# Aquator User Group – 6th October 2011

## Optimising a 5 reservoir system using Genetic Algorithms

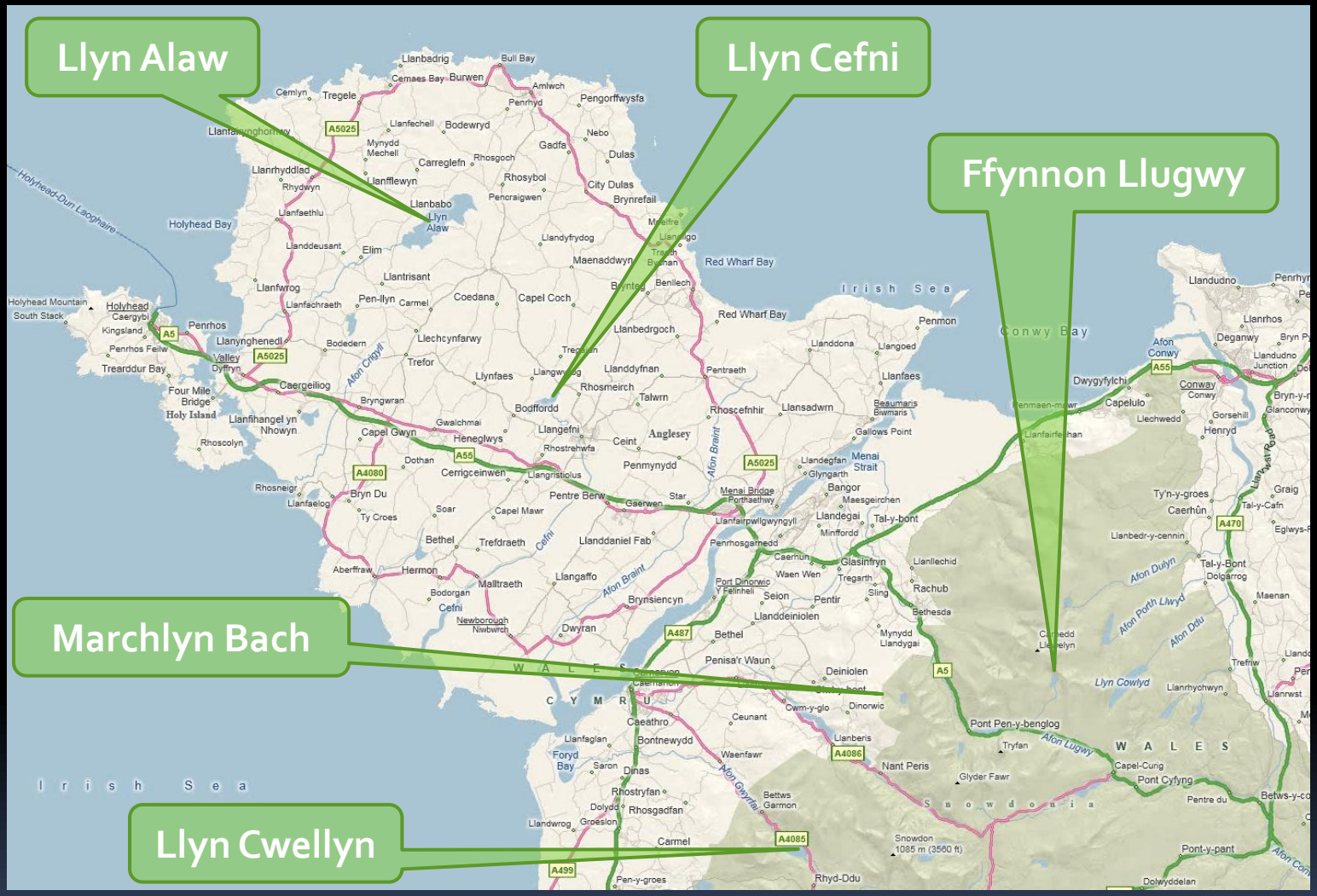
Chris Green (OSS)
Mark Morley (University of Exeter)

*Note that the results presented here have been superseded by better (increased DO) solutions obtained after 6th October*

# Overview

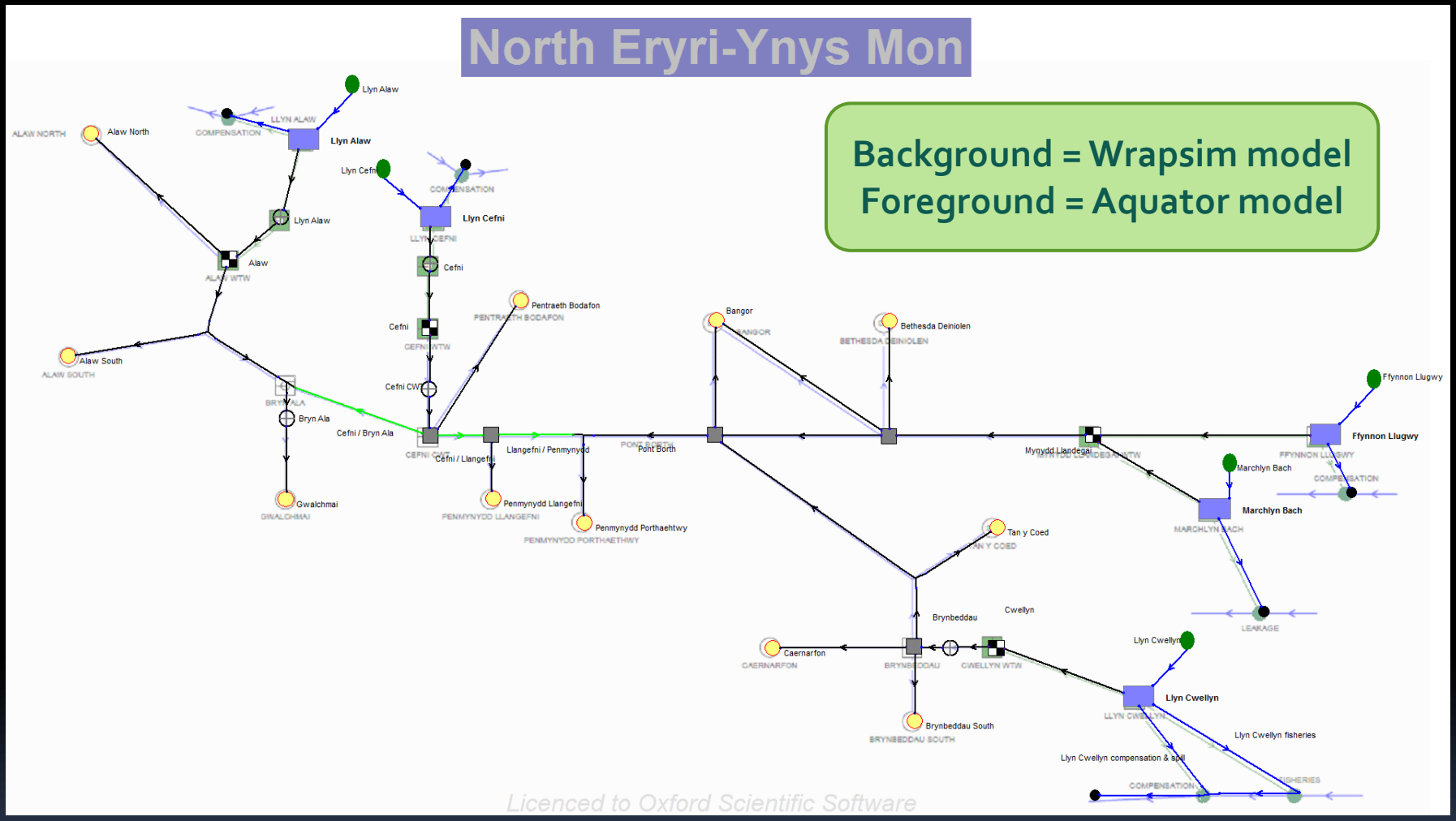
1. The Model (Chris)
2. Objectives (Chris)
3. Genetic Algorithms (Mark)
4. Results (Mark)
5. Conclusions (Mark & Chris)

# The North Eryri-Ynys Mon system



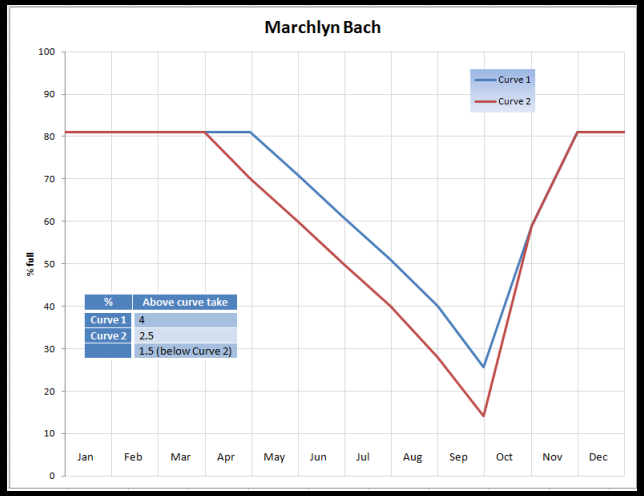

- Thanks to Dwr Cymru for permission to discuss
- All results are provisional

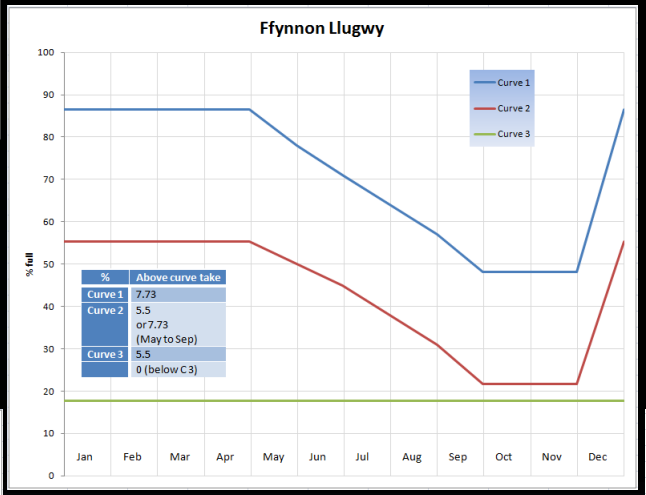
# The Wrapsim & Aquator models

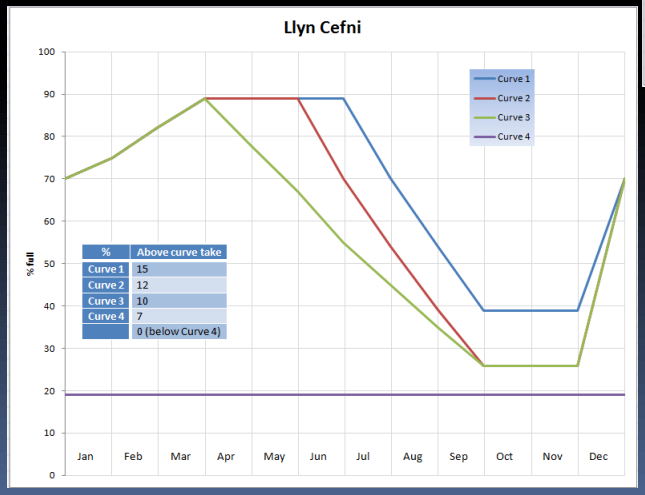


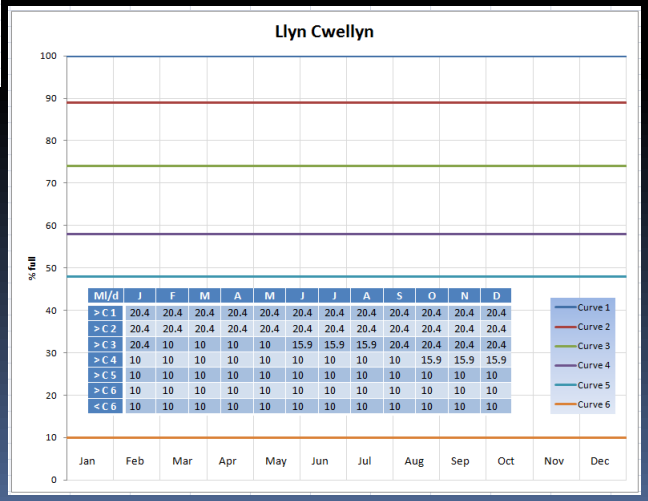

- Aquator model duplicates Wrapsim model
- Why create an Aquator model?

# Current reservoir control curves


| Ml/d | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| > C 1 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 |
| > C 2 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 | 20.4 |
| > C 3 | 20.4 | 10 | 10 | 10 | 10 | 15.9 | 15.9 | 15.9 | 20.4 | 20.4 | 20.4 | 20.4 |
| > C 4 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 15.9 | 15.9 | 15.9 |
| > C 5 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| > C 6 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| < C 6 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |

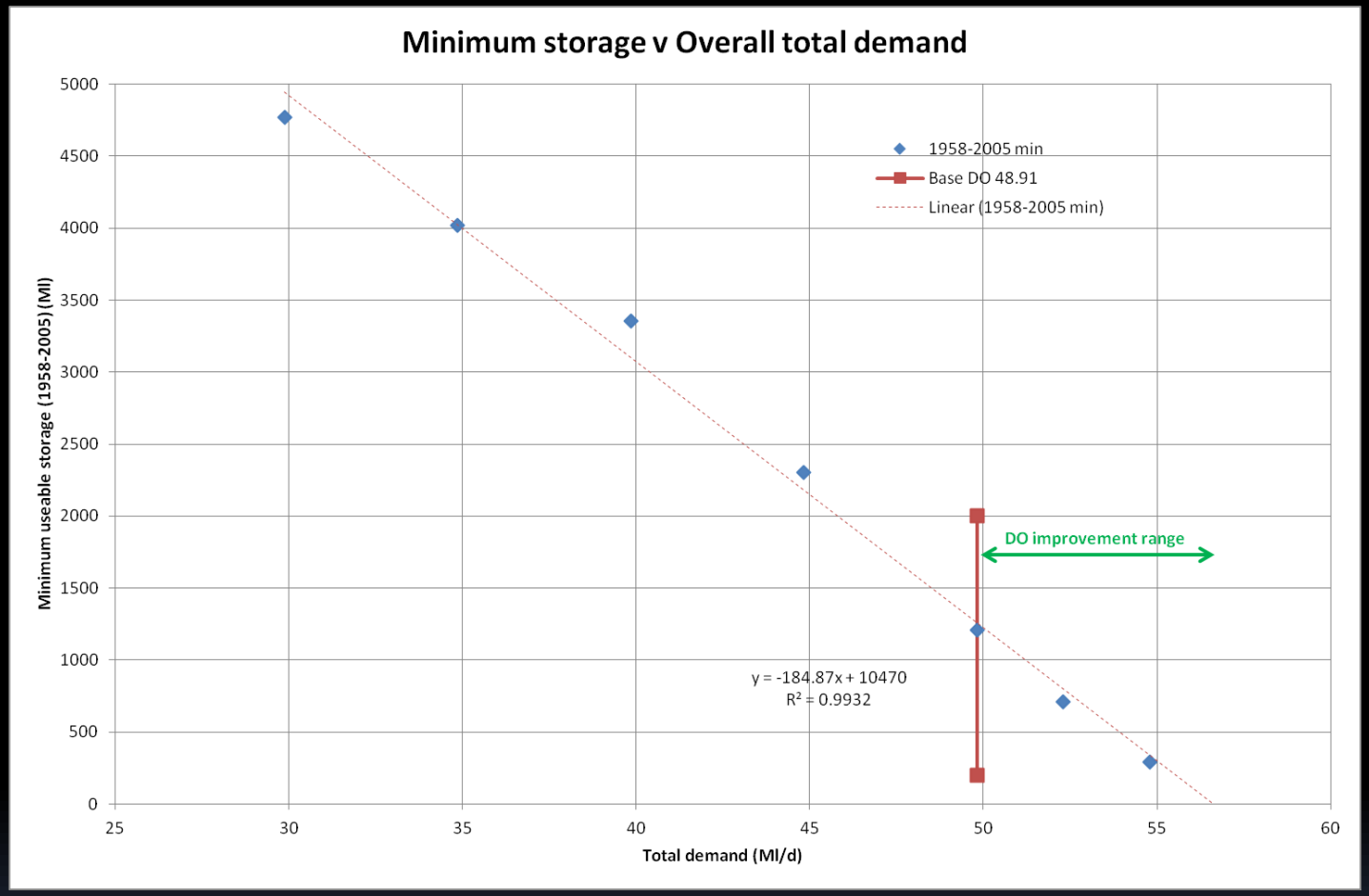
# Current DO

- No failure to supply over whole record 1958 – 2005
- 4 x Level 1 demand restrictions
- 1 x Level 2 demand restrictions
- Achieved with 17 control curves and variable band maxima
- **DO = 49.81 Ml/d**

# The task

- No failure to supply over whole record 1958 – 2005
- No Level of Service failures
- Increase the DO beyond the current 49.81 Ml/d
- Simplify the curves – just one per reservoir

# What is the maximum possible DO ?




- Approximate – higher demands were causing failures
- Does not include Level of Service failures which could reduce the DO
- Does not include network constraints which could reduce the DO
- Conclusion: DO cannot be more than 56-57 Ml/d

# Single curve Aquator model

- No cost information so simply optimising on resource use
- Single control curve used to calculate reservoir's 'resource state' each day
- Resource state determines priority of use to keep the model in 'balance'

Operating strategies considered:

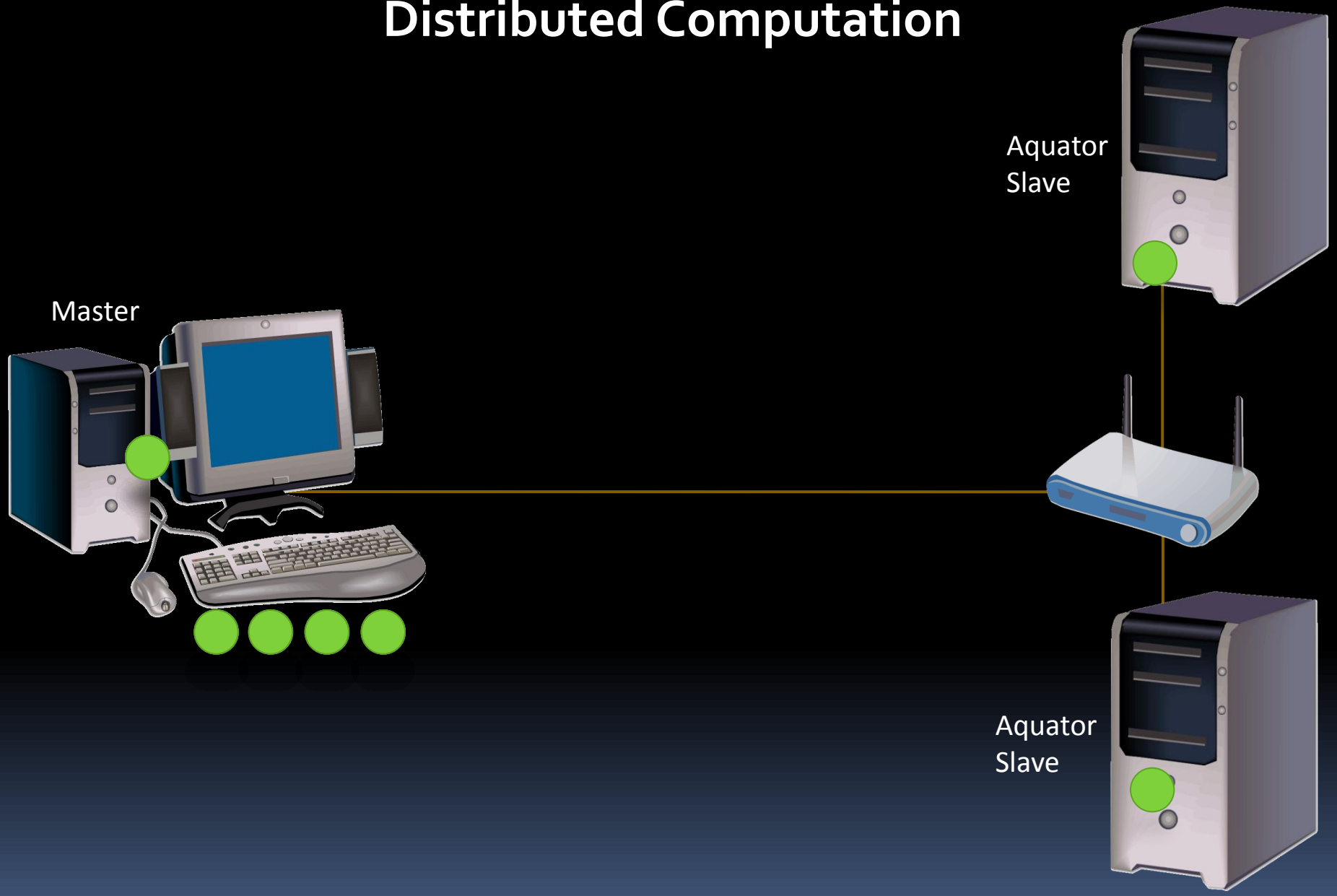
1. No below or above curve maxima
   (simply priority of use based on resource state)
2. Include below and above curve maxima

# Mark…

# Genetic Algorithms

- A computational technique for "evolving" solutions to problems using a population of individual, different solutions
- Based on Darwinian "survival of the fittest"
- "Genes" represent decisions to be made – e.g. reservoir control curve levels
- Solutions inherit genetic traits from their "parents"
- Can provide solutions to problems that would otherwise be intractable – e.g. this case study has $> 1.5 \times 10^{174}$ solutions

# Distributed Computation



# Problem Formulation #1

- **Decision Variables:**
  - **60 Reservoir levels (5 reservoirs × 12 monthly values)**

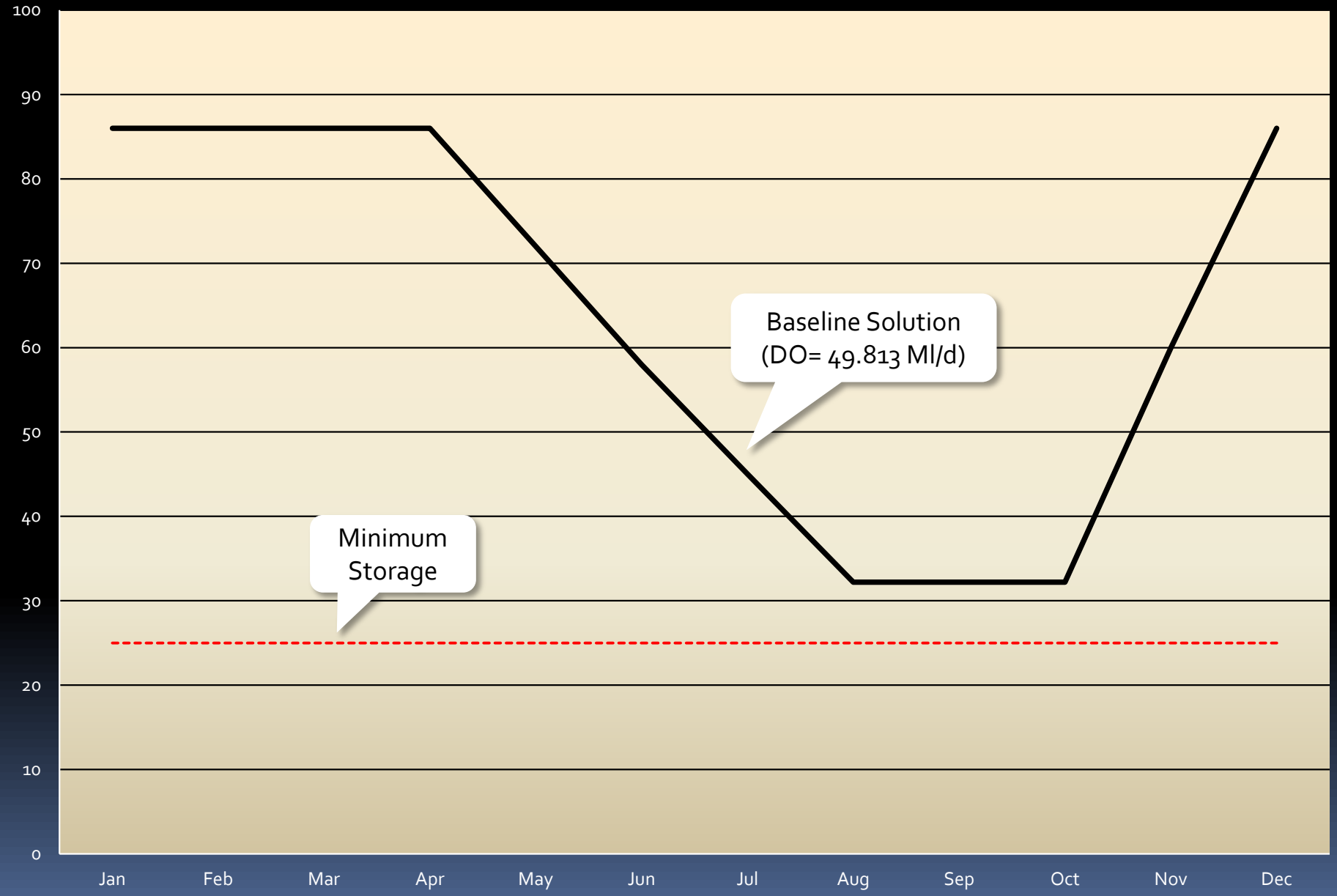
- **Objectives:**
  - **Maximize:**
    - Deployable Output
    - Curve "Smoothness"
  - **Minimize:**
    - Number of "Events"

# Problem Formulation #2

- **Hard Constraints:**
  - **No supply deficits**
  - **When modelled over full data set:**
    - No more than two Level 1 Events associated with each reservoir
    - No more than one Level 2 Event over the whole system

- **Soft Constraints**
  - **No. of days affected by Level 1 or 2 Events**

# Llyn Alaw – Curve Smoothness



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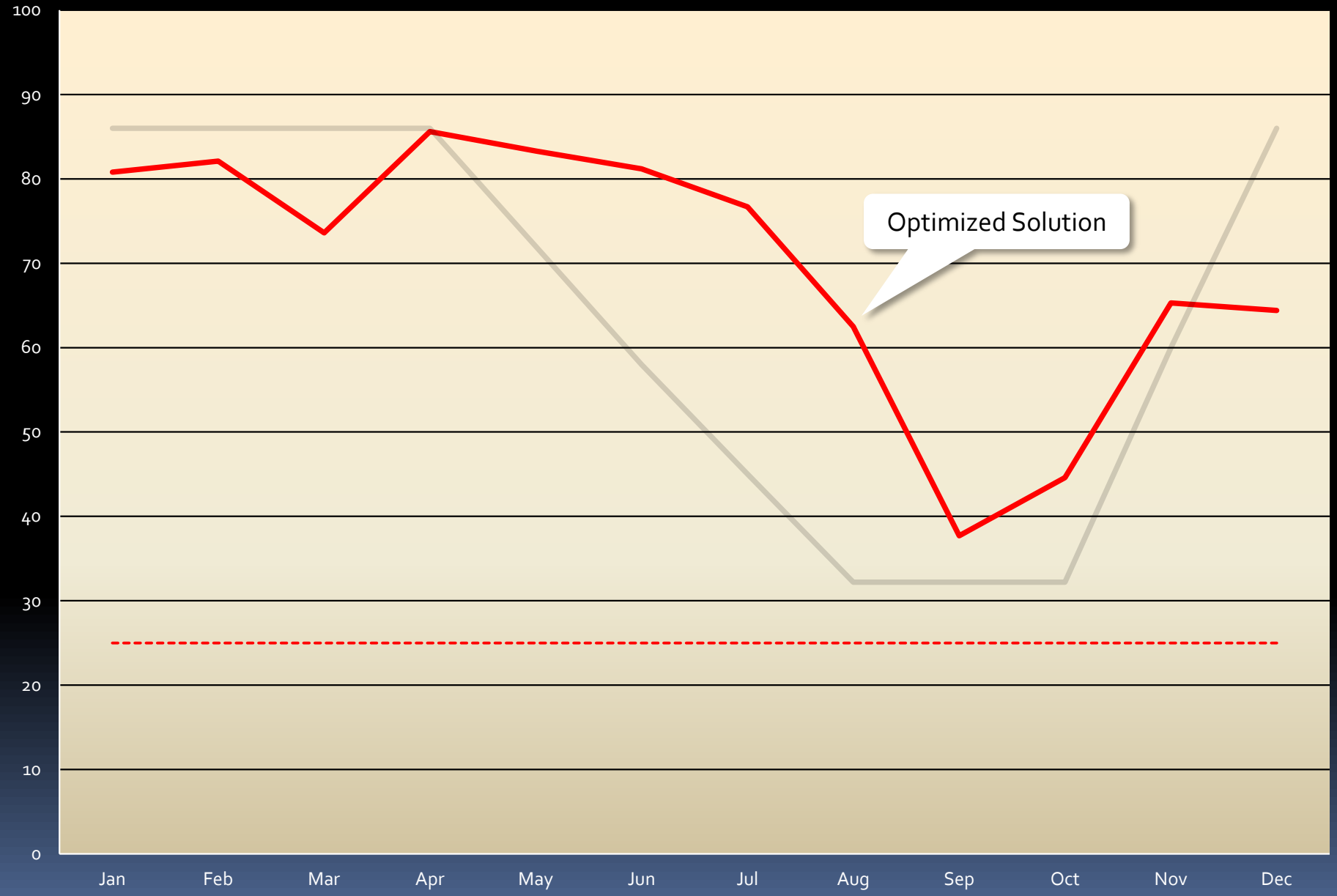

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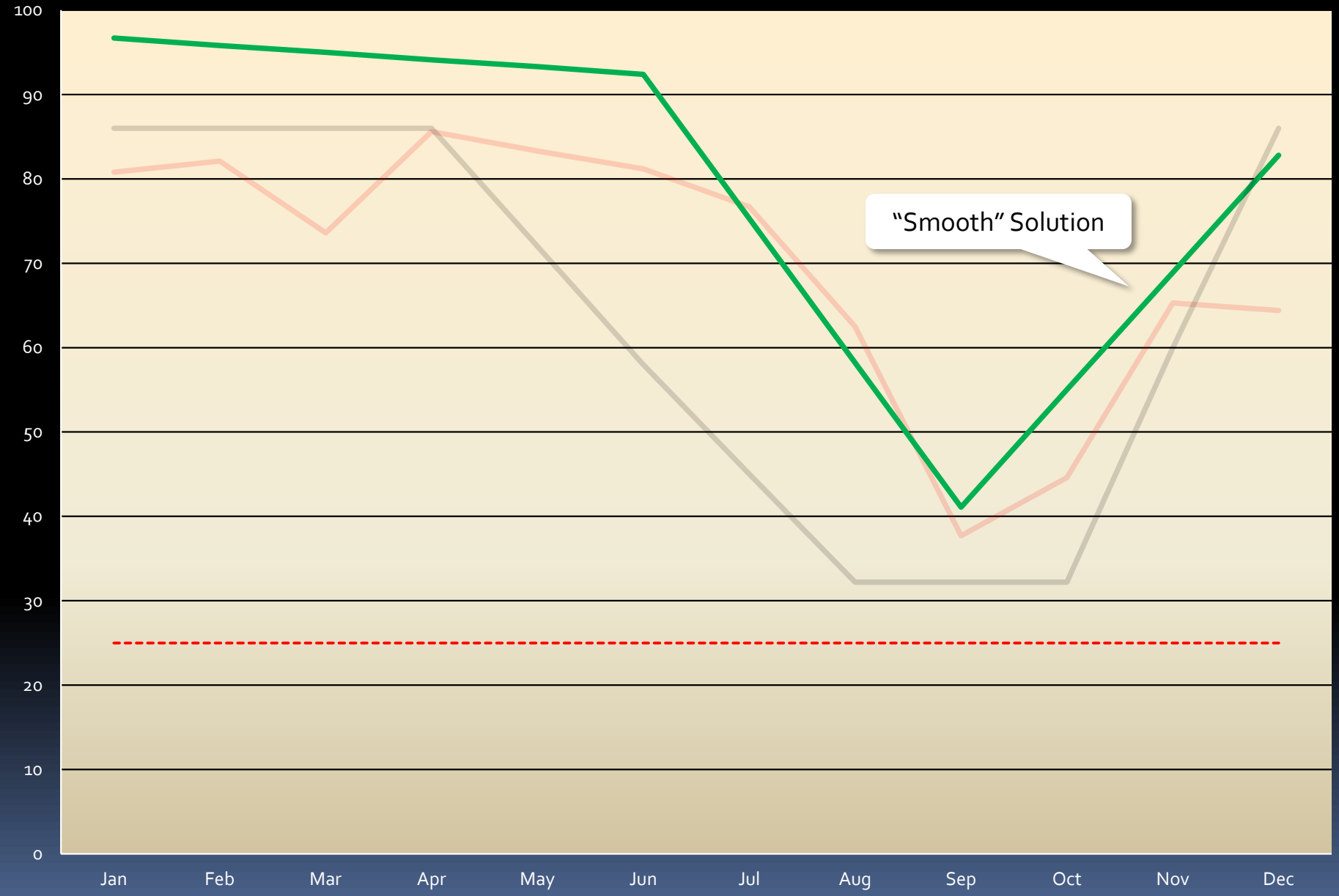

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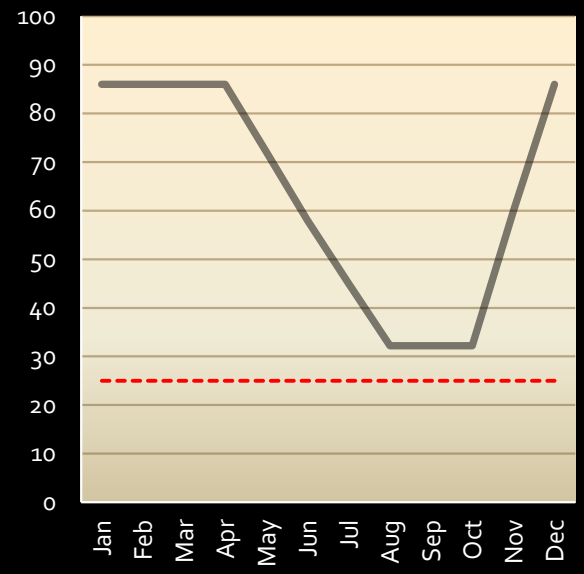


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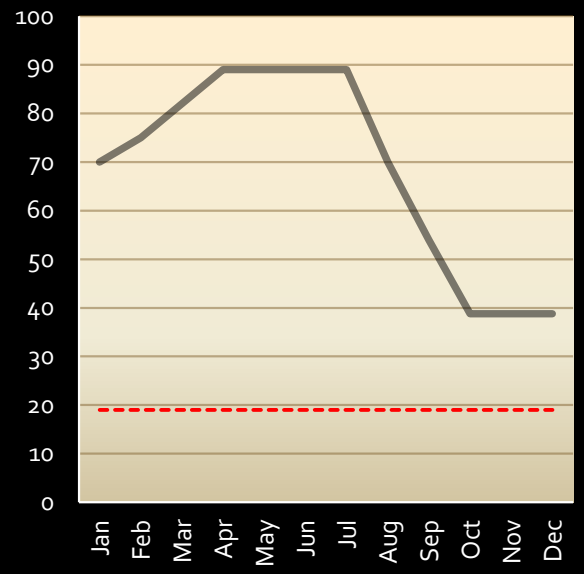


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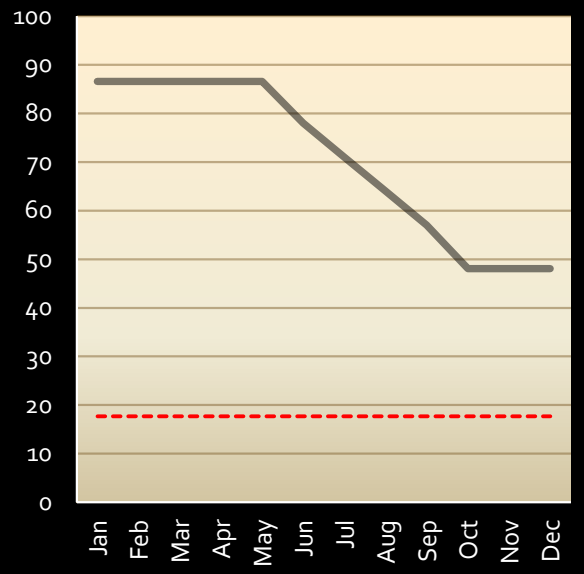


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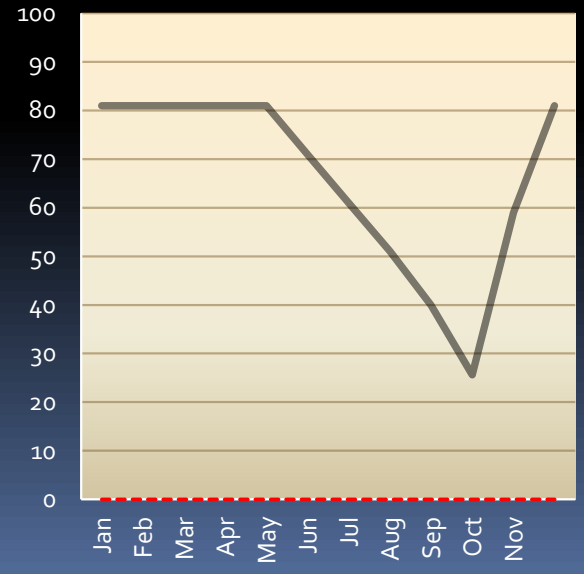


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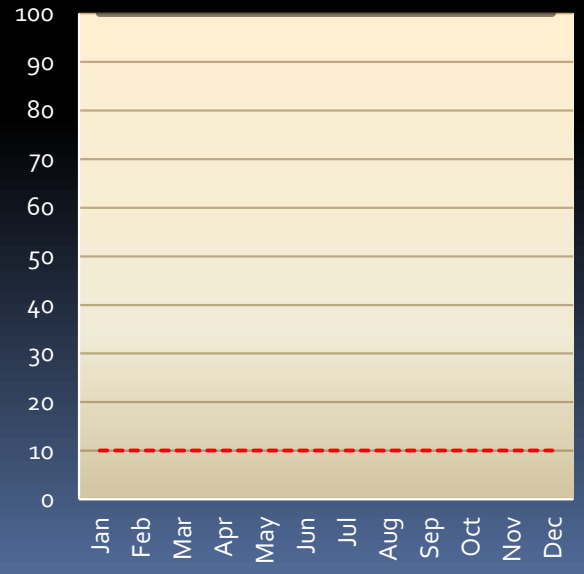

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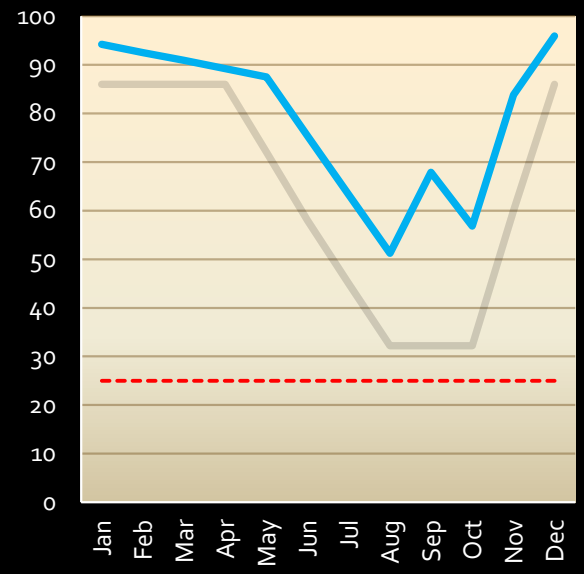


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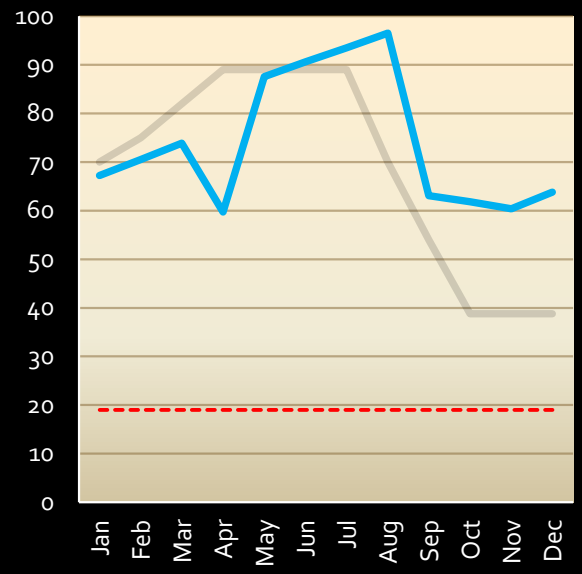


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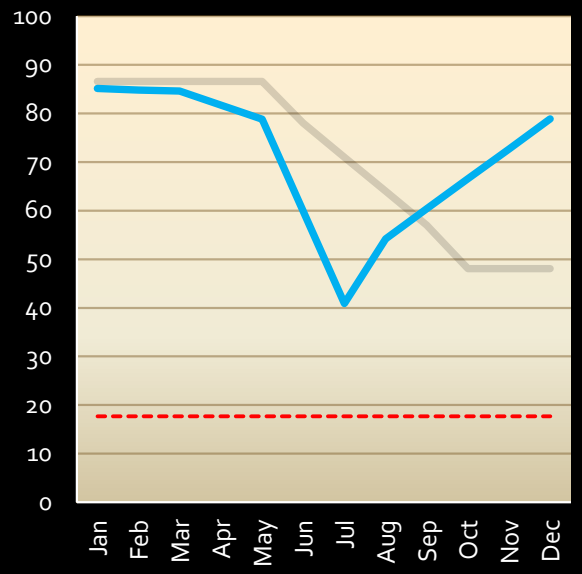


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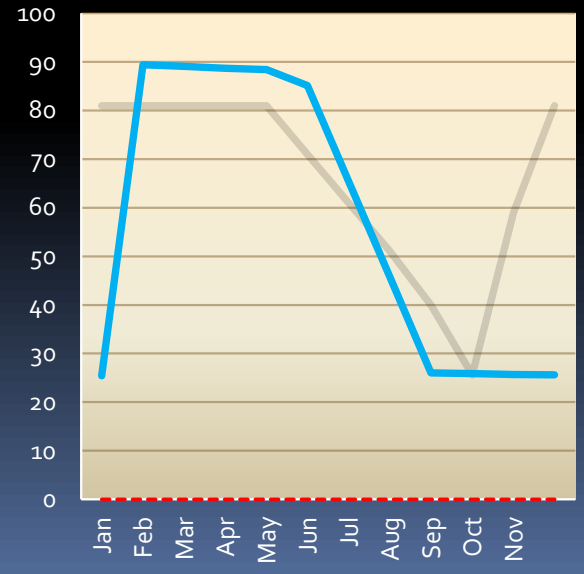


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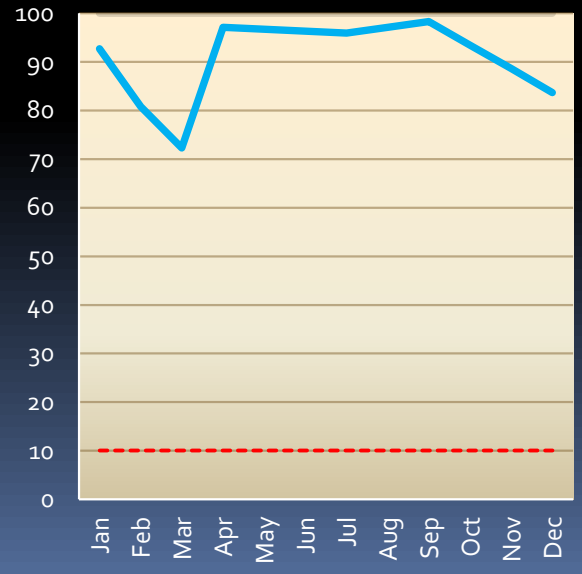


DO: 51.75

*Increase of 1.94 Ml/d (+3.9%)*

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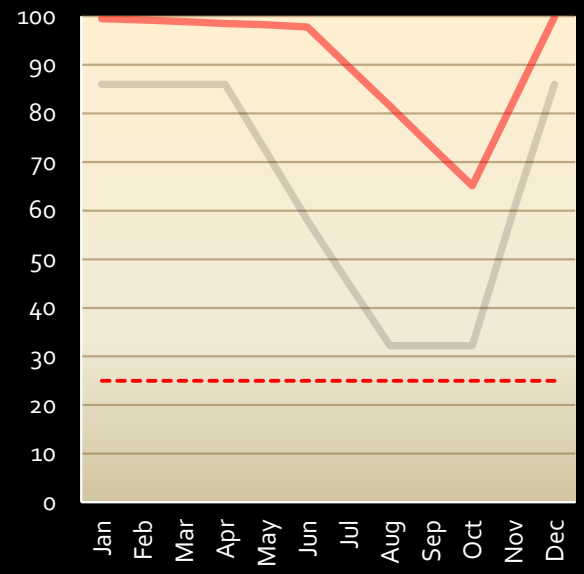


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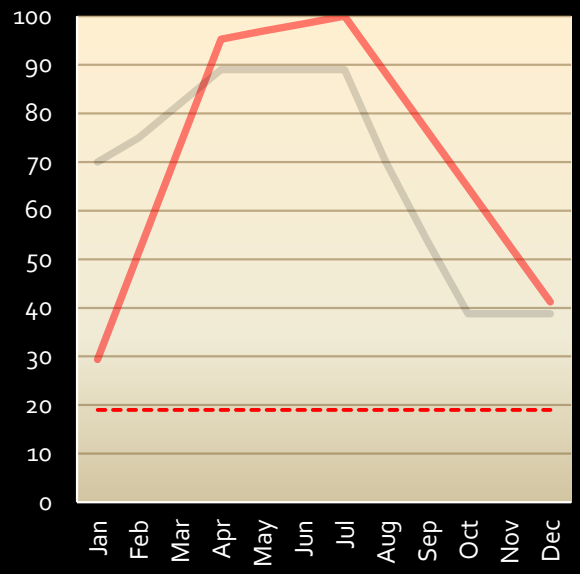


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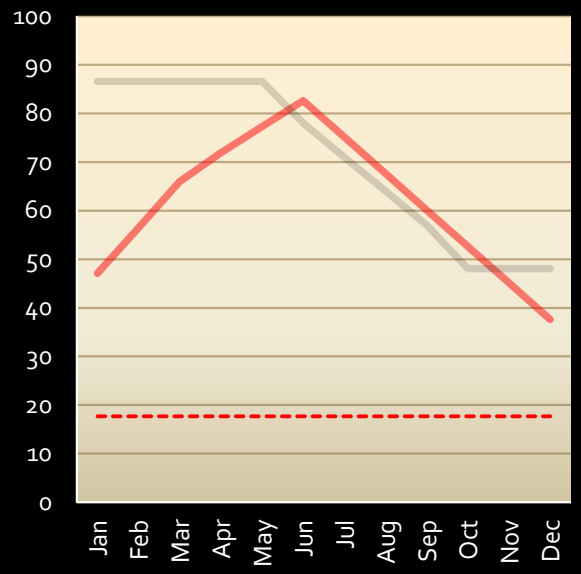


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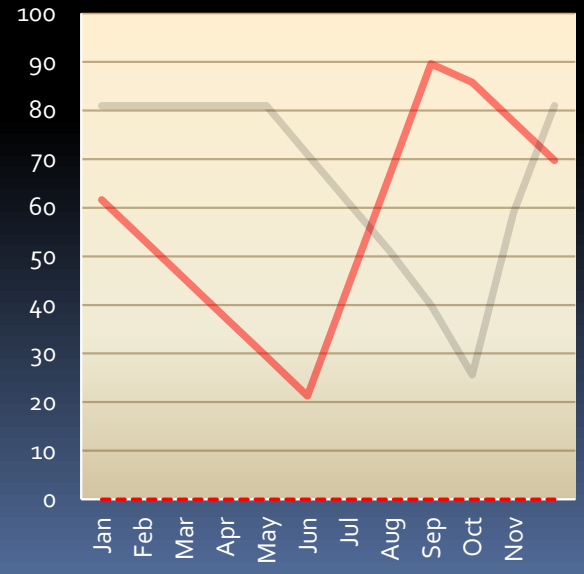


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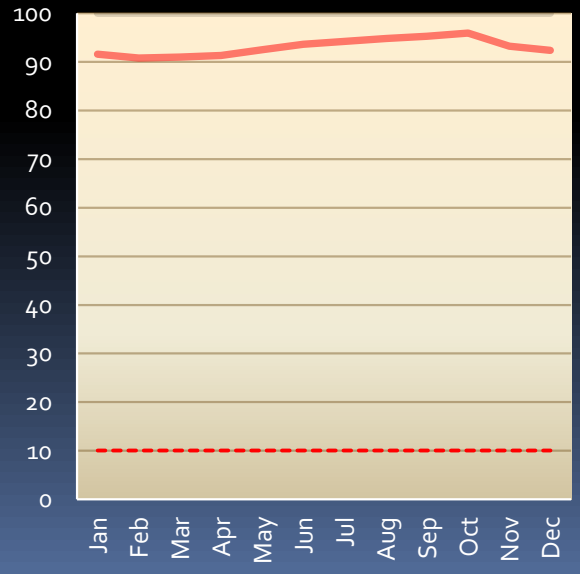
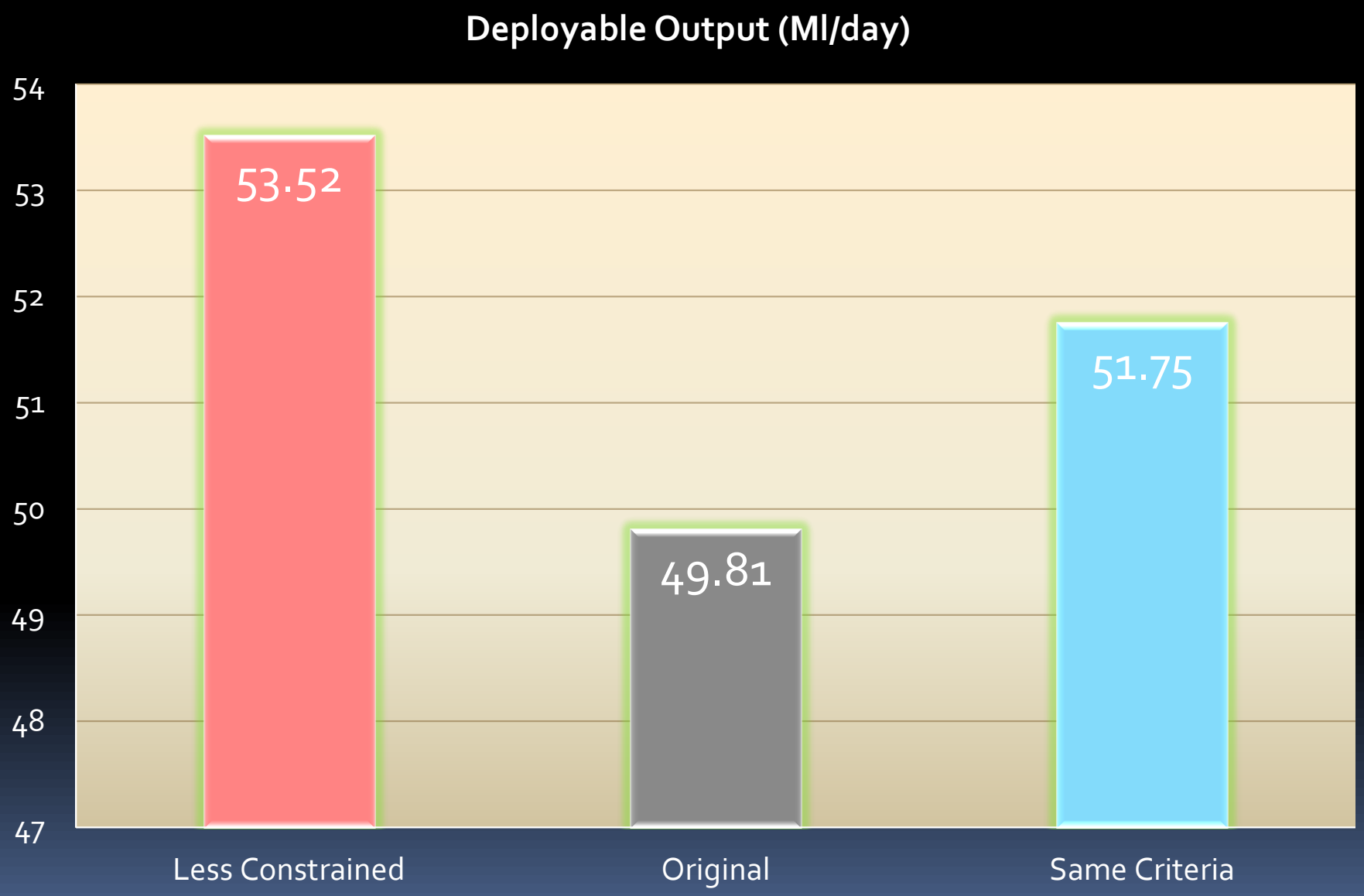



DO: 53.52

*Increase of 3.71 Ml/d (+7.5%)*


Deployable Output (Ml/day)
54
53
52
51
50
49
48
47
53.52
49.81
51.75
Less Constrained
Original
Same Criteria

# Conclusions

- DO has been increased (>3.5%)
- Single control curves on each reservoir
- Simple control curves
- Reservoirs are now working together rather than independently
- Potential for also reducing operating costs if cost information becomes available