

Optimal Phosphorus (P) Abatement – The Role of the Metric

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Eutrophication and P



Eutrophication and different forms of P

Total P =

Soluble P + Particulate P (PP)

Soluble P =

Soluble Reactive P (SRP)

Soluble Unreactive P

SRP fully available to algae

PP partly available, even in the long run

Agriculture, conservation measures and different forms of P

Dodd & Sharpley (2016):

Conservation measures that reduce PP tend to increase SRP loading considerably.

Jarvie et al (2017):

Substantial increases in SRP loading to Lake Erie most likely due to land use changes (no-till, conservation tillage)

Table 1. USDA-NCRS promoted conservation practices to minimize the loss of P from agriculture and the range of effectiveness for dissolved P (as DRP) and particulate P found in field experiments across the U.S. and Canada

Practice	Description	Effectiveness (% reduction)		References
		Dissolved P	Particulate P	
Farm inputs				
Dietary P	Match animals nutritional requirements to feed	13-89	<1	Ebding et al. (2002) ^a , Ghobrehmehad et al. (2007) ^a , Hamesdan et al. (2009) ^a and Jokela et al. (2012) ^a
Corn hybrids	Use of low phytic-acid corn in feed to reduce rumen P	45-68	Negligible	Leytem et al. (2008) ^a , Penn et al. (2004) ^a and Smith et al. (2004a) ^b
Feed additives	Addition of phytase enzyme to increase P utilization	n.a.—52	Negligible	Penn et al. (2004) ^a and Smith et al. (2004a, b) ^b
Source management/Avoid				
Nutrient management	Rate—based on soil testing, P inputs are based on crop requirements	10 % reduction for every 10 % reduction in STP	n.d.	Vadas et al. (2005) ^a
	>80 % reduction moving from N based to STP based litter application	Negligible		Sharpley et al. (2009a) ^a
	60-88 % reduction moving from N based to P based litter application	Negligible—67		Eggleston and Gilkey (1999) ^a , Miller et al. (2011) ^b and Swanson et al. (2012) ^b
	Application timing—apply during seasons with low runoff potential	41-62	Negligible	Schneider et al. (2004) ^b and Sharpley (1997) ^b
Application method—incorporate, band or inject P into conservation tilled soil	20-98 ¹	n.a.—60 % increase	Eggleston and Gilkey (1999) ^a , Kibet et al. (2011) ^a , Kimmitt et al. (2010) ^a , Little et al. (2005) ^a , Rutz et al. (2011) ^a , Yankowski and Mielniczen (2004) ^b and Sweeney et al. (2012) ^b	
Conservation crop rotation	Sequence different rooting depth and plant acquisition mechanisms to optimize soil P uptake	85	Negligible	Smith et al. (2015a) ^a
Soil inversion	Reduce P enrichment in topsoil	n.a.—92	Negligible—59 % increase	Quince et al. (2007) ^a , Sharpley (2003) ^a and Smith et al. (2007) ^a
Transport management/Trap				
Conservation cover	Permanent vegetative cover to increase soil infiltration and remove sediment bound P	n.a.—63	65-90	Sharpley and Smith (1991) ^a and Zhu et al. (1989) ^a
Buffer strips/riparian zones	Slows flow, increases infiltration and removes sediment bound P	-258 to 88	35-96	Abu-Zreig et al. (2011) ^{a,b} , Blanco-Casqui et al. (2004) ^a , Chantrey et al. (1995) ^a , Daniels and Gillman (1996) ^a , Dillaha et al. (1999) ^a , Schmitt et al. (1999) ^a , Lee et al. (2000) ^b , Lawrence and Sheridan (2005) ^{a,b}
Constructed wetlands	Removes sediment bound P	-72 ² to 94	47-70	Boutel et al. (2014) ^{a,b} , Jordan et al. (2013) ^{a,b} , Kavacic et al. (2003) ^{a,b} , Maynard et al. (2009a, 2009b) ^{a,b} and Pietro and Ivanoff (2015) ^{a,b}
Transport management/Control				
Strip cropping/conservation tillage/ terraces	Reduces erosion and transport of sediment bound P	Negligible—63	32-91	Alberts et al. (1978) ^a , Gassman et al. (2006) ^a and Langdale et al. (1985) ^a
Conservation tillage	Reduces erosion and increases infiltration	-308 to -40	-33 to 96	Gaynor and Findlay (1995) ^a , Schreiber and Cullum (1996) ^a , Sharpley and Smith (1994) ^a , Skarlatos et al. (2013) ^a and Smith et al. (2015a) ^a
Grass waterways	Slows flow, increases infiltration and removes sediment bound P	-83 to 81	45-89	Gassman et al. (2006) ^a and Smith et al. (2015a) ^a
Drainage water management	Control drainage to reduce outflow volumes	Negligible—68	15-31	Evans et al. (1995) ^a , Littlejohn et al. (2014) ^{a,b} , Yan and Zhang (2011) ^a and Williams et al. (2015) ^b

¹ Model simulation of P loss following implementation of a 95 % reduction in dietary P intake

SRP-PP trade-off, impact on efficiency of conservation measures? Example.

Consider a parcel (one hectare) with initial P loading:

- PP 2kg
- SRP 0.5kg

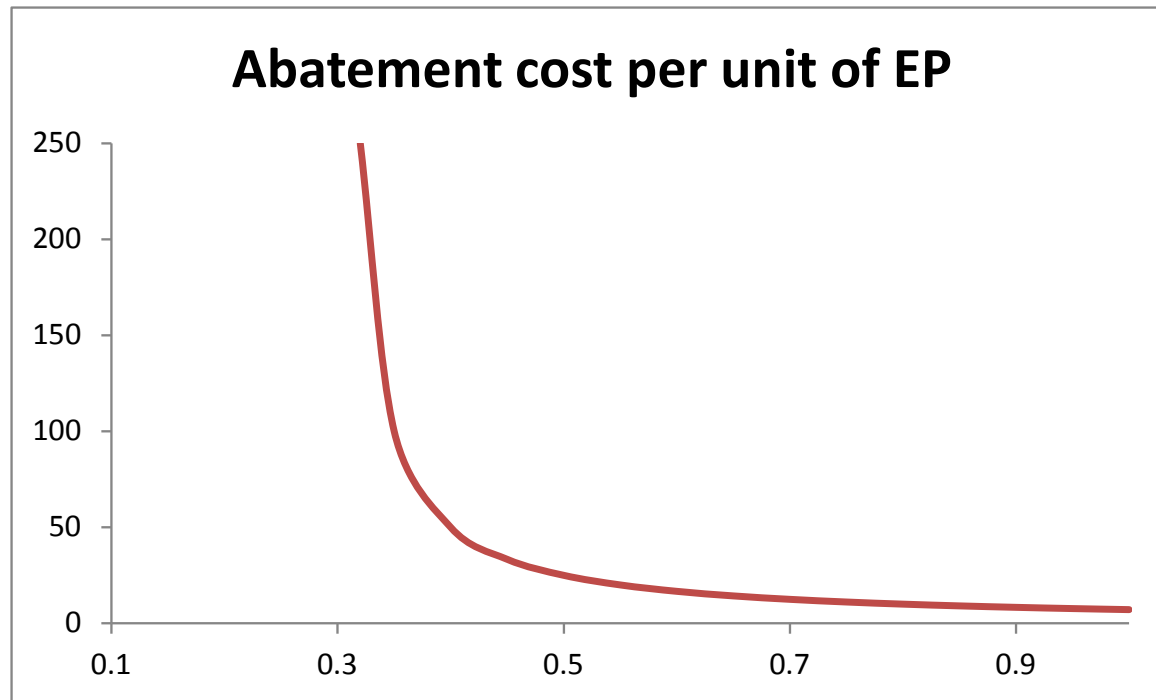
A measure, say permanent vegetative cover:

- Costs 5\$/ha
- Reduces PP by 1kg
- Increases SRP by 0.3kg

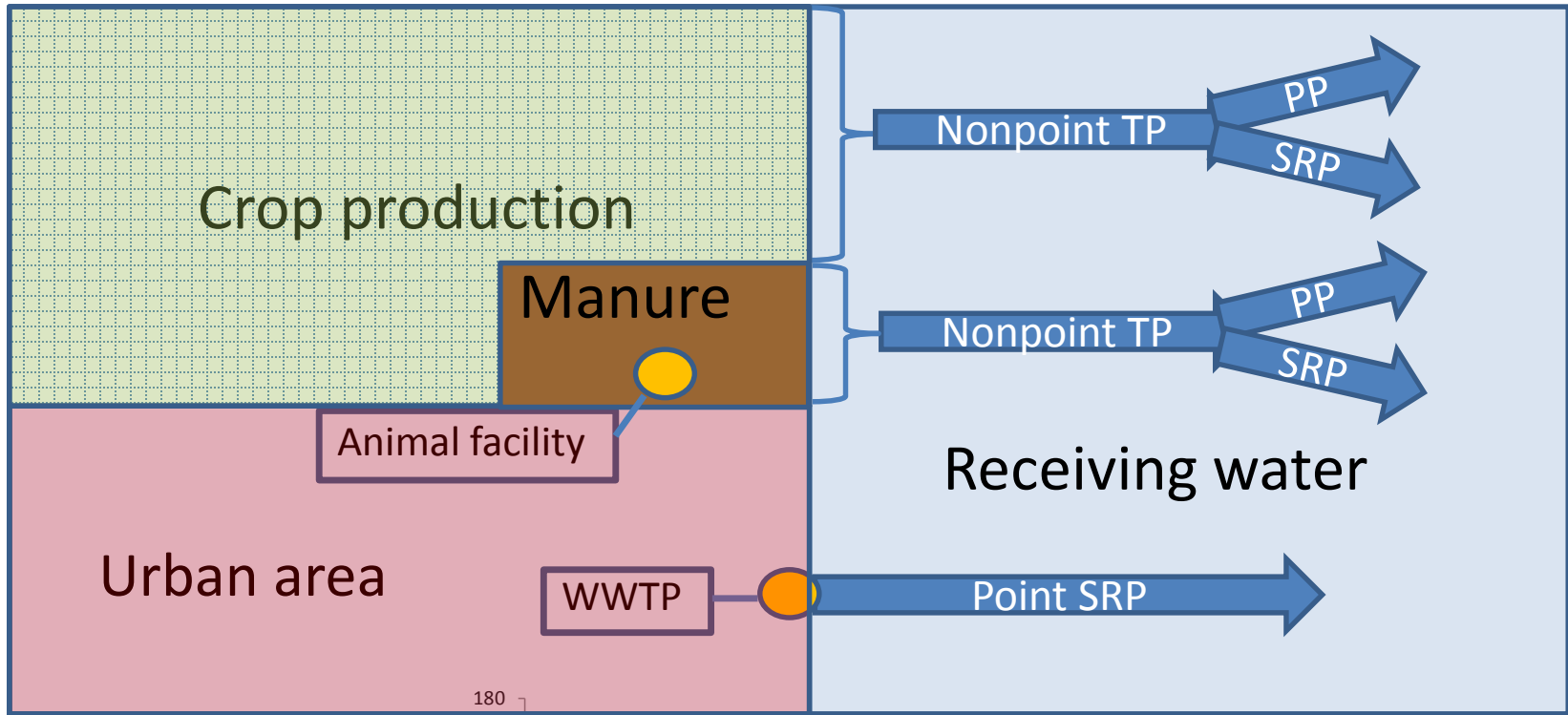
TP reduction 0.7kg; Abatement cost 7 \$/kg

SRP-PP trade-off, impact on efficiency of conservation measures? Example.

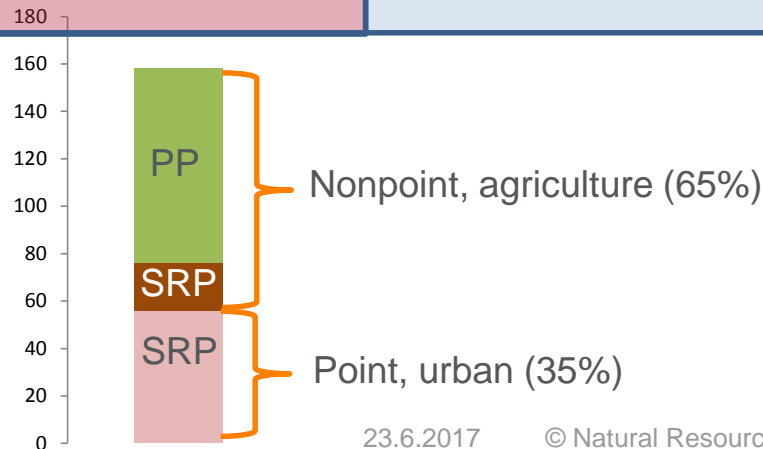
Bioavailability of PP	100%	90%	80%	70%	60%	50%	40%	30-0%
Abatement in terms of Eutrophying P (EP)	0.7	0.6	0.5	0.4	0.3	0.2	0.1	≤ 0
Abatement cost (\$/kg EP)	7	8	10	13	17	25	50	→INF



Efficiency and bioavailability of PP, illustration



Total P loading
158 kg.
Distribution:



Abatement measures and their costs

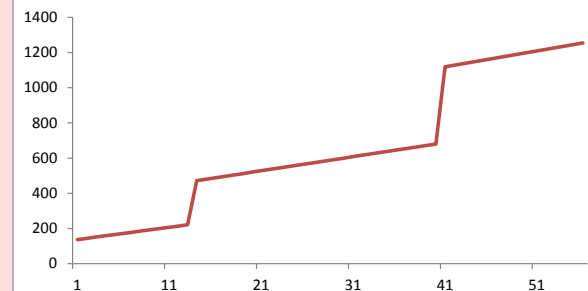
Three measures:

- 1) **"No-till"** Permanent vegetative cover (currently all ploughing)
- 2) **"Manure"** Hauling manure beyond economic threshold distance
- 3) **"WWTP"** Further investments in point source abatement

Costs:

- 1) **"No-till"** 1\$/ha
- 2) **"Manure"** 20\$/ha
- 3) **"WWTP"** Lumpy investment & unit costs:

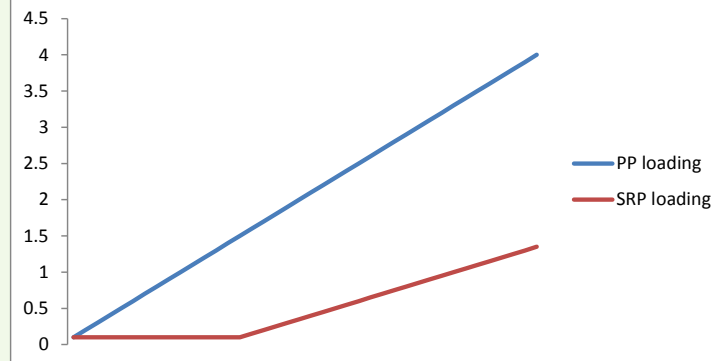
WWTP abatement costs (\$/kg)



Effects:

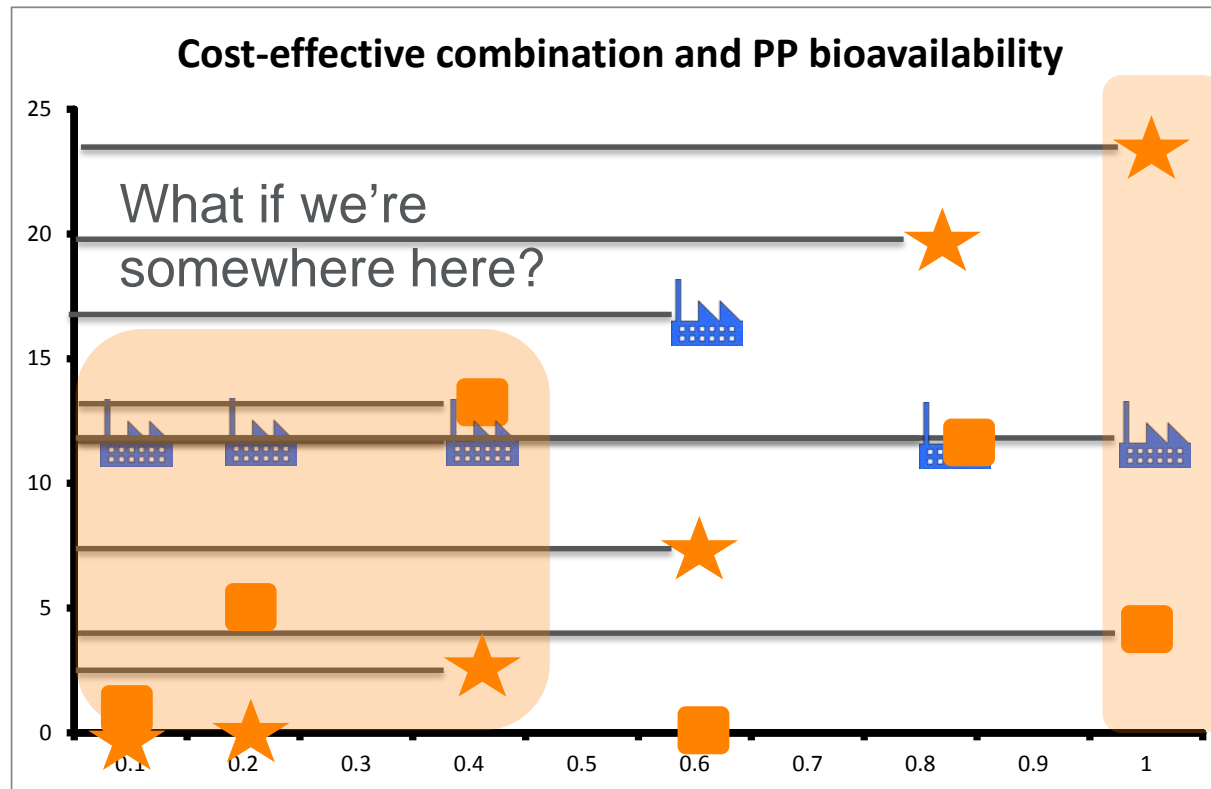
- 1) **"No-till"** Reduce PP 30%, increase SRP by 0.5kg/ha
- 2) **"Manure"** Reduce SRP 30%, no effect on PP

Initial Nonpoint Loading (kg/parcel)



How to cut down eutrophying P loading by 15% with the least costs?

Depends on the bioavailability of PP.



Bioavailability
100%, current
(implicit)

assumption:
 $TP = PP + SRP$

★ No-till

■ Manure

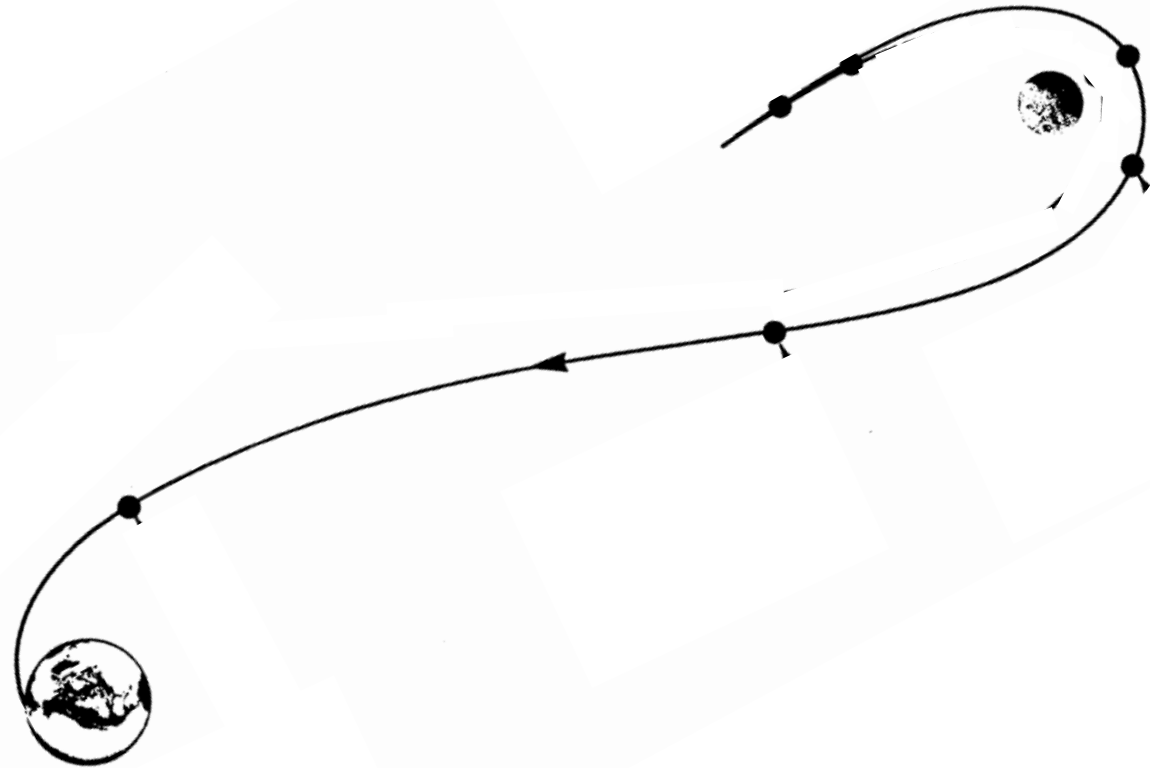
🏭 WWTP

Mimic CO₂-equivalents of GHGs? P fractions summed up as phosphate equivalents?

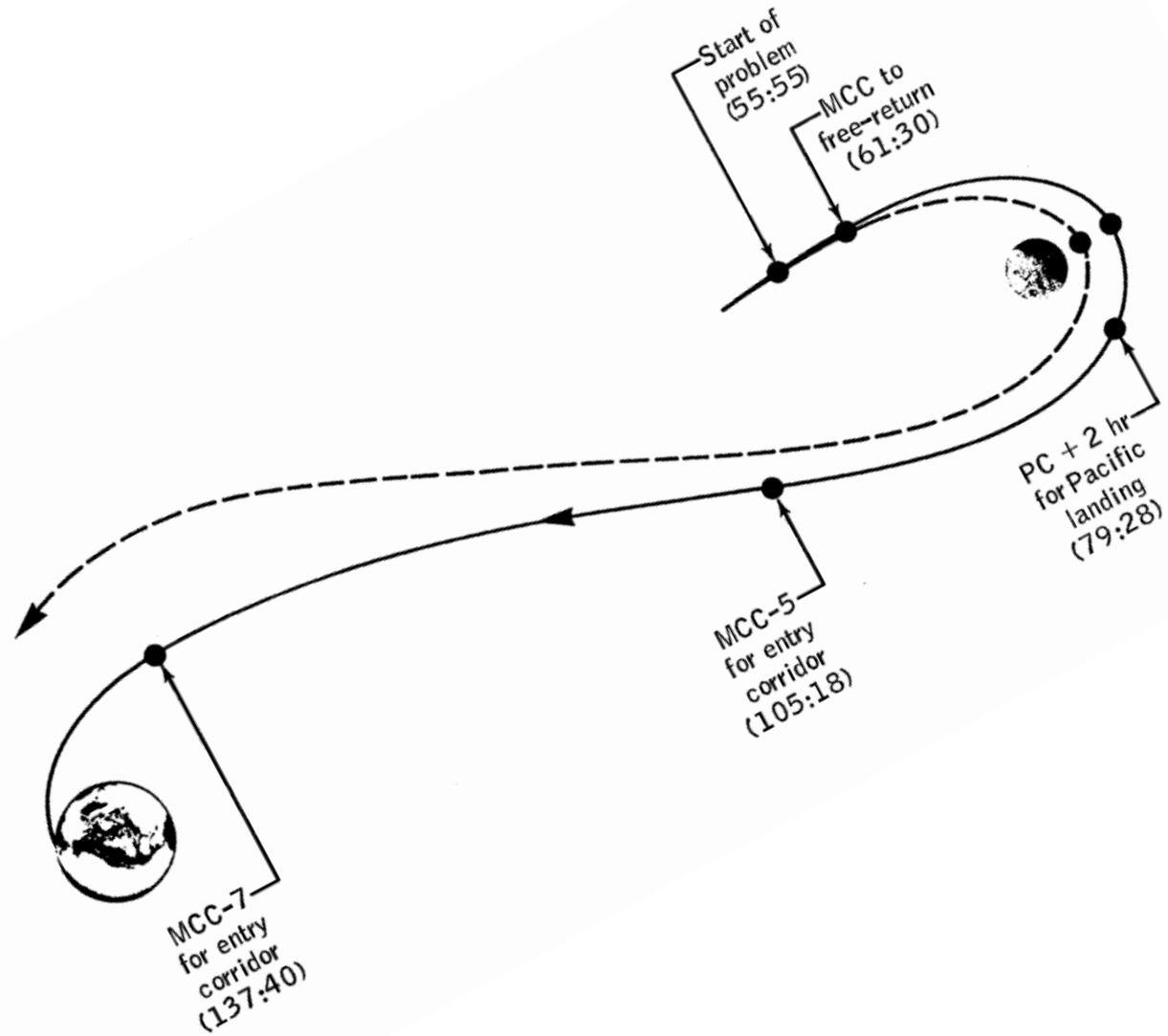
- Upper level targets the most important
- TMDL / BSAP units cascade to all levels of government
- Challenge: GHGs global whereas phosphorus fractions' eutrophying potential depends on, e.g.
 - Source area soils
 - Morphology, ecological status of the receiving water body
- But: best uncertain guess beats the certainly wrong one.
- Unambiguity of CO₂ conversion?

GWP of methane and Nitrous oxide as indicated by IPCC reports	Time horizon		
	20	100	500
Carbon dioxide	1	1	1
Methane (1990)	63	21	9
Methane (1995)	56	21	6.5
Methane (2001)	62	23	7
Methane (2007)	72	25	7.6
Methane (2013)	84-86	28-34	
Nitrous oxide (1990)	270	290	190
Nitrous oxide (1995)	280	310	170
Nitrous oxide (2001)	275	296	156
Nitrous oxide (2007)	289	298	153
Nitrous oxide (2013)	264-268	265-298	

Moon flights and water protection



Apollo 13 and water protection



Thank you!