MANAGEMENT OF SULFIDIC MATERIALS IN DISPOSAL BASINS: THE LOVEDAY SWAMP CASE STUDY

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INTRODUCTION

In the Lower River Murray region, a number of floodplain wetlands were converted into disposal basins to store and evaporate excess irrigation water during the 20th century. The aim of these disposal basins was to prevent saline irrigation returns from discharging into the river, at least outside of major flood events. However, recent management policies by state and basin agencies aim to remove all disposal basins from Murray River floodplains and to return these wetlands to a more natural state. The remediation of these highly salinised and degraded systems will be a challenge for managers during the next decade.

In a survey of nine wetlands and disposal basins located in the Riverland region of South Australia, Lamontagne *et al*. (2004) determined that wetlands converted as disposal basins contained large deposits of sulfidic materials (soils and sediments enriched in sulfides). They hypothesised that these deposits formed because conditions in disposal basins were conducive to high rates of sulfate reduction and the preservation of sulfides. Sulfidic materials are an environmental issue for the remediation of saline wetlands, especially if remediation involves exposing sulfidic materials to the atmosphere (such as following the re-introduction natural wetting-drying cycles). Possible environmental hazards associated with sulfidic materials include: 1) acidification; 2) deoxygenation of the water column; and, 3) production of noxious smells (from the emission of H_2S and volatile organic sulfur compounds).

Loveday Swamp (Figure 1) was converted into a disposal basin during the 1970s to service the Cobdogla irrigation district. However, as a result of improved irrigation efficiency in the area, Loveday is no longer required for use as a disposal basin. Due to the combination of decreased irrigation disposal and the drought in the Murray Basin, Loveday Swamp has been partially dried since 2000. The partial drying of the wetland has resulted in hypersaline conditions and the production of noxious smells. During their survey, Lamontagne *et al*. (2004) determined that Loveday Swamp had large sulfidic material deposits and these appeared to be involved in the production of the noxious smells.

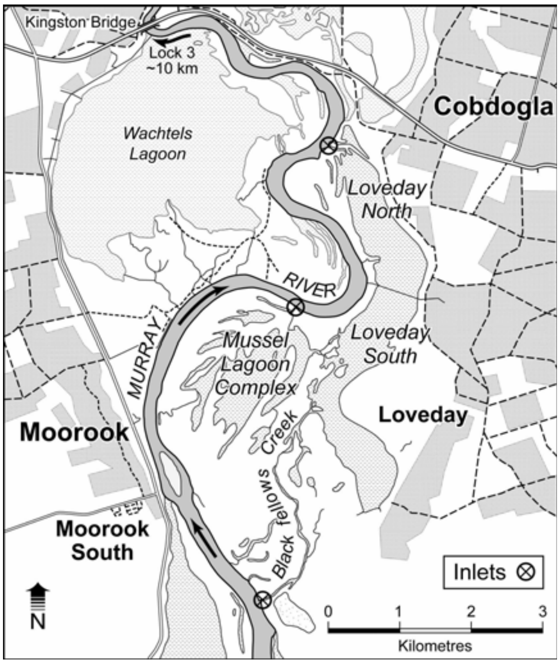

Figure 1. Loveday Swamp (Barmera, SA). Shaded zones represent irrigated areas. The wetland is divided into two ca. 300 ha basins by a causeway. Currently, only 1/3 of the North Basin is permanently inundated.

Loveday Swamp has been selected by the Murray-Darling Basin Commission to be the test case for the remediation of disposal basins in the Lower River Murray region. The South Australian Department of Water, Land and Biodiversity Conservation has entered a partnership with the CRC LEME to develop a management plan for the rehabilitation of Loveday Swamp. The preliminary goals of the rehabilitation effort are: 1) to prevent the generation of noxious smells; and, 2) to return the wetland to a “healthier” ecosystem, including the presence of native aquatic plants and fish.

PROJECT OUTLINE

Two CRC LEME projects (projects 3.18 – *Drawdown Geochemistry* and 3.19 – *Geomicrobiology of Acid Sulfate Soils*) and one CRC LEME-sponsored PhD study (Luke Wallace, ANU) have a focus at Loveday Swamp. The contributions of the CRC LEME towards the rehabilitation effort will include:

- Review the past sulfur balance from the wetland;
- Measure how much sulfur is currently stored in the wetland and in what forms;

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- Evaluate if the wetland has a net acidification or neutralisation potential;
- Design and carry out a surface water quality monitoring program to evaluate the effects of filling and drying on the sulfur cycle;
- A literature review, to evaluate the potential magnitude of gaseous sulfur losses from the wetland and the gases that could be involved in noxious smell events;
- Evaluate sulfate reduction rates when the wetland is filled and the sulfide oxidation rates when it is dried;
- Evaluate salt precipitation/dissolution under changes in water regime; and,
- Provide recommendations on how to reduce the environmental risks associated with the presence of sulfidic materials during the rehabilitation.

In the following, a summary of the preliminary outputs specific to Project 3.18 is presented.

HYDROLOGY

Prior to river regulation, Loveday Swamp was an ephemeral wetland that would have filled in late spring and dried during the summer months. As for many floodplain wetlands in the Lower Murray, the hydrology of the wetland has now been significantly modified (Figure 2). River regulation during the 20th century has significantly decreased the frequency and magnitude of flooding events (Jolly 1996). In addition, river levels are now raised by weirs along the river, which would result in Loveday being permanently inundated if control structures had not been installed at its various inlets (Figure 1). Lastly, following decades of irrigation in the nearby uplands, a groundwater mound now discharges to Loveday. Essentially, Loveday is now a terminal basin because it has the lowest water level in the landscape. Loveday Swamp is still periodically inundated by larger floods, but these have been uncommon in the last two decades.

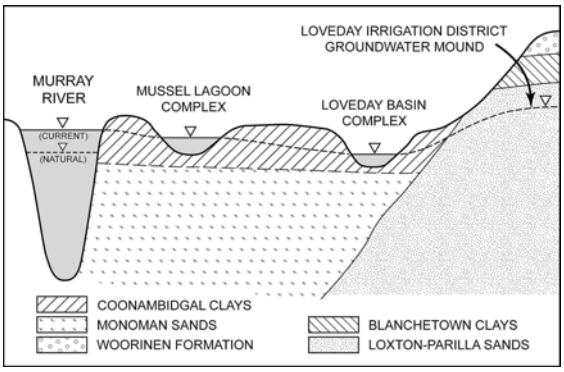

Figure 2: Conceptual cross-section of the floodplain hydrological system in the vicinity of Loveday Swamp (not to scale).

PRELIMINARY WALT, SALT AND SULFUR BALANCES

Preliminary water and salt balances are available for Loveday Swamp (Table 1). During 1970-2000 (when the wetland was used as a disposal basin), the main inputs of water were from irrigation disposal (ca. 2,869 ML year^{-1}) and rainfall (ca. 1,718 ML year^{-1}), while the only significant loss was as evapotranspiration (ca. 6,175 ML year^{-1}). While a small input of water to the wetland (316 ML year^{-1}), groundwater was discharging a similar load of salt as irrigation disposal (7,900 and 7,327 tons year^{-1}, respectively). Thus, while irrigation disposal has now been significantly reduced since 2000 (< 400 ML year^{-1}), the salt load has only been reduced by 43%.

Preliminary estimates of the sulfur balance for the wetland indicate that a large supply of sulfur is probably stored in surface sediments (Table 1). The sulfur load from 1970-2000 would have been approximately 761 tons year^{-1}, mostly from groundwater (380 ton year^{-1}) and irrigation disposal (370 ton year^{-1}). The emission of sulfurous gases was likely to be the main export of sulfur from the wetland, but this flux cannot be precisely quantified at present. Based on literature values, the sulfur gas emission rate could range from 30 to 940 tons year^{-1}. Thus, a significant proportion of sulfur inputs to Loveday could be removed by sulfur gas emissions.

Based on the input estimates, the sulfur storage in Loveday from 1970 to 2005 would be ca. 16,500 tons. Based on the limiting sampling of the Lamontagne *et al.* (2004) survey, approximately 9,000 tons are present in the wetland. However, an ongoing assessment of the sulfur pools at Loveday (Wallace *et al.* 2005) indicates that up to 40,000 tons of sulfur could be stored in the wetland. Thus, a substantial proportion of past sulfur inputs to the wetland are still stored there. Work is ongoing to refine these mass-balance estimates.

MONITORING PROGRAM

A monthly surface water quality monitoring program was initiated in June 2005 with the aim of assessing future changes in the geochemistry of Loveday Swamp following modifications to its water regime. Samples are currently collected in Loveday Swamp North basin (two sites), Loveday Swamp South basin, the River Murray and the nearby freshwater Mussel Lagoon as a reference. A range of field (pH, Eh, oxygen, temperature, unfiltered alkalinity and EC) and laboratory measurements (including major and minor ions, nutrients, pH, filtered alkalinity, stable isotopes of water and $\delta^{34}S$-SO_4^{2-}) are made on each sample. Groundwater quality in the vicinity of the basin will be measured using a well monitoring network to be installed by DWLBC in 2005–06.

Table 1: Preliminary water, salt and sulfur balances for Loveday Swamp for 1970-2000 (water and salt data from GHD 2004).

	Water balance (ML year^{-1})	Salinity (mg L^{-1})	Salt load (ton year^{-1})	S load (ton S year^{-1})
Inputs				
Irrigation disposal	2,869	2,554	7,327	370
Groundwater mound	316	25,000	7,900	380
Rainfall	1,718	10	17	0.4
Upstream wetlands	586	350	205	5.5
Surface runoff	363	200	73	1.9
Seepage from river	167	350	62	1.7
Surface inputs from river	177	350	58	1.6
Outputs				
Evapotranspiration	–6,175	0	0	
Surface flow to river	–22	25,000	–550	–28
Gaseous losses				–30 to –940[a]
Total Inputs	6,196		15,643	761
Total Outputs	–6,197			–58 to –968

[a]Assuming S emission rates ranging from 5 to 150 g S m^{-2} year^{-1} (Giblin & Wieder 1992, Crozier *et al.* 1995)

Early results from the monitoring program (June-August 2005) indicate that Loveday Swamp is currently hypersaline and slightly alkaline (Table 2). The brine is Na-Cl dominated and depleted in Ca^{2+}, K^+ and carbonates relative to what would be expected from the evaporation of River Murray water. Nutrient levels, especially phosphorous, are surprisingly low. This suggests high rates of photosynthesis by the algal biofilm covering the bottom of the Swamp.

Table 2: Range in physicochemical water quality parameters in Loveday Swamp (North and South basins), Mussel Lagoon and the River Murray between June–August 2005. FRP – Filterable reactive P; DOC – Dissolved organic C.

		Murray River	Mussel Lagoon	Loveday-North	Loveday-South
Field EC	(dS m^{-1})	0.25 – 0.45	0.39 – 0.56	39 – 73	39 – 80
Field pH		7.0 – 8.5	6.9 – 7.5	8.6 – 9.5	6.4 – 8.4
Field alk.	(meq L^{-1})	0.5 – 1.6	0.72 – 0.42	1.5 – 3.3	2.6 – 6.8
Lab EC	(dS m^{-1})	0.35 – 0.41	0.38 – 0.55	43 – 73	49 – 88
TDS	(g L^{-1})	0.19 – 0.19	0.19 – 0.24	36 – 66	42 – 78
Ca^{2+}	(mg L^{-1})	8.3 – 8.5	8.3 – 9.5	900 – 1,160	954 – 1150
Mg^{2+}	(mg L^{-1})	7.5 – 8.6	8.3 – 9.5	1,310 – 2,110	1,380 – 2,870
Na^+	(mg L^{-1})	50 – 58	56 – 68	10,770 – 19,900	12,200 – 23,900
K^+	(mg L^{-1})	3.0 – 3.9	3.3 – 3.8	67 – 125	85 – 157
Cl^-	(mg L^{-1})	72 – 92	89 – 115	18,900 – 37,200	21,700 – 41,100
SO_4^{2-}	(mg L^{-1})	17 – 20	19 – 25	4,520 – 6,310	5,610 – 8,480
Br^-	(mg L^{-1})	0.14 – 0.15	0.14 – 0.15	41 – 108	48 – 118
FRP	(mg L^{-1})	<0.005 – 0.011	<0.005 – 0.012	<0.005 – 0.015	0.018 – 0.026
NH_4^+	(mg L^{-1})	0.022 – 0.068	<0.005 – 0.018	0.45 – 2.2	0.44 – 2.2
NO_3^-	(mg L^{-1})	<0.005 – 0.011	0.007 – 0.041	<0.02 – 5.0	<0.005 – 0.93
DOC	(mg L^{-1})	5.2 – 8.1	7.3 – 12.8	41 – 112	51 – 71

Monitoring in Loveday is expected to continue up to 2007, during which period a new water regime will be initiated for the wetland. While the exact nature of the new water regime is yet to be defined, it will involve converting the wetland from its current closed hydrological system into a more open one. This could be achieved by either recirculating Loveday water to the river or to other nearby disposal basins. A key challenge for the management of acidification under an open system will be to ensure that an imbalance does not result between the storage of sulfides and alkalinity during "wet" stages. Currently, despite high sulfide concentrations, Loveday has a low acidification risk because of a large sediment carbonate pool (Lamontagne *et al*. 2004). Part of this carbonate pool is present because of the "closed" nature of Loveday, which results in the alkalinity produced during sulfate reduction to be stored within the wetland. If some alkalinity is lost from the system during recirculation, potential acid sulfate soil conditions may develop over time. Ongoing and future studies at Loveday will help determine suitable water regimes for the rehabilitation of floodplain disposal basins.

REFERENCES

CROZIER C.R., DEVAI I. & DELAUNE R.D. 1995. Methane and reduced sulfur gas-production by fresh and dried wetland soils. *Soil Science Society of America Journal* **59,** 277–284.

GHD 2004. Loveday Wetlands. Stage 3 – Salt and Water Balances. *Report for Berri-Barmera Local Action Planning Association*, 48 p.

GINLIN A.E. & WIEDER R.K. 1992. Sulfur cycling in marine and freshwater wetlands. *In:* HOWARTH R.W., STEWART J.W.B. & IVANOV M.V. eds. *Sulfur Cycling on the Continents: Wetlands, Terrestrial Ecosystems and Associated Water Bodies*. Available online at: http://www.icsu-scope.org/downloadpubs/scope48/contents.html.

JOLLY I.D. 1996. The effects of river management on the hydrology and hydroecology of arid and semi-arid floodplains. *In*: ANDERSON M.G., WALLING D.E. & BATES D.E. eds. *Floodplain Processes*. Wiley, New York. pp. 577–609.

LAMONTAGNE S., HICKS W.S., FITZPATRICK R.W. & ROGERS S. 2004. Survey and description of sulfidic materials in wetlands of the lower River Murray floodplains: Implications for floodplain salinity management. *CRC LEME* **Open File Report 28/04**, 65 p.

WALLACE L., WELCH S., KIRSTE D., BEAVIS S. & MCPHAIL D.C. 2005. Characteristics of inland acid sulfate soils of the Lower Murray floodplains, South Australia. *In:* ROACH I.C. ed. *Regolith 2005 – Ten Years of CRC LEME*. CRC LEME, pp. 326-328.