經濟部

地下水水位之獨立成分分析

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WATER RESOURCES AGENCY

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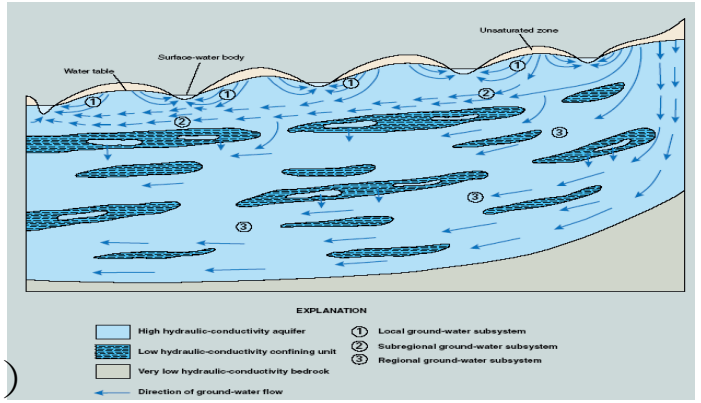
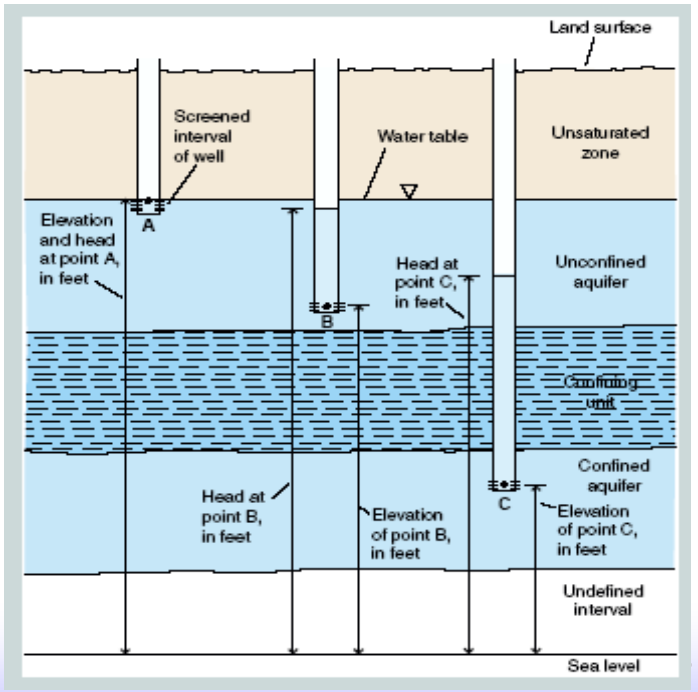
—簡報大綱—

- 前言
- 獨立成分分析(ICA)
- ICA於地下水水位分析上之應用
- 結語

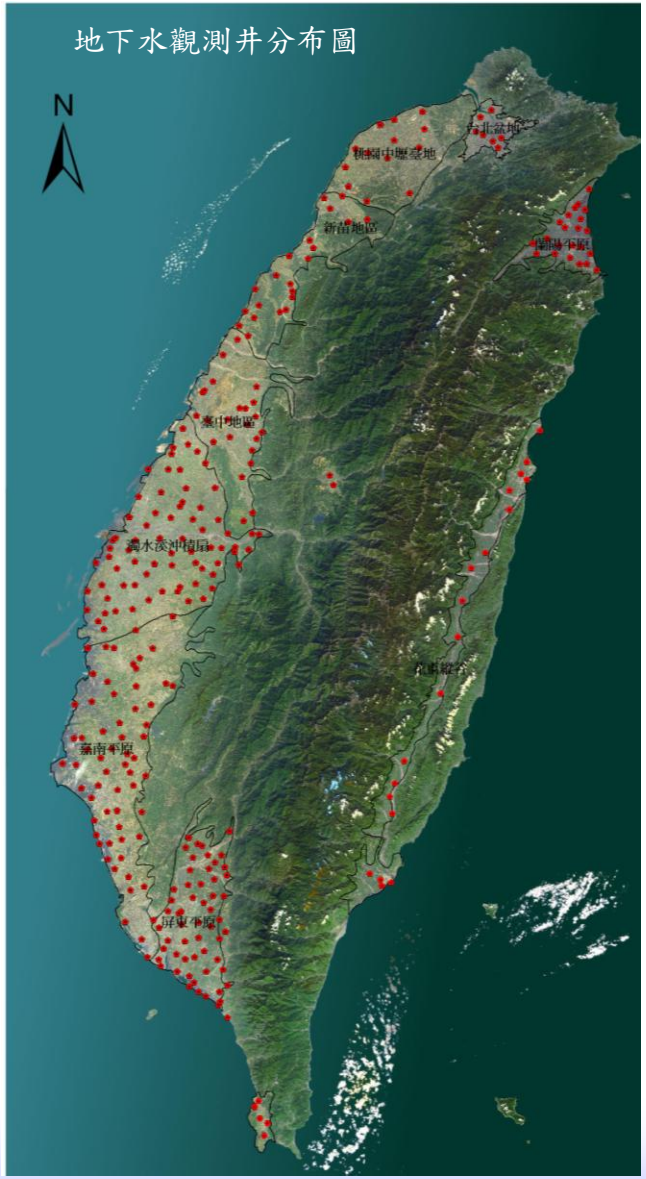
➢水井是學習地下水環境主要且直接窗口

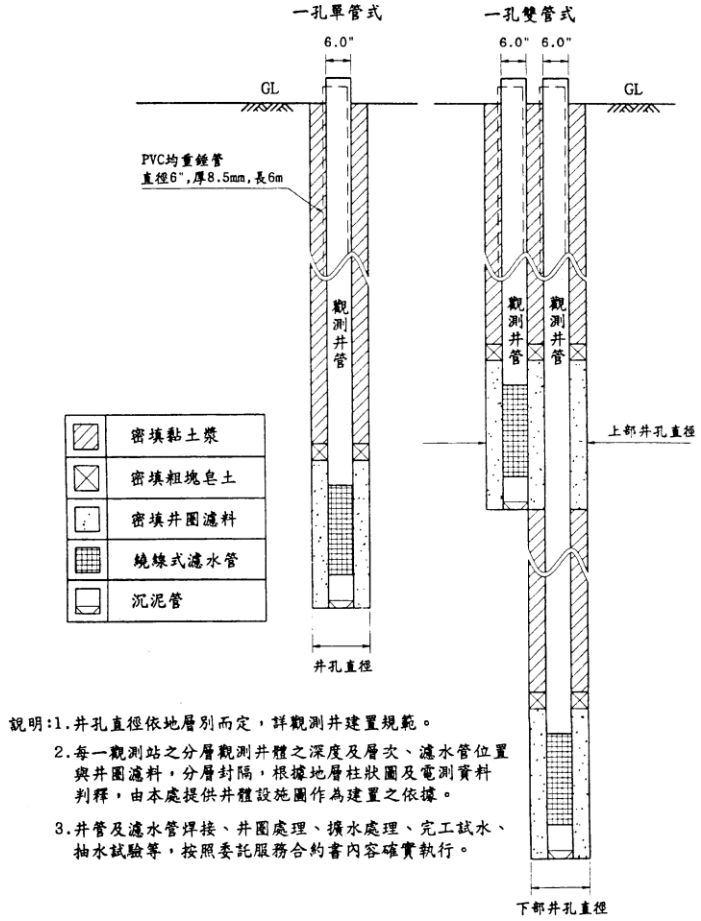
- 可抽汲地下水(抽水井或排水井)
- 可直接量測地下水水位(觀測井)
- 可直接取得不同深度土壤樣本
- 可提供地下水化學分析採樣(觀測井)
- 可提供一系列鑽孔地球物理量測(鑽孔地質物理紀錄)，得到水流與水井鄰近區域土壤材料特性間接資訊。
- 允許在水井附近區域進行水力試試驗(含水層試驗)，決定當地傳輸值與貯蓄特性。





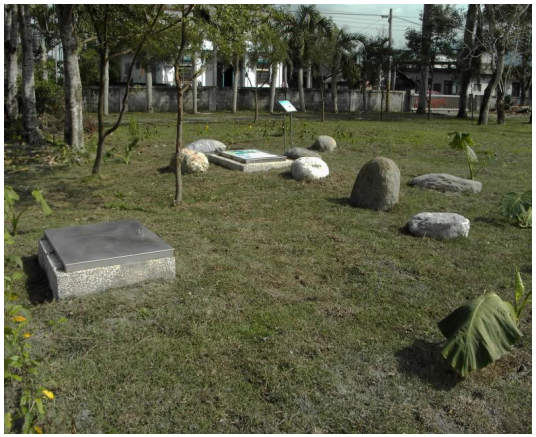
- 至99年9月底止，地下水觀測網已初具觀測規模及功能，於台灣各地下水區建置有：
  - →自記分層地下水觀測井計711口
  - →自記混層地下水觀測井計18口
  - →人工觀測混層地下水觀測井計148口
- 目前地下水觀測網已有**877**口地下水觀測井進行地下水水位觀測。





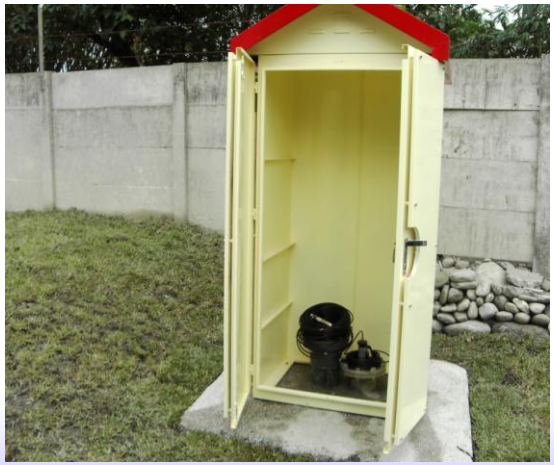
自記分層地下水觀測井結構示意圖

傳統式觀測站房外觀圖



平面式觀測站房外觀圖

觀測井所量測到之水位，除可做為區域性地下水水資源情勢研判外，還可從這些觀測資料中用什麼分析方法擷取出哪些訊息？



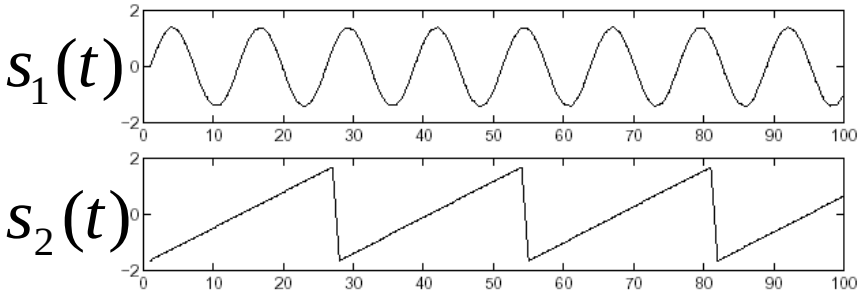
Cocktail Party Problem

Motivation: cocktail party with many speakers as sound sources and array of microphones, where each microphone is picking up a different mixture of the speakers.

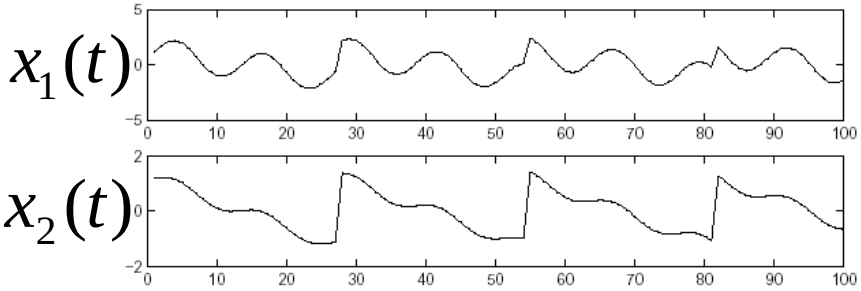
Question: Can you "tease apart" the individual speakers just given **x**, i.e. without knowing how the speakers' signals got mixed? (Blind Source Separation , BSS)

Blind Source Separation Example

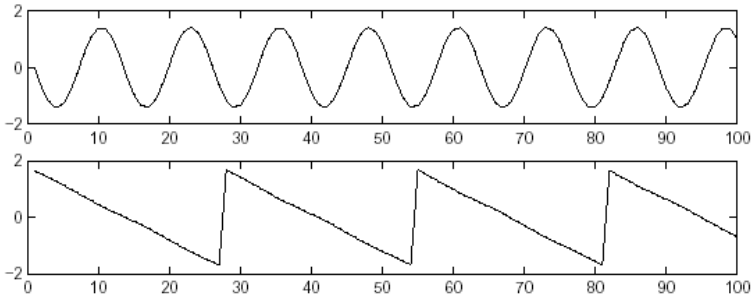
original time series of source **s**



linear mixture **x**



unmixed signals:



$$x_1(t) = a_{11}s_1 + a_{12}s_2$$
$$x_2(t) = a_{21}s_1 + a_{22}s_2$$

Definition of ICA

Note: there are several, this is the simplest and most restrictive:

- sources are **independent** and **non-gaussian**: $s_1, \ldots, s_n$
- sources have **zero mean**
- n observations are linear mixtures: $\mathbf{x}(t) = \mathbf{A}\mathbf{s}(t)$
- the **inverse** of **A exists**: $\mathbf{W} = \mathbf{A}^{-1}$

Goal: find this inverse. Sine we do not know the original, cannot compute it directly but we will have to estimate it: $\hat{\mathbf{s}}(t) = \hat{\mathbf{W}}\mathbf{x}(t)$

- once we have our estimate, we can compute the sources: $\mathbf{y}(t) = \hat{\mathbf{W}}\mathbf{x}(t)$

Relation of BSS and ICA:

- ICA is one method of addressing BSS, but **not the only one**
- BSS is not the only problem where ICA can be usefully applied

Restrictions of ICA

Need to require: (it's surprisingly little we have to require!)

- **sources are independent**.
- **sources are non-gaussian** (at most one can be gaussian)

Ambiguities of solution:

(a) sources can be estimated only up to a constant scale factor

(b) may get permutation of the sources, i.e. sources may not be recovered in their right order

(a) multiplying source with constant and dividing that source's matrix entries by same constant leaves **x** unchanged

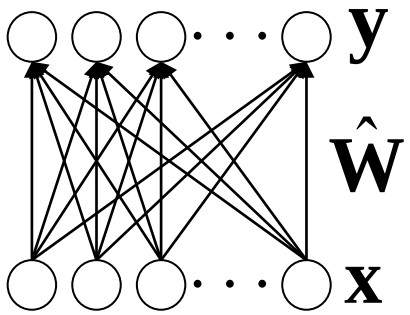
$$x_1(t) = a_{11}s_1 + a_{12}s_2$$
$$x_2(t) = a_{21}s_1 + a_{22}s_2$$

(b) switching these columns leaves **x** unchanged

Principles for Estimating $\hat{\mathbf{W}}$: $\mathbf{y}(t) = \hat{\mathbf{W}}\mathbf{x}(t)$

ICA versus whitening :

- requiring outputs y_i to be uncorrelated, e.g. by whitening, is **not** sufficient
- but typically whitening is used as a pre-processing stage (reduces number of parameters that need to be estimated)



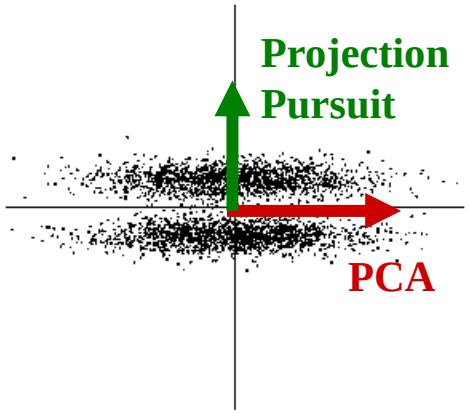
Three basic approaches :(with interesting connections between them)

(1) maximizing non-gaussianity (related to *projection pursuit*)

(2) minimizing the mutual information between the y_i

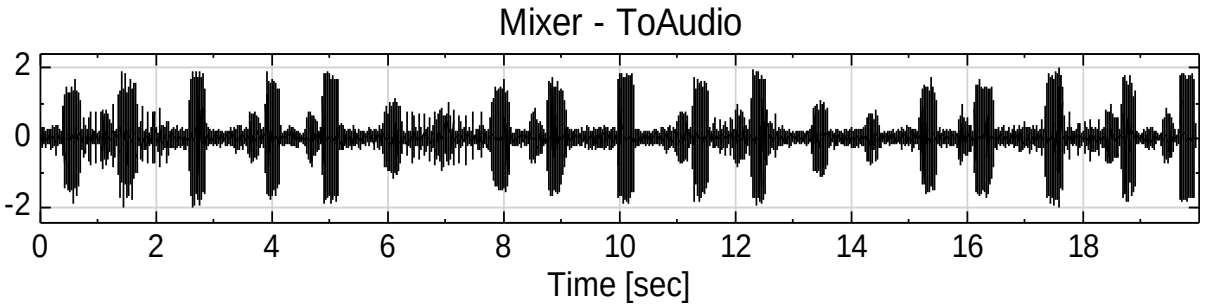
(3) maximum likelihood estimation (can exploit knowledge about the marginal distributions of the sources)

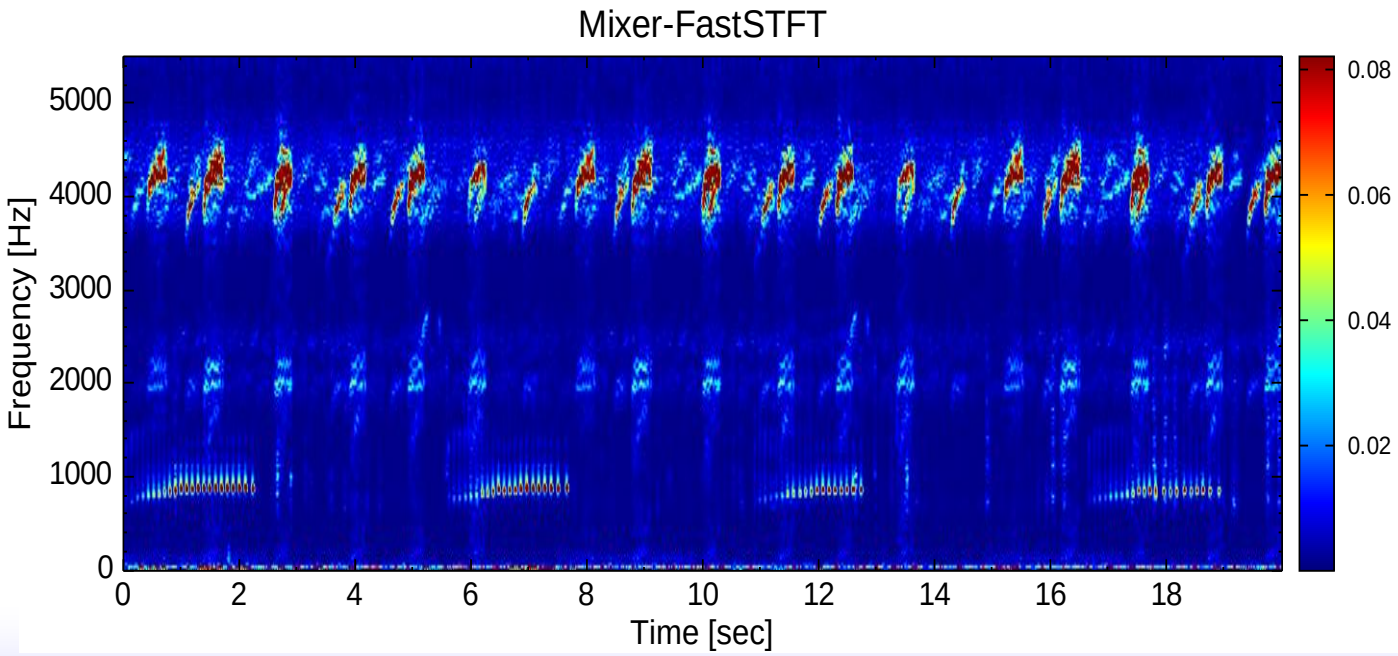
Projection Pursuit:
find projection along which data looks most "interesting"



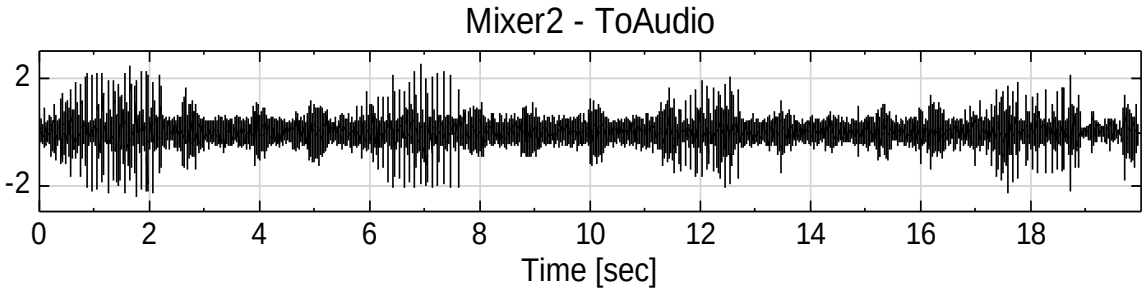
生態監測中是如何藉由「獨立成分分析」 (ICA)來「尋聲辨源」？

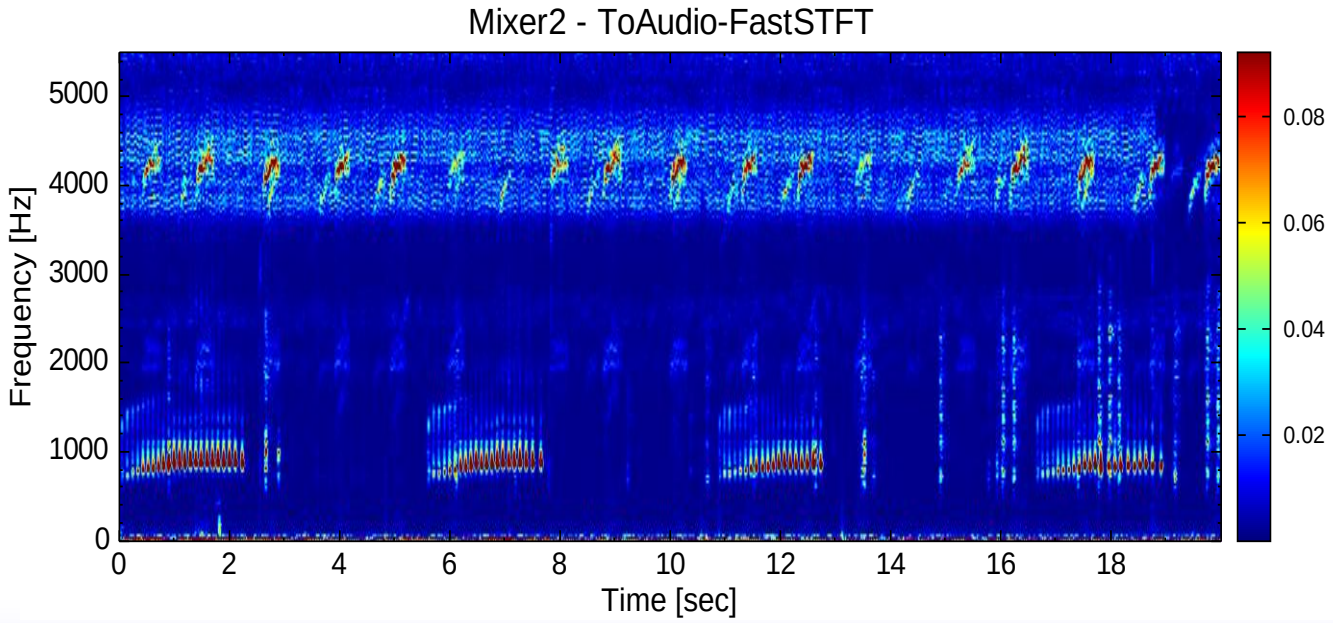
生態監測（Microphone I）



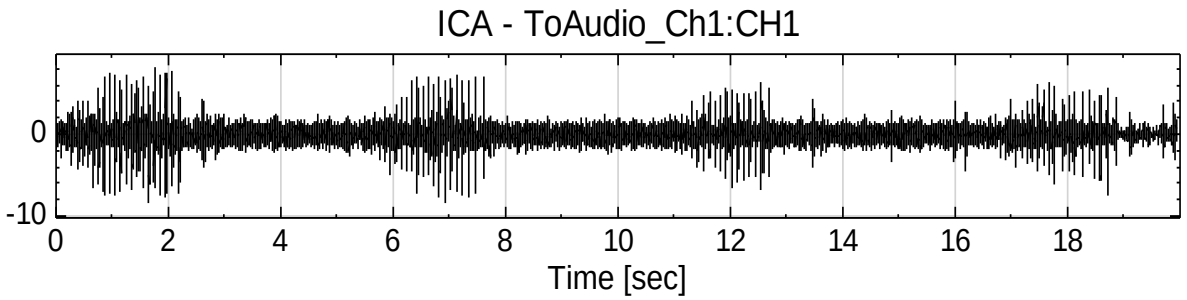


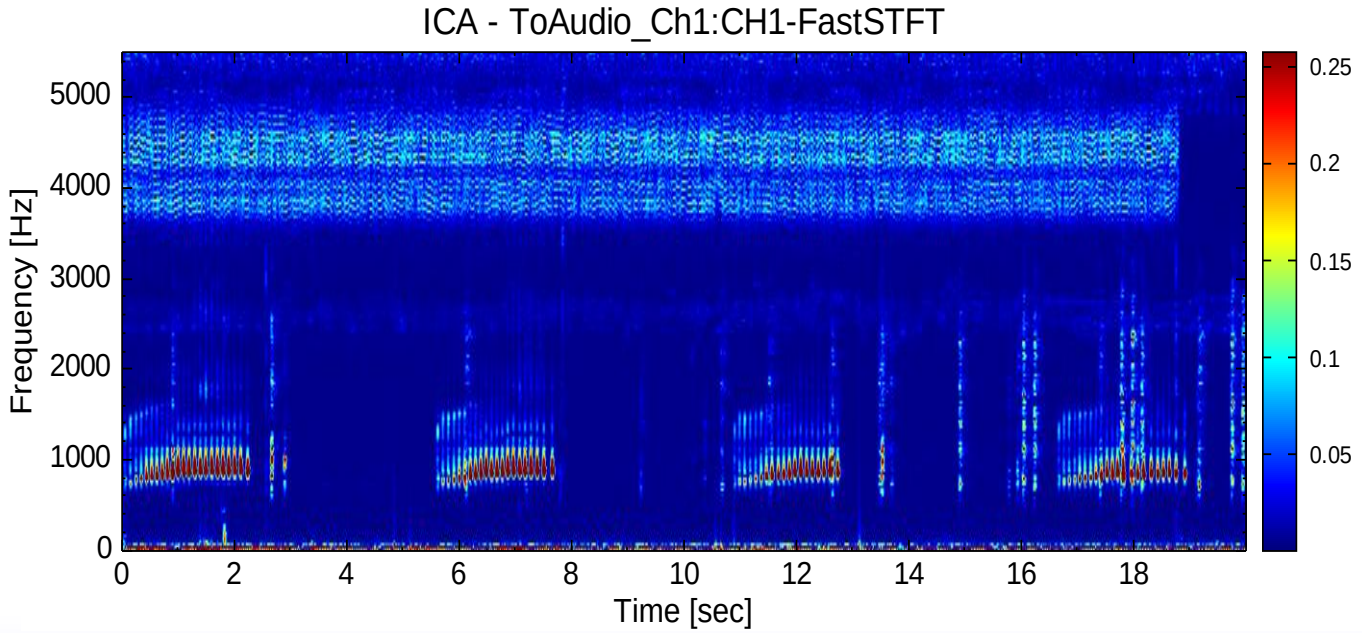
生態監測（Microphone II）



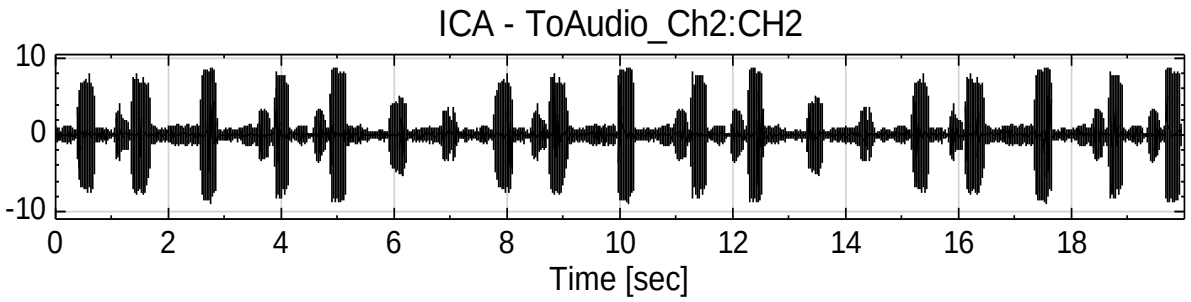


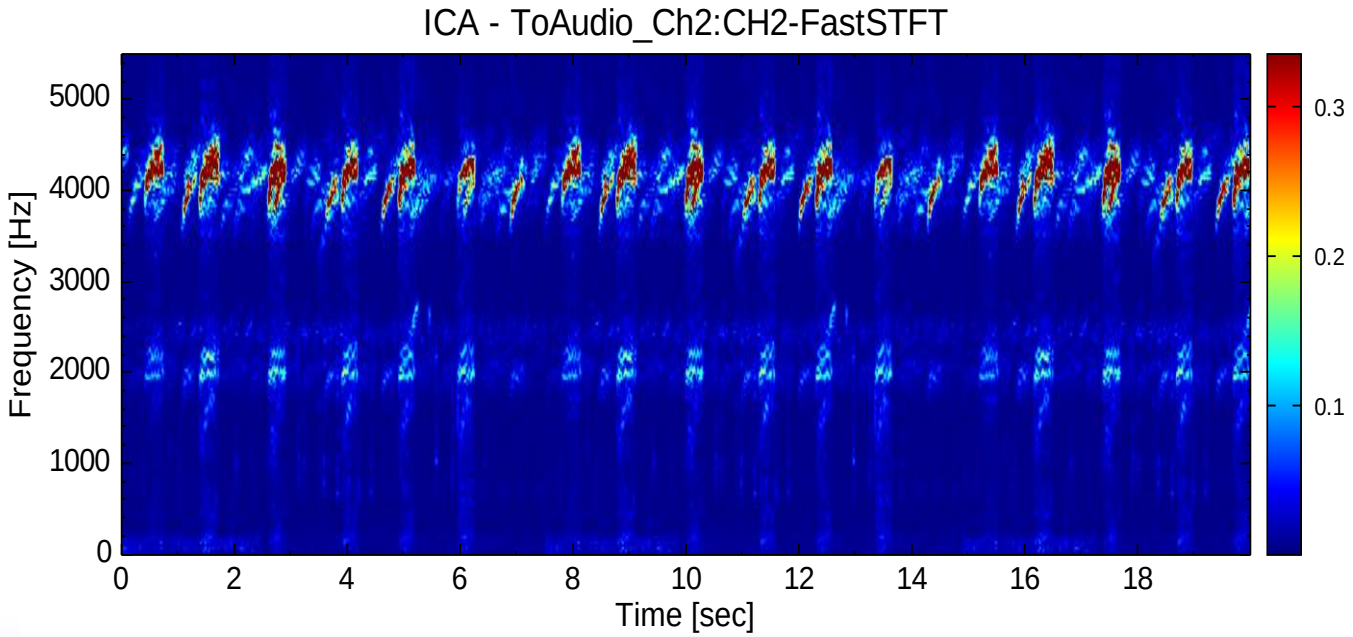
After ICA （豎琴蛙）





After ICA （中國樹蟾）



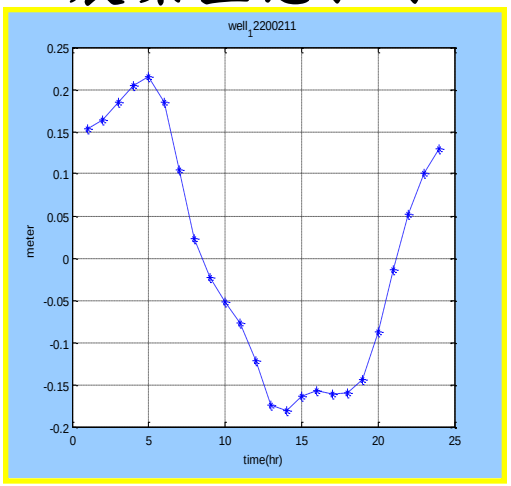


—ICA於地下水水位分析上之應用—

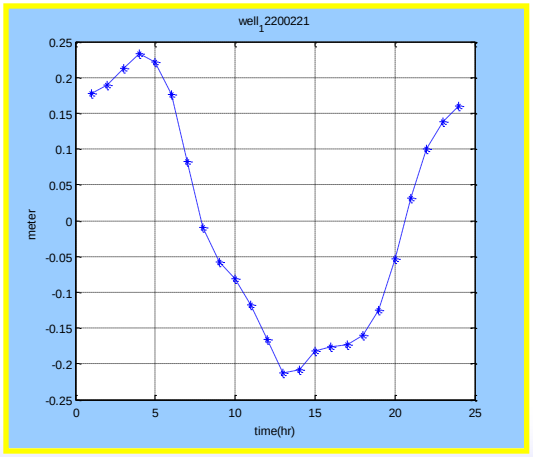
應用ICA於地下水水位分析？
可從這些觀測資料中擷取出
哪些訊息？

抽水型態分類-日均水位分析

農業型態抽水

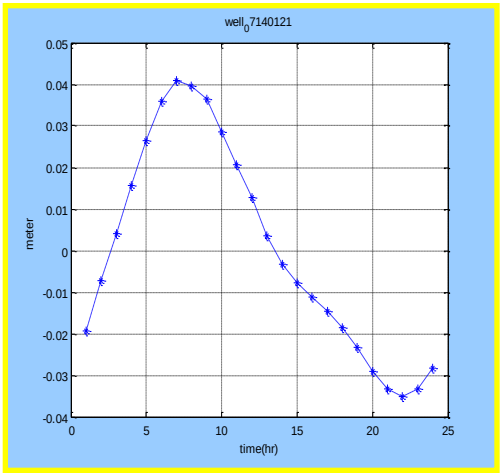


高雄美濃(1)



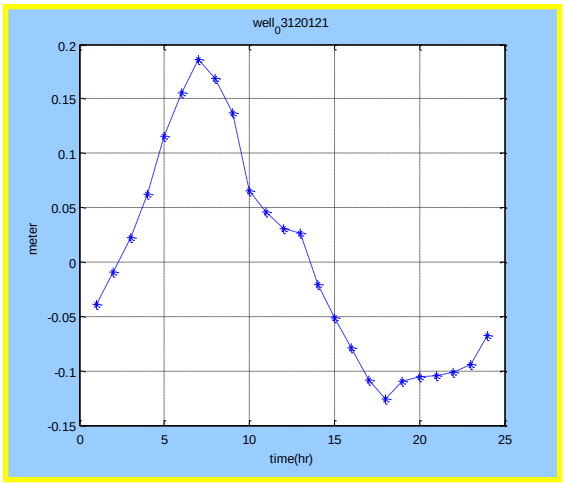
高雄美濃(2)

工業型態抽水



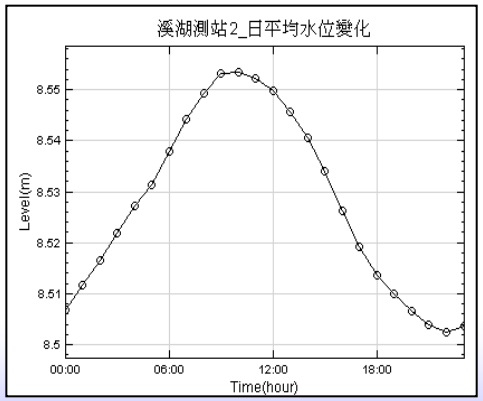
彰化好修 (2)

工農混和型態抽水



桃園樹林 (2)

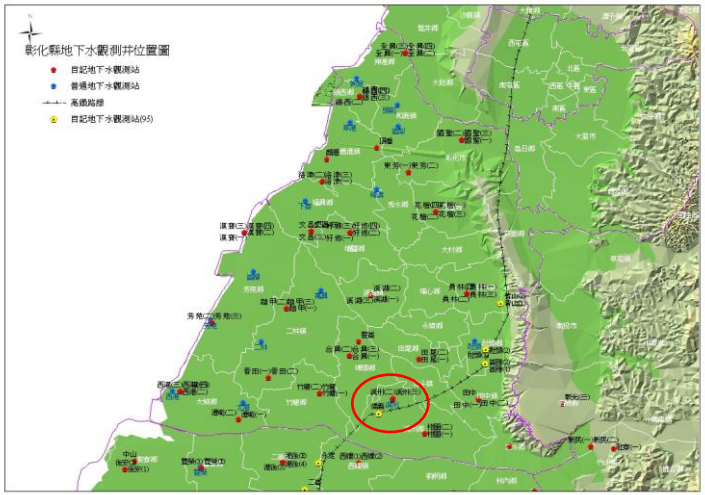
節費型態抽水

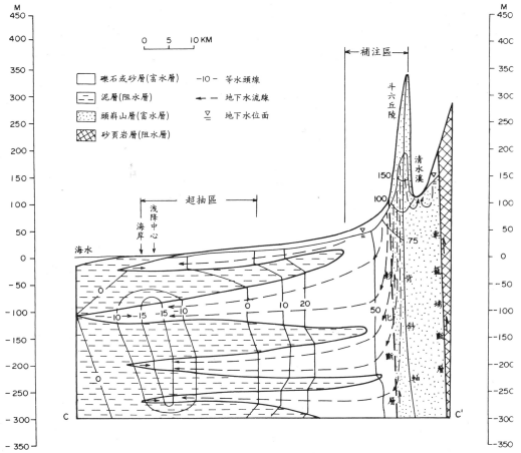


電費計算時段:

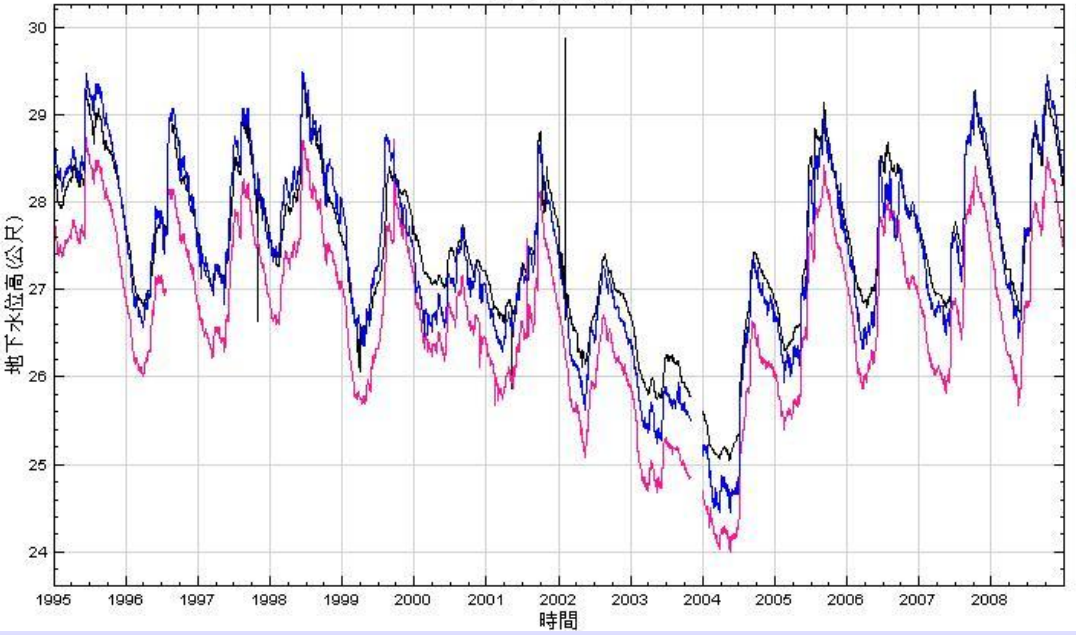
- 尖峰時間:早上7:30~晚上10:30。
- 離峰時間:晚上10:30~早上7:30。
- 半尖峰時間:
  - ◎星期六早上7:30~晚上10:30。
  - ◎星期日一整天。

以彰化溪洲地下水觀測井為例



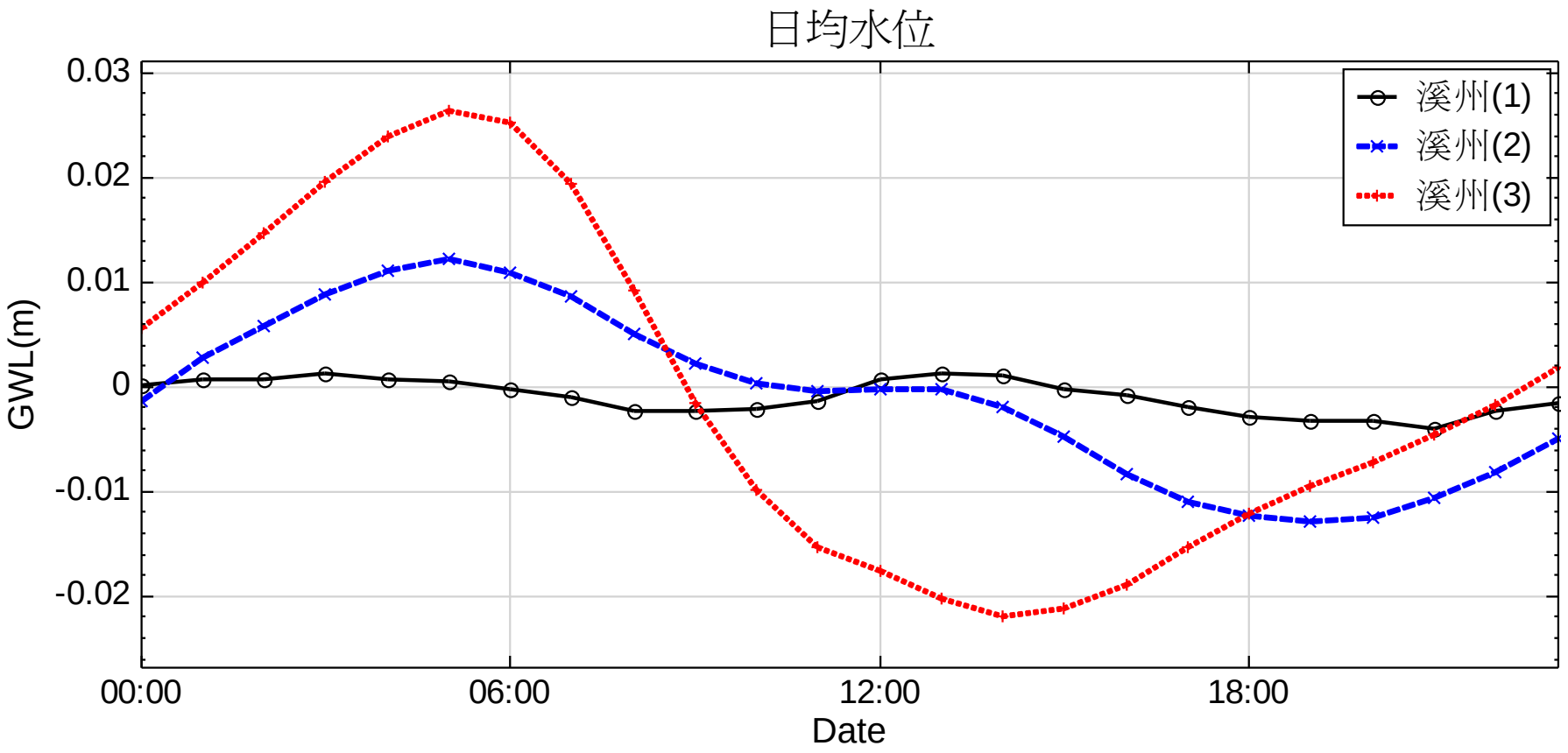


地下水位歷線圖

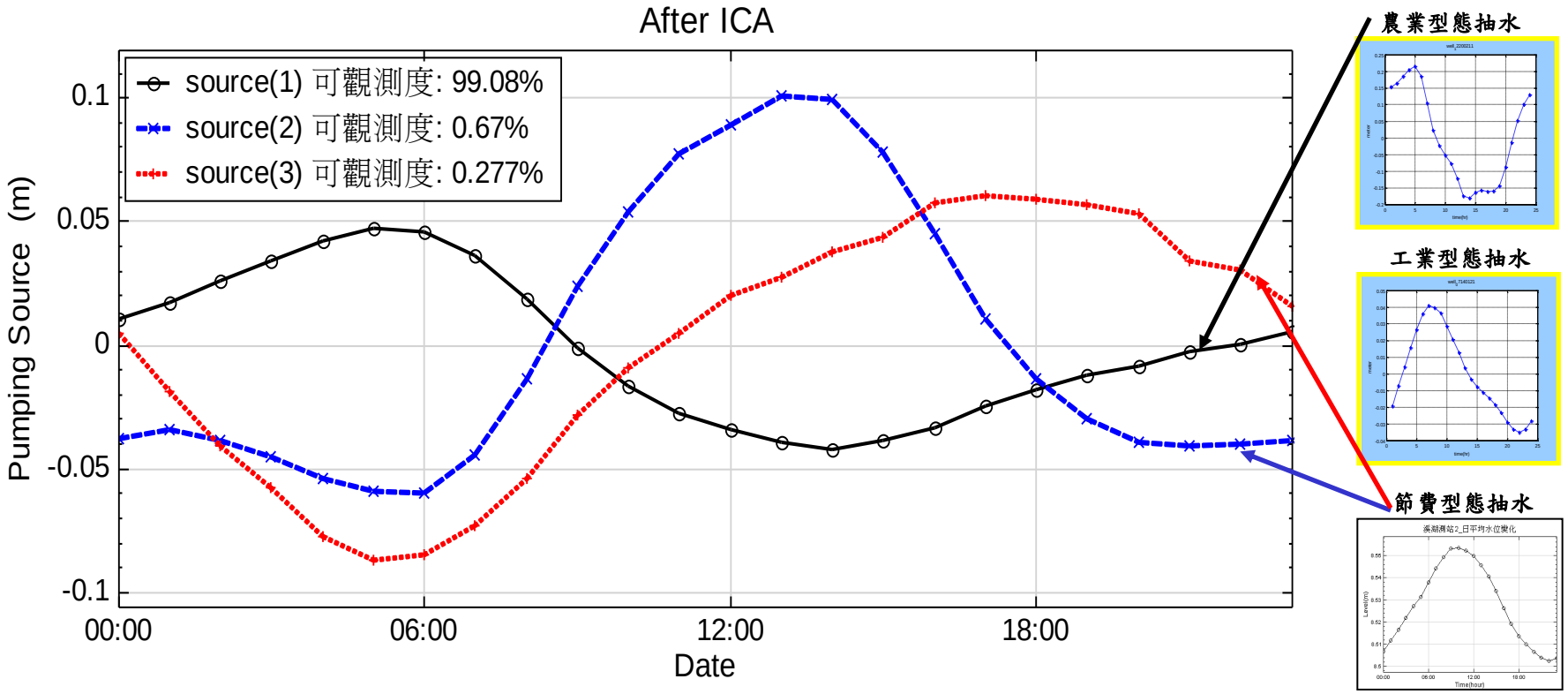


- 溪州(1)：
  井深30.95m，
  觀測含水層1。
- 溪州(2)：
  井深65.00m，
  觀測含水層2。
- 溪州(3)：
  井深76.49m，
  觀測含水層2-2。

以彰化溪洲地下水觀測井為例-日均水位分析



以彰化溪洲地下水觀測井為例-日均水位分析



- 經ICA 分離後，由結果顯示，可知影響溪洲觀測井抽水行為有三種模式：第一種為**農業型態抽水**，有最佳可觀測度，亦即由溪洲站三口井所量測到水位中可擷取到之隱含抽水型態以**農業型態抽水為最明顯**。
- 第二及三種比較偏向節費型抽水，來源可能離觀測井較遠，可觀測度較差。

結語

- 以**獨立成分分析**（ ICA ）可從所量測到地下水水位資訊中擷取並解讀出不易顯現之各種樣態抽水行為訊息。
- 不同型式抽水行為（如農業、工業、民生、養殖或節費型等）會產生不同型態之地下水水位變化。
- 地下水觀測井水位變化來自不同抽水行為之組合，且距觀測井較遠或較深之抽水行為不易被觀測到。

簡報完畢
敬請指教

經濟部水利署