.155	0.304	4.17	57	69
7110121	溪 湖(二)	18.91	29837	4.9	81	100	116	扇央	21189	-0.155	0.304	4.76	91	103
7110131	溪 湖(三)	18.88	29837	4.9	81	100	116	扇央	21189	-0.155	0.304	5.15	176	224
7120111	田 中(一)	49.56	17512	5.1	125	191	143	扇頂	11909	-0.135	0.591	0.34	98	134
7120121	田 中(二)	49.68	17512	5.1	125	191	143	扇頂	11909	-0.135	0.591	-2.47	243	266
7140111	好 修(一)	10.82	34179	4.8	93	116	102	扇央	23526	-0.094	0.261	3.51	48	66
7140121	好 修(二)	10.79	34179	4.8	93	116	102	扇央	23526	-0.094	0.261	5.28	102	120

Other Approaches on the Groundwater Anomalies Associated with Earthquake

- Preparation for Long-Term Monitoring
- Planning for the Standard Procedures for detecting the Anomalies
- Research for theoretical support of observation results



Item 1: Construction of the Well-Aquifer System

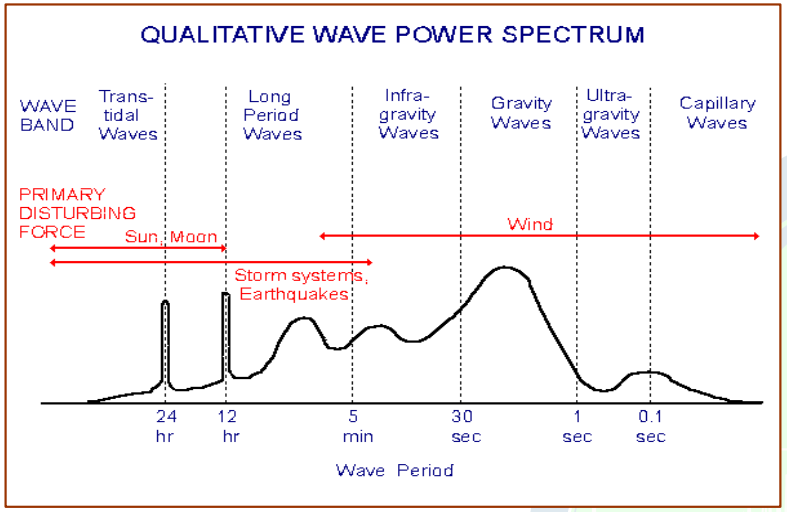


Well-Aquifer System (Cooper et al.,1965)

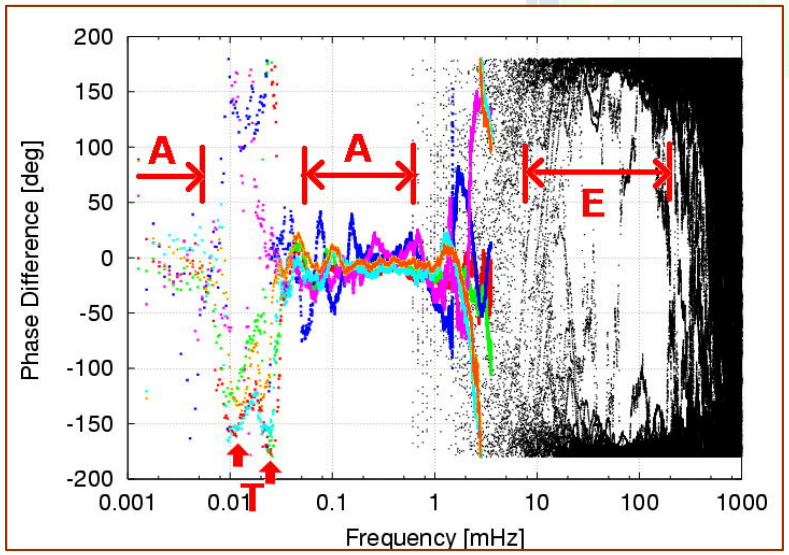
- The components of well-aquifer system
  - **Mass** (Water in well and parts of the water in aquifer)
  - **Restoring Force** (the difference between well and aquifer)
  - **Damping Force** (the friction along the well body and flow through the well and aquifer)
  - **Surface Tension Force** of the water in well

- The limitation of the observation made by Well Radius、Properties of Aquifer (Conductivity、Storativity)
- The amplify or attenuation factors for pressure between the well and aquifer

Item 2：Extracting the Differential Components of the Water Level fluctuations



The spectrum of different sources (long period)

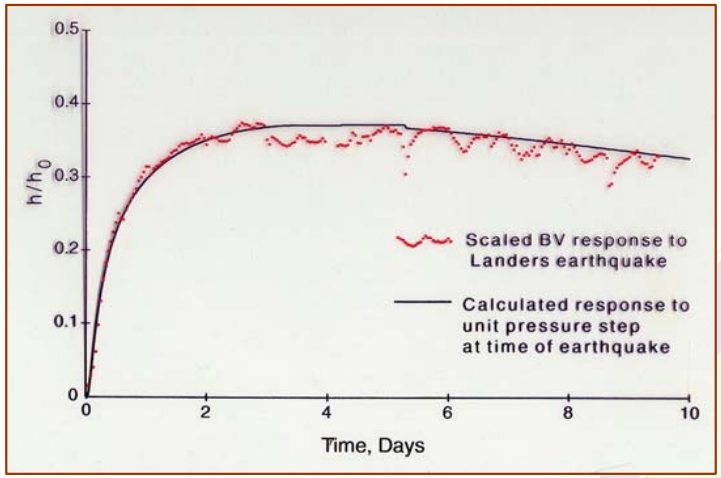


The spectrum of different sources (short period)

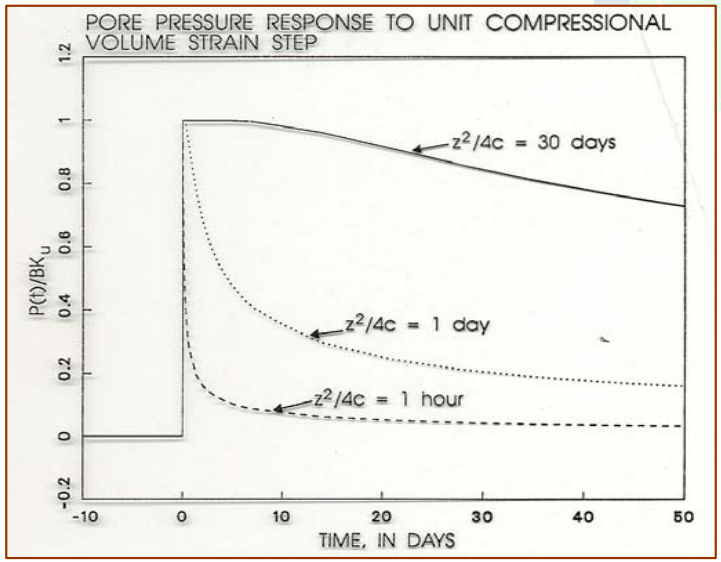
(Ishimura, 2002)

- Extract the different components of the water level fluctuations to estimate the response of the well-aquifer system to different sources.
- Using the characteristic responses to estimate the material parameters of well-aquifer system .
- Setup the system parameters and boundary condition prepare for testing the assumption.

Item 3：Derived the Poroelastic Properties of the Well-Aquifer System by Stochastic Methods



Curve Fitting

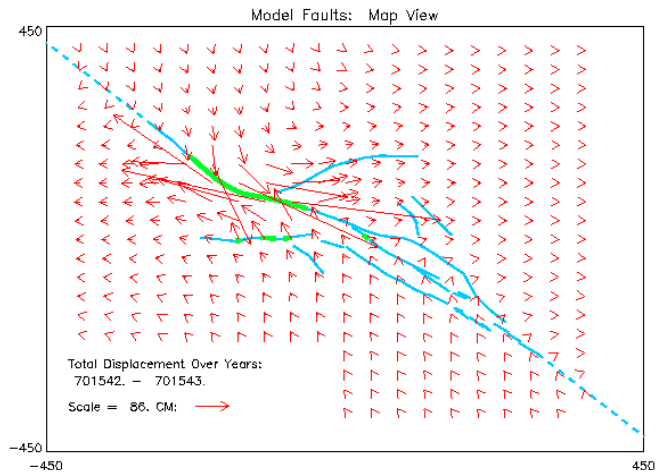


Type Curve Plotting

(Roeloffs, 1996)

- Using the stochastic and statistical methods to estimate the poroelastic parameters of the well-aquifer system

Item 4： Construction of the Faulting and Water Pressure Coupling Processes



Faulting and stress field distribution

(USGS , 2002)

- Precursory changes got no spatial relation with source region of earthquake.
- Difference between sensitive and non- sensitive wells
- Material properties of aquifer
- Characteristic of signal propagation
- Characteristic of faulting processes

- Resonance of well-aquifer system