# Status of Field Data for Faro Pit-Lakes Stability, 2004

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## Introduction

Assessing remediation options for the Faro pit-lakes (Faro, Grum and Vangorda) requires an understanding of the dynamics within each water body, including the likelihood of meromixis. To address this and other issues, a field program was undertaken by SRK Consulting (program oversight), Lorax Environmental (program design) and Laberge Environmental Services (program execution). Our role is program design and data analysis in regard to physical circulation and stability of these pit-lakes. Here we summarize and assess the data collected in 2004 as it relates to the physical limnology.

Typically lakes undergo fall overturn when surface waters cool through 4 °C. If a lake has a significant salinity contrast, this may inhibit the mixing of the surface layer beyond a certain depth and the lake is meromictic. The critical time period for observing meromixis is during lake cooling from the end of summer to freeze up. The purpose of data collection was to compare the salinity stability of the pit-lake at the end of the warming period (late August), St*, to the reduction in salinity stability during the cooling period, ΔSt. The meromictic ratio St*/ΔSt is an indicator of the likelihood of meromixis.

## Data Collected

Data collected to date is summarized as follows:

CTD (Conductivity-Temperature-Depth) profiles collected with a Seabird SBE-19plus:

| Faro | Grum | Vangorda |
|---|---|---|
| June 30 | June 30 | |
| | July 7, 14 & 28 | July 7 |
| | Aug 10, 18 & 25 | |
| | Sept 1 & 8 | |

Temperature chain and meteorological data from Grum raft:

- **June 29 – Sept 9:** Onset Hobo Water Temp Pro instruments at 1, 2, 3, 5, 7, 10, 15, 20, 30, and ~40 m from surface, and RBR TR1050 at ~42 m (depths to be confirmed), in total water depth of 44.2 m.
- **Aug 12 – Sept 9:** Meteorological data.

Temperature monitoring of creeks:

- **June 29 – Sept 9:** Record of stream temperature (Hobo Water Temp Pro) for Faro, Grum and Vangorda Creeks.

Additional data include pit-lake levels, stream flows and a shore based meteorological station; these have not been assessed.

**Data Overview**

CTD profiles from all three pits in early summer are given in Figure 1. Each profile shows a thin, warm and fresh surface layer, likely the result of ice melt and spring runoff. In Grum and Vangorda the surface layer was 3 m deep, but in Faro it was close to 6 m deep, reflecting the larger surface area of Faro. Surface layer temperatures were similar in all three pits (15-17 °C, Fig. 1a). What is notable is the large range of deep conductivity (Fig. 1b), with deep conductivity in Vangorda (~2000 μS/cm) about double that in Grum (~1050 μS/cm); deep conductivity in Faro was intermediate (~1400 μS/cm). Both Vangorda and Faro show a step in deep-water conductivity near 20 m, perhaps a remnant of fall mixing in the previous year. In contrast the deep conductivity in Grum pit is relatively uniform. In Vangorda, despite the high conductivity at depth, the surface layer conductivity was similar to that of Faro and Grum. Note record rainfall occurred during a period in mid-June that resulted in a breach of the diversion ditch for Vangorda Creek.

The evolution of Grum pit through the summer is well documented; selected CTD profiles are shown in Figure 2. The decrease in surface conductivity from June 30 onward suggests significant input of fresh water. By the end of August, the surface layer begins to cool and deepens to ~4.5 m by September 8. The cooling and deepening of the pit-lake had only begun by this early date, with the surface layer still near 8 °C.

Since the given data ends in early fall, we are unable to compute the change in stability during the cooling period and hence unable to assess the likelihood of meromixis. Changes during the cooling period could be determined from CTD profiles collected after freeze up.

The moored data for summer and early fall are shown in Figure 3. Winds are moderate (Fig. 3a). Air temperatures (Fig. 3b) generally decline from mid-August and vary around 0 °C at the end of the record. Solar radiation is beginning to decline through the period of record (Fig. 3c). The surface layer temperature in the pit-lake (Fig 3d) varies from 14 to 18 °C during the summer with diurnal warming evident on sunny days. Surface layer cooling is greatest during periods of high wind and low air temperature. For example, during the storm of Aug 26-28 the surface layer deepened just beyond 3 m. By the end of the record the surface layer has almost deepened to 5 m.

The deep (>10 m) temperature of Grum was 4.5 ºC and warmed slightly to 4.7 ºC over the summer as a result of low-level mixing in the hypolimnion as occurs in most temperate lakes. Note the small, but sudden, jump in deep temperature on July 18 (Fig.

3d). This jump is also seen in the CTD data and may have resulted from a rock fall and associated mixing.

**Conclusion**

A tantalizing picture is emerging of three quite different pit-lakes. The deep-water conductivity varies significantly between the lakes. Vangorda has the highest salinity contrast between surface and deep water. In contrast, Grum has the smallest salinity contrast and has a relatively uniform deep-water profile.

Unfortunately only one CTD profile was collected from Faro and Vangorda, making it difficult to assess changes over the summer. CTD profiles from Grum suggest significant fresh water input to the surface and shows the evolution of surface layer though summer and early fall. Both mooring and CTD data from Grum extend only to September 9, and do not cover the critical isothermal period of late fall needed to assess stability. The temperature mooring and meteorological station have been redeployed (Rob Goldblatt pers. com.). However, as salinity is key to meromixis, under-ice CTD sampling from all three pit-lakes is crucial to making stability assessments.

**Recommendations**

1. ***Under-ice CTD profiles*** We highly recommend that under-ice Seabird CTD profiles be taken in all three pit-lakes from surface to bottom. Without this information we cannot assess the changes that took place during the cooling period when the surface layer was mixed down. Without this additional data, the value of the earlier data is lost. We recommend that this sampling be conducted as soon as the ice thickness allows.

2. ***Late August CTD casts*** CTD casts should not only be taken at the start of summer (showing initial conditions) but also at end of August/early September in all pits to characterize fresh water input over summer.

3. ***Ice samples*** We recommend that ice samples be taken during under-ice profiling. This will provide important information about the amount of salts trapped in the ice. Solid pieces of ice should be put in a clean dry container such as wide mouth jar, allowed to melt and decanted into a 500 mL HDPE narrow mouth Nalgene bottle for conductivity analysis.

4. ***Conductivity bottles*** Whenever water samples are collected from the open pit, please include a 500 mL HDPE narrow mouth Nalgene bottle (airtight) for conductivity analysis. These bottles should be kept cool and shipped directly to UBC as soon as possible. Conductivity bottles from diverted streams, from any waterfalls and seeps entering the pits are also requested. These flows should be sampled during freshet and summer flow.

5. ***Thermistor chains and weather station*** We recommend that thermistor chains and weather station remain moored throughout the year, including the high accuracy RBR TR1050. This provides important data, especially during the ice-on and ice-off periods when profile sampling is not possible.

6. ***CTD calibration*** We recommend that the Seabird CTD profiler be calibrated twice a year in our calibration facility here at UBC. This will help provide error bounds for changes observed in the pit-lakes.

7. ***Flow estimates*** We recommend that site staff provide quick estimates of diverted creeks and of any pit inflows they encounter. Flow estimates can be made by visually estimating the width, depth and velocity (from the transit time of 'orange peels' moving an estimated distance down the creek). These estimates should also be undertaken during diversion breaches. Such quick estimates, while very approximate, give the order of magnitude and bound changes observed in the pit-lakes.

8. ***Pit wall photos*** To assess pit wall failures, a series of overlapping photos should be taken from a standard location (e.g. raft) during each sampling trip.

9. ***Secchi depths*** Measurement of the Secchi depth should accompany each CTD cast as a quick, easy and useful estimate of surface water clarity. Secchi data indicates the penetration depth of solar radiation.

10. ***CTD Cast rate*** Seabird suggests a cast rate of 1 m/s appropriate for oceanographic observations. However, with surface layers as small as 2 m in these pit-lakes, we recommend that the cast rate be reduced to 0.25 m/s. This increases the cast time from ~ 1 minute to ~ 4 minutes. (The CTD should be soaked for 2 minutes at the start of the cast, internal data averaging should be turned off, and casts should always profile the entire water column.)

11. ***Relative humidity*** A relative humidity sensor should be added to the weather station on the Grum raft. Relative humidity is important to computing air-water fluxes.

**Figure 1.** CTD profiles, Early Summer, 2004

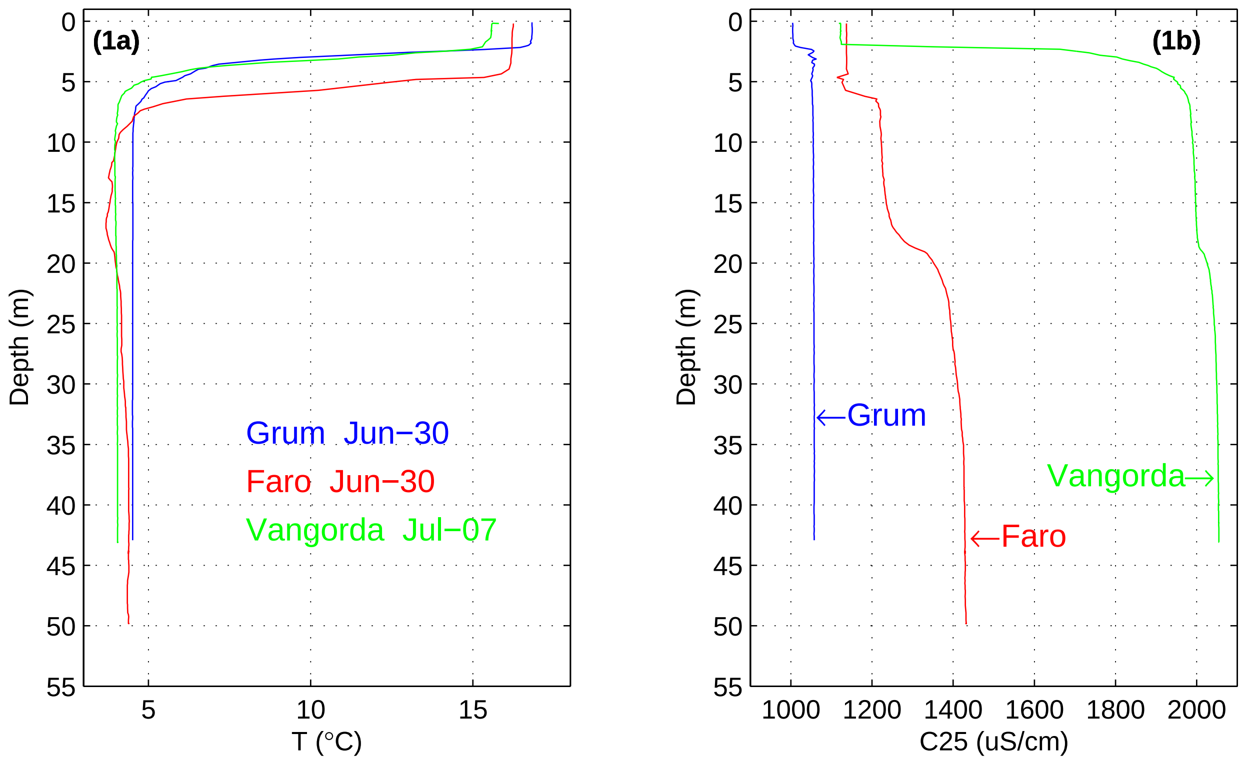


**Figure 2.** Selected CTD profiles, Grum, 2004

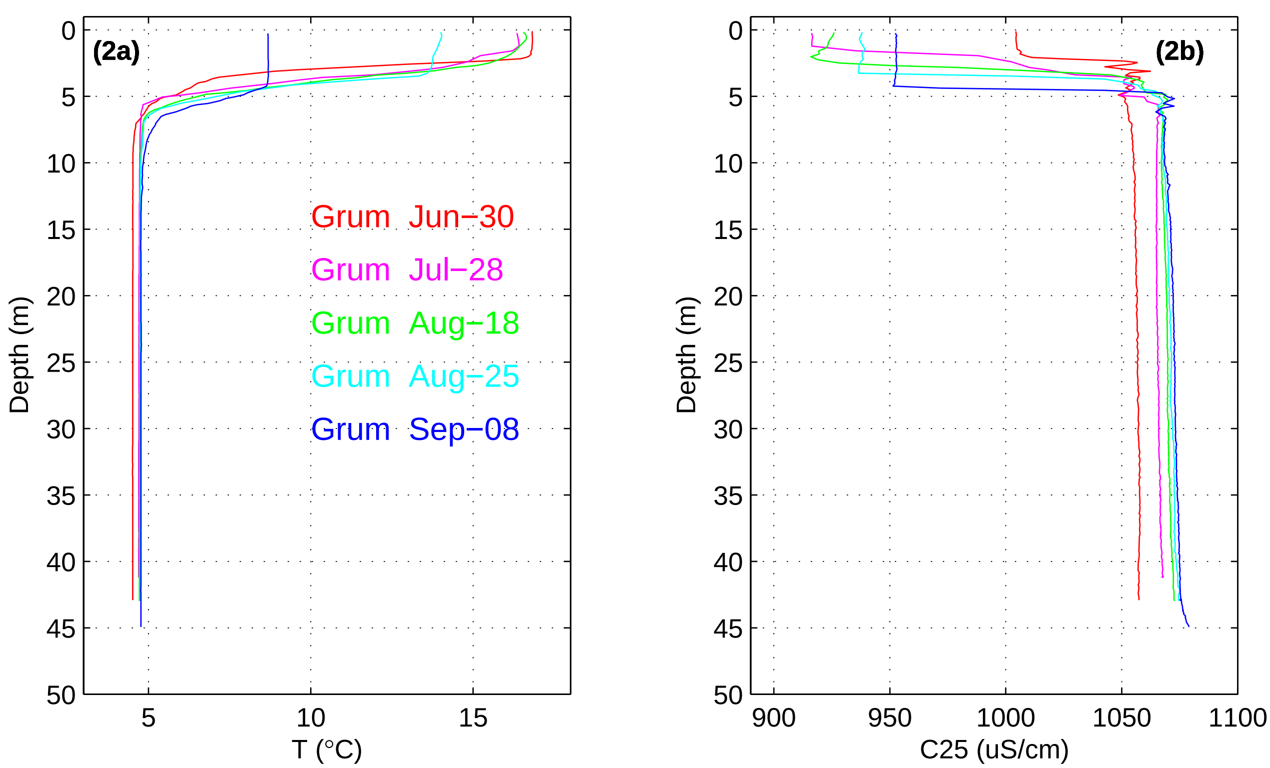

**Figure 3.** Grum Meteorological and Mooring Data, 2004