# A study of the hydraulic response of landfills to infiltration events

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Sponsors:
Norlands Foundation, 2000 - 2005
Environment Agency, 2006 - 2008

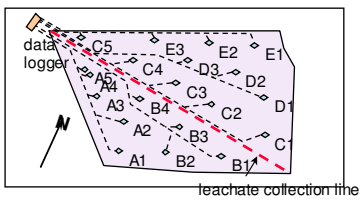
**Hydrogeological group of the Geological Society of London**
**LANDFILL HYDROGEOLOGY, Burlington House, 28 February 2008**

## Background and scope of project

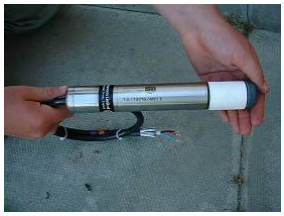
- For all materials except those that are non-polluting, it will be necessary to pass water through the landfill to flush out soluble pollutants.
- There is a need to understand how liquid moves, under the specific conditions created within compacted wastes in landfills
- The study is based on a grid of 20 vibrating wire piezometers (VWPs) installed in the ~1 ha base of a new landfill cell
- Main aspects investigated:
  - **the delay between an infiltration event occurring at the landfill surface (e.g. rainfall or leachate recirculation) and its effects being felt at the base of the landfill;**
  - **the extent to which intermittent infiltration events at a landfill surface are smoothed and attenuated during downwards vertical flow through unsaturated wastes.**

## Project details

- The study was undertaken at Beddington Farmlands landfill, Croydon, UK, from July 2000 to January 2006.
- The study was funded by the Norlands Foundation, using Landfill Tax credits.
- The landfill was operated by Thames Waste Management Ltd at the start of the study, and since 2005 by Viridor Waste Management Ltd.
- Follow-on funding has been obtained from the Environment Agency for a further 2 years experimental work.




**JULY 2000**



**AUGUST/SEPTEMBER 2000**

**27 SEPTEMBER 2000**

**OCTOBER 2000**

**DECEMBER 2000**

**FEBRUARY 2001**

**JUNE 2001**

**JULY 2001**

**DECEMBER 2001**

**MAY 2002**

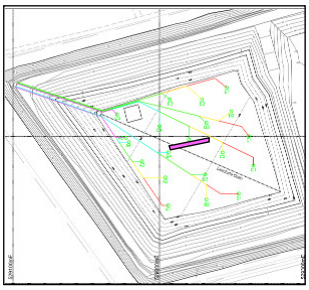
**FEBRUARY 2003**

JUNE 2006

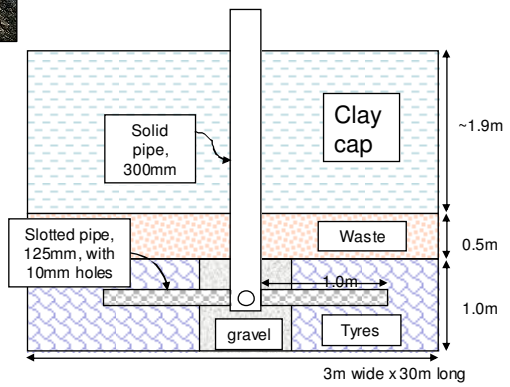
Leachate Management

November 2000

**June 2001**



**December 2001: Leachate recirculation trench installed; access pipes R3 and R4**

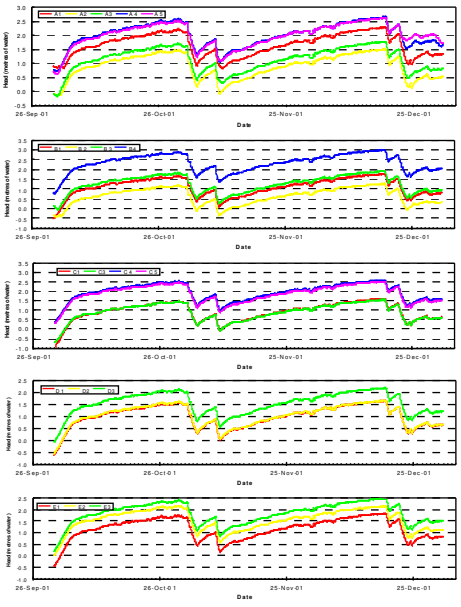


R4, July 2005

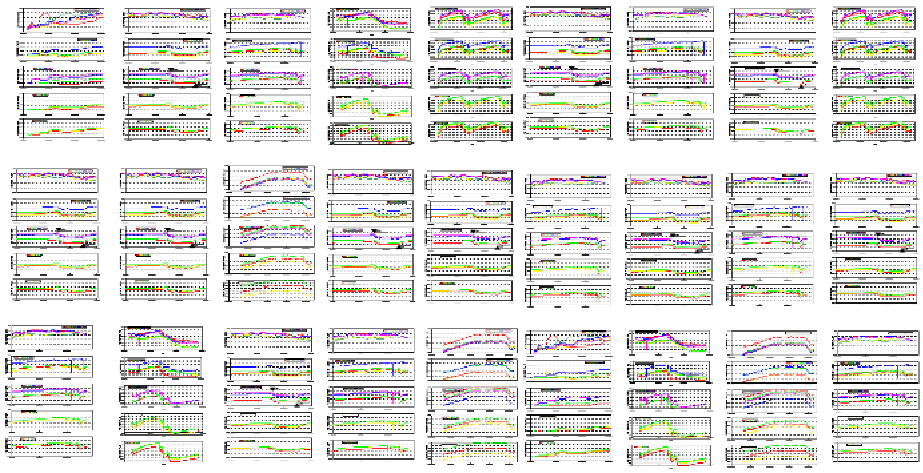
R3 & R4, Feb 2006

**Cell 1B abstraction sump, July 2005**

## Data output from study



## Data output from study



## Aspects investigated

Completed or on-going

- Performance of equipment
- Performance of drainage blanket over 7 years+
- Response of heads to rainfall events during infilling
- Response of heads to abstraction events
  - estimates of drainable porosity
- Recovery of heads when recirculation interrupted

Under way

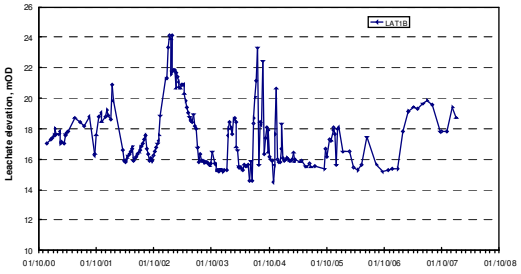
- Response to injection of water/leachate

Future possibilities

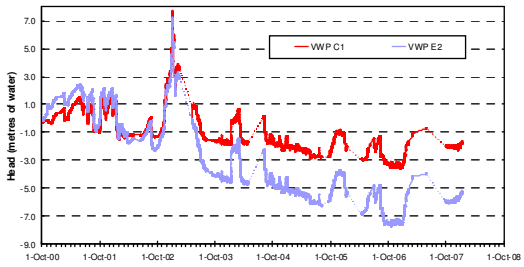
- Tracer trial during injection of water/leachate
- Flushing trials

## Performance of equipment

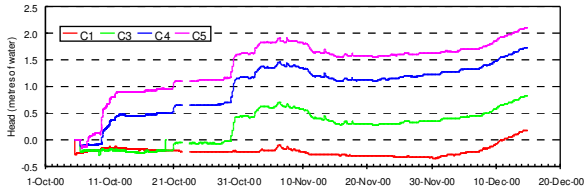
Routine level monitoring at sump



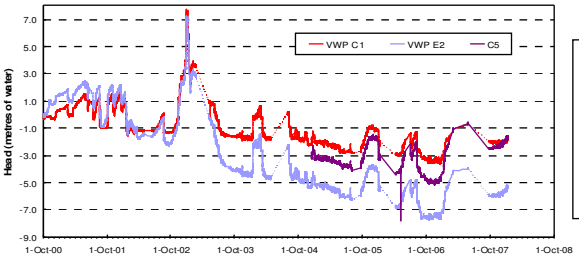

VWPs:
Long term downward drift, slow, ~linear.
600 – 1200mm/a

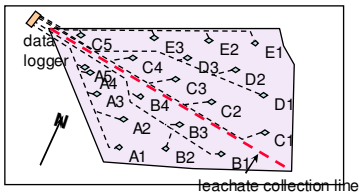


## Results 1. Performance of drainage blanket

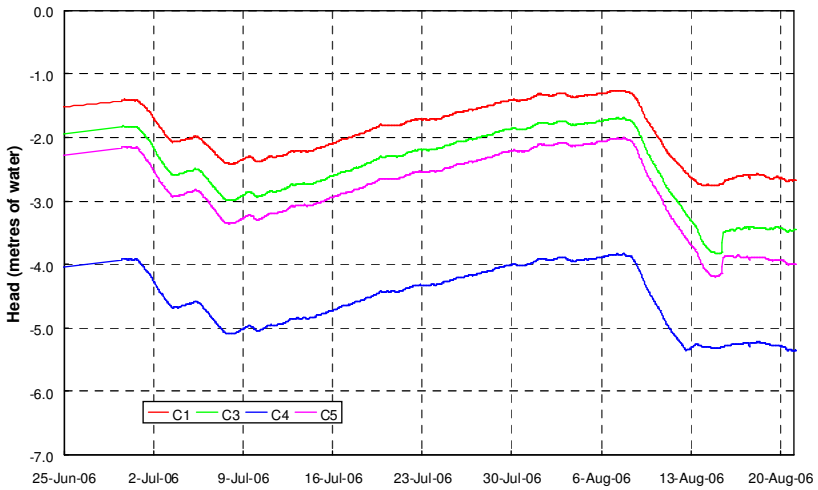



Initial development of leachate heads in the 'C' line piezometers, October to December 2000

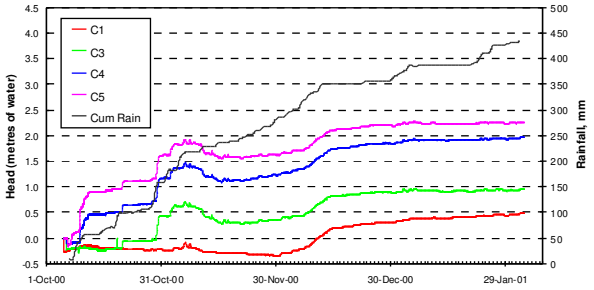



Comparison of responses to hydraulic events, December 2006 to Feb 2007



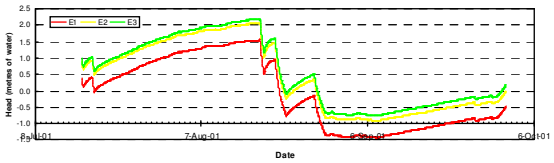
## Results 2. Response of leachate heads to rainfall events




| period | duration (days) | waste depth (m) | rainfall (mm) | lag time (days) | head increase (mm) |
|---|---|---|---|---|---|
| 9/10/00 | 1 | ~1 | 27.4 | <0.5 | C5: ~1,000<br>C4: ~500<br>C3: zero |
| 20/10/00 | 1 | ~1.5 | 26.8 | <0.5 | C3-C5: ~150 |
| 29/10/00-30/10/00 | 2 | ~2 | 47 | <0.5 | C3-C5: ~450 |
| 7/12/00-12/12/00 | 6 | ~5 | 48 | ~2 | C1-C5: ~400 |
| 31/12/00-4/1/01 | 5 | 6-7 | 29.3 | ~2 | <50 |
| 21/1/01-26/1/01 | 6 | 8-9 | 38.6 | - | none measurable |

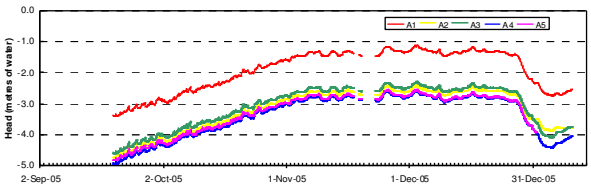
## Results 3. Response of leachate heads to abstraction

| | Observed drawdown | Apparent drainable porosity |
|---|---|---|
| ***May-June 2001*** | mm | %v/v |
| 29/05/01 | 411 | 3.4 |
| 30/05/01 | 274 | 5.1 |
| 02/06/01 | 246 | 2.5 |
| 05/06/01 | 289 | 4.8 |
| 07/06/01 | 269 | 5.2 |
| 11/06/01 | 312 | 4.0 |
| 12/06/01 | 1060 | 5.7 |
| ***August 2001*** | | |
| 17/08/01 | 1000 | 3.0 |
| 20/08/01 | 1638 | 4.7 |
| 27/08/01 | 1128 | 6.5 |
| ***November 2001*** | | |
| 01/11/01 | 1229 | 5.9 |
| 08/11/01 | 872 | 3.4 |
| ***December 2001*** | | |
| 18/12/01 | 591 | 4.3 |
| 21/12/01 | 1086 | 6.0 |
| ***Dec 05- Aug 06*** | | |
| 27/12/05 | 1500 | 1.6 |
| 30/06/06 | 768 | 1.0 |
| 05/07/06 | 483 | 1.3 |
| 08/08/06 | 2093 | 0.8 |




- **For MSW up to 1 year old, mean drainable porosity was ~4.6% v/v, [range 2.5 – 6.5%]**
- **Values ranging 0.8 - 1.6% obtained after 5+ years (mean 1.2%)**

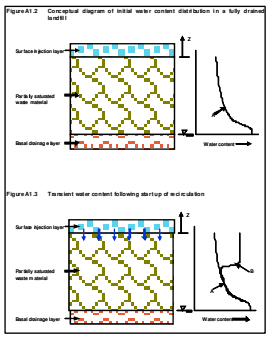
## Results 4. Head recovery after pumping stops



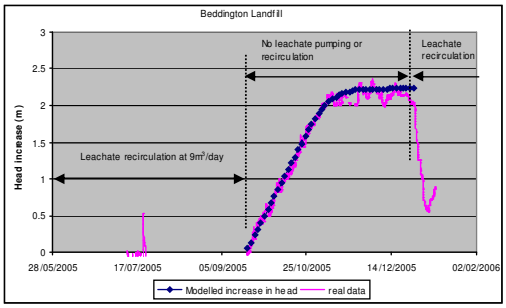

| Pumping stops | Pumping re-starts | Interval | Overall recovery | Initial recovery rate | Final recovery rate | Average recovery rate |
|---|---|---|---|---|---|---|
| | | days | mm | mm/d | mm/d | mm/d |
| 18/07/01 | 17/08/01 | 30 | 1500 | 74 | 14 | 50 |
| 09/11/01 | 19/12/01 | 40 | 1678 | 167 | 19 | 42 |
| 20/09/05 | 07/11/05 | 48 | 2100 | ~linear | ~linear | 44 |

- Results show 'drain-down' continuing for at least 48 days following cessation of pumping.
- Total increase in leachate head of up to 2.1m
- While pumping continues, heads decline or remain stable, regardless of whether the abstracted leachate is re-injected or removed from site.

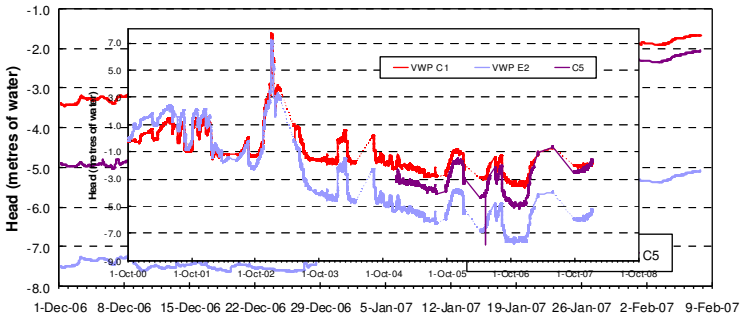
## Modelling of head recovery (White, Beaven)



1-D model calibrated against Beddington data

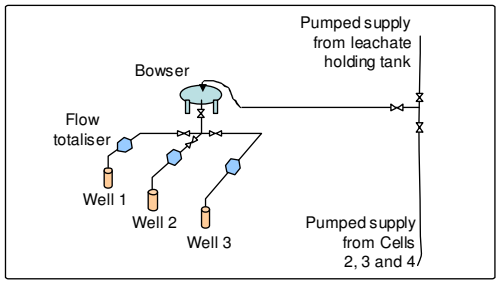


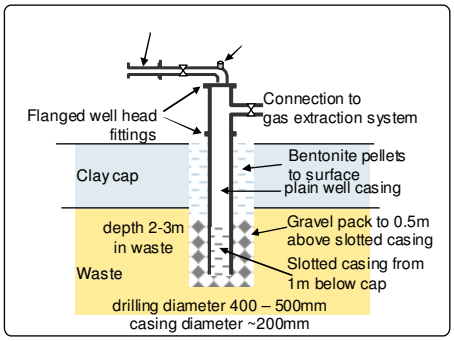
## Response of heads to water injection, January 2007



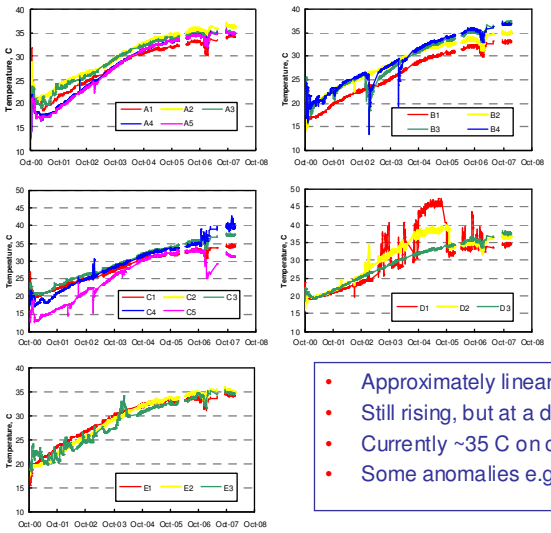

| | | |
|---|---|---|
| Head rise at top (SE) corner of cell, C1 | 2.5 | m |
| Head rise at sump (NW) corner of cell, C5 | 4 | m |
| Area of cell base | 9,000 | $m^2$ |
| Assume saturated storage coefficient | 1.2 | % v/v |
| Volume from 1.5m to 4.0m depth<br>$9000m^2$ x 2.5 x 1.2% | 270 | $m^3$ |
| Volume from 0 to 1.5m depth<br>1/3 x $9000m^2$ x 1.5m x 1.2% | 45 | $m^3$ |
| Recorded volume of water injected | xxxx | $m^3$ |

## Injection wells, October 2007




## Results 5. Temperatures recorded by VWPs




- Approximately linear rise during first 4 years
- Still rising, but at a decreasing rate
- Currently ~35 C on cell base, ±
- Some anomalies e.g. water injection 2007

## CONCLUSIONS

- Gravel drainage layer remains effective at equalising heads across cell base after 7 years. Little or no evidence of any differential responses.
- Lag time for 20-50mm rain events increased from <12 hours for 2m waste depth, to ~2 days for 5m waste depth.
- Above ~9m waste depth, rain events of this magnitude produced no discrete response at the site base.
- Rapidly drainable porosity ranged from 2.5 to 6.5 %v/v (mean ~4.6%) for fresh MSW, similar to other studies.
- Average value of 1.2% after 5-7 years indicates a significant decrease in drainable porosity.
- Ultimate drainable porosity is greater, as shown by continuing drain-down after cessation of abstraction.
- Still a need to do large volume re-injections under the cap, to assess lag times etc. for high rate recirculation.