Aspects influencing energy requirements of irrigation systems

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Overview of presentation

- Energy use by irrigation systems
- Guidelines for farmers, advisors / designers
- Case studies
- Conclusion

Useful Point of Use cost

(University of the Free State, 2015)

Energy Cost In				
Fuel Type	**Cost**	**Units**	**R/GJ**	**R/kWh**
Coal	726.00	R/tonne	25.93	0.09
Parraffin	7.23	R/litre	193.87	0.70
PV Solar	1.15	R/kWh	319.00	1.15
Heavy Fuel Oil	9.50	R/litre	250.00	0.90
Electricity	1.28	R/kWh	355.56	1.28
Diesel	10.77	R/litre	276.15	0.99
Natural Gas	300.00	R/GJ	300.00	1.08
Petrol	12.41	R/litre	354.57	1.28
LPG	20.82	R/kg	456.08	1.64

Eskom’s average nominal tariff adjustments for the last 18 years

Year	Average Tariff Adjustment (%)
1 January 1998	5.00
1 January 1999	4.50
1 January 2000	5.50
1 January 2001	5.20
1 January 2002	6.20
1 January 2003	8.43
1 January 2004	2.50
1 January 2005	4.10
1 April 2006/7	5.10
1 April 2007/8	5.90
1 April 2008/9	27.50
1 April 2009/10	31.30
1 April 2010/11	24.80
1 April 2011/12	25.80
1 April 2012/13	16.00
1 April 2013/14	8.00
1 April 2014/15	8.00
1 April 2015/16	12.08

Energy cost (k_p)

$$k_{\mathrm{p}} = \mathrm{P_i} \times \mathrm{t} \times \mathrm{k_e}$$

Where:

P_i = input power requirement of the electrical motor, kW

t = total nr of hours the pump is operated for at P_i, hours

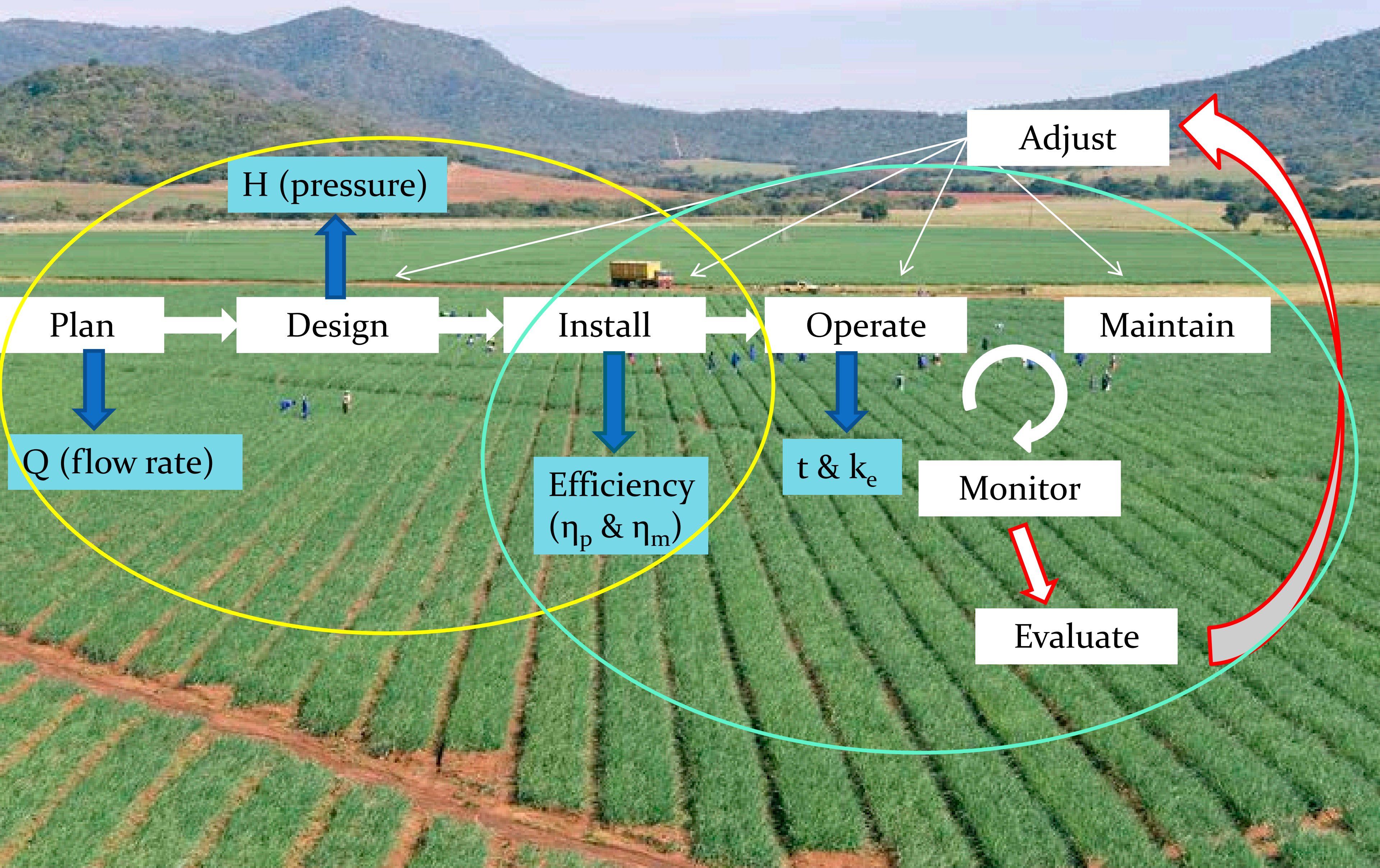
k_e = energy tariff, Rand per kWh

Energy use in pumping systems

$$P_i = \frac{\rho \times g \times H_{pump} \times Q_{pump}}{360 \times \eta_p \times \eta_m}$$

Where	P_i	=	input power requirement of the electrical motor, kiloWatt
	ρ	=	density of water, kg/m^3
	g	=	gravitational acceleration, m/s^2
	H_{pump}	=	pressure requirement at the pump station, m
	Q_{pump}	=	system discharge, m^3/h
	η_p	=	pump efficiency, %
	η_m	=	motor efficiency, %

Irrigation system life cycle



Guidelines (1/3)

- Ruraflex is more profitable than Landrate irrespective of system size and irrigation system delivery capacity
- However, profitability of Ruraflex is closely related to irrigation scheduling practices and system design, and Ruraflex availability is limited / restricted
- During peak irrigation demand periods, the value of the marginal product is much higher than the marginal cost of applying irrigation water at a higher rate
- Smaller delivery capacities proved to be the most profitable for all the system sizes and electricity tariff structures investigated but **require much more intensive management**

Guidelines (2/3)

- Larger irrigation systems resulted in higher NPVs per hectare compared to the smaller systems
- An estimate of variable as well as fixed electricity costs should be considered together with the investment costs
- Irrigation systems should be operated at the correct pressure
- Irrigation systems need to be maintained properly in order to ensure water is applied at an acceptable uniformity

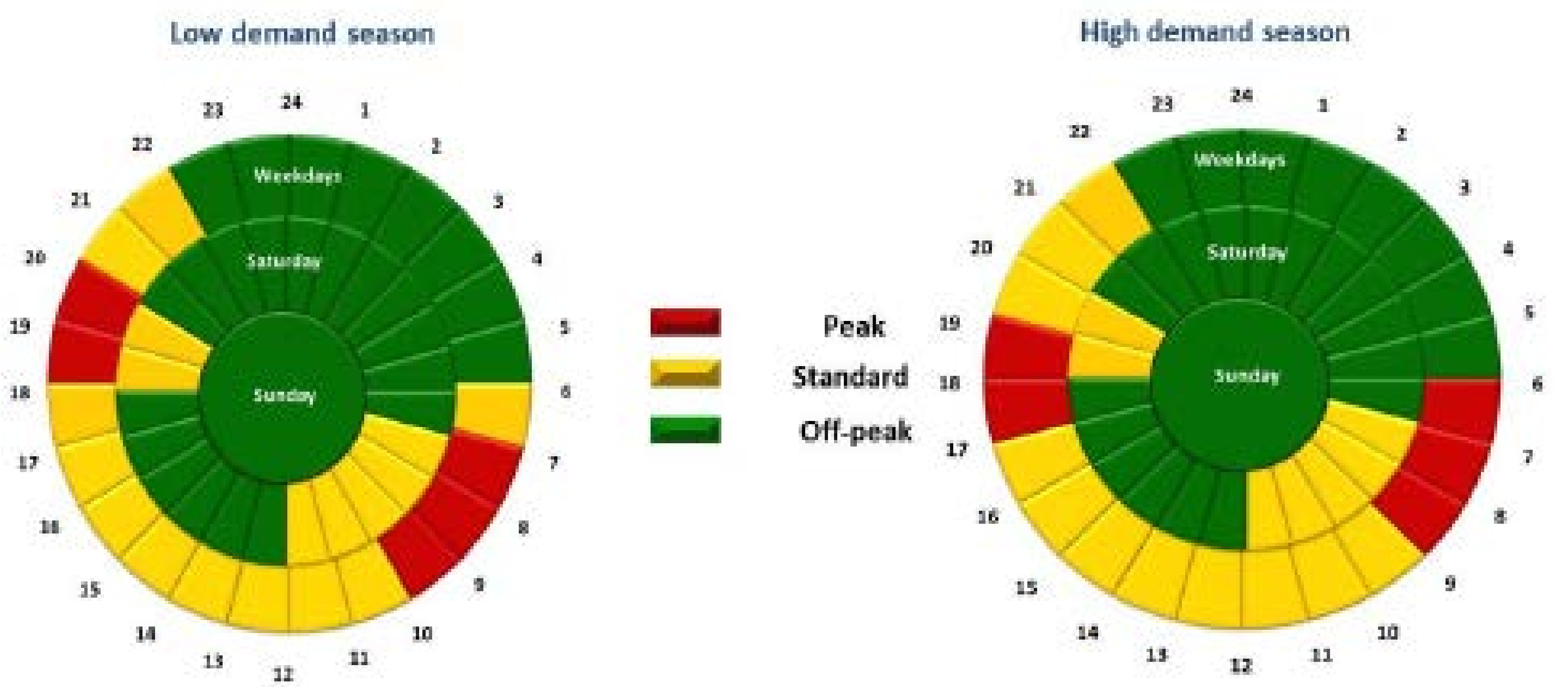
Guidelines (3/3)

- The friction loss gradient for mainlines should be less than 0.6% but the minimum critical velocity for the pipe slope should be met
- Various factors have an influence on the economic benefit of a VSD. Greatest benefits were shown for systems:
  - where the duty points vary because of elevations differences between delivery points
  - especially center pivots operating against slopes greater than 2% and static irrigation systems where block inlets are located at different elevations.

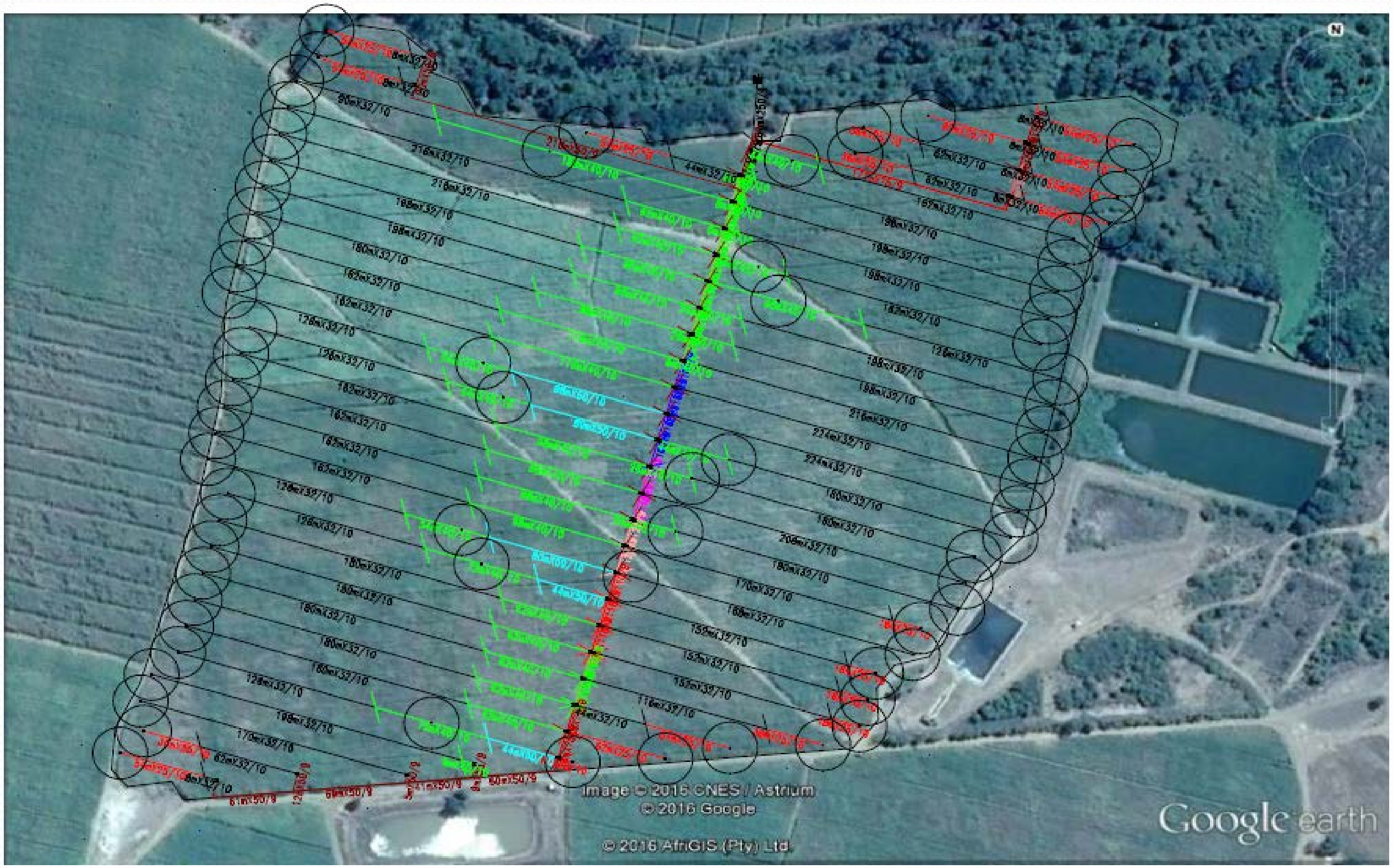
Case studies

Landrate vs Ruraflex

WEPS, Megaflex, Miniflex, Megaflex Gen, Ruraflex Gen and Ruraflex



Sprinkler system



Sprinkler system

Pressure required at pump: Valve inlet pressure = 52m Elevation difference = 25.59m Mainline head loss = 6.32m Secondary losses = 7.2m Safety factor = 5%	96m
Flow required at pump: Including 10% safety factor	130 m^3/h
Output power (required by pump)	47 kW
Power factor (cos φ)	0.87
Motor efficiency	92%
Input power (drawn from transformer)	51.1 kW

Sprinkler system

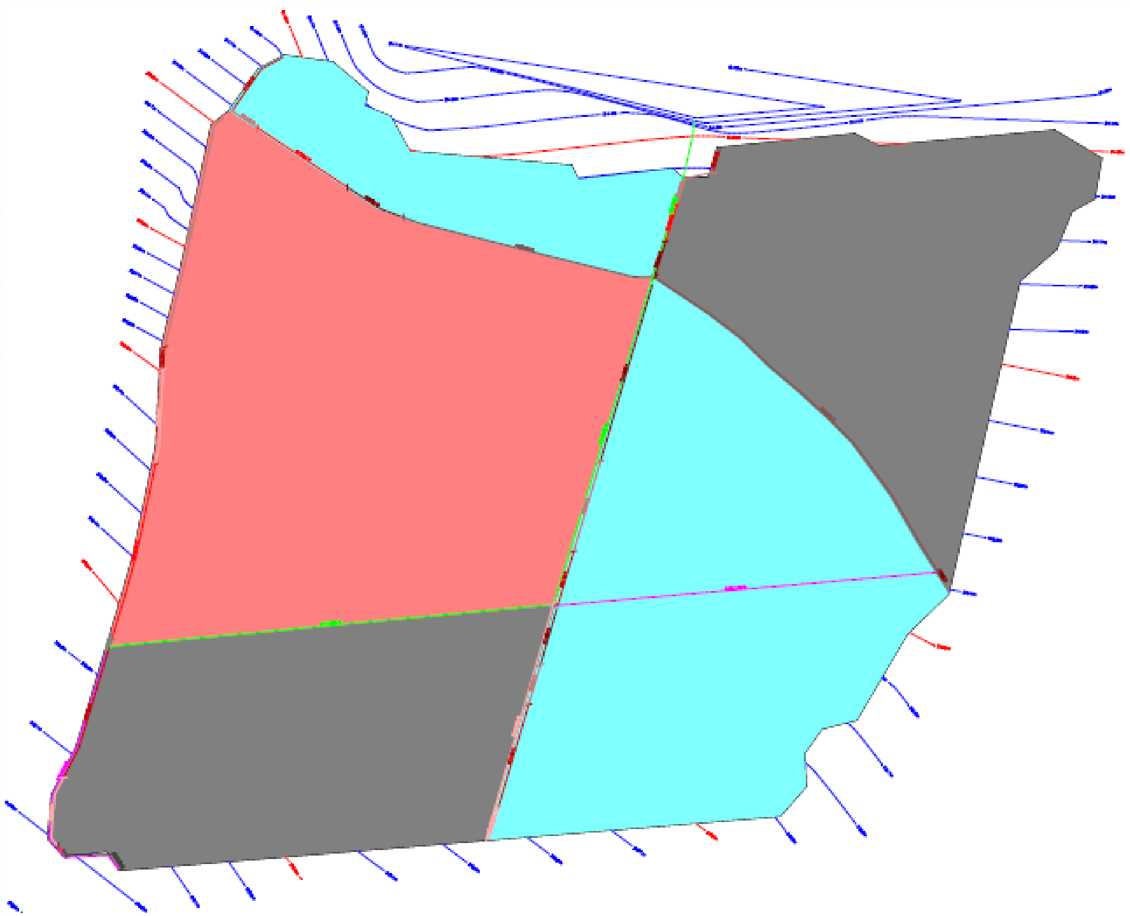
	Landrate	Ruraflex
Motor input power, kW	51.1	51.1
Energy consumption, kWh	106237	106237
Variable electricity costs, R	110433	75470
R/ha	4961	3390
R/mm	4.09	2.79
R/kWh	1.04	0.71
Total electricity costs, R	130008	96513
R/kWh	1.22	0.91
kW/ha	2.30	2.30

Case study

Irrigation system selection

Effect of VSDs

Drip irrigation



Drip irrigation

Pressure required at pump: Valve inlet pressure = 20m Elevation difference = 25.24m Mainline head loss = 10.37m Secondary losses = 6.14m Safety factor = 5%	65m
Flow required at pump: Including 10% safety factor	106 m^3/h
Output power (required by pump)	26 kW
Power factor (cos φ)	0.8
Motor efficiency	90%
Input power (drawn from transformer)	28.9 kW

Drip irrigation with VSD

	Setpoint 1	Setpoint 2	Setpoint 3
Pressure required at pump: (m)	55	60	65
Flow required at pump: (m3/h)	95	97	106
Pump efficiency (%)	70.5	71	72
Output power (required by pump)	20.3	22.4	26.1

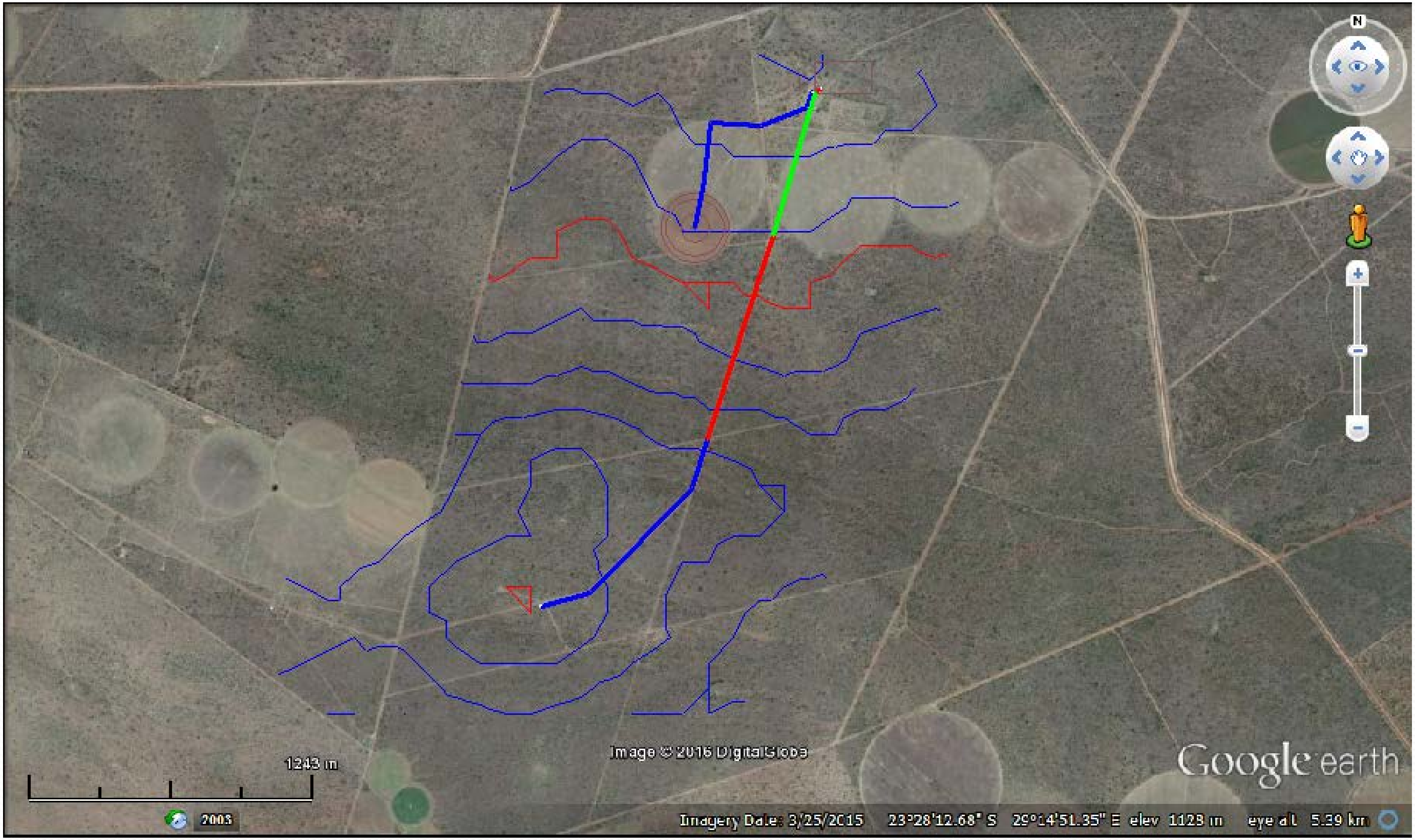
Drip irrigation

	No VSD		VSD	
	Landrate	Ruraflex	Landrate	Ruraflex
Motor input power, kW	28.9	28.9	25.5	25.5
Energy consumption, kWh	38957	38957	34349	34349
Variable electricity costs, R	40496	23466	35705	20759
R/ha	1819	1054	1604	933
R/mm	2.83	1.64	2.67	1.55
R/kWh	1.04	0.60	1.04	0.60
Total electricity costs, R	60071	36301	55280	32288
R/kWh	1.54	0.93	1.61	0.94
kW/ha	1.30	1.30	1.15	1.15

Case study

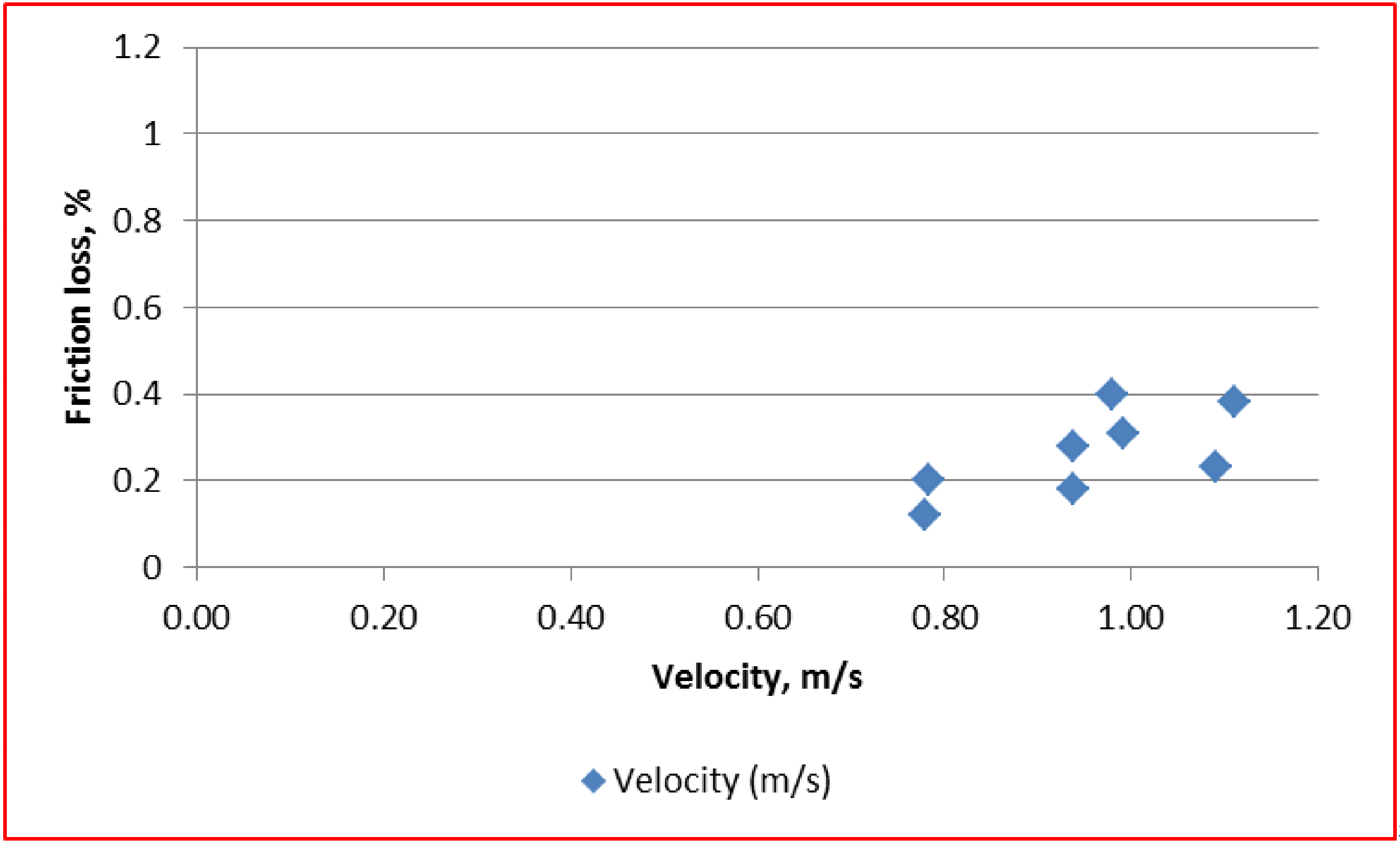
Mainline optimisation

Case study: Borehole → Dam→ Pivot

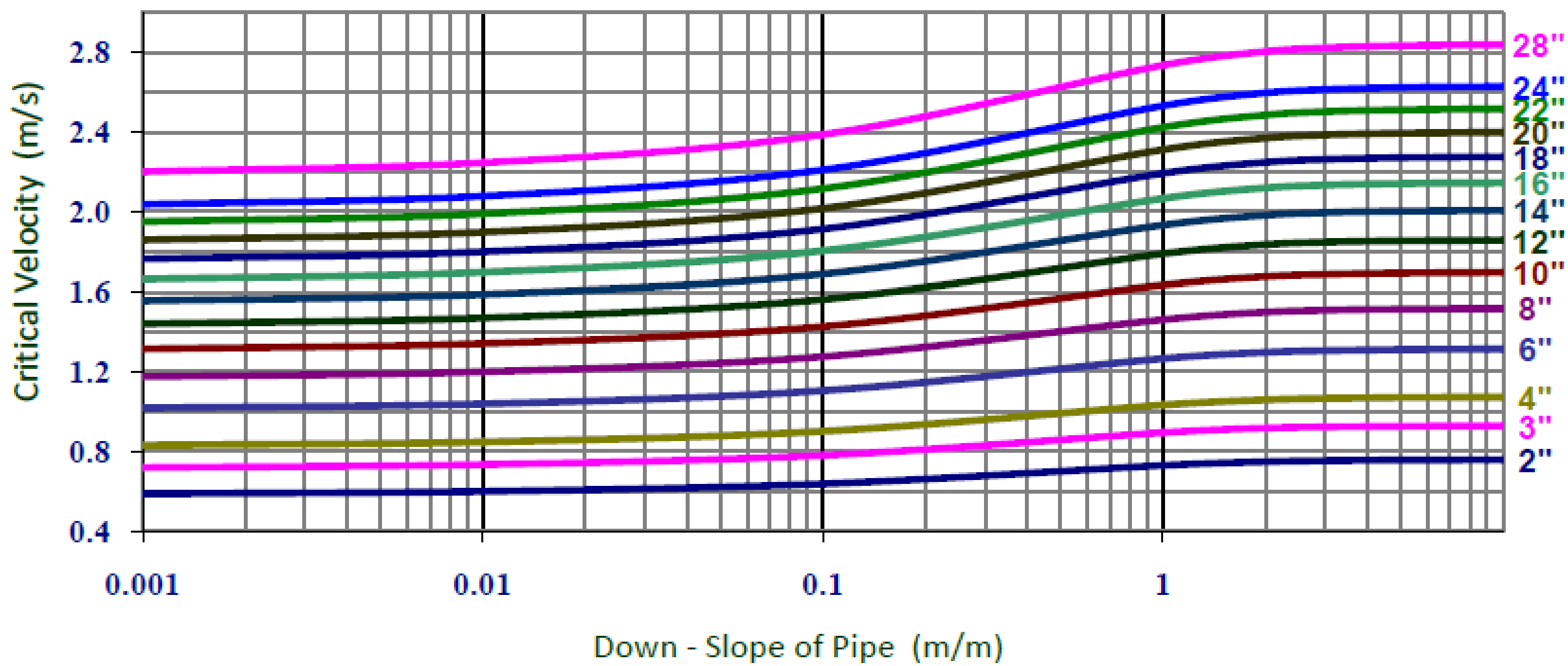


		Ruraflex	
Irrigation		**Optimal**	**Current**
Total	mm.ha	3923	3923
	mm	530	530
Pumping hours			
Total	hours/7.4ha	1226	1226
VARIABLE ELECTRICITY			
Active	R/7.4ha	10610	12458
Reactive	R/7.4ha	569	995
Reliability	R/7.4ha	81	95
Demand	R/7.4ha	5222	6131
Total	**R/7.4ha**	**16483**	**19679**
	R/ha	**2227**	**2659**
	R/mm	**4.20**	**5.02**
	R/kWh	**0.67**	**0.68**
	kW/ha	**2.72**	**3.19**
	kWh/ton	**410.71**	**482.23**

Typical results – mainline optimisation:



Critical velocity for air transport

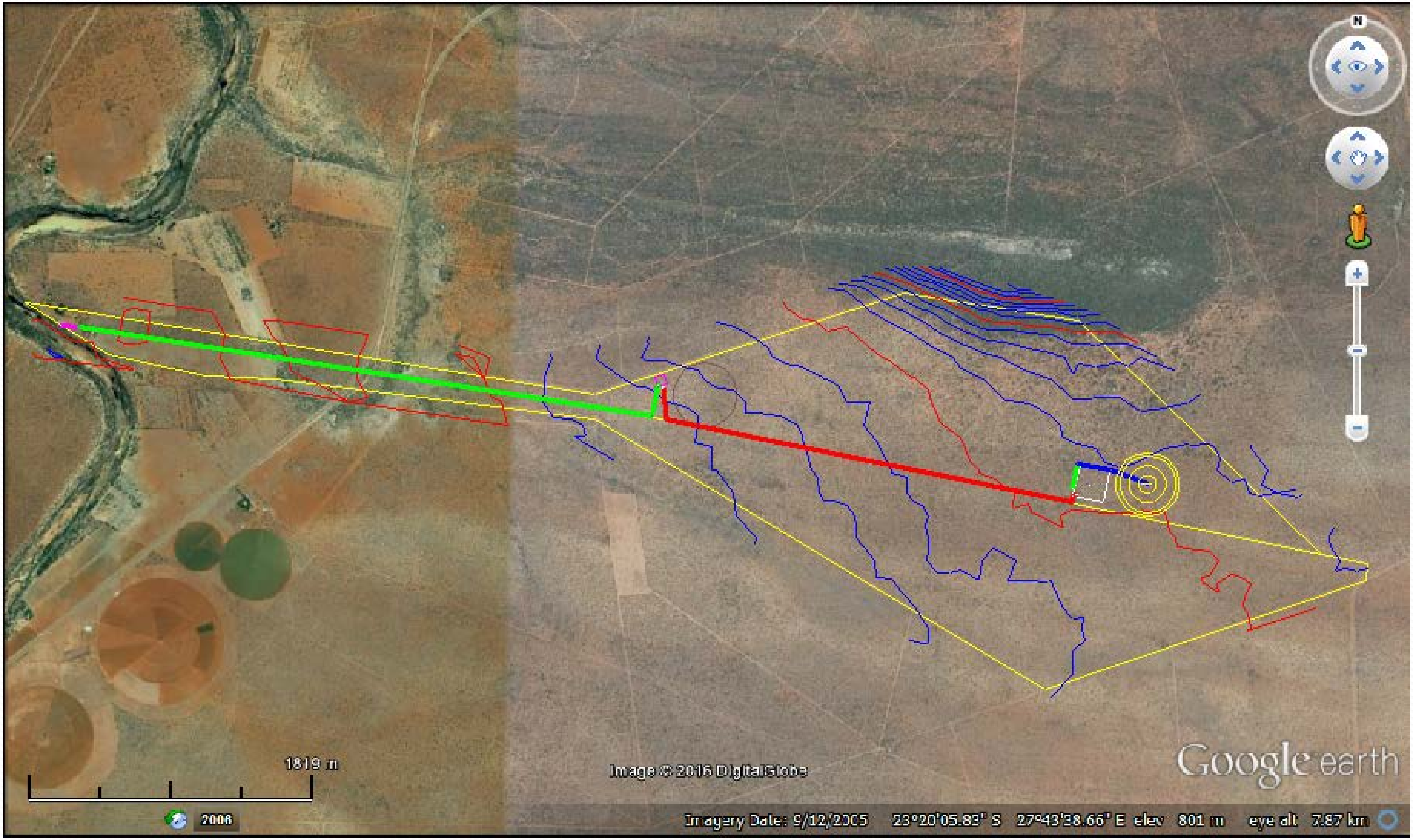


(Netafim, 2014)

Case study

Effect of VSDs

Case study: River → Dam → Pivot

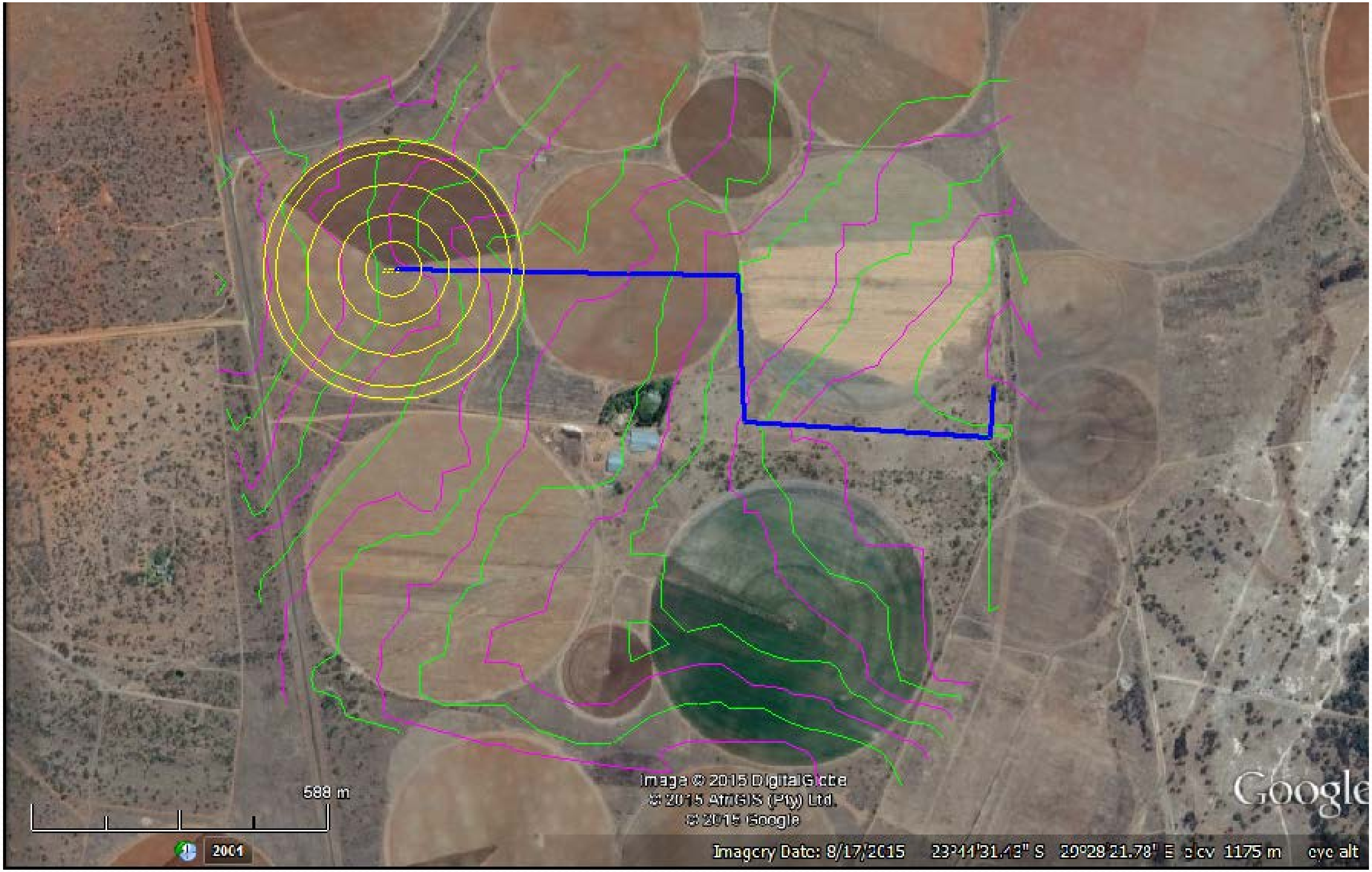


		Ruraflex		Landrate	
Irrigation		**No VSD**	**VSD**	**No VSD**	**VSD**
Total	mm.ha	6975	6975	6975	6975
	mm	537	537	537	537
Pumping hours					
Total	hours/13ha	1395	1395	1395	1395
VARIABLE ELECTRICITY					
Active	R/13ha	19630	14354	37864	27688
Reactive	R/13ha	1692	587	0	0
Reliability	R/13ha	147	108	147	108
Demand	R/13ha	9459	6917	9459	6917
Total	**R/13ha**	**30929**	**21966**	**47470**	**34713**
	R/ha	**2379**	**1690**	**3652**	**2670**
	R/mm	**4.43**	**3.15**	**6.81**	**4.98**
	R/kWh	**0.69**	**0.67**	**1.06**	**1.06**
	kW/ha	**2.46**	**1.80**	**2.46**	**1.80**
	kWh/ton	**811.64**	**593.51**	**811.64**	**593.51**

Case study

Effect of operation and maintenance

Case study: Borehole → Pivot



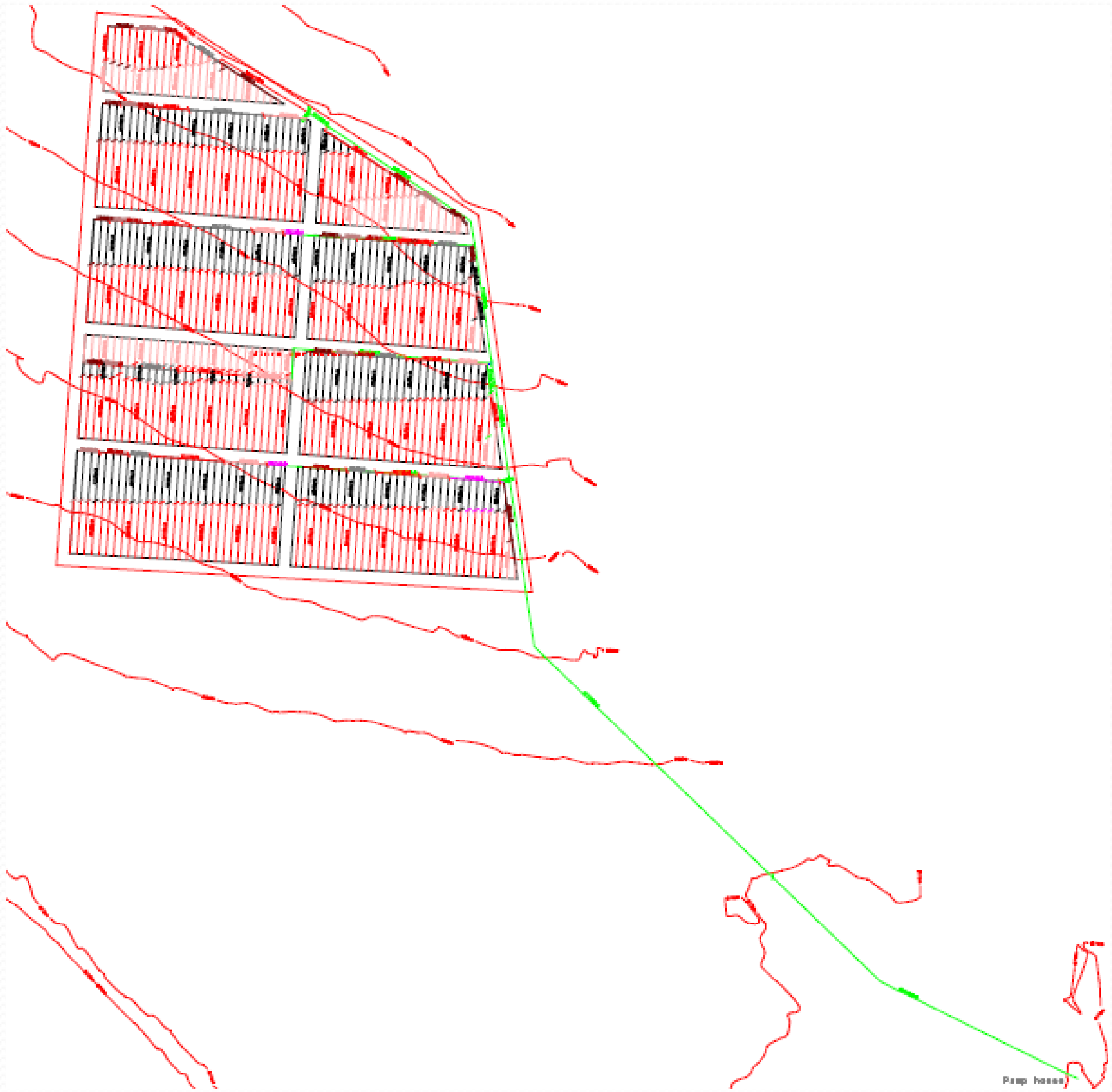
		Ruraflex		Landrate	
Irrigation		**100m3/h**	**63/m3/h**	**100m3/h**	**63/m3/h**
Total	mm.ha	10400	10401	10400	10401
	mm	520	520	520	520
Pumping hours					
Total	hours/20ha	1040	1651	1040	1651
VARIABLE ELECTRICITY					
Active	R/20ha	14214	16818	27787	30808
Reactive	R/20ha	772	849	0	0
Reliability	R/20ha	108	120	108	120
Demand	R/20ha	6942	7697	6942	7697
Total	**R/20ha**	**22036**	**25483**	**34837**	**38625**
	R/ha	**1102**	**1274**	**1742**	**1931**
	R/mm	**2.12**	**2.45**	**3.35**	**3.71**
	R/kWh	**0.67**	**0.70**	**1.06**	**1.06**
	kW/ha	**1.58**	**1.10**	**1.58**	**1.10**
	kWh/ton	**655.20**	**726.44**	**655.20**	**726.44**

Case study

Effect of VSDs

Mainline optimisation

Micro-sprinkler system



Micro-sprinkler system

Pressure required at pump: Valve inlet pressure = 20m Elevation difference = 25.24m Mainline head loss = 10.37m Secondary losses = 6.14m Safety factor = 5%	72m
Flow required at pump: Including 10% safety factor	87 m^3/h
Output power (required by pump)	24 kW
Power factor (cos φ)	0.8
Motor efficiency	90%
Input power (drawn from transformer)	26.7 kW

Micro-sprinkler system – with VSD

	Setpoint 1	Setpoint 2	Setpoint 3	Setpoint 4	Setpoint 5	Setpoint 6	Setpoint 7	Setpoint 8
Flow required at pump: (m3/h)	62.81	87.13	67.78	86.42	85.81	77.70	84.10	83.24
Pressure required at pump:(m)	72	72	70	66	59	64	54	56
Pump efficiency (%)	63	70.5	68	70.5	70.5	69	68	70
Output power (required by pump, kW)	19.56	24.25	19.01	22.05	19.57	19.64	18.20	18.15
Power factor (cos φ)	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Motor efficiency	90%	90%	90%	90%	90%	90%	90%	90%
Frequency (Hz)	50	50	49	48	45	47	43	44
Motor speed (rpm)	2900	2900	2859	2777	2625	2734	2511	2558
Input power (from transformer, kW)	21.7	26.9	21.1	24.5	21.7	21.8	20.2	20.2

Micro-sprinkler system

	No VSD		VSD	
	Landrate	Ruraflex	Landrate	Ruraflex
Motor input power, kW	26.7	26.7	22.2625	22.2625
Energy consumption, kWh	80527	80527	67144	67144
Variable electricity costs, R	83708	49633	69796	41581
R/ha	4445	2636	3707	2208
R/mm	3.19	1.89	2.92	1.74
R/kWh	1.04	0.62	1.04	0.62
Total electricity costs, R	103283	62005	89371	53054
R/kWh	1.28	0.77	1.33	0.79
kW/ha	1.42	1.42	1.18	1.18

Micro-sprinkler system

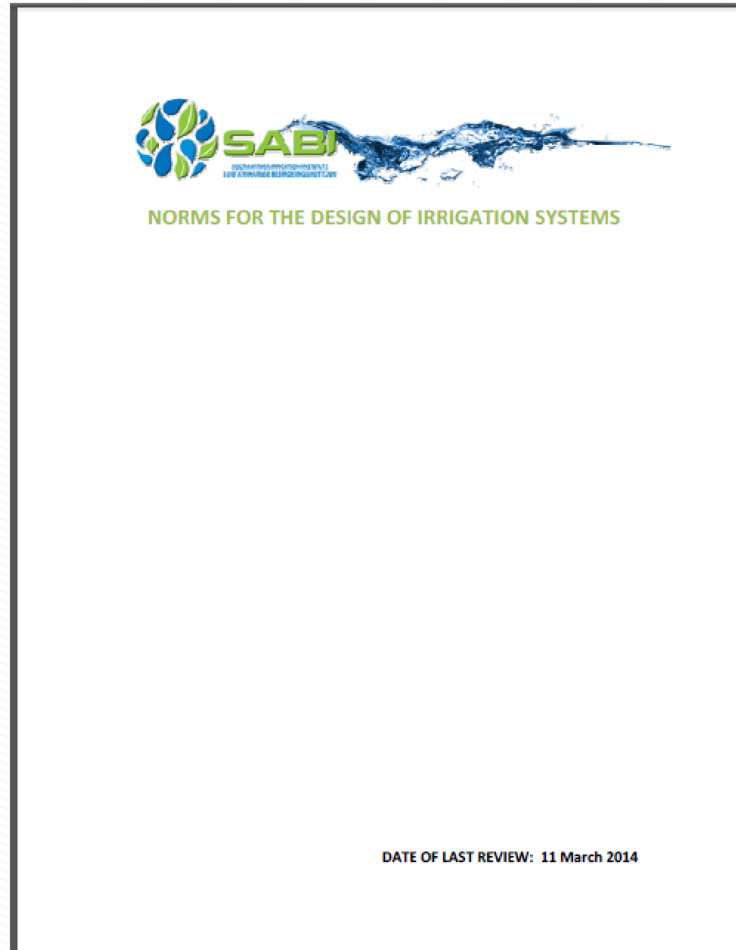
	No VSD		VSD		Optimised mainline (no VSD)	
	Landrate	Ruraflex	Landrate	Ruraflex	Landrate	Ruraflex
Motor input power, kW	26.7	26.7	22.2625	22.2625	25.83	26.58
Energy consumption, kWh	80527	80527	67144	67144	77893	80180
Variable electricity costs, R	83708	49633	69796	41581	80969	49419
R/ha	4445	2636	3707	2208	4300	2624
R/mm	3.19	1.89	2.92	1.74	3.09	1.88
R/kWh	1.04	0.62	1.04	0.62	1.04	0.62
Total electricity costs, R	103283	62005	89371	53054	100544	61780
R/kWh	1.28	0.77	1.33	0.79	1.29	0.77
kW/ha	1.42	1.42	1.18	1.18	1.37	1.41

Summary

- Use Ruraflex rather than Landrate
- Avoid peak periods but apply good scheduling practices at all times
- Lowest system capacities is most profitable but requires careful management
- An irrigation system design should be provided with both investment and electricity cost estimates
- Friction loss gradients of 0.6% is recommended but when Ruraflex is used, smaller pipes may be used (0.7%-1%)
- VSDs should only be used when an economic analysis shows that the extra cost is justified by the benefits
- Correct operation and maintenance practices save energy

Irrigation design norms

- The norms address most aspects of the design process
- The SABI design norms is a living document
- Annual update incorporating project recommendations
  Available to download at www.sabi.co.za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NORMS FOR THE DESIGN OF IRRIGATION SYSTEMS

DATE OF LAST REVIEW: 11 March 2014

Thank you