Ecological engineering of a novel lake district new landscape: new approaches for new landscapes

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Mine Pit Lakes Formation

- International phenomenon
  - Open-cut mining more common
  - Technological advances; larger pit voids



Source: National Geographic

Pit Lakes Internationally

- Legacy of many mine pit lakes worldwide
  - Athabascan Oil Sands Region, Canada: 26 proposed[1]
  - Germany e.g., Lusatia mining region: 100 current[2]
  - Collie Lake District, Australia: 13 lakes current[3]


[1]Westcott & Watson (2007). *End Pit Lakes Technical Guidance (EPLTGD) Document. Report number 2005-61.* Clearwater Environmental Consultants, Alberta, Canada. 51+ pp. Unpublished report to the Cumulative Environmental Management Association, End Pit Lakes Subgroup.
[2]Bozau *et al*. (2007). Biotechnological remediation of an acidic pit lake: modelling the basic processes in a mesocosm experiment. *Geochemical Exploration 92: 212-221.*
[3]Kumar *et al.* (2009). Water resources in Australian mine pit lakes. *Mining Technology* 118: 205-211.

Aquatic Habitat Loss

- Pressure on water resources increasing
  - Increasing demand
  - Climate change predictions
  - International loss of aquatic habitats


Pit Lake Resources

- Typically have reduced environmental values
  - Low pH (Acid Mine Drainage, 'AMD')
  - High metals/other contaminants
  - Low nutrients
- Large water bodies represent:
  - Social and environmental liabilities[1]
  - Valuable resources to *environment*

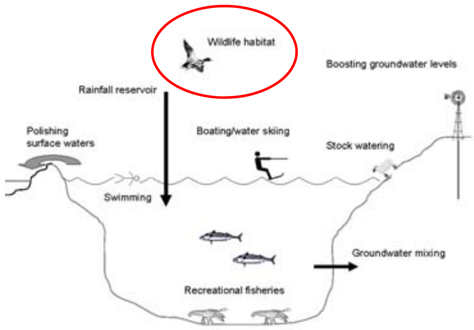


[1]Doupé & Lymbery (2005). Environmental risks associated with beneficial end uses of mine lakes in south-western Australia. *Mine Water and the Environment 24: 134-138*

Novel Lake Districts

Lake Name	Depth[1)] (m)	Area[1)] (Ha)	Perimeter[1)] (m)	Shape
Black Diamond A	8	4.6	1500	
Blue waters	24	13.7	2260	
Centaur	9	4.5	1590	
Stockton	47	15.4	1740	
Chicken Creek 4	41	21.6	2690	
Chicken Creek 5	24	15.5	2000	
Kepwari	65	98.5	5470	
WON9	33	7.8	1140	
WO3	8	4.7	1200	
WO5H	81	43.5	2840	
WO5C	49	14.2	2340	
WO5D	22	5.5	1480	
WO5F	2			

Restoration Opportunities



McCullough & Lund (2006). Opportunities for sustainable mining pit lakes in Australia. *Mine Water and the Environment 25: 220-226.*

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Restoration Goals

- 'Identifiable Desired State'[1]
- Environmental values often recommended for pit lakes
  - 'Gold standard' of rehabilitation
  - Water quality guidelines well developed: most common criteria chosen by regulators
  - Other important ecological variables not considered
- Few examples of restored pit lakes internationally
  - Most incidental
  - **Most countries/regions/mining types = none.**

[1]Grant (2006). State-and-transition successional model for bauxite mining rehabilitation in the jarrah forest of Western Australia. *Restoration Ecology 14: 28-37.*
[2]Williams (2009). Regulatory Issues. In, *Mine Pit Lakes: Characteristics, Predictive Modeling, and Sustainability Castendyk, D.; Eary, T. & Park, B. (eds.) Society for Mining Engineering (SME), Kentucky, USA, 13-17pp.*

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Ecological Restoration Principles

- General restoration guidelines and theory
  - Well developed for terrestrial ecosystems
- Restoring to a "analogue system"
  - Rehabilitation vs. restoration
  - Integrated into landscape as primary goal
- Sustainability
  - Independently self-sustaining ecosystems

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Environmental Values

- Desired environmental values?
  - Charismatic spp.
  - Endangered spp. e.g., refugia
  - Treaty/legislatively mandated spp. e.g., migratory birds/RAMSAR
  - Regionally representative community (c.f. regional examples)

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Compromised Ecosystems

- Some will be 'Un-fixable'
  - Environmental legacies
  - Degraded local stable-states[1]

- Impaired ecosystems?
  - Target = novel?[2]
  - 'Natural experiments'
  - Provision of ecosystem services
  - Processes v. species

[1]Suding & Hobbs (2009). Threshold models in restoration and conservation: a developing framework. *Trends in Ecology & Evolution* 24: 271-279.
[2]Hobbs *et al*. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography* 15: 1-7.

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Degraded Ecological Values

- Succession driven
  - But time scales too long to achieve?
- Chemically-driven alternative stable states
  - Stable, poor water quality
  - Abiotic processes the major determinator e.g., salinity
  - Biotic remediation processes weaker than current abiotic processes e.g., AMD

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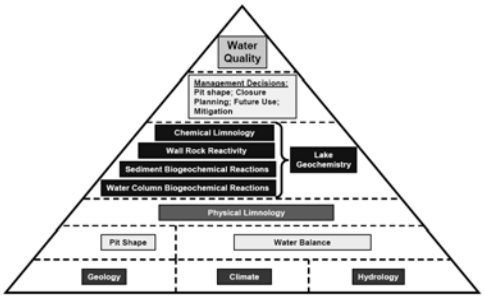
Water Quality



Castendyk & Eary (2009). The Nature and Global Distribution of Pit Lakes. In, *Mine Pit Lakes: Characteristics, Predictive Modeling, and Sustainability Castendyk, D.; Eary, T. & Park, B. (eds.) Society for Mining Engineering (SME), Kentucky, USA, 1-11pp.*

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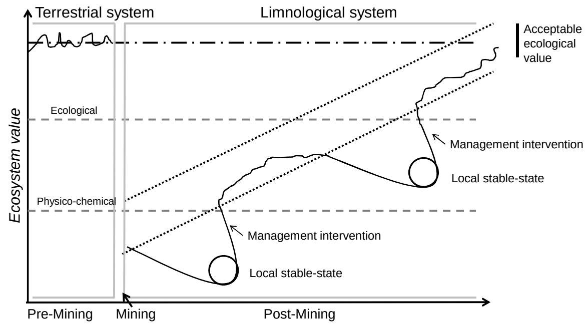
Local Stable-States



Modified after Grant (2006). State-and-transition successional model for bauxite mining rehabilitation in the jarrah forest of Western Australia. *Restoration Ecology 14: 28-37.*

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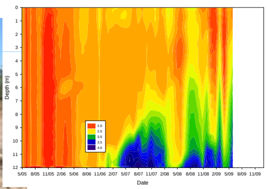
Restoration - Remediation

- Biotic processes need assistance from abiotic factors that buffer development e.g., AMD
  - Water quality e.g., nutrients (P, DOC), pH, metals



[1]McCullough *et al.* (2008). *Field scale trials treating acidity in coal pit lakes using sewage and green waste. Proceedings of the 10th International Mine Water Association (IMWA) Congress. Karlovy Vary, Czech Republic. Rapantova, N. & Hrkal, Z. (eds.), 599-602pp.*

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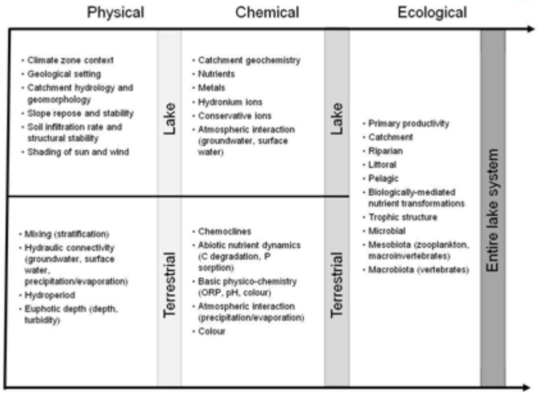
Ecological Development Obstacles



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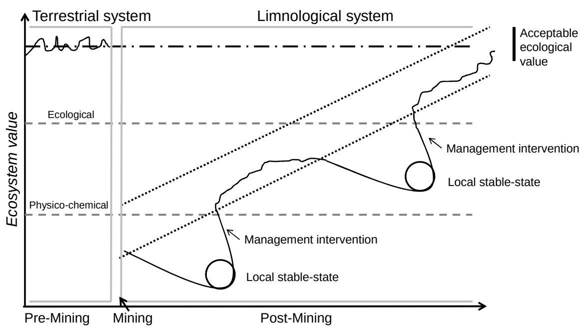
Local Stable-States



Modified after Grant (2006). State-and-transition successional model for bauxite mining rehabilitation in the jarrah forest of Western Australia. *Restoration Ecology 14: 28-37.*

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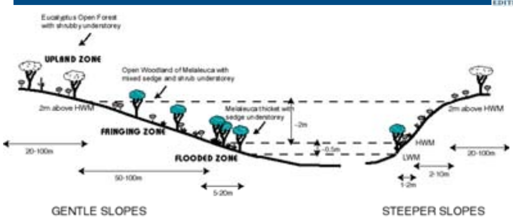
Using Regional References



- Regional examples
  - Reference systems e.g., wetlands provide restoration guidance
  - Acknowledgement of seration important

[1]Van Etten *et al.* (submitted). How Precisely do we Need to Match Topsoil to Site for Successful Restoration of Post-Mining Environments? – a Case Study from Wetland Margins in South-Western Australia *Restoration Ecology*

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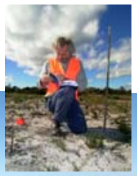
Restoration - Revegetation

- Ecological successions mediated by interventions
  - Riparian vegetation; bank stabilisation, vegetation establishment



Conclusions

- Pit lakes growing landscape restoration
  - Issues
  - *Opportunities*
- Aquatic habitats diminishing

➢ ***Opportunities for significant, new, aquatic landscapes***

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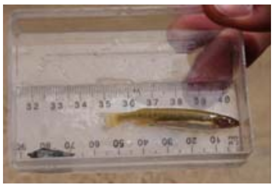
Conclusions

- Pit lake ecology more than just water quality
  - Water quality guidelines only a *beginning*
- Pit lake biota and their ecological requirements
  - Rarely studied, poorly understood
- Need for catchment-scale restoration studies



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