

Interventions Measures Matrix

Intervention	Mitigation Category	Discussion	Benefits		Feasibility	Maintenance	Effectiveness	Case Studies
Reduction of Agricultural Phosphorus at source	Category 2	 This solution focusses on changing farming practices. Advantages: Removes P at source, thus reducing pressure on traditional WwTW and nature-based solutions. Increases sustainability of soil. Associated pre-treated sludge biosolid spreading by DCWW as a single accredited stakeholder. Disadvantages: Multiple stakeholders required to change long standing practices. Difficult to manage / monitor. Legacy P requires consideration i.e., 20years of continued P export needs to be considered in the land use change. Delivery Partners: Landowners, WG, The Council, NRW, NFU Cymru, DCWW, Env. NGOs 		Increased biodiversity from a reduction in nutrient enrichment and in soil Aesthetic value Carbon sequestration	Low	Medium	High	Dairy Project Wales Land Management Forum Wales Water Management Forum Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative
Farming Source Control	Category 2	 Farm improvement works to prevent Phosphorus from entering watercourses, which can include fencing. Advantages: A simple scheme that increases farm value and there is already an existing grant scheme, which can last a long time (50+ years) Disadvantages: Multiple stakeholders which may create long term management difficulties and requires seasonal vegetation management. Delivery Partners: DCWW, NRW, NFU Cymru, Landowners/land managers, The Council, WG: WG Spending Commitments, Basic Payment Scheme, SFS, Glastir Advanced, Commons and Organic contracts scheme, National Forest for Wales, Food accreditation scheme, Farm Business Grant Scheme post 2024 		Increased biodiversity in watercourse habitats from a reduction in nutrient enrichment and in soil Aesthetic value	High	Medium	High	Dairy Project Wales Land Management Forum Wales Water Management Forum Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative
Surface Water Separation	Category 1 & Category 2	 This solution focuses on separating wastewater flows from new and existing developments to capture stormwater. Advantages: Already normal practice for new developments, leads to reduced CSO discharges into the watercourse and reduced sewage treatment costs. Similar compensatory surface water removal approach already in place for Carmarthen Bay and Estuaries European Marine site. Disadvantages: Costly to retrofit in urban areas, limited reduction in Phosphorus unless effective SuDS are incorporated, long term effectiveness depends on operating practices at WwTWs. Delivery Partners: Developers, The Council, DCWW, Wales Green Infrastructure Forum 	Ч Ч	Increased Capacity and efficiencies at WwTW	High	Low	Low	Wales Land Management Forum Wales Water Management Forum Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative
Enhanced Wastewater Treatment Works	Category 1	Increasing the ability of WwTWs to remove Phosphate. Advantages: Increase headroom for new development, clear delivery mechanisms within DCWW. Opportunity to explore developer contributions. Disadvantages : Requires long term investment and long lead times. May transfer issues to biosolid spreading which would require extra controls. Delivery Partners: DCWW: Existing and new WWTW funding, Spending commitments. Developers, NRW, Ofwat, NFU Cymru, WG Spending Commitments.		Improved Water Efficiency and water quality	Medium	High	High	Wales Land Management Forum Wales Water Management Forum Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative

Intervention	Mitigation Category	Discussion	Benefits		Feasibility	Maintenance	Ef
SuDS Source	Category 1	Permeable paving	(+)				
Control		Advantages: Reduces peak flows and enhance water quality treatment. Dual use of the landscape, prevents ponding, can be used in high density	***	Natural Flood mitigations			
		developments	-0-	Temperature Regulation			
		Disadvantages: Not compatible with large sediment loads, only suitable for low traffic volume areas, maintenance to minimise silt clogging.	B			1 mm	
		Delivery Partners: Developers, The Council.			wedium	LOW	

Category 1	Green roofs				
	Advantages: Reduced peak waste water flows and enhanced water quality treatment along with reduced storm water overloading and CSO discharges,		Increased Biodiversity		
	Mimics predevelopment state of water flows, can be retrofitted (site dependant), no additional land, can provide a return on investment from energy savings.		Aesthetic value		
	Disadvantages: High cost compared to conventional roof, not appropriate for all sites and limited retrofitting abilities, requires high maintenance as any damage to roof membrane is more critical as water is encouraged to remain on	-0-	Thermal attenuation		
	the roof, limited impact of phosphate removal.	00	Climate resilience		
	Delivery Partners: Developers, The Council, DCWW, Business Improvements Districts for retrofits.		Water efficiency	Medium	Medium
		₽ ₽	Noise Attenuation		
			Air Quality improvements		
		ALA	Health and wellbeing if accessible		
			Increased longevity of roofs		

fectiveness Case Studies

Rainscape National Surface Water Management and SuDS Group Members Teifi SAC Catchment Phosphate Reduction and Mitigation Project Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative

Medium

Intervention	Mitigation Category	Discussion	Benefits		Feasibility	Maintenance	Effectiveness	Case Studies
Swales	Category 1	 Shallow broad and vegetated channels designs to store and convey runoff to remove pollutants. Advantages: Easy to incorporate into landscaping, good removal of urban pollutants, reduces runoff rates and volumes and low capital cost. Maintenance can be incorporated into general landscape management, pollution and blockages are visible and easily dealt with. Disadvantages: Not suitable for steep areas with roadside parking, limits the opportunities to use trees for landscaping, risks of blockages in existing pipework. Delivery Partners: Developers, The Council, Local Highways Agencies, WG, National Surface Water Management and SuDS Group, Ofwat, Innovation Fund, Water Breakthrough Challenge, Water Discovery Challenge, NRW, Four Rivers for Life, Sustainable Drainage Feasibility Grant, DCWW: Spending Commitments, Rivers in Wales Environmental Investment, DCWW Community Fund, Wales Green Infrastructure Forum, Living Streets Cymru, Active Travel and Safe Routes in Communities (SRiC) schemes, Heritage Lottery Fund, Esmee Fairburn Foundation 		Biodiversity Amenity Aesthetic value Passive cooling	Medium	Low	Medium	Rainscape National Surface Water Management and SuDS Group Members Teifi SAC Catchment Phosphate Reduction and Mitigation Project Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative
Conveyance Chanels	Category 1	Channels and rills are open surface water channels with hard edges that can be planted with vegetation. Advantages: Effective water and pollution treatment can act as pre-treatment to remove silt before water is conveyed into further SuDS features, easy to construct. Disadvantages: Incorrect planting can cause silt build up, Need to give careful consideration to crossings, routine maintenance to remove litter/debris, large maintenance required every 5 years. Delivery Partners: Same as Swales		Biodiversity Increase Amenity Aesthetic value Passive cooling	Medium	Medium	Medium	Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative
Filtration Strips	Category 1	 Filter strips of gently sloping grass and street trees Advantages: Well suited to implementation in areas with heavy traffic, encourages evaporation, infiltration and interception. Easy to construct and low construction cost, effective pre-treatment option Disadvantages: Not suitable for all locations. No significant attenuation or reduction of extreme flows. Delivery Partners: Same as Swales 		Biodiversity Amenity Aesthetic value Health and wellbeing Can encourage active transport	Medium	Medium	Medium	Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative
	Category 1	 Filter drains are stone filled trenched with underdrains alongside roads, paths or rail lines. Advantages: They can capture specific pollutants if there is a layer of treatment media included (the amount removed will depend on the treatment media used). Large ability for treatment since they are often created to be in parallel to the length of roads and paths. Disadvantages: It does not capture pollutants directly if treatment media is not added, No vegetation, Depending on the soil conditions and/or pollutant loads, there is risk of filter drains enabling phosphate pollution migration into the underlying ground water, Flow exceedance could lead to temporary flooding. Delivery Partners: Same as Swales 		Biodiversity (microorganisms, insects and amphibians) Amenity Can filter out fine sediments, metals and hydrocarbons (depending on filter media used) Encourage adsorption and biodegradation process	Medium	Low	Medium	Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative

Intervention	Mitigation Category	Discussion	Benefits		Feasibility	Maintenance	Eff
	Category 1	Shallow landscaped areas with engineered soils, enhanced vegetation and filtration, which can also include trees.		Biodiversity Amenity / Aesthetic value			
		Advantages: Very effective in removing urban pollutants which can also reduce volume and runoff rates. Flexible layout to fit into landscape. Well-suited for installation in highly impervious areas, Good retrofit capability and when lined, can be used to manage surface water runoff from areas with high groundwater pollution risks.			Medium	Low	
		Disadvantages: Requires landscaping and management. Susceptible to clogging if surrounding landscape is not managed. Not suitable for areas with steep slope. Should be used in conjunction with other SuDS components					
		Delivery Partners: Same as Swales					
Infiltration Basins	Category 1	A solution based around, rain gardens, infiltration trenches and basins, soakaways, tree pits.		Biodiversity			
		Advantages:	~~~~~	Amenity / Aesthetic value			
		Rain gardens – Small and easy to retrofit, minimal land take, easy to maintain, flexible layout to fit into landscape and can be installed in impervious areas if designed correctly.		Natural flood mitigation			
		Soakaways – Particulate P removal through sedimentation of solids upstream of soakaway and infiltration in the soakaway. Can reduce rate of run off and some volume reduction		Can reduce the risk of waterborne diseases			
		Tree pits – Can enhance the performance of other green infrastructure technologies.	<u>N</u>		Medium	Medium	
		Disadvantages:					
		Rain gardens – As they are often small, their impact can be limited, requires landscaping and management, susceptible to clogging if surrounding landscape is not managed. Not suitable for areas with steep slopes or impermeable soils.					
		Soakaways – Phosphorus removal highly dependent on infiltration rate and if there is an overflow.					
		Tree pits – Nutrients can be cascaded downstream in extreme events.					
		Delivery Partners: Same as Swales					
Retention Ponds	Category 1	Building of ponds to retain water (retention ponds)		Biodiversity			
		Advantages: Can cater for all storms and has good removal capability of urban pollutants. Can be used where groundwater is vulnerable, if lined.		Thermal attenuation			
		Disadvantages: No reduction in runoff volume. Anaerobic conditions can occur without regular inflow. Land take may limit use in high density sites. May not be suitable for steep sites, due to requirement for high embankments.		Climate resilience			
		Colonisation by invasive species could increase maintenance. Perceived health & safety risks may result in fencing and isolation of the pond.			Medum	Medium	
		Delivery Partners: Same as Swales	$\wedge \Delta \wedge$	Amenity			
			科科	Aesthetic value			
			(\pm)	Recreation			
			₩₩	Natural flood mitigation			

fectiveness	Case Studies
	Four Rivers for LIFE
	National Surface Water Management and
	SuDS Group Members
	Rivers Trust of Wales (Welsh Rivers Trust)
	Afonydd Cymru
	The West Wales Rivers Trust
	Taclo'r Tywi Initiative
High	

Natural Flood management plus in the Cadoxton catchment Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative

Medium

Natural Flood management plus in the
Cadoxton catchment
Four Rivers for LIFE
National Surface Water Management and
SuDS Group Members
Rivers Trust of Wales (Welsh Rivers Trust)
Afonydd Cymru
The West Wales Rivers Trust
Taclo'r Tywi Initiative

High

Intervention	Mitigation Category	Discussion	Benefits		Feasibility	Maintenance	Effectiveness	Case Studies
Detention Basins	Category 1	 Detention basins are shallow vegetated areas which retain water at times. Advantages: Can cater for a wide range of rainfall events and can be used where groundwater is vulnerable, if lined. Simple to design and construct with a potential for dual land use. Easy to maintain. Safe and visible capture of accidental spillages. Disadvantages: Little reduction in runoff volume. Detention depths may be constrained by system inlet and outlet levels Delivery Partners: Same as Swales 		Biodiversity Amenity Aesthetic value Health and wellbeing can double up as play and recreation areas Natural flood mitigation	High	Low	Medium	Natural Flood management plus in the Cadoxton catchment Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative
Ponds	Category 1	Larger bodies of standing water. Water is moved in out of the pond through runoff and flow. Can be surrounded by vegetation, grass, hard landscapes, and other surroundings Advantages: Uptake of phosphate by plants and aquatic flora. Phosphate can also sediment out onto the base of the pond Disadvantages: Good practice for construction must be followed as badly		Biodiversity Amenity Aesthetic value Recreation Thermal attenuation				Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative
		designed ponds can act as exporters of dissolved phosphate. Minimal direct infiltration potential. Cannot manage large inputs of water or exceedance flows Development Partners: Developers, The Council, Local Highways Agencies, WG, WG Spending Commitments, Besic Payment Scheme, SFS, National Surface Water Management and SuDS Group, DCWW Spending Commitments, Rivers in Wales Environmental Investment, DCWW Community Fund, NRW, Sustainable Drainage Feasibility Grant, Four Rivers for Life, Wales Green Infrastructure Forum			Medium	Medium	Medium	

Intervention	Mitigation Category	Discussion	Benefits		Feasibility	Maintenance	Ef
Constructed Wetlands	Category 1	 Wetland creation designed and maintained specifically for maximising P reduction from both storm and foul water discharges. Plant roots can absorb nutrients and incorporate them into the plant structure. Can provide for tertiary treatment after effective primary and secondary foul treatment processes. Advantages: Good removal capability for pollutants and can trap large volumes of sediments. If lined, can be used where groundwater is vulnerable. Large wider environmental benefits and high longevity for functioning effectively (50+ years), Reed bed systems can be incorporated into wetlands which can further enhance biodiversity. Disadvantages: Land take is high. Requires maintaining sufficient baseflows in dry periods and there is limited depth range for flow attenuation. May release nutrients during non-growing season, which must be mitigated by good design and maintenance. Little reduction in runoff volume and less effective for steep sites and will require significant earthworks. Colonisation by invasive species could increase maintenance. Performance vulnerable to high sediment inflows. P will be bound in sludge which may require disposal and will require extra pretreatment with solar drying and well managed biosolid spreading to satisfy crop need. Desludging could be every 10 years but depends on the wetland design. May need to replace bed material if it is saturated with nutrients if artificial bed material is used. Seasonal vegetation removal and management. Potential mosquito habitat. Development Partners: Developers, The Council, Welsh Rivers Trust, DCWW Spending Commitments, Rivers in Wales Environmental Investment, DCWW Community Fund, NRW, Sustainable Drainage Feasibility Grant, Four Rivers for Life, NFU Cymru, Local Nature Partnership for North East Wales, United Utilities, DCWW, WG, WG Spending Commitments, Besic Payment Scheme, SFS, Heritage Lottery Fund, Esmee Fairburn Foundation Ofwat Innovation Fund, Water Breakthrough Challenge, Water Discove		Biodiversity Amenity Aesthetic value Recreation Thermal attenuation/temperature regulation Climate resilience Carbon sequestration Natural flood mitigation Potential for water reuse	Medium	Medium	
Integrated Buffer Zones	Category 2	A solution involving increasing grassland, floodplain grassland, beetle banks, woodland and hedgerows. Advantages: Good capability for capture of pollutants and wider environmental benefits. Disadvantages: Reduced productive area under agriculture may release nutrients during non-growing season. Risk of increasing emissions of nitrous oxide and methane (greenhouse gases) Development Partners: Developers, The Council, Welsh Rivers Trust, DCWW, Rivers in Wales Environmental Investment, DCWW Community Fund, NRW, Sustainable Drainage Feasibility Grant, Four Rivers for Life, NFU Cymru, Cities for Trees, Local Nature Partnership Carmarthenshire , United Utilities, Salmon and Trout Conservation', WG, WG Spending Commitments, Besic Payment Scheme, SFS, Glastir Small Grant Scheme, Heritage Lottery Fund, Woodlands for Wales		Biodiversity Climate resilience Air quality Health and Wellbeing Educational Pest control Noise attenuation Amenity Aesthetic value	Medium	Medium	

fectiveness Case Studies

Upper Tywi Restoration Project
The Wetlands Project
The Pontbren Project
Four Rivers for LIFE
National Surface Water Management
and SuDS Group Members
Wales Water Management Forum
Rivers Trust of Wales (Welsh Rivers
Trust) Afonydd Cymru
The West Wales Rivers Trust
Taclo'r Tywi Initiative
Teifi SAC Catchment Phosphate
Reduction and Mitigation Project

High

The Pontbren Project Four Rivers for LIFE National Surface Water Management and SuDS Group Members Wales Water Management Forum Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative Teifi SAC Catchment Phosphate Reduction and Mitigation Project

High

Intervention	Mitigation Category	Discussion	Benefits		Feasibility	Maintenance	Effectiveness	Case Studies
Private Sewerage Drainage Fields	Category 2	Category 2 Network of discharge pipes from septic tank or Package Treatment Plant (PTP) laid in trenches under the ground surface so that effluent can be discharged to the ground. Effluent percolates through soil. Sediment bound P is immobilised and soluble P is bound to soils and sediments.	T S	Efficiency and increased capacity at WwTW				National Surface Water Management and SuDS Group Members Wales Water Management Forum Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru
		Advantages: Likely to be less costly than a wetland system with less maintenance for same P removal performance. Can be delivered up to medium spatial scale (<100 units / <2.0 ha)			Modium		High	The West Wales Rivers Trust Taclo'r Tywi Initiative
		Disadvantages: Longevity of scheme anticipated to be low (10-20 years). Increased usage of the drainage field with time can result in the soils or filter materials sorption capacity being reached. Fields where ground water flood risk is high or water table is within 2.0 m of ground surface are unsuitable. Provides no additional environmental benefits.				LUW	'''gı	
		Development Partners: Developers, DCWW Spending Commitments, NFU Cymru, The Council.						
River Channel Re-naturalisation	Category 2	 Category 2 Works to return rivers to a more 'natural state' including: re-meandering, creating berms, pool-riffle systems, riparian planting and reconnecting channel to floodplain. Advantages: Good capability for capture of pollutants and wider environmental benefits. Can have high longevity for functioning effectively (50+ years). Minimal maintenance required during the establishment phase of the river channel. Disadvantages: Currently no industry standard regarding the design of larger scale river and floodplain re-naturalisation schemes to support the achievement of nutrient removal. Baseline and longer-term monitoring will be required prior to and following the implementation of a scheme in order to 	⊕ ≋≋≋	Natural flood mitigation Biodiversity			Medium	Natural Flood management plus in the Cadoxton catchment Four Rivers for LIFE National Surface Water Management and SuDS Group Members Wales Water Management Forum Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative
			Amenity Aesthet Carbon Addition Health a Air qual Climate	Amenity Aesthetic value Carbon sequestration				
				Additional pollutant removal Health and well being Air quality				
		determine how much P the scheme is removing. P absorption to sediments is primary process of nutrient removal, however, the process is reversible with desorption occurring if P concentration of water drops below a threshold. Threshold is dynamic as the sorption capacity of sediments changes over time. Management regime may depend on the local context and degree of re- naturalisation. Potentially will be over a year until additional benefits are		Climate resilience	High	Low		
		realised. Development Partners: The Council, DCWW Spending Commitments, Rivers in Wales Environmental Investment, DCWW Community Fund, Welsh Rivers Trust , Salmon and Trout Conservation', Land owners / land managers, NRW, Sustainable Drainage Feasibility Grant, Four Rivers for Life, WG, WG Spending Commitments, Besic Payment Scheme, SFS, Heritage Lottery Fund, Ofwat, Innovation Fund, Water Breakthrough Challenge, Water Discovery Challenge		<u>}</u> ?∕				

Intervention	Mitigation Category	Discussion	Benefits		Feasibility	Maintenance
Drainage Ditch Blocking	Category 2	 Placing of barriers across ditches to slow the flow, increase residence times and prevent downstream transport of sediments. Advantages: Easy to construct, low construction cost and low maintenance (mainly visual inspections needed). Disadvantages: Low predictability / certainty of success, and low removal performance. Lack of UK based evidence for effectiveness; baseline and long-term monitoring is recommended pre-and post-implementation and may result in localised flooding during heavy rainfall events. Dam failure would have implications for P removal efficiency. Limited research currently available on the effectiveness of this method for nutrient removal. Development Partners: Land owners / land managers, DCWW, DCWW Spending Commitments, Rivers in Wales Environmental Investment, DCWW Community Fund, The Council, NFU Cymru, Environmental NGOs, NRW, Sustainable Drainage Feasibility Grant, WG. 		Natural flood mitigation Biodiversity Additional pollutant removal Carbon sequestration	Medium	Low
Engineered log Jams	Category 2	 Leaky dams made of woody debris constructed to mimic beaver dams and slow flows and re-naturalise river reaches. Advantages: P removal achieved through sedimentation, chemicals sorption and biomass assimilation. Well-designed schemes will require little maintenance and could serve up to 100 units. Disadvantages: Risk being washed away in flood events – best suited to small watercourses < 2m wide. Lack of research for engineered log jams / beaver dams to confirm potential nutrient removal estimates; monitoring will be required pre/post scheme introduction to determine effectiveness. Potential for increased localised flooding. Adaptive management needed in case repairs are needed. Possibility that P removal may be short-term and that nutrients could be remobilised during floods. Development Partners: The Council, NRW, Sustainable Drainage Feasibility Grant, Four Rivers for Life, DCWW, DCWW Spending Commitments, Rivers in Wales Environmental Investment, DCWW Community Fund, Welsh Rivers Trust , Salmon and Trout Conservation', Landowners / land managers, WG, WG Spending Commitments, Besic Payment Scheme, SFS, Heritage Lottery Fund, Esmee Fairburn Foundation, Ofwat, Innovation Fund, Water Breakthrough Challenge, Water Discovery Challenge 		Natural flood mitigation Biodiversity Carbon sequestration Additional pollutant removal	Medium	Low
Granular Treatment Media	Category 2	 Granular treatment media that has been designed to treat various pollutants. There are phosphorus specific granular treatment media. Advantages: Up to 100% TP removal (if infiltration possible and depending on the manufacturer) Disadvantaged: P removal highly dependent on manufacturer and how well assets are maintained. Filter media will need to be changed periodically. Development Partners: Landowners / land managers, The Council, NRW, Sustainable Drainage Feasibility Grant, Developers, Local Highways Agencies, National Surface Water Management and SuDS Group, Living Streets Cymru. 		Potential for grey water recycling May reduce unpleasant odours	Medium	Medium

fectiveness	Case Studies
Low	Natural Flood management plus in the Cadoxton catchment Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative

Natural Flood management plus in the Cadoxton catchment Four Rivers for LIFE National Surface Water Management and SuDS Group Members Wales Water Management Forum Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative

Low

Wales Water Management Forum
National Surface Water Management
and SuDS Group Members
Rivers Trust of Wales (Welsh Rivers
Trust) Afonydd Cymru
The West Wales Rivers Trust
Taclo'r Tywi Initiative.Medium

Intervention	Mitigation Category	Discussion	Benefits		Feasibility	Maintenance	E
Willow Beds	Category 2	 Willow beds can be designed to treat stormwater from low/medium risk surfaces of small catchments. They allow capturing, attenuation, and evapotranspiration of captured flows. Advantages: Capture, attenuation and evapotranspiration of all flows so no discharge occurs. Uptake of P by the willow. Harvesting willow can be a valuable resource. If built as part of a closed systems, it is effective immediately. Disadvantages: Not commonly used in the UK, and where they are, they tend to be for private sewage treatment installations. To have optimal TP removal performance harvesting of willow will be required. Harvesting of willow is a valuable resource but the process is of harvesting it is onerous. Some sediment removal is required at the inlet and any suspended sediment may have to be removed periodically. Little information available currently regarding regulations on their implementation of water treatment. Effective only during the willow growing season. Development Partners: Landowners / land managers, The Council , NRW, Sustainable Drainage Feasibility Grant, Four Rivers for Life, DCWW, DCWW Spending Commitments, Rivers in Wales Environmental Investment, DCWW Community Fund, Developers: Could help to deliver Net Benefit for Biodiversity, DCWW, WG, WG Spending Commitments, Besic Payment Scheme, SFS, Heritage Lottery Fund, Ofwat, Innovation Fund, Water Breakthrough Challenge, Water Discovery Challenge. 		Biodiversity Natural flood mitigation Aesthetic value Amenity value Carbon sequestration Can harvest the willow which could then be sold (offsets some of the maintenance costs)	Medium	Low	
Attenuation storage tanks (lined)	Category 2	 Lined cellular/crated or other storage below ground (no infiltration). Advantages: Particulate P removal through sedimentation of solids upstream of attenuation tank. Disadvantages: Attenuation tank is not designed to provide any P removal on its own. P removal highly dependent on upstream features and how well assets are maintained. Filters need changing every few years. Development Partners: Landowners / land managers, The Council, NRW, DCWW, DCWW Spending Commitments, Developers: Could help to deliver Net Benefit for Biodiversity, DCWW, WG, WG Spending Commitments, Besic Payment Scheme 	⊕ ≋≋≋	Natural flood mitigation	Medium	High	

ffectiveness Case Studies

The Pontbren Project Natural Flood management plus in the Cadoxton catchment Four Rivers for LIFE National Surface Water Management and SuDS Group Members Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative

High

Natural Flood management plus in the Cadoxton catchment Wales Water Management Forum Rivers Trust of Wales (Welsh Rivers Trust) Afonydd Cymru The West Wales Rivers Trust Taclo'r Tywi Initiative

High

Appendix E

Wetland Calculations Technical Notes

30192602-ARC-XX-XX-CA-CE-0001-P1 – Cenarth and Cilgerran 30192602-ARC-XX-XX-CA-CE-0002-P1 – Llandysul, Tregaron and Adpar



Phosphate Reduction and Mitigation (PRAM)

Wetland Calculations Technical Note

Doc Ref: 30192602-ARC-XX-XX-CA-CE-0001-P2 DECEMBER 2023

Version Control (optional)

Version	Date	Author	Checker	Reviewer	Approver
P1	08/12/2023	Elliot Blount- Powell	Matt Brown	Luis Vergara Romero	Renuka Gunasekara
P2	20/12/2023	Elliot Blount- Powell	Matt Brown	Luis Vergara Romero	Renuka Gunasekara

This report dated 20 December 2023 has been prepared for Ceredigion County Council (the "Client") in accordance with the terms and conditions of appointment (the "Appointment") between the Client and **Arcadis (UK) Limited** ("Arcadis") for the purposes specified in the Appointment. For avoidance of doubt, no other person(s) may use or rely upon this report or its contents, and Arcadis accepts no responsibility for any such use or reliance thereon by any other third party.

Contents

1	Introd	uction	1
2	Waste	water Treatment Works Summary	2
	2.1.1	Phosphorus concentration	2
	2.1.2	Permitted Flows and Estimated Design Flows	3
	2.1.3	Summary of WwTW Model Inputs	4
3	Initial	Wetland Model Analysis	5
:	3.1 C	enarth	5
	3.1.1	k-C* Model	5
	3.1.2	P-K-C* Model	7
	3.1.3	Regression	9
:	3.2 C	ilgerran	.10
	3.2.1	k-C* Model	.11
	3.2.2	P-K-C* Model	.13
	3.2.3	Regression	.16
4	Refine	d Wetland Model Analysis	.18
4	4.1 C	ilgerran	.19
4	4.2 C	enarth	.20
5	Summ	ary	.21
Ар	pendix A	۹	.23
I	Refined \	Netlands Analysis with P-K-C* Model – Cenarth	.23
Ар	pendix E	3	.25
I	Refined \	Wetlands Analysis with P-K-C* Model – Cilgerran	.25

Tables

Table 2-1 Dry Weather Flow Estimation	4
Table 2-2 Influent Concentration and Design Flow Values	4
Table 3-1 Cenarth K-C* Inputs and Results	5
Table 3-2 Cenarth P-K-C* Results	7
Table 3-3 Summary of Regression Model Outputs for Cenarth	10
Table 3-4 Cilgerran k-C* Permitted Design Flow Results	11
Table 3-5 Cilgerran k-C* Estimated Design Flow Results	12
Table 3-6 Cilgerran Permitted Design Flow P-K-C* Results	14
Table 3-7 Cilgerran Estimated Design Flow P-K-C* Results	15

Table 3-8 Summary of Regression Model Outputs for Cilgerran for Permitted Q 17
Table 3-9 Summary of Regression Model Outputs for Cilgerran for Estimated Q 17
Table 5-1 Summary wetland area requirements and effective removal of TP for Cenarth and Cilgerran
Wetlands 22

Figures

Figure 2-1: Average (Orthophosphate) at Cenarth WwTW - Sep 2023 to Sep 2022	2
Figure 2-2 Average (Orthophosphate) at Cilgerran WwTW - Oct 2023 to Sep 2021	3
Figure 3-1 TP Regression Curve for Low flow scenario (with DWF of 15.41m ³ /day)	9
Figure 3-2 TP Regression Curve for High flow scenario (with DWF of 79.83 m3/day)	10

Appendices

Appendix A Refined Wetlands Analysis with P-K-C* Model - Cenarth Appendix B Refined Wetlands Analysis with P-K-C* Model – Cilgerran

1 Introduction

To support the outline design of the Cenarth and Cilgerran wetlands being progressed under the Phosphate Reduction and Mitigation (PRAM) project, this technical note provides a summary of the estimated nutrient reductions and wetland area requirements using the following approaches:

- The P-K-C* model approach
- A plug flow model termed the k-C* model approach
- Regressions (or exponential decay) equations

P-K-C* Model

The P-K-C* model described in Kadlec and Wallace (2009)¹ is considered to be the most robust approach and is strongly recommended. This model is a 'First Order' reaction model. That is to say, the rate of reaction (the nutrient removal processes) assumed is dependent upon the concentration of the parameter in question. Such a model may be used either to derive a treatment area based upon target performance (load removal or outlet concentration), or else to derive the expected nutrient removal from a wetland with a particular treatment area.

The P-K-C* model is used to calculate the average estimated percentage of remaining contaminants (after treatment), for a given area and hydraulic loading rate (HLR). The parameters P, K and C* describe the way the contaminant of interest is processed within the wetland. C* is the 'background concentration' of a particular parameter, such as Total Phosphorus (TP). The background concentration is a parameter that represents an irreducible concentration that will exist in the water of a wetland that results from internal biogeochemical processes i.e. the contaminant would be present without the addition of the influent. It represents a concentration below which further removal of contaminant is impossible. K is the reaction rate, which describes the speed with which contaminants at any particular concentration (above C*) are removed from incoming water by the wetland. P is a parameter that describes both the hydraulic efficiency of the wetland, and the way in which contaminants 'weather' or breakdown as they pass through the wetland. Note that if contaminants are a mix of chemicals (e.g. TP), some of the chemicals that make up TP will break down more readily than others².

k-C* Model

The k-C* model has been widely applied to the design of treatment wetlands. As with the P-k-C* model, the k-C* model is a first order reaction model that similarly incorporates a background concentration value below which further nutrient removal is not possible.

Regression

There are numerous regression equations proposed in the literature to calculate the removal rates of different parameters, including TP. Different equations will have limitations on their input and output range and the hydrological parameters used. The regression-based model is based on datasets generated from three Integrated Constructed Wetlands (ICWS): Glaslough, County Monaghan, Ireland; Northrepps, Norfolk; and Ingol, Norfolk³. The results of long-term monitoring have been combined to generate an exponential decay curve. The exponential decay curve equation has been used to estimate the size of the wetland required to achieve a desired outlet effluent quality for TP. A TP exponential decay curve has been carried out for a low flow scenario and a high flow scenario.

¹ Kadlec, R.H. and Wallace, S., 2009. Treatment wetlands. CRC press.

² Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals.

³ The Wye & Usk Foundation (July 2022) Wetland Feasibility, Design and Offsetting. Wetland Development on the River Wye SAC – Titley.

2 Wastewater Treatment Works Summary

2.1.1 Phosphorus concentration

Dŵr Cymru Welsh Water (DCWW) have provided Orthophosphate sampling data for outflow from the Cenarth and Cilgerran Wastewater Treatment Works (WwTWs) for the past 2 years where data exists. Figure 2-1 and Figure 2-2 present the average Orthophosphate at Cenarth WwTW and Cilgerran WwTW respectively. These values have been obtained to understand the fluctuations in TP concentrations and how that impacts the wetland area requirements and treatment efficiencies, compared to the 5 mg/l backstop limit, which will be imposed on both WwTWs over the DCWW Investment Programme period (ending 2032). Currently there is no TP permit limit at either of these WwTW locations.

As a conservative basis, the wetland design calculations were undertaken based on the observed Orthophosphate concentration data (rather than TP conservations) for the most recent 12 months period, but comparison was also made against the 5 mg/l backstop limit to check the implication on the wetland performance.

The average Orthophosphate concentration over the last year (Sep 2022 – Sep 2023) at Cenarth were 4.33mg/l, which is slightly below the 5mg/l backstop limit. However, as shown in Figure 2-1, there have been fluctuations in the Orthophosphate concentrations above the proposed backstop limit of 5mg/l.



Figure 2-1: Average (Orthophosphate) at Cenarth WwTW - Sep 2023 to Sep 2022

For Cilgerran, the average Orthophosphate concentrations over the last year (Oct 2022 – Oct 2023) were 2.37mg/l, and the year before that (Sep 2021 – Sep 2022) they were 2.48mg/l. As shown in Figure 2-2, there have been no record incidents where the Orthophosphate concentrations exceed the 5mg/l backstop limit. Therefore, it is worth considering whether the wetland would realistically receive a concentration of 5mg/l considering the average is typically half of that. However, reaching 5mg/l can still potentially occur with the fully permitted Dry Weather Flow (DWF) conditions as more new homes in future Local Development Plans (LDPs) are connected to the WwTW.

Section 2.1.2 below details the DWF estimates and permitted values at the two WwTW locations and Section 2.1.3 provides a summary of key model inputs.

Section 3 and Section 4 of this technical note then show how the various Orthophosphate concentrations and other model inputs impact wetland requirements and nutrient reduction, for the different modelling approaches used.



Figure 2-2 Average (Orthophosphate) at Cilgerran WwTW - Oct 2023 to Sep 2021

2.1.2 Permitted Flows and Estimated Design Flows

Table 2-1 summarises the projected Dry Weather Flow (DWF) from Cenarth and Cilgerran WwTW respectively when the proposed site allocations in the Local Development Plan (LDP) accounted for.

In order to calculate the existing and future developments DWF, the following equation has been used:

DWF = PG + I

Where:

P = population

G = water consumption

I = Infiltration rate

	G – Water Consumption	I = Infiltration
Existing Population	50%	144**
New Dwellings	30%*	108***

* irrespective of good construction of infrastructure

** (assuming 90% returned back into sewer) - assumed 160 l/p/d current consumption

*** 120 l/p/d for PCC - 90% returned to sewer

Table 2-1 Dry Weather Flow Estimation

	Existing			Existing Proposed LDP Addition			Predicted Total	
WwTW	Population Equivalent	Consented DWF (m³/day)	Estimated Existing DWF (m ³ /day)	New Homes	New Populati on	Extra DWF (m³/day)	Total Populati on	Total DWF (m³/day)
Cenarth	680	152	147	38	87	12	767	159
Cilgerran	1,033	408	223	50	115	16	1,148	239

*Assumed average household occupancy rate as 2.3

2.1.3 Summary of WwTW Model Inputs

Table 2-2 summarises the input data into the P-K-C* Model, k-C* and regression models.

Table	2-2	Influent	Concentration	and	Desian	Flow	Values
rubic	~ ~	macm	0011001111 411011	unu	Design	11000	values

WwTW Ci, Influent Concentration (mg/l)*		Q, Design Flow (m3/day)
	4.33 (Sep 2023 - Sep 2022)	152
Cenarth	5 (backstop TP limit concentration)	152
	2 37 (Oct 2023 to Oct 2022)	408**
	2.57 (001 2025 10 001 2022)	239***
Cilgorran	2 48 (Son 2022 to Son 2021)	408**
Cilgertan	2.46 (Sep 2022 to Sep 2021)	239***
	5 (backstop TP limit	408**
	concentration)	239***

*Influent concentration of Total Phosphorus

** Permitted Flow

*** Estimated Flow

Based on Table 2-1, the estimated flow (159m³/day) for Cenarth WwTW was very similar to the permitted flow (152m³/day). Therefore, the permitted flow value was used for the wetland design purpose.

For Cilgerran WwTW, the estimated flow (239m³/day) is substantially lower than the permitted value (408m³/day). Therefore, the wetland design for this is primarily based on the estimated flow, but the permitted flow was also used for sensitivity testing purpose.

3 Initial Wetland Model Analysis

The following sections present the outcomes of the initial model development for nutrient removal at the proposed wetlands for Cenarth and Cilgerran. A summary and interpretation of results is presented in Sections 4 and 5.

3.1 Cenarth

3.1.1 k-C* Model

The plug-flow k-C* model is based on the below equation; with the inputs and results summarised in Table 3-1, in which the input values are shaded in grey for clarity.

A=(0.0365*Q/k)*ln[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m³/d), k: apparent rate coefficient (m/year), Ci: inlet TP concentration (gP/m³ or mg/l); C*: background Concentration (mgP/l); Ce=Target Effluent Concentration (mg/l)

The model was run with the following values:

Co: The target TP concentration for the wetland is 1mg/l.

C*: The wetland background concentration is estimated at 0.05mg/l.

k: The apparent rate coefficient used was 12 m/year.

The analysis is undertaken for two different Ci values (4.33mg/l and 5mg/l) using the fully permitted DWF value of 152m³/d at the WwTW. Once the wetland area is calculated, the Hydraulic Retention Time (HRT) was determined using the following equation:

HRT = V/Q

Where HRT (days), V= Wetland Volume (m^3), Q=design flow (m^3/d)

Parameter	Design Scenario 1 – See Note 1 Values	Design Scenario 2 – See Note 2 Values	Unit	Comment
Q	152	152	m ³ /d	Design flow (Permitted Flow) – see
Ci	4.33	5	gP/m³ or mg/l	Inlet TP concentration - see Table 2.2
Се	1	1	mg/l	Target effluent concentration
C*	0.05	0.05	mg/l	Wetland background concentration (estimated value) – see Note 4

Table 3-1 Cenarth K-C* Inputs and Results

Parameter	Design Scenario 1 – See Note 1	Design Scenario 2 – See Note 2 Unit		Comment
	Values	Values		
k	12	12	m/year	Apparent rate coefficient - see Note 5
Water depth	0.2	0.2	m	Treatment water depth – see Note 6
Total wetland area	0.71	0.78	ha	Estimated wetland area (ha) for the specified Ci and Ce
	7,075	7,783	m²	Estimated wetland area (m²) for the specified Ci and Ce
Wetland volume	1,415	1,557	m ³	Estimated wetland volume (m ³) for the specified Ci and Ce
Hydraulic Retention Time (HRT)	9.31	10.24	days	The average time taken for water to pass through a wetland - see Note 7

Notes

- 1. Design Scenario 1 is based on Ci value of 4.33mg/l from the observed Orthophosphate values (Sep 2023 Sep 2022), as per Table 2.2.
- 2. Design Scenario 2 is based on Ci value of 5.0mg/l from the backstop TP limit, as per Table 2.2 this is a hypothetical scenario mainly for sensitivity testing.
- Design flow for both Design Scenario 1 and 2 is based on the fully permitted DWF of 152m³/d, as per Table 2.2
- 4. C* value of 0.05mg/l is assumed, as per Wetland Feasibility, Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation
- Apparent rate coefficient is assumed as 12m/year, as per Wetland Feasibility, Design and Offsetting: Wetland Development on the River Wye SAC – Titley Report (July 2022) by The Wye & Usk Foundation
- 6. Treatment depth is taken as 0.2m, as per Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals
- Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation sates to achieve <1 mg/l TP a minimum HRT of 6.5 days is required. Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals states HRT is scheme dependent and typically 12-24hrs may be needed.

3.1.2 P-K-C* Model

The P-K-C* Model builds on the results of the k-C* model results shown in

Table 3-1, specifically the total wetland area, which is used the derive the hydraulic loading rate (q) (m/yr). The P-K-C model is defined as¹:

 $\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \right]^{-P}$

 $\begin{aligned} &C_i = \text{Influent concentration of contaminant (mg/l)} \\ &C_e = \text{Effluent concentration of contaminant (mg/l)} \\ &C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)} \\ &k = \text{Rate coefficient for reduction of contaminant (m/yr)} \\ &P = \text{Apparent no. of tanks in series (PTIS - dimensionless)} \\ &q = \text{Hydraulic loading rate (m/yr)} \end{aligned}$

Table 3-2 summarises the P-K-C^{*} inputs and outputs for both the permitted Q (Orthophosphate Sep 2023 – Sep 2022) and the permitted Q (5 mg/l backstop limit) scenarios. The input values are shaded in grey for clarity and Italic text in italics are information related calculating hydraulic loading rate (q).

Parameter	Design Scenario 1 – See Note 1 Value	Design Scenario 2 – See Note 2 Value	Unit	Comment
C _{i-}	4.33	5	mg/l	Influent concentration of Total Phosphorus - see Table 2.2
C*	0.022	0.022	mg/l	Background concentration of Total Phosphorus (estimated value) – see Note 3
Р	6	6	-	Apparent no. of tanks in series
k	10	10	m/yr	Rate coefficient for reduction of Total Phosphorus – see Note 4
Design Flow	152	152	m³/d	Design flow (Permitted Flow) – see Table 2.2 and Note 5
Total annual hydraulic throughput	55,480	55,480	m³/yr	Design Flow (m ³ /d) X 365

Table 3-2 Cenarth P-K-C* Results

Parameter	Design Scenario 1 – See Note 1 Value	Design Scenario 2 – See Note 2 Value	Unit	Comment
Total wetland area	7,076	7,784	<i>m</i> ²	Active cell area (i.e. excluding diving berms, spreader channels and level control structures) – directly taken from Table 3-1 (from k-C* Model) for each Design Scenario
q	7.841	7.127	m/yr	Hydraulic loading rate = Total annual hydraulic throughput (m³/yr) / Total wetland area (m²)
Amount of remaining contaminant.	1.36	1.72	mg/l	NB. treated discharge from the wetland cannot be less than the background concentrations, as
Ce - C*	31.46	28.34	%	it is not possible to achieve i.e. background concentration will always be present
Treatment efficiency of wetland	68.54	71.66	%	% of contaminant removed

Notes:

- 1. Design Scenario 1 is based on Ci value of 4.33mg/l from the observed Orthophosphate values (Sep 2023 Sep 2022), as per Table 2.2.
- 2. Design Scenario 2 is based on Ci value of 5.0mg/l from the backstop TP limit, as per Table 2.2 this is undertaken for mainly sensitivity testing purpose should the average inlet concentration is reached the backstop TP limit of 5mg/l for the WwTW effluent.
- C* value of 0.022mg/l is assumed, based on Kadlec & Wallace report (2009) for the median flowweighted TP concentration in 85 relatively undeveloped basins of the United States. It also states levels are very low in Florida Everglades, often in the range of 0.006-0.010. FWS wetlands receiving low strength wastewater. Kadlec & Wallace report (2009) also advises C* typical values of 0.010 – 0.040 mg/l for rainfall driven Water Surface (FWS) systems.
- 4. For total phosphorus (TP) reduction, Kadlec & Wallace report (2009) advises that adjustment of the rate constant using a temperature coefficient , Θ , is not a good model with the equation $k_T = k_{20}\Theta(^{T-20})$ where T is the operating temperature. Studies of FWS wetlands in cold climates gave a median value of 0.986, meaning that the rate constant decreased with increasing temperature. It is therefore more

appropriate to look at actual rate constants from existing FWS wetlands. Kadlec & Wallace report that the median rate constant for 282 studied wetlands was 10.0m/yr.

5. Design flow for both Design Scenario 1 and 2 is based on the fully permitted DWF of 152m³/d, as per Table 2.2.

3.1.3 Regression

The regression results below are based on the phosphorus exponential curves shown in The Wye & Usk Foundation (July 2022) Wetland Feasibility, Design and Offsetting³. The results below are therefore an interpretation of those results rather than based on a published equation. Further research undertaken to date could not find a regression equation specific for wetland P removal. Therefore, there is low confidence in the results below and these should not be used for design purposes.

The inputs into the Regression model are based on the Orthophosphate values shown in Section 2.1.1 for the period between Sep 2023 and Sep 2022. Figure 3-1 and Figure 3-2 show derived TP exponential decay curve for a wetland under a low flow scenario and a high flow scenario. However, one of the main limitations of this exercise is that the regression equation used in the analysis is based on a DWF of much lower value of circa 15m³/day and TP level 5.6mg/l for the low flow scenario and 79.83m³/day and TP of 2.82mg/l for the high flow scenario.

Therefore, the initial estimated wetland area was then normalised with the fully permitted design flow of 152 m^3 /day to recalculate the wetland areas for low flow and high flow scenarios, as shown in Table 3-3.



Figure 3-1 TP Regression Curve for Low flow scenario (with DWF of 15.41m³/day)



Figure 3-2 TP Regression Curve for High flow scenario (with DWF of 79.83 m3/day)

Regression	Permitted Q , Orthophosphate data (Sep 2023 - Sep 2022)			
	Low Flow Scenario	High Flow Scenario		
Desired TP value (mg TP/l)	1	1		
Initially Estimated Wetland Area (m ²)	508.7	1,205		
Normalised Wetland Area (m²)*	5,018	11,883		

Table 3-3 Summary of Regression Model Outputs for Cenarth

* The Normalised Wetland Area (m²) is calculated by multiplying the Estimated Wetland Area with the ratio of Permitted Flow (152 m³/d) and mean flow used in the Titley Regression curve (15.41 m³/d).

3.2 Cilgerran

As discussed in Section 2.1.1, Orthophosphate concentrations data for Cilgerran showed an average of 2.37mg/l in the period of Oct 2022 – Oct 2023 and 2.48mg/l in the period of Sep 2021 – Sep 2022. Also, as discussed in 2.1.2, the projected DWF, as a result of the proposed allocations under the LDP could increase the flow entering the wetlands. Therefore, a number of calculations have been undertaken to understand the impact of the design and estimated flow, against the different Orthophosphate concentrations.

As explained in Section 2.1.3, the estimated flow (239m³/day) is substantially lower than the permitted value (408m³/day) for Cilgerran WwTW. Therefore, the wetland design for this is primarily based on the estimated flow, but the permitted flow was also used for sensitivity testing purpose.

3.2.1 k-C* Model

As discussed in Section 3.1.1, the following are the same across all the models and therefore, Table 3-4 and Table 3-5 only present the other specific parameters and outputs related to the Cilgerran WwTW:

- K = 12 m/year
- C* = 0.05 mg/l
- Water depth = 0.20m

Table 3-4 Cilgerran k-C* Permitted Design Flow Results

Parameter	Design Scenario 1 – See Note 1 Values	Design Scenario 2 – See Note 2 Values	Design Scenario 3– See Note 3 Values	Unit	Comment
Q	408	408	408	m³/d	Design flow (Permitted Flow) - see Table 2.2 and Note 4
Ci	2.37	2.48	5	gP/m ³	Inlet TP concentration – see Table 2.2
Се	1	1	1	mg/l	Target effluent concentration
Total wetland	1.10	1.16	2.09	ha	Estimated wetland area (ha) for the specified Ci and Ce
area	10,994 11,599 20,893 m ²	m²	Estimated wetland area (m²) for the specified Ci and Ce		
Wetland volume	2,199	2,320	4,179	m ³	Estimated wetland volume (m ³) for the specified Ci and Ce
Hydraulic Retention Time (HRT)	5.39	5.69	10.24	days	The average time taken for water to pass through a wetland - see Note 5

Notes:

- 1. Design Scenario 1 is based on Ci value of 2.37 mg/l from the observed Orthophosphate values (Oct 2023 Oct 2022), as per Table 2.2.
- 2. Design Scenario 2 is based on Ci value of 2.48 mg/l from the observed Orthophosphate values (Sep 2022 Sep 2021), as per Table 2.2.
- 3. Design Scenario 3 is based on Ci value of 5.0mg/l from the backstop TP limit, as per Table 2.2.
- 4. Design flow for all three scenarios is based on the fully permitted DWF of 408 m³/d, as per Table 2.2 this is undertaken for mainly sensitivity testing purpose should the full permitted flow to be treated in the future.
- Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation sates to achieve <1 mg/l TP a minimum HRT of 6.5 days is required. Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals states HRT is scheme dependent and typically 12-24hrs may be needed.

Table 3-5 Cilgerran k-C* Estimated Design Flow Results

Parameter	Design Scenario 1 – See Note 1	Design Scenario 2 – See Note 2	Design Scenario 3– See Note 3	Unit Comment	
	Values	Values	Values		
Q	239	239	239	m ³ /d	Design flow (Estimated Flow) - see Table 2.2 and Note 4
Ci	2.37	2.48	5	gP/m ³	Inlet TP concentration – see Table 2.2
Се	1	1	1	mg/l	Target effluent concentration
Total wetland	0.64	0.68	1.22	ha	Estimated wetland area (ha) for the specified Ci and Ce
area	6,440	6,794	12,239	m ²	Estimated wetland area (m²) for the specified Ci and Ce
Wetland volume	1,288	1,359	2,448	m ³	Estimated wetland volume (m ³) for the specified Ci and Ce

Parameter	Design Scenario 1 – See Note 1 Values	Design Scenario 2 – See Note 2 Values	Design Scenario 3– See Note 3 Values	Unit	Comment
Hydraulic Retention Time (HRT)	5.39	5.69	10.24	days	The average time taken for water to pass through a wetland - see Note 5

Notes:

- 1. Design Scenario 1 is based on Ci value of 2.37 mg/l from the observed Orthophosphate values (Oct 2023 Oct 2022), as per Table 2.2.
- 2. Design Scenario 2 is based on Ci value of 2.48 mg/l from the observed Orthophosphate values (Sep 2022 Sep 2021), as per Table 2.2.
- 3. Design Scenario 3 is based on Ci value of 5.0mg/l from the backstop TP limit, as per Table 2.2 this is undertaken for mainly sensitivity testing purpose should the average inlet concentration is reached the backstop TP limit of 5mg/l for the WwTW effluent.
- 4. Design flow for all three Scenarios is based on the estimated DWF of 239 m³/d, as per Table 2.2.
- Design and Offsetting: Wetland Development on the River Wye SAC Titley Report (July 2022) by The Wye & Usk Foundation sates to achieve <1 mg/l TP a minimum HRT of 6.5 days is required. Natural England (June 2022) Framework Approach for Responding to Wetland Mitigation Proposals states HRT is scheme dependent and typically 12-24hrs may be needed.

3.2.2 P-K-C* Model

As discussed in Section 3, the following parameters are standard across all the P-K-C models and therefore are not presented in Table 3-6 and Table 3-7 below:

- C* = 0.022
- k = 10
- θ- = 0.986
- Water depth = 0.20m

Table 3-6 Cilgerran Permitted Design Flow P-K-C* Results

Parameter	Design Scenario 1 – See Note 1 Values	Design Scenario 2 – See Note 2 Values	Design Scenario 3– See Note 3 Values	Unit	Comment
Ci-	2.37	2.48	5	mg/l	Influent concentration of Total Phosphorus - see Table 2.2
Р	6	6	6	-	Apparent no. of tanks in series
Design Flow	408	408	408	m³/d	Design flow (Permitted Flow) – see Table 2.2 and Note 4
Total annual hydraulic throughput	148,920	148,920	148,920	m³/yr	Design Flow (m3/d) X 365
Total wetland area	10,994	11,599	20,893	m ²	Active cell area (i.e. excluding diving berms, spreader channels and level control structures) – directly taken from Table 3-4 (from k-C* Model) for each Design Scenario
q	13.5	12.8	7.13	m/yr	Hydraulic loading rate = Total annual hydraulic throughput (m ³ /yr) / Total wetland area (m ²)
Amount of	nt of hing minant, 1.17 1.18 1.41 mg 49.85 48.08 28.34 %	1.18	1.41	mg/l	NB. treated discharge from the wetland cannot be less than the
contaminant, Ce - C*		%	background concentrations, as it is not possible to achieve i.e. background concentration will always be present		
Treatment efficiency of wetland	50.15	51.92	71.66	%	% of contaminant removed

Notes

- 1. Design Scenario 1 is based on Ci value of 2.37 mg/l from the observed Orthophosphate values (Oct 2023 Oct 2022), as per Table 2.2.
- 2. Design Scenario 2 is based on Ci value of 2.48 mg/l from the observed Orthophosphate values (Sep 2022 Sep 2021), as per Table 2.2.
- 3. Design Scenario 3 is based on Ci value of 5.0mg/l from the backstop TP limit, as per Table 2.2.
- Design flow for all three scenarios is based on the fully permitted DWF of 408 m³/d, as per Table 2.2 this is undertaken for mainly sensitivity testing purpose should the full permitted flow to be treated in the future.

Table 3-7 Cilgerran Estimated Design Flow P-K-C* Results

Parameter	Design Scenario 1 – See Note 1 Values	Design Scenario 2 – See Note 2 Values	Design Scenario 3 – See Note 3 Values	Unit	Comment
Ci	2.37	2.48	5	mg/l	Influent concentration of Total Phosphorus - see Table 2.2
Р	6	6	6	-	Apparent no. of tanks in series
Design Flow	239	239	239	m³/d	Design flow (Estimated Flow) – see Table 2.2 and Note 4
Total annual hydraulic throughput	87,235	87,235	87,235	m³/yr	Design Flow (m³/d) X 365
Total wetland area	6,440	6,794	12,239	m ²	Active cell area (i.e. excluding diving berms, spreader channels and level control structures) – directly taken from Table 3-4 (from k-C* Model) for each Design Scenario

Parameter	Design Scenario 1 – See Note 1 Values	Design Scenario 2 – See Note 2 Values	Design Scenario 3 – See Note 3 Values	Unit	Comment	
q	13.546	12.840	7.128	m/yr	Hydraulic loading rate = Total annual hydraulic throughput (m ³ /yr) / Total wetland area (m ²)	
Amount of remaining contaminant, Ce - C*	1.17	1.18	1.41	mg/l	NB. treated discharge from the wetland cannot be less than the background	
	49.85	48.08	28.34	%	concentrations, as it is not possible to achieve i.e. background concentration will always be present	
Treatment efficiency of wetland	50.15	51.92	71.66	%	% of contaminant removed	

Notes:

- 1. Design Scenario 1 is based on Ci value of 2.37 mg/l from the observed Orthophosphate values (Oct 2023 Oct 2022), as per Table 2.2.
- 2. Design Scenario 2 is based on Ci value of 2.48 mg/l from the observed Orthophosphate values (Sep 2022 Sep 2021), as per Table 2.2.
- Design Scenario 3 is based on Ci value of 5.0mg/l from the backstop TP limit, as per Table 2.2 2 this is undertaken for mainly sensitivity testing purpose should the average inlet concentration is reached the backstop TP limit of 5mg/l for the WwTW effluent.
- 4. Design flow for all three Scenarios is based on the estimated DWF of 239 m³/d, as per Table 2.2

3.2.3 Regression

As discussed in Section 3, the Regression model has been undertaken to compare the wetland area requirements against the k-C* and P-K-C* model results. However, there is limited confidence in the results as they are based on the phosphorus exponential decay curve of a much smaller WwTW (Titley) rather than an equation. The main limitation of this exercise is that the regression equation used in the analysis is based on a DWF of much lower value of circa 15m3/day and TP level 5.6mg/l for the low flow scenario and 79.83m3/day and TP of 2.82mg/l for the high flow scenario. Table 3-8 below summarises the wetland area requirements for Permitted Design Flow and Estimated Design Flow, based on the Orthophosphate data set being used.

Table 3-8 Summary of	Pearession M	odel Outnuts for i	Cilcerran for	Permitted O
Table 3-0 Summary Or	Regression in	ouel Oulpuis Iol V	Cilgerrari IOr	remilled Q

Regression	Orthophosphate v Oct 2022), as per Ta	values (Oct 2023 - able 2.2	Orthophosphate values (Sep 2022 – Sep 2021), as per Table 2.2			
	Low Flow Scenario	High Flow Scenario	Low Flow Scenario	High Flow Scenario		
Desired TP value (mg TP/I)	1	1	1	1		
Initially Estimated Wetland Area (m²)	650	1,666	764	2,414		
Normalised Wetland Area (m²)*	17,203	44,118	20,217	63,908		

* The Normalised Wetland Area (m2) is calculated by multiplying the Estimated Wetland Area with the ratio of Permitted Flow (408 m³/d) and mean flow used in the Titley Regression curve (15.41 m³/d)

Table 3-9 Summary of Regression Model Outputs for Cilgerran for Estimated Q

Regression	Orthophosphate va Oct 2022), as per Tat	lues (Oct 2023 - ble 2.2	Orthophosphate values (Sep 2022 – Sep 2021), as per Table 2.2			
	Low Flow Scenario	High Flow Scenario	Low Flow Scenario	High Flow Scenario		
Desired TP value (mg TP/I)	1	1	1	1		
Initially Estimated Wetland Area (m²)	650	1,666	764	2,414		
Normalised Wetland Area (m²)*	10,077	25,843	11,843	37,437		

* The Normalised Wetland Area (m2) is calculated by multiplying the Estimated Wetland Area with the ratio of Estimated flow (239m³/d) and mean flow used in the Titley Regression curve (15.41 m³/d)

4 Refined Wetland Model Analysis

Section 4 presents the further results from the P-K-C* model, which was deemed to provide the most robust approach. The results include the findings for the wetland sizes shown in current design drawings for the PRAM project as well as a potential larger wetland scheme that may form under a future phase.

Wetland areas used in this final P-K-C* modelling exercise to estimate the wetland removal % efficiencies have been informed by the initial values obtained (in Section 3) from the K-C* model to achieve the intended 1 mg/l effluent outlet concentration.

Section 4.1 and **Error! Reference source not found.** present a summary of the P-K-C* model results for the Cilgerran and Cenarth wetlands respectively and the complete results can also be found in Appendix A and Appendix B.

These calculations are performed on the basis of having a minimum of six wetland cells at each location for Cilgerran and Cenarth. The outline design drawings currently show that at Cenarth there are four main wetland areas, which can be further subdivided to potentially create up to eight wetland cells in total. Similarly, the outline design drawings currently show that at Cilgerran there are four main wetland areas, which can be further subdivided to potentially create up to eight wetland areas, which can be further subdivided to potentially create up to eight wetland cells in total. Therefore, the design calculations currently adopt a sufficient precautionary approach.

During the period of January to March, it was assumed that winter maintenance activities may be performed, which may reduce the available wetland treatment area by up to 50%, causing a lowered wetland performance. Therefore, effective annual TP removal quantities were also presented to reflect this possibility alongside the normal annual TP removal quantities for comparison. They show that the predicted outlet effluent quality following the wetland treatment is broadly as shown below when they are operating at an optimum level (without any winter wetland maintenance activities).

Current Wetland Scheme:

- At Cilgerran 1.25 to 1.5 mg/l
- At Cenarth 1.25 to 1.5 mg/l

Potentially Expanded Wetland Scheme:

- At Cilgerran 0.5 to 1.5 mg/l
- At Cenarth 1.0 mg/l

Also note that the above outlet effluent quality values are based on the estimated DWF and observed Orthophosphate inlet concentration values (i.e. rather than the fully permitted DWF and backstop TP limit values, which were mainly used for sensitivity scenario testing purposes only).

4.1 Cilgerran

						P-K-C* model - 100% performance		P-K-C* model – 50% performance (Jan – March)		Effective Annual Tp removal	P-K-C* model - 100% performance	P-K-C* model - 50% performance (Jan - March)
	Ci (mg/l)	Q (m3/day)	Wetland (ha)	Volume (m3)	HRT (days)	Removal efficiency (%)	Annual Tp removal (Kg/year)	Removal efficiency	Annual Tp removal, (Kg/year)	Annual Tp removal (kg/yr)	Final Effluent TP (mg/l)	Final Effluent TP (mg/l))
	2.37	408**	1.500	3000	7.35	60.59	213.85	38.34	33.37	193.75	0.93	1.46
	2.37	239***	1.500	3000	12.55	77.95	161.16	55.22	28.15	149.02	0.52	1.06
Cilgerran	2.48	408**	1.500	3000	7.35	60.59	223.77	38.34	34.91	202.74	0.98	1.53
(potential	2.48	239***	1.500	3000	12.55	77.95	168.64	55.22	29.46	155.94	0.55	1.11
expanded												
scheme)	5*	408**	1.500	3000	7.35	60.59	451.15	38.34	70.39	408.76	1.97	3.08
	5*	239***	1.500	3000	12.55	77.95	340.00	55.22	59.39	314.39	1.10	2.24
	2.37	408**	0.600	1200	2.94	32.29	113.96	17.97	15.64	101.11	1.60	1.94
	2.37	239***	0.600	1200	5.02	47.86	98.95	28.42	14.49	88.70	1.24	1.70
Cilgerran												
- 0.6ha	2.48	408**	0.600	1200	2.94	32.29	119.25	17.97	16.36	105.80	1.68	2.03
(current	2.48	239***	0.600	1200	5.02	47.86	103.54	28.42	15.16	92.82	1.29	1.78
uesigii)												
	5*	408**	0.600	1200	2.94	32.29	240.43	17.97	32.99	213.32	3.39	4.10
	5*	239***	0.600	1200	5.02	47.86	208.75	28.42	30.57	187.13	2.61	3.58

* Backstop TP Limit ** Permitted DWF *** Estimated DWF

4.2 Cenarth

						P-K-C* 100% pe	model - rformance	P-K-C* perforn N	model - 50% nance (Jan - ⁄Iarch)	Effective Annual Tp removal
						Remova	Annual	Remov		
		Q		Volum		efficienc	removal,	efficien	Annual Tp	
	Ci (ma/l)	(m3/ dav)	Wetlan d (ha)	e (m3)	HRT (davs)	y, P = 6 (%)	P = 6 (Kɑ/vear)	cy, P = 6 (%)	removal, P = 6 (Kg/vear)	P = 6 (ka/vr)
Cenarth						/				
1.0ha	4.33	152*	1.000	2000	13.16	79.32	190.55	56.81	33.65	176.56
(potential										
expanded	5*	152*	1.000	2000	13.16	79.32	220.03	56.81	38.86	203.88
scheme)										
Conarth										
0 7ha	4.33	152*	0.700	1400	9.21	68.18	163.79	45.11	26.72	149.56
(current										
design)	5*	152*	0.700	1400	9.21	68.18	189.13	45.11	30.86	172.70
acsign)										

`	
P-K-C* model – 100% performanc e	P-K-C* model - 50% performance (Jan - March)
Final Effluent TP (mg/l), P = 6	Final Effluent TP (mg/I), P = 6)
0.90	1.87
1.03	2.16
1.38	2.38
1.59	2.74

* Backstop TP Limit ** Permitted DWF/ Estimated DWF

5 Summary

This technical note provides a summary of the nutrient reductions and estimated wetland area requirements using the following approaches:

- The P-K-C* approach
- A plug flow model termed the k-C* approach
- Regressions (or exponential decay) equations

Using the approaches above, a number of scenarios have been run to understand the impact of the design and estimated flow, against the different Orthophosphate concentrations on the wetland area requirements and effectiveness.

The P-K-C* model is considered to be the most robust approach based on industry guidance. Therefore, this approach has been used in the final design analysis to understand the effectiveness of the current wetland designs for Cenarth and Cilgerran under the PRAM project.

Table 5-1 below summarises the wetland area requirements and effective removal of TP for Cenarth and Cilgerran wetlands. The results show that the current design wetland areas, 0.7 ha for Cenarth and 0.6 ha for Cilgerran, the wetlands would provide in excess of the treatment performance to mitigate for the proposed developments under the current LDPs of Ceredigion and Pembrokeshire to achieve nutrient neutrality requirement. The results also show that future growth in Ceredigion and Pembrokeshire could be potentially mitigated for by expanding these wetland areas. If additional houses are not to come forward at these WwTW locations then both the current wetland designs and future expanded schemes would help to achieve favourable ecological conditions of the Afon Teifi SAC.

Key advantages of the wetland scheme at Cenarth over Cilgerran wetland scheme include:

- It can also offset the increased phosphorus discharges from the downstream Abercych and Cilgerran WwTW locations
- It has a higher phosphorus inlet concentration than Cilgerran, allowing a larger TP annual budget to be removed with a smaller wetland area

As mentioned before, these calculations are performed on the basis of having a minimum of six wetland cells at each location for Cilgerran and Cenarth. The outline design drawings currently show that at Cenarth there are four main wetland areas, which can be further subdivided to potentially create up to eight wetland cells in total to maximise the treatment performance. Similarly, the outline design drawings currently show that at Cilgerran there are four main wetland areas, which can be further subdivided to potentially create up to eight wetland cells in total. Therefore, the design calculations currently adopt a sufficient precautionary approach.

Finally, it is important to build suitable additional contingency in the design approach to account for potential reduced wetland performance during the early wetland plant establishment period, winter maintenance months etc. Therefore, the current design approach would account for this, but ongoing monitoring of the wetland treatment performance is strongly recommended to inform future designs.
Table 5-1 Summary wetlan	nd area requirements and	l effective removal of TP :	for Cenarth and Cilgerran Wetlands.
--------------------------	--------------------------	-----------------------------	-------------------------------------

		Teifi SAC - Total Annual		Total Annual Phosph	Total Annual Phosph		P-K-C model, 6 wetland cells (using latest 12 months DCWW P performance data + projected estimated DWF)				P-K-C model, 6 wetland cells (using Backstop TP Permit + Full Permitted DWF)				
Wetland Locatio n	nd io Downstrea m WwTWs Mitigated Mitigated Downstrea m WwTWs Mitigated Mitigated Downstrea m WwTWs Budget/ per Wetland Location (Kg TP/Year/Wet land)	Teifi SAC - Total Houses/ per Wetland	eifi SAC - Total buses/ per Wetland Wetland (Kg TP/Year/ Wetland/ home)		Wetland annual TP removal - 100% performance nutrient credits(Kg TP/year)	Wetland annual TP removal - Effective performan ce nutrient credits (Kg TP/year)	Max Housing No Unlocked - 100% wetland performance	Max Housing No Unlocked - Effective wetland performance	Wetland annual TP removal - 100% performance nutrient credits(Kg TP/year)	Wetland annual TP removal - Effectiv e perform ance nutrient credits (Kg TP/year)	Max Housing No Potentially Unlocked - 100% wetland performance	Max Housing No Potentially Unlocked - Effective wetland performanc e	Wetland Capital Cost + 50% contingency (£ -in M)		
Cenarth	Cenarth Abercych	65.51	99	0.662	10,000 (Including Future Expansion)	190.550	176.550	288	267	220.030	203.880	333	308	0.450	
	Cilgerran	(see Note 1)	(see note 1)		7,000 (Current Scheme)	163.790	149.56	248	226	189.130	172.700	286	261	0.315	
Cilgerra	Cilgerran	32.45 (see Note 2)	50	0.649	15,000 (Including Future Expansion)	161.160	149.020	248	230	451.150	408.760	695	630	0.675	
	-				6,000 (Current Scheme)	98.95	88.7	152	137	240.43	213.32	370	329	0.270	

Note 1 - Cenarth Wetland

Ceredigion County Council (CeCC) LDP Total Houses to mitigate = 38 (all 38 houses at Cenarth WwTW) CeCC LDP Total Annual Phosphorus Budget = 25.38 Kg TP/Year

Pembrokeshire County Council (PCC) LDP Total Houses to mitigate = 61 (50 houses at Cilgerran WwTW and 11 houses at Abercych WwTW) PCC LDP Total Annual Phosphorus Budget = 40.13 Kg TP/Year

Combined CeCC and PCC LDP houses to mitigate = 99

Combined CeCC and PCC Total Annual Phosphorus Budget to mitigate = 65.51 Kg TP/year

Note 2- Cilgerran Wetland

PCC LDP Total Houses to mitigate = 50 (all 50 houses at Cilgerran WwTW) PCC LDP Total Annual Phosphorus Budget to mitigate = 32.45 Kg TP/Year

Appendix A Refined Wetlands Analysis with P-K-C* Model – Cenarth Current Design

	ARCADIS					PROJECT No:	30192602		
	5-015		CALCU	LATIONS		GBA:	Resilience -	Water	
CLIENT:	Ceredigion Cou	unty Council				REVISION:	P01		
						AUTHOR:	RG		
PROJECT:	Wetland Sites	- Teifi Wetland	S			CHECKER:	EBP		
						APPROVER:			
SUBJECT:	Process Design	Calculations -	Cenarth			DATE:	30/11/2023		
	Permitted Q, C	Orthophosphate	e Sep 2023 - S	Sep 2022		DOC. No:			
SECTION:	Front Sheet					SHEET:	1	OF	4
ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMM	MENTS
P01	4	RG	30/11/23	EBP	30/11/23	LV	12/01/23		
DESIGN BASIS S	TATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	lculations)			

ARCADIS		CALCULATIO	ONS	PROJECT No:	30192602				
VEV	CLIENT			GBA:	Resilience - Water				
KET	CLIENT:	Ceredigion County Council		REVISION:	P01				
the second secon	PROJECT			AUTHOR:	RG				
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP				
Linked values	SURIECT			APPROVER:	30/11/2023				
Assumed values	Sobler.	Process Design Calculations - Cenarth		DOC No:	0				
Iterated values	SECTION:			SHEET:					
		Р-к-с		-	2	OF	4		
Process Coloulations									
Process Calculations									
Parameter	Unit	Value	References/Comments						
C _{I-TP}	mg/l	4.33	Influent concentration of Total Phospho	rus (Sep 2022 - Sep 2023)					
С* _{тр}	mg/l	0.022	Background concentration of Total Phos	phorus					
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Ph	nosphorus					
θ. _{тр}	-	0.986	Median Temp coefficient for Total Phosp	Total Phosphorus					
т	°C	8	Average operating temperature						
No. of treatment stages	-	3							
Р	-	6	For one treatment stage i.e. 1 cell in seri	es/three treatment stages i.e 3	3 cells in series - P is 2 or 6 resp	ectively (conservative value)			
Design Flow	m3/d	152	Input flow rate into here						
Total annual hydraulic	3,	55490							
throughput	m /yr	55480							
Total wetland area	m²	7,000	Active cell area (i.e. excluding diving ber	ms, spreader channels and lev	el control structures)				
q	m/yr	7.925714286							
Total Phosphorus		1 37	ND treated discharge from the wetland				and an a will always be account		
contaminant Ce - C*	-	1.37	No. created discharge from the wetland	cannot be less than the backgi	round concentrations, as it is no	it possible to achieve i.e. backg	round conc will always be present		
Treatment efficiency of wotland	70 92	51.82	% of contaminant removed						
meatment enciency of wetland	70	00.18	% or contaminant removed						

ARCADIS		CALCULATIO	NS	PROJECT No:	30192602		
KEY	CLIENT			GBA:	Resilience - Water		
KET .	CLIENT.	Ceredigion County Council		AUTHOR:	RG		
Input values	PROJECT:			CHECKER:	EBP		
Calculated values		Wetland Sites - Teifi Wetlands		APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Conarth		DATE:	30/11/2023		
Assumed values		Frocess Design Calculations - Cenarth		DOC. No:	0		
Iterated values	SECTION:	P-k-c		SHEET:	3	OF	4
Process Calculations	Unite	Value	Defense (formation				
Cim	mg/l	4.33	Influent concentration of Total Phospho	rus (Sep 2022 - Sep 2023)			
C*m	mg/l	0.022	Background concentration of Total Pho	shorus			
k _{TP}	m/vr	10	Rate coefficient for reduction of Total P	hosphorus			
f m	-	0.986	Median Temp coefficient for Total Phos	nhorus			
Т	°C	8	Average operating temperature				
No. of treatment stages	-	3	· · · · · · · · · · · · · · · · · · ·				
P	-	6	For one treatment stage i.e. 1 cell in ser	ies/three treatment stages i.e	3 cells in series - P is 2 or 6 respect	ively (conservative value)	
Design Flow	m3/d	152	Input flow rate into here				
Total annual hydraulic throughput	m³/yr	55480					
Total wetland area	m²	3,500	Active cell area (i.e. excluding diving be	rms, spreader channels and le	vel control structures)		
q	m/yr	15.85142857					
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	2.36 54.89 45.11	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the back	ground concentrations, as it is not p	oossible to achieve i.e. backgro	ound conc will always be present

<u>6</u> A			PROJECT No:	3019260	2	
-/-	ARUADIS	CALCOLATIONS	GBA:	Resilienc	e - Water	
CLIENT:	Corodigion County Co	uncil	REVISION:	P01		
	Cerealgion County Co		AUTHOR:	RG		
PROJECT:	Wotland Sitos Toifi M	latlands	CHECKER:	EBP		
	vvetianu sites - reni v	vetialius	APPROVER:	0		
SUBJECT:	Process Design Calcul	ations Conarth	DATE:	45260		
	Process Design Calcula		DOC. No:	0		
SECTION:	References		SHEET:	4	OF	4

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic (parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-1}$$

 C_i = Influent concentration of contaminant (mg/l)

 C_e = Effluent concentration of contaminant (mg/l) C* = Background concentration of contaminant (in the wetland water column) (mg/l)

k = Rate coefficient for reduction of contaminant (m/yr)

P = Apparent no. of tanks in series (PTIS - dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- Co: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

						PROJECT No:	30192602		
	JADIS		CALCUI			GBA:	Resillience -	Water	
CLIENT:	Ceredigion Cou	unty Council				REVISION:	P01		
						AUTHOR:	RG		
PROJECT:	Wetland Sites -	- Teifi Wetland	is - reduced to	o 0.7ha (current d	design)	CHECKER:	EBP		
						APPROVER:			
SUBJECT:	Process Design	Calculations -	Cenarth			DATE:	30/11/2023	,	
	Permitted Q, A	ssumed Backs	top/ Current	TP		DOC. No:			
SECTION:	Front Sheet					SHEET:	1	OF	4
ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMN	1ENTS
P01	4	RG	30/11/23	EBP	30/11/23	LV	12/01/23		
DESIGN BASIS S	STATEMENT (Inc.	high level des	cription of sit	te/process and p	urpose of ca	Iculations)			

ARCADIS		CALCULATIO	DNS	PROJECT No:	30192602		
KEY	CHENT:			GBA:	Resilience - water		
KET .	CLIENT.	Ceredigion County Council		AUTHOR:	RG		
Input values	PROJECT			CHECKER.	EBP		
Calculated values	- Hoseen	Wetland Sites - Teifi Wetlands - reduce	d to 0.7ha (current design)	APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cenarth		DATE:	30/11/2023		
Assumed values		Frocess Design Calculations - Cenartin		DOC. No:	0		
Iterated values	SECTION:	P-k-c		SHEET:	2	OF	4
Process Calculations							
Parameter	Unit	Value	Poforoncos/Commonts				
C _{LTP}	mg/l	5	Influent concentration of Total Phospho	orus (Assumed Backstop)			
C* _{TP}	mg/l	0.022	Background concentration of Total Pho	sphorus			
k _{TP}	m/yr	10	Rate coefficient for reduction of Total P	hosphorus			
θ.τρ	-	0.986	Median Temp coefficient for Total Phos	phorus			
Т	°C	8	Average operating temperature				
No. of treatment stages	-	3					
Р	-	6	For one treatment stage i.e. 1 cell in ser	ries/three treatment stages i.	e 3 cells in series - P is 2 or 6 respectiv	ely (conservative value)	
Design Flow	m3/d	152	Input flow rate into here				
Total annual hydraulic throughput	m³/yr	55480					
Total wetland area	m ²	7,000	Active cell area (i.e. excluding diving be	rms, spreader channels and I	evel control structures)		
q	m/yr	7.925714286		-,-,-	,		
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % d %	1.58 31.82 68.18	NB. treated discharge from the wetland % of contaminant removed	l cannot be less than the bac	kground concentrations, as it is not po	ssible to achieve i.e. background co	onc will always be present

ARCADIS		CALCULATIO	ONS	PROJECT No:	30192602			
		0,120012,111		GBA:	Resillience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduce	ed to 0.7ha (current design)	CHECKER:	EBP			
Linked values	SURIECT			APPROVER:	30/11/2023			
Assumed values	Sobject.	Process Design Calculations - Cenarth		DOC No:	0			
Iterated values	SECTION:	D.L.		SHEET:	2	05		
		Р-к-с			3	UF	4	
Process Calculations								
Parameter	Unit	Value	References/Comments					
C _{I-TP}	mg/I	5	initial concentration of Total Phospho	rus (Assumed Backstop)				
C* _{TP}	mg/I	0.022	Background concentration of Total Phos	phorus				
K _{TP}	m/yr	10	Rate coefficient for reduction of Total Pr	nosphorus				
θ _{-т}	-	0.986	Median Temp coefficient for Total Phose	phorus				
Т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
Р	-	6	For one treatment stage i.e. 1 cell in seri	es/three treatment stages i.e	e 3 cells in series - P is 2 or 6 resp	ectively (conservative valu	ie)	
Design Flow	m3/d	152	Input flow rate into here					
Total annual hydraulic	m ³ /vr	55480						
throughput								
Total wetland area	m²	3,500	Active cell area (i.e. excluding diving ber	ms, spreader channels and le	evel control structures)			
q	m/yr	15.85142857						
Total Phosphorus								
Amount of remaining	-	2.73	NB. treated discharge from the wetland	cannot be less than the back	ground concentrations, as it is no	t possible to achieve i.e. b	packground conc will always be r	present
contaminant, Ce - C*	%	54.89						
Treatment efficiency of wetland	%	45.11	% of contaminant removed					

			PROJECT No:	3019260	2		
/-	ARUADIS	CALCULATIONS	GBA:	Resillien	ce - Water		
CLIENT:	Corodigion County Co	uncil	REVISION:	P01			
	Cerealgion County Co	diicii	AUTHOR:	RG			
PROJECT: Wotland Sites Toifi		Vationds reduced to 0.7bp (current design)	CHECKER:	EBP			
	Wetianu Sites - Tein V	veriands - reduced to 0.7na (current design)	APPROVER:	0			
SUBJECT:	Brocoss Design Coloul	ations Conorth	DATE:	45260			
	Process Design Calcula	ations - Cenarth	DOC. No:	0			
SECTION:	References		SHEET:	4	OF	4	

Ebnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \end{array} \right]^{-\rho}$$

C_i = Influent concentration of contaminant (mg/l)

- C_e = Effluent concentration of contaminant (mg/l)
- C* = Background concentration of contaminant (in the wetland water column) (mg/l) k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (*P*TIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

Future Expansion

						PROJECT No:	30192602		
	JADIS		CALCUI	LATIONS		GBA:	Resilience -	Water	
CLIENT:	Ceredigion Cou	unty Council				REVISION:	P01		
						AUTHOR:	RG		
PROJECT:	Wetland Sites	- Teifi Wetland	S			CHECKER:	EBP		
						APPROVER:			
SUBJECT:	Process Design	Calculations -	Cenarth			DATE:	24/11/2023		
	Permitted Q, C	Orthophosphate	e Sep 2023 - S	Sep 2022		DOC. No:			
SECTION:	Front Sheet					SHEET:	1	OF	4
ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS	
P01	4	RG	29/11/23	EBP		LV	12/01/23		
							1 1		
DESIGN BASIS S	TATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	alculations)			

ARCADIS		CALCULATIO	ONS	PROJECT No:	30192602			
KEY	CUENT			GBA:	Resilience - Water			
NE1	CLIENT:	Ceredigion County Council		REVISION:	P01			
Input values	DROJECT:			AUTHOR:	ERD			
Calculated values	PROJECT.	Wetland Sites - Teifi Wetlands		ADDDOV/CD:	0			
Linked values	SUBJECT:			DATE:	24/11/2023			
Assumed values	Sobler.	Process Design Calculations - Cenarth		DOC. No:	0			
Iterated values	SECTION:			SHEET:	2	05		
		Р-к-с			2	UF		4
Process Calculations								
Process Calculations								
Parameter	Unit	Value	References/Comments					
C _{i-TP}	mg/l	4.33	Influent concentration of Total Phosphor	us (Sep 2022 - Sep 2023)				
C* _{TP}	mg/l	0.022	Background concentration of Total Phose	phorus				
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Ph	osphorus				
θ.τρ	-	0.986	Median Temp coefficient for Total Phosp	horus				
т	°C	8	Average operating temperature					
No. of treatment stages	-	3	······································					
Р	-	6	For one treatment stage i.e. 1 cell in serie	es/three treatment stages i.e.3	cells in series - P is 2 or 6 resp	ectively (conservative value)		
Design Flow	m3/d	152	Input flow rate into here	,		,		
Total annual hydraulic		102	input new rate into here					
throughput	m³/yr	55480						
Total wetland area	m ²	10.000	Active cell area (i.e. excluding diving ber	ms spreader channels and leve	el control structures)			
	mhur	5 549		ins, spreader endrinels and ret				
Ч	in/yi	5.540						
Total Phosphorus								
Amount of remaining		0.89	NB treated discharge from the wetland	cannot be less than the backer	ound concentrations as it is not	nossible to achieve i.e. back	ground conc will always	he present
contaminant Ce - C*	%	20.68	the a cated discharge from the wedding	cannot be ress than the backgr		possible to defleve her buck	5. outra conc will diways	be present
Treatment efficiency of wetland	%	79.32	% of contaminant removed					
cathene encledy of wedding	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	. 5152						

ARCADIS		CALCULATIO)NS	PROJECT No:	30192602			
		6,12602,111		GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Calculated values	CUDIFOT			APPROVER:	24/11/2022			
Assumed values	SUBJECT:	Process Design Calculations - Cenarth		DATE:	0			
Iterated values	SECTION			SHEET:	0			
	SECTION.	P-k-c		SHEET.	3	OF	4	
Process Calculations Parameter	Unit	Value	References/Comments					
C _{L-TP}	mg/l	4.33	Influent concentration of Total Phospho	rus (Sep 2022 - Sep 2023)				
С*тр	mg/l	0.022	Background concentration of Total Phos	phorus				ľ
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Pl	nosphorus				
θ.τρ	-	0.986	Median Temp coefficient for Total Phos	phorus				
Т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
P	-	6	For one treatment stage i.e. 1 cell in ser	ies/three treatment stages i.e	3 cells in series - P is 2 or 6 respe	ctively (conservative value)		
Design Flow	m3/d	152	Input flow rate into here					
Total annual hydraulic throughput	m³/yr	55480						
Total wetland area	m²	5,000	Active cell area (i.e. excluding diving be	rms, spreader channels and le	vel control structures)			
q	m/yr	11.096						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	1.86 43.19 56.81	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the backg	round concentrations, as it is not	possible to achieve i.e. back	ground conc will always be present	

			PROJECT No:	3019260)2		
/-	ARUADIS	CALCULATIONS	GBA:	Resilienc	e - Water		
CLIENT:	Corodigion County Co	uncil	REVISION:	P01			_
	Cerealgion County Co		AUTHOR:	RG			
PROJECT:	Wotland Sitos Toifi V	Votlands	CHECKER:	EBP			
	Wetianu Sites - Tein V	vetialius	APPROVER:	0			_
SUBJECT:	Brocoss Dosign Coloul	ations Conarth	DATE:	45254			
	Process Design Calcul		DOC. No:	0			
SECTION:	References		SHEET:	4	OF	4	

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):



C_i = Influent concentration of contaminant (mg/l)

 $\begin{array}{l} C_e = {\sf Effluent \ concentration \ of \ contaminant \ (mg/l)} \\ C^* = {\sf Background \ concentration \ of \ contaminant \ (in \ the \ wetland \ water \ column) \ (mg/l)} \end{array}$

- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

						PROJECT No:	30192602		
	JADIS		CALCUI			GBA:	Resillience -	Water	
CLIENT:	Ceredigion Cou	unty Council				REVISION:	P01		
						AUTHOR:	RG		
PROJECT:	Wetland Sites -	- Teifi Wetland	S			CHECKER:	EBP		
						APPROVER:			
SUBJECT:	Process Design	Calculations -	Cenarth			DATE:	24/11/2023	i	
	Permitted Q, A	ssumed Backst	top/ Current	ТР		DOC. No:			
SECTION:	Front Sheet					SHEET:	1	OF	4
ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMM	MENTS
P01	4	RG	29/11/23	EBP	30/11/23	LV	12/01/23		
	1 1			1					
								L	
DESIGN BASIS S	TATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	lculations)			

			าพร	PROJECT No:	30192602			
		CALCOLAIN	5115	GBA:	Resillience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Calculated values				APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cenarth		DATE:	24/11/2023			
Assumed values	CECTION .			DOC. NO:	0			
Iterated values	SECTION:	P-k-c		SHEET	2	OF	4	
Process Calculations								
Parameter	Unit	Value	References/Comments					
C _{LTP}	mg/i	5	Influent concentration of Total Phosphor	us (Assumed Backstop)				
C* _{TP}	mg/l	0.022	Background concentration of Total Phose	bhorus				
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Ph	osphorus				
θ. _{тр}	-	0.986	Median Temp coefficient for Total Phosp	horus				
т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
Р	-	6	For one treatment stage i.e. 1 cell in serie	es/three treatment stages i.e 3	cells in series - P is 2 or 6 respe	ctively (conservative value)		
Design Flow	m3/d	152	Input flow rate into here					
Total annual hydraulic throughput	m³/yr	55480						
Total wetland area	m ²	10,000	Active cell area (i.e. excluding diving ber	ms, spreader channels and level	control structures)			
q	m/yr	5.548						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	1.03 20.68 79.32	NB. treated discharge from the wetland of % of contaminant removed	cannot be less than the backgro	und concentrations, as it is not	possible to achieve i.e. backgro	ound conc will always be pr	esent

			NE	PROJECT No:	30192602			
AROADIS		CALCOLATIC		GBA:	Resillience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Calculated values				APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cenarth		DATE:	24/11/2023			
Iterated values	SECTION			DUC. NO:	0			
	SECTION.	P-k-c		SHEET.	3	OF		4
Process Calculations								
Parameter	Unit	Value	References/Comments					
C _{i-TP}	mg/l	5	Influent concentration of Total Phospho	rus (Assumed Backstop)				
C* _{TP}	mg/l	0.022	Background concentration of Total Phos	phorus				
k _{TP}	m/yr	10	Rate coefficient for reduction of Total P	hosphorus				
θ-τΡ	-	0.986	Median Temp coefficient for Total Phos	phorus				
т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
Р	-	6	For one treatment stage i.e. 1 cell in ser	ies/three treatment stages i.e 3	cells in series - P is 2 or 6 respec	tively (conservative value)		
Design Flow	m3/d	152	Input flow rate into here					
Total annual hydraulic	2.							
throughput	m³/yr	55480						
Total wetland area	m ²	5,000	Active cell area (i.e. excluding diving be	rms, spreader channels and leve	el control structures)			
q	m/yr	11.096						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % 1 %	2.15 43.19 56.81	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the backgro	ound concentrations, as it is not p	ossible to achieve i.e. backgro	ound conc will always be p	iresent

<u>6</u> A			PROJECT No:	3019260	2		
- / -	ARUADIS	CALCULATIONS	GBA:	Resillien	ce - Water		
CLIENT:	Corodigion County Co	uncil	REVISION:	P01			
	Cerealgion County Co		AUTHOR:	RG			
PROJECT:	Wotland Sitos Toifi M	latlands	CHECKER:	EBP			
	vvetianu Sites - Tenri v	Vetialius	APPROVER:	0			
SUBJECT:	Brocoss Dosign Calcul	ations Conarth	DATE:	45254			
	Process Design Calcula		DOC. No:	0			
SECTION:	References		SHEET:	4	OF	4	

Ebnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \left[\begin{array}{c} 1 + \frac{k}{Pq} \right]^{p}$$

 C_i = Influent concentration of contaminant (mg/l)

- C_e = Effluent concentration of contaminant (mg/l)
- C^* = Background concentration of contaminant (in the wetland water column) (mg/I)
- k = Rate coefficient for reduction of contaminant (m/yr) P = Apparent no. of tanks in series (PTIS – dimensionless)
- q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

Appendix B Refined Wetlands Analysis with P-K-C* Model – Cilgerran

Current Design

			CALCU			PROJECT No:	30192602	
	UADI3		CALCUI	LATIONS		GBA:	Resilience -	Water
CLIENT:	Ceredigion Cou	unty Council				REVISION:	P01	
						AUTHOR:	RG	
PROJECT:	Wetland Sites -	 Teifi Wetland 	s - reduced t	o 0.6ha		CHECKER:	EBP	
						APPROVER:		
SUBJECT:	Process Design	Calculations -	Cilgerran			DATE:	30/11/2023	
	Estimated Q, C)rthophosphate	e Oct 2022 - (Oct 2023		DOC. No:		
SECTION:	Front Sheet					SHEET:	1	OF 4
ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS
P01	4	RG	30/11/23	EBP	30/11/23	LV	12/01/23	
DESIGN BASIS	STATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	Iculations)		

	I		ONS	PROJECT No:	30192602		
		CALCULATI	0115	GBA:	Resilience - Water		
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01		
		cerealizion county council		AUTHOR:	RG		
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduc	ced to 0.6ha	CHECKER:	EBP		
Calculated values				APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cilgerra	n	DATE:	30/11/2023		
Assumed values				DOC. No:	0		
Iterated values	SECTION:	P-k-c		SHEET:	2	OF	4
Durange Colouidations							
Parameter	Unit	Value	References/Comments				
C _{i-TP}	mg/l	2.37	Influent concentration of Total Phospho	rus (Oct 2022 - Oct 2023)			
C* _{TP}	mg/l	0.022	Background concentration of Total Phos	phorus			
к _{тр}	m/yr	10	Rate coefficient for reduction of Total Pl	nosphorus			
θ. _{тр}	-	0.986	Median Temp coefficient for Total Phos	bhorus			
т	°C	8	Average operating temperature				
No. of treatment stages	-	3					
Р	-	6	For one treatment stage i.e. 1 cell in ser	es/three treatment stages i.	e 3 cells in series - P is 2 or 6 respe	ectively (conservative value)	:)
Design Flow	m3/d	239	Input flow rate into here				
Total annual hydraulic	31	07225					
throughput	m /yr	87255					
Total wetland area	m²	6,000	Active cell area (i.e. excluding diving be	ms, spreader channels and l	evel control structures)		
q	m/yr	14.53917					
Total Phosphorus		1.22	ND second discharge for solution of	and a large that the set of the set		and the second second second	
Amount or remaining	-	1.22	NB. treated discharge from the wetland	cannot be less than the back	ground concentrations, as it is not	possible to achieve i.e. bac	ckground conc will always be present
contaminant, Ce - C*	%	52.14	0/ F				
I reatment efficiency of wetland	%	47.86	% of contaminant removed				
1							

	Ι		ONS	PROJECT No:	30192602			
AROADI3		CALCOLATI	0143	GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduc	ed to 0.6ha	CHECKER:	EBP			
Calculated values				APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cilgerran	1	DATE:	30/11/2023			
Assumed values	SECTION			DUC. NO:	0			
	SECTION.	P-k-c		SHEET.	3	OF	4	I
Process Calculations								I
Parameter	Unit	Value	References/Comments					
C _{i-TP}	mg/l	2.37	Influent concentration of Total Phospho	rus (Oct 2022 - Oct 2023)				
C* _{TP}	mg/l	0.022	Background concentration of Total Phos	phorus				
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Pl	iosphorus				
θ. _{тр}	-	0.986	Median Temp coefficient for Total Phos	horus				
т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
Р	-	6	For one treatment stage i.e. 1 cell in ser	es/three treatment stages i.e	e 3 cells in series - P is 2 or 6 respe	ectively (conservative value)		
Design Flow	m3/d	239	Input flow rate into here					
Total annual hydraulic	.31	97335						
throughput	m /yr	67255						
Total wetland area	m²	3,000	Active cell area (i.e. excluding diving be	ms, spreader channels and le	evel control structures)			
q	m/yr	29.07833333						
Total Dhoonhorus								
Amount of remaining	_	1.68	NB treated discharge from the wetland	cannot he less than the hack	ground concentrations as it is not	nossible to achieve i.e. hack	kground conc will always be present	
contaminant Ce - C*	%	71 58	No. a carea aischarge nom the wettand	cannot be read than the back		. possible to demete i.e. back	Broand cone will diways be present	
Treatment efficiency of wetland	%	28.42	% of contaminant removed					
meaninence incidity of wetland	<i>,</i> ,,	20112	, so a containmant removed					
1								

			PROJECT No:	3019260	2		
	ARUADIS	CALCULATIONS	GBA:	Resilienc	e - Water		
CLIENT:	Corodigion County Co	uncil	REVISION:	P01			
	Cerealgion County Co		AUTHOR:	RG			
PROJECT: Wotland Sites Taifi V		latiands reduced to 0 6ha	CHECKER:	EBP			
	vvetianu sites - reni v		APPROVER:	0			
SUBJECT:	Process Design Calcul	stions Cilgorran	DATE:	45260			
	Process Design Calcula	ations - Cligerian	DOC. No:	0			
SECTION:	References		SHEET:	4	OF	4	

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-1}$$

 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- Co: The target TP concentration for the wetland is 1mg/l.
- (C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

						PROJECT No:	30192602	
	UADIS		CALCUI			GBA:	Resilience -	Water
CLIENT:	Ceredigion Cou	unty Council		-		REVISION:	P01	
						AUTHOR:	RG	
PROJECT:	Wetland Sites -	 Teifi Wetland 	s - reduced t	o 0.6ha (current)	design)	CHECKER:	EBP	
						APPROVER:		
SUBJECT:	Process Design	Calculations -	Cilgerran			DATE:	30/11/2023	1
	Estimated Flov	v, Orthophosph	nate Sep 202	1 - Sep 2022		DOC. No:		
SECTION:	Front Sheet					SHEET:	1	OF 4
ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS
P01	4	RG	30/11/23	EBP	30/11/23	LV	12/01/23	
			ļ]	ļ				
				l				
			1					
				<u> </u>				
DESIGN BASIS	STATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	alculations)		

			ONS	PROJECT No:	30192602		
		CALCOLAIN		GBA:	Resilience - Water		
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01		
		cerealgion county council		AUTHOR:	RG		
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduc	ed to 0.6ha (current design)	CHECKER:	EBP		
Calculated values				APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	30/11/2023		
Assumed values				DOC. No:	0		
Iterated values	SECTION:	P-k-c		SHEET:	2	OF	4
Process Calculations							
Parameter	Unit	Value	References/Comments				
C _{i-TP}	mg/l	2.48	Influent concentration of Total Phosph	orus (Sep 2021 - Sep 2022)			
C* _{TP}	mg/l	0.022	Background concentration of Total Pho	sphorus			
k _{TP}	m/yr	10	Rate coefficient for reduction of Total	hosphorus			
θ. _{тр}	-	0.986	Median Temp coefficient for Total Pho	sphorus			
Т	°C	8	Average operating temperature				
No. of treatment stages	-	3					
Р	-	6	For one treatment stage i.e. 1 cell in se	ries/three treatment stages i.e	3 cells in series - P is 2 or 6 respe	tively (conservative value)	
Design Flow	m3/d	239	Input flow rate into here				
Total annual hydraulic	31	97335					
throughput	m /yr	67255					
Total wetland area	m²	6,000	Active cell area (i.e. excluding diving b	erms, spreader channels and lev	vel control structures)		
q	m/yr	14.53916667					
Total Phosphorus							
Amount of remaining	-	1.28	NB. treated discharge from the wetlan	a cannot be less than the backg	round concentrations, as it is not	possible to achieve i.e. back	kground conc will always be present
contaminant, Ce - C*	%	52.14					
Treatment efficiency of wetland	%	47.86	% of contaminant removed				
1							

			ONE	PROJECT No:	30192602		
AROADIS		CALCOLATI	0143	GBA:	Resilience - Water		
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01		
				AUTHOR:	RG		
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduc	ed to 0.6ha (current design)	CHECKER:	EBP		
Calculated values				APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	30/11/2023		
Assumed values	SECTION:			DOC. No:	0		
	SECTION:	P-k-c		SHEET	3	OF	4
Process Calculations							
	-			_			
Parameter	Unit	Value	References/Comments				
C _{i-TP}	mg/l	2.48	Influent concentration of Total Phosph	orus (Sep 2021 - Sep 2022)			
C* _{TP}	mg/l	0.022	Background concentration of Total Pho	sphorus			
k _{TP}	m/yr	10	Rate coefficient for reduction of Total I	Phosphorus			
θ _{-τP}	-	0.986	Median Temp coefficient for Total Pho	sphorus			
Т	°C	8	Average operating temperature				
No. of treatment stages	-	3					
Р	-	6	For one treatment stage i.e. 1 cell in se	ries/three treatment stages i.e	3 cells in series - P is 2 or 6 respec	tively (conservative value)	
Design Flow	m3/d	239	Input flow rate into here				
Total annual hydraulic	.31	97335					
throughput	m /yr	87235					
Total wetland area	m²	3,000	Active cell area (i.e. excluding diving b	erms, spreader channels and le	evel control structures)		
q	m/yr	29.07833333					
Tabal Dhaashama							
Amount of remaining	_	1 76	NB treated discharge from the workan	d cannot he less than the back	round concentrations as it is not r	ossible to achieve i el backe	round conc will always be present
contaminant Ce - C*	-	71 59	ND. treated discharge non the wellan	a cannot be less than tile bdtk	ground concentrations, as it is not p	ossible to achieve i.e. Ddukg	ground cone win always be present
Treatment efficiency of wetland	76 96	71.30	% of contaminant removed				
reachence enciency of wetland	20	20.42	76 of containinant removed				

ARCADIS			PROJECT No:	3019260			
		CALCULATIONS	GBA:	Resilienc	e - Water		
CLIENT:	Corodigion County Co	uncil	REVISION:	P01			
	Cerealgion County Co		AUTHOR:	RG			
PROJECT:	Wotland Sites Toifi M	(atlands reduced to 0 6ba (surrent design)	CHECKER:	EBP			
	Welland Siles - Tent V		APPROVER:	0			
SUBJECT:	Drogoss Dosign Coloul	ations Cilgorran	DATE:	45260			
	Process Design Calcula	ations - Cilgerran	DOC. No:	0			
SECTION:	References		SHEET:	4	OF	4	

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- Co: The target TP concentration for the wetland is 1mg/l.
- (C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

				PROJECT No:	30192602						
	UADIS		CALCU			GBA:	Resilience -	Resilience - Water			
CLIENT:	Ceredigion Cou	unty Council				REVISION:	P01				
						AUTHOR:	RG				
PROJECT: Wetland Sites - Teifi Wetlands						CHECKER:	EBP				
						APPROVER:					
SUBJECT: Process Design Calculations - Cilgerran - reduced to 0.6ha (current desi						i DATE:	30/11/2023	<u> </u>			
l	Estimated Flov	v, A <u>ssumed Ba</u>	ckstop TP			DOC. No:					
SECTION: Front Sheet S						SHEET:	1	OF 4			
ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS			
P01	4	RG	30/11/23	EBP	30/11/23	LV	12/01/23				
				İ			+				
			ļ/	ļ	ļ						
				1							
	CTATCACNT (I						·				
DESIGN BASIS	STATEMENT (Inc.	nign level des	cription of si	te/process and p	urpose or ca	liculations)					
ĺ											

			ONS	PROJECT No:	30192602	
		CALCOLATIO		GBA:	Resilience - Water	
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01	
				AUTHOR:	RG	
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP	
Calculated values				APPROVER:	0	
Linked values	SUBJECT:	Process Design Calculations - Cilgerran	 reduced to 0.6ha (current design) 	DATE:	30/11/2023	
Assumed values				DOC. No:	0	
Iterated values	SECTION:	P-k-c		SHEET:	2 OF	4
Dracocc Calculations						
Parameter	Unit	Value	References/Comments			
C _{i-TP}	mg/l	5	Influent concentration of Total Phospho	rus (Assumed Backstop TP)		
С* _{тр}	mg/l	0.022	Background concentration of Total Phos	phorus		
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Pl	nosphorus		
θ-τρ	-	0.986	Median Temp coefficient for Total Phos	ohorus		
т	°C	8	Average operating temperature			
No. of treatment stages	-	3				
P	-	6	For one treatment stage i.e. 1 cell in ser	ies/three treatment stages i.	e 3 cells in series - P is 2 or 6 respectively (conservative value)	
Design Flow	m3/d	239	Input flow rate into here			
Total annual hydraulic	2.		P			
throughput	m³/yr	87235				
Total wetland area	m²	6,000	Active cell area (i.e. excluding diving be	rms, spreader channels and I	evel control structures)	
q	m/yr	14.53916667				
Total Phosphorus						
Amount of remaining	-	2.60	NB. treated discharge from the wetland	cannot be less than the back	ground concentrations, as it is not possible to achieve i.e. back	ground conc will always be present
contaminant, Ce - C*	%	52.14				
Treatment efficiency of wetland	%	47.86	% of contaminant removed			

		CALCULATI	IONS PROJECT No: 30192602
	-	0,0000,000	GBA: Resilience - Water
KEY	CLIENT:	Ceredigion County Council	REVISION: P01
			AUTHOR: RG
Input values	PROJECT:	Wetland Sites - Teifi Wetlands	CHECKER: EBP
Calculated values			APPROVER: 0
Linked values	SUBJECT:	Process Design Calculations - Cilgerran	an - reduced to 0.6ha (current design) DATE: 30/11/2023
Assumed values	CECTION		DOC. No: 0
	SECTION:	P-k-c	SHEEL: 3 OF 4
Process Calculations			
Parameter	Unit	Value	Pafaransat/Commante
Cim	mg/l	5	Influent concentration of Total Phosoborus (Assumed Backston TP)
C*	mg/l	0.022	Beckground conceptation of Tatal Deschools
C TP	111g/1	0.022	
K _{TP}	m/yr	10	Rate coefficient for reduction of rotal Phosphorus
θ _{-TP}	-	0.986	Median Temp coefficient for Total Phosphorus
Т	°C	8	Average operating temperature
No. of treatment stages	-	3	
Р	-	6	For one treatment stage i.e. 1 cell in series/three treatment stages i.e 3 cells in series - P is 2 or 6 respectively (conservative value)
Design Flow	m3/d	239	Input flow rate into here
Total annual hydraulic throughput	m³/yr	87235	
Total wetland area	m²	3,000	Active cell area (i.e. excluding diving berms, spreader channels and level control structures)
q	m/yr	29.07833333	
Tatal Dhaamhanna			
Amount of romaining		2.50	
contaminant Co. C*	-	3.50	No. treated discharge from the wedand cannot be less than the background concentrations, as it is not possible to achieve i.e. background concential always be present
contaminant, ce - c	%	/1.58	
i reatment efficiency of wetland	1 %	28.42	% of contaminant removed

ARCADIS			PROJECT No:	3019260			
		CALCULATIONS	GBA:	Resilienc	e - Water		
CLIENT:	Corodigion County Co	uncil	REVISION:	P01			
	Cerealgion County Co		AUTHOR:	RG			
PROJECT:	Wotland Sitos Toifi M	latlands	CHECKER:	EBP			
	Wetianu Sites - Tenri V	venanus	APPROVER:	0			
SUBJECT:	Brocoss Design Calcul	otions Cilgorran reduced to 0 6ha (surrant decign)	DATE:	45260			
	Process Design Calcula		DOC. No:	0			
SECTION:	References		SHEET:	4	OF	4	

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- Co: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

						PROJECT No:				
	UADIS	l	CALCU			GBA:	Resilience - Water			
CLIENT:	Ceredigion Cou	unty Council				REVISION:	P01			
						AUTHOR:	RG			
PROJECT:	Wetland Sites	- Teifi Wetland	is - reduced t	to 0.6ha (current	design)	CHECKER:	EBP			
						APPROVER:				
SUBJECT:	Process Design	Calculations -	Cilgerran			DATE:	30/11/2023			
	Permitted Q, C)rthophosphate	e Oct 2022 -	Oct 2023		DOC. No:				
SECTION:	Front Sheet					SHEET:	1	OF 4		
ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS		
P01	4	RG	30/11/23	EBP	30/11/23	LV	12/01/23			
		l	++	l	+	<u> </u>	+ +			
		l	ļļ	 	 					
		I		l						
	STATEMENT (Inc.	high loval dag	eription of ci	te process and p	wrpaca of cr	leulations)				
DESIGN DASIS	STATEMENT (Inc.	Ilight level des	cription of si	te/process and p	urpose or co					

			אר	PROJECT No:	30192602		
		CALCOLAIR	2143	GBA:	Resilience - Water		
KEY	CLIENT:	Ceredigion County Council	REVISION:	P01			
		cerealizion county counter		AUTHOR:	RG		
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduce	ed to 0.6ha (current design)	CHECKER:	EBP		
Calculated values				APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	30/11/2023		
Assumed values				DOC. No:	0		
Iterated values	SECTION:	P-k-c		SHEET:	2	OF	4
Process Calculations							
Parameter	Unit	Value	References/Comments				
C _{i-TP}	mg/l	2.37	Influent concentration of Total Phos	phorus			
C* _{TP}	mg/l	0.022	Background concentration of Total P	hosphorus			
k _{τP}	m/yr	10	Rate coefficient for reduction of Tota	al Phosphorus			
Ө. _{тр}	-	0.986	Median Temp coefficient for Total P	hosphorus			
т	°C	8	Average operating temperature				
No. of treatment stages	-	3					
Р	-	6	For one treatment stage i.e. 1 cell in	series/three treatment stages i.e	e 3 cells in series - P is 2 or 6 respec	ively (conservative value)	
Design Flow	m3/d	408	Input flow rate into here				
Total annual hydraulic	m^3hr	148920					
throughput	III / yi	140520					
Total wetland area	m²	6,000	Active cell area (i.e. excluding diving	berms, spreader channels and le	evel control structures)		
q	m/yr	24.82					
Total Phosphorus							
Amount of remaining	-	1.59	NB. treated discharge from the wet	and cannot be less than the back	ground concentrations, as it is not p	ossible to achieve i.e. backg	ground conc will always be present
contaminant, Ce - C*	%	67.71					
Treatment efficiency of wetland	%	32.29	% of contaminant removed				
1							

	I		ONS	PROJECT No:	30192602			
AROADIS		CALCOLAIN	0145	GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduc	ed to 0.6ha (current design)	CHECKER:	EBP			
Calculated values				APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cilgerran	1	DATE:	30/11/2023			
Assumed values	CECTION:			DOC. No:	0			
Iterated values	SECTION:	P-k-c		SHEET:	3	OF	4	
Process Calculations								
Parameter	Unit	Value	References/Comments					
C _{i-TP}	mg/l	2.37	Influent concentration of Total Phospho	rus				
C* _{TP}	mg/l	0.022	Background concentration of Total Phoe	phorus				
k _{TP}	m/yr	10	Rate coefficient for reduction of Total P	hosphorus				
θ-τρ	-	0.986	Median Temp coefficient for Total Phos	phorus				
Т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
P	-	6	For one treatment stage i.e. 1 cell in ser	ies/three treatment stages i.e	e 3 cells in series - P is 2 or 6 respective	ly (conservative value)		
Design Flow	m3/d	408	Input flow rate into here					
Total annual hydraulic throughput	m³/yr	148920						
Total wetland area	m²	3,000	Active cell area (i.e. excluding diving be	rms, spreader channels and le	evel control structures)			
q	m/yr	49.64						
Total Phosphorus								
Amount of remaining	-	1.93	NB. treated discharge from the wetland	cannot be less than the back	ground concentrations, as it is not poss	ible to achieve i.e. backgroun	d conc will always be present	
contaminant, Ce - C*	%	82.03						
Treatment efficiency of wetland	%	17.97	% of contaminant removed					

ARCADIS			PROJECT No:	3019260			
		CALCULATIONS	GBA:	Resilienc	e - Water		
CLIENT:	Corodigion County Co	uncil	REVISION:	P01			
	Cerealgion County Co		AUTHOR:	RG			
PROJECT:	Wotland Sitos Taifi M	(atlands reduced to 0 6ba (current decign)	CHECKER:	EBP			
	Wetianu Sites - Tenri V		APPROVER:	0			
SUBJECT:	Drogoss Dosign Coloul	tions Cilgorran	DATE:	45260			
	Process Design Calcula	ations - Cilgerran	DOC. No:	0		-	
SECTION:	References		SHEET:	4	OF	4	

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.
| | | | | | | PROJECT No: | 30192602 | | |
|--------------|-----------------|---|----------------|--------------------|--------------|-------------|--------------|----------|---|
| | UADIS | | CALCU | | | GBA: | Resilience - | Water | |
| CLIENT: | Ceredigion Cou | unty Council | | | | REVISION: | P01 | | |
| | | | | | | AUTHOR: | RG | | |
| PROJECT: | Wetland Sites | - Teifi Wetland | s - reduced t | o 0.6ha (current) | design) | CHECKER: | EBP | | |
| | | | | | | APPROVER: | | | |
| SUBJECT: | Process Design | Calculations - | Cilgerran | | | DATE: | 30/11/2023 | , | |
| | Permitted Q, C | rthophosphate | e Sep 2021 - S | Sep 2022 | | DOC. No: | | | |
| SECTION: | Front Sheet | | | | | SHEET: | 1 | OF 4 | 4 |
| ISSUE | TOTAL
SHEETS | TOTAL
SHEETSAUTHORDATECHECKED BYDATEAPPR4RG30/11/23EBP30/11/23 | | APPROVED BY | DATE | COMMENTS | 5 | | |
| P01 | 4 | RG | 30/11/23 | EBP | 30/11/23 | LV | 12/01/23 | | _ |
| | | | | | | | | | |
| | | | ļ/ | | ļ | | ļ | | |
| | | | | | | | | | |
| | | | | | | | \Box | | |
| | | | | | | | | | |
| DÉSIGN BASIS | STATEMENT (Inc. | high level des | cription of si | te/process and p | urpose of ca | lculations) | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

			ONS	PROJECT No:	30192602		
AROADI3		CALCOLATIN	0113	GBA:	Resilience - Water		
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01		
		cerealizion county council		AUTHOR:	RG		
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduc	ed to 0.6ha (current design)	CHECKER:	EBP		
Calculated values	······································			APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cilgerran	I	DATE:	30/11/2023		
Assumed values	SECTION			DOC. NO:	0		
iterated values	SECTION:	P-k-c		SHEET:	2	OF	4
Process Calculations							
Parameter	Unit	Value	References/Comments				
C _{i-TP}	mg/l	2.48	Influent concentration of Total Phosp	orus (Sep 2021 - Sep 2022)			
C* _{TP}	mg/l	0.022	Background concentration of Total Ph	osphorus			
k _{TP}	m/yr	10	Rate coefficient for reduction of Total	Phosphorus			
θ.τρ	-	0.986	Median Temp coefficient for Total Pho	sphorus			
т	°C	8	Average operating temperature				
No. of treatment stages	-	3					
P	-	6	For one treatment stage i.e. 1 cell in s	eries/three treatment stages i.e 3	3 cells in series - P is 2 or 6 respe	ctively (conservative value)	
Design Flow	m3/d	408	Input flow rate into here				
Total annual hydraulic	31	148030					
throughput	m /yr	148920					
Total wetland area	m²	6,000	Active cell area (i.e. excluding diving l	erms, spreader channels and lev	el control structures)		
q	m/yr	24.82					
Total Phosphorus							
Amount of remaining	-	1.66	NB. treated discharge from the wetlan	d cannot be less than the backgr	ound concentrations, as it is not	possible to achieve i.e. backg	ground conc will always be present
contaminant, Ce - C*	%	67.71					
Treatment efficiency of wetland	%	32.29	% of contaminant removed				
1							

			ONS	PROJECT No:	30192602			
		CALCOLATI	ONS	GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - redu	ced to 0.6ha (current design)	CHECKER:	EBP			
Calculated values	Calculated values				0			
Linked values	SUBJECT:	Process Design Calculations - Cilgerra	n	DATE:	30/11/2023			
Assumed values				DOC. No:	0			
Iterated values	SECTION:	P-k-c		SHEET:	3	OF	4	
Process Calculations								
Parameter	Unit	Value	References/Comments					
C _{i-TP}	mg/l	2.48	Influent concentration of Total Phospho	rus (Sep 2021 - Sep 2022)				
C* _{TP}	mg/l	0.022	Background concentration of Total Phoe	phorus				
k _{TP}	m/yr	10	Rate coefficient for reduction of Total P	hosphorus				
θ. _{тр}	-	0.986	Median Temp coefficient for Total Phos	phorus				
т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
Р	-	6	For one treatment stage i.e. 1 cell in ser	ies/three treatment stages i.e	e 3 cells in series - P is 2 or 6 respect	tively (conservative value)		
Design Flow	m3/d	408	Input flow rate into here					
Total annual hydraulic throughput	m³/yr	148920						
Total wetland area	m²	3,000	Active cell area (i.e. excluding diving be	rms, spreader channels and le	evel control structures)			
q	m/yr	49.64						
Total Phosphorus								
Amount of remaining	-	2.02	NB, treated discharge from the wetland	cannot be less than the back	ground concentrations, as it is not p	ossible to achieve i.e. backgro	und conc will always be present	
contaminant. Ce - C*	%	82 03			8			
Treatment efficiency of wetland	1 %	17.97	% of contaminant removed					
required endericy of wedding								ļ
1								

			PROJECT No:	3019260	2		
-	ARUADIS	CALCULATIONS	GBA:	Resilienc	e - Water		
CLIENT:		uncil	REVISION:	P01			
Ceredigion County Co			AUTHOR:	RG			
PROJECT:	Wotland Sitos Toifi M	(atlands reduced to 0 6ba (current design)	CHECKER:	EBP			
	Wetianu Sites - Tenri V		APPROVER:	0			
SUBJECT:	Drogoss Dosign Coloul	tions Cilgorron	DATE:	45260			
	Process Design Calcula	ations - Cligerran	DOC. No:	0			
SECTION:	References		SHEET:	4	OF	4	

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- Co: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

						PROJECT No:	30192602		
	UADIS	l	CALCU			GBA:	Resilience -	Water	
CLIENT:	Ceredigion Cou	unty Council				REVISION:	P01		
						AUTHOR:	RG		
PROJECT:	Wetland Sites	- Teifi Wetland	s - reduced t	ιο 0.6ha (current d	design)	CHECKER:	EBP		
						APPROVER:			
SUBJECT:	Process Design	· Calculations -	Cilgerran			DATE:	30/11/2023	J	
	Permitted Q, B	ackstop TP				DOC. No:			
SECTION:	Front Sheet				SHEET:	1	OF	4	
ISSUE	TOTAL SHEETSAUTHORDATECHECKED BYDATEAPPROVED4RG30/11/23EBP30/11/23LV		APPROVED BY	DATE	COMMENTS	S			
P01	4	RG	30/11/23	EBP	30/11/23	LV	12/01/23		
		1	!	1					
						· · · · · · · · · · · · · · · · · · ·			
DESIGN BASIS	STATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	liculations)			

			NS PROJECT No: 30192602
		CALCOLATIC	GBA: Resilience - Water
KEY	CLIENT:	Ceredigion County Council	REVISION: P01
		, ,	AUTHOR: RG
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduce	d to 0.6ha (current design) CHECKER: EBP
Calculated values			APPROVER: 0
Linked values	SUBJECT:	Process Design Calculations - Cilgerran	DATE: 30/11/2023
Assumed values	CECTION		
	SECTION:	P-k-c	SHEEL: 2 OF 4
Process Calculations Parameter	Unit	Value	References/Comments
CITE	mg/l	5	Influent concentration of Total Phosphorus (Backstop TP)
C****	mg/l	0.022	Background conceptration of Total Phosphorus
k	mbr	10	Data, conficient for reduction of Total Descendary
NTP O	iii/yi	10	Nacional Tarra de filiarté a Tarra De se barra
O_TP	-	0.986	Wedian temp coefficient for total Phosphorus
N	-0	8	Average operating temperature
No. of treatment stages	-	3	
P	-	6	For one treatment stage. I. et ell in series/three treatment stages i.e.s cells in series - P is 2 or 6 respectively (conservative value)
Design Flow	m3/d	408	input now rate into nere
throughout	m³/yr	148920	
	2	6.000	
Iotal wetland area	m	6,000	Active cell area (i.e. excluding diving berms, spreader channels and level control structures)
q	m/yr	24.82	
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	3.37 67.71 32.29	NB. treated discharge from the wetland cannot be less than the background concentrations, as it is not possible to achieve i.e. background conc will always be present % of contaminant removed

			NS	PROJECT No:	30192602		
		CALCOLAIR	5115	GBA:	Resilience - Water		
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01		
				AUTHOR:	RG		
Input values	PROJECT:	Wetland Sites - Teifi Wetlands - reduce	ed to 0.6ha (current design)	CHECKER:	EBP		
Calculated values				APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	30/11/2023		
Assumed values	CECTION			DUC. No:	0		
Iterated values	SECTION:	P-k-c		SHEET:	3	OF	4
Process Calculations	1			_			
Parameter	Unit	Value	References/Comments	(2.1.1.1.72)			
C _{I-TP}	mg/i	5	Influent concentration of Total Phosp	norus (Backstop TP)			
C* _{TP}	mg/l	0.022	Background concentration of Total Pr	osphorus			
k _{TP}	m/yr	10	Rate coefficient for reduction of Total	Phosphorus			
θ. _{тр}	-	0.986	Median Temp coefficient for Total Ph	osphorus			
т	°C	8	Average operating temperature				
No. of treatment stages	-	3					
Р	-	6	For one treatment stage i.e. 1 cell in s	eries/three treatment stages i.e	3 cells in series - P is 2 or 6 respec	tively (conservative value)	
Design Flow	m3/d	408	Input flow rate into here				
Total annual hydraulic throughput	m³/yr	148920					
Total wetland area	m²	3,000	Active cell area (i.e. excluding diving	perms, spreader channels and le	vel control structures)		
q	m/yr	49.64					
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	4.08 82.03 17.97	NB. treated discharge from the wetla % of contaminant removed	nd cannot be less than the $back_{\xi}$	ground concentrations, as it is not p	oossible to achieve i.e. backgr	round conc will always be present

			PROJECT No:	3019260	2		
-	ARUADIS	CALCULATIONS	GBA:	Resilienc	e - Water		
CLIENT:		uncil	REVISION:	P01			
Ceredigion County Co			AUTHOR:	RG			
PROJECT:	Wotland Sitos Toifi M	(atlands reduced to 0 6ba (current design)	CHECKER:	EBP			
	Wetianu Sites - Tenri V		APPROVER:	0			
SUBJECT:	Drogoss Dosign Coloul	tions Cilgorron	DATE:	45260			
	Process Design Calcula	ations - Cligerran	DOC. No:	0			
SECTION:	References		SHEET:	4	OF	4	

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- Co: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

Future Expansion

		CALCU			PROJECT No:	30192602		
ADIS		CALCUI			GBA:	Resilience -	Water	
Ceredigion Cou	inty Council				REVISION:	P01		
					AUTHOR:	RG		
Wetland Sites -	Teifi Wetland	S			CHECKER:	EBP		
					APPROVER:			
Process Design	Calculations -	Cilgerran			DATE:	24/11/2023		
Estimated Q, O	rthophosphate	e Oct 2022 - 0	Oct 2023		DOC. No:			
Front Sheet					SHEET:	1	OF	4
TOTAL SHEETS	TOTAL AUTHOR 4 RG 2		CHECKED BY	DATE	APPROVED BY	DATE	COMM	MENTS
4	RG	29/11/23	EBP	30/11/23	LV	12/01/23		
TATEMENT (Inc.	high level des	cription of sit	te/process and p	urpose of ca	lculations)			
	Ceredigion Cou Wetland Sites - Process Design Estimated Q, Q Front Sheet TOTAL SHEETS 4 Image: Construction of the structure A Image: Constructure A Image: Constructure A	Ceredigion County Council Wetland Sites - Teifi Wetland Process Design Calculations - Estimated Q, Orthophosphate Front Sheet TOTAL SHEETS AUTHOR 4 RG Image: Construction of the structure TOTAL AUTHOR 4 RG Image: Constructure Author Author RG Image: Constructure Author A RG Image: Constructure Author Au	CALCUI Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Estimated Q, Orthophosphate Oct 2022 - O Front Sheet TOTAL AUTHOR DATE 4 RG 29/11/23	CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Estimated Q, Orthophosphate Oct 2022 - Oct 2023 Front Sheet TOTAL AUTHOR SHEETS AUTHOR 4 RG 29/11/23 EBP	CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Estimated Q, Orthophosphate Oct 2022 - Oct 2023 Front Sheet TOTAL AUTHOR DATE CHECKED BY DATE 4 RG 29/11/23 EBP 30/11/23 L L L L L AUTHOR DATE CHECKED BY 4 RG 29/11/23 EBP 30/11/23 L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L L Z L L L L L L L L L TOTAL RE CHECKED BY DATE <t< td=""><td>XDDS CALCULATIONS PROJECT No: GBA: Ceredigion County Council REVISION: AUTHOR: AUTHOR: AUTHOR: CHECKER: APPROVER: Wetland Sites - Teifi Wetlands CHECKER: APPROVER: DOC.NO: Process Design Calculations - Cilgerran Estimated Q, Orthophosphate Oct 2022 - Oct 2023 DOC.NO: Front Sheet SHEET: OC.NO: TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY 4 RG 29/11/23 EBP 30/11/23 LV</td><td>ADIS CALCULATIONS PROJECT No:: 30192602 GBA: Resilience - Ceredigion County Council REVISION: R0 Wetland Sites - Teifi Wetlands CHECKER: P01 AUTHOR: R6 CHECKER: EBP Process Design Calculations - Cilgerran DATE: 24/11/2023 Estimated Q, Orthophosphate Oct 2022 - Oct 2023 DOC. No: Pront Sheet TOTAL SHEET: 1 TOTAL AUTHOR DATE CHECKED BY DATE APPROVED BY DATE 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV 12/01/24 4 RG</td><td>ADIS CALCULATIONS PROJECT No: 30192602 GBA: Resilience - Water Receigion County Council REVISION: P01 AUTHOR: RG Wetland Sites - Telfi Wetlands CHECKER: EBP Process Design Calculations - Cligerran DATE: 24/11/2023 Estimated Q, Orthophosphate Oct 2022 - Oct 2023 DOC. No: Process Design Calculations - Cligerran Front Sheet SHEET: 1 OF TOTAL AUTHOR DATE CHECKEB BY DATE APPROVED BY DATE COMM 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 Image: Common com</td></t<>	XDDS CALCULATIONS PROJECT No: GBA: Ceredigion County Council REVISION: AUTHOR: AUTHOR: AUTHOR: CHECKER: APPROVER: Wetland Sites - Teifi Wetlands CHECKER: APPROVER: DOC.NO: Process Design Calculations - Cilgerran Estimated Q, Orthophosphate Oct 2022 - Oct 2023 DOC.NO: Front Sheet SHEET: OC.NO: TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY 4 RG 29/11/23 EBP 30/11/23 LV	ADIS CALCULATIONS PROJECT No:: 30192602 GBA: Resilience - Ceredigion County Council REVISION: R0 Wetland Sites - Teifi Wetlands CHECKER: P01 AUTHOR: R6 CHECKER: EBP Process Design Calculations - Cilgerran DATE: 24/11/2023 Estimated Q, Orthophosphate Oct 2022 - Oct 2023 DOC. No: Pront Sheet TOTAL SHEET: 1 TOTAL AUTHOR DATE CHECKED BY DATE APPROVED BY DATE 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/23 EBP 30/11/23 LV 12/01/24 4 RG	ADIS CALCULATIONS PROJECT No: 30192602 GBA: Resilience - Water Receigion County Council REVISION: P01 AUTHOR: RG Wetland Sites - Telfi Wetlands CHECKER: EBP Process Design Calculations - Cligerran DATE: 24/11/2023 Estimated Q, Orthophosphate Oct 2022 - Oct 2023 DOC. No: Process Design Calculations - Cligerran Front Sheet SHEET: 1 OF TOTAL AUTHOR DATE CHECKEB BY DATE APPROVED BY DATE COMM 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 Image: Common com

			ONS	PROJECT No:	30192602		
AROADIS		CALCOLATI	0145	GBA:	Resilience - Wate	r	
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01		
				AUTHOR:	RG		
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP		
Calculated values				APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cilgerrar	1	DATE:	24/11/2023		
Iterated values	SECTION			SHEET.	0		
Incluted values	Section.	P-k-c		SHEET.	2	OF	4
	_						
Process Calculations							
	•						
Parameter	Unit	Value	References/Comments				
C _{i-TP}	mg/l	2.37	Influent concentration of Total Phosphore	rus (Oct 2022 - Oct 2023)			
C* _{TP}	mg/l	0.022	Background concentration of Total Phos	phorus			
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Ph	iosphorus			
θτρ	-	0.986	Median Temp coefficient for Total Phosp	horus			
т	°C	8	Average operating temperature				
No. of treatment stages	-	3					
Р	-	6	For one treatment stage i.e. 1 cell in seri	es/three treatment stages i	i.e 3 cells in series - P is 2 or 6 res	pectively (conservative value	2)
Design Flow	m3/d	239	Input flow rate into here				
Total annual hydraulic		97325					
throughput	111 / 91	67255					
Total wetland area	m²	15,000	Active cell area (i.e. excluding diving ber	ms, spreader channels and	level control structures)		
q	m/yr	5.81567					
Total Phosphorus							
Amount of remaining	-	0.52	NB. treated discharge from the wetland	cannot be less than the bac	kground concentrations, as it is n	ot possible to achieve i.e. bac	ckground conc will always be present
contaminant, Ce - C*	%	22.05					
Treatment efficiency of wetland	%	77.95	% of contaminant removed				
1							

ARCADIS		CALCULATIO	ONS	PROJECT No:	30192602			
MARCADIG		0.1001		GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Linked values	CUDICCT			APPROVER:	24/11/2022			
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	24/11/2023			
Iterated values	SECTION				0			
Incluted voldes	SECTION.	P-k-c		SHEET.	3	OF		4
Process Calculations								
Parameter	Unit	Value	References/Comments					
Cim	mg/l	2.37	Influent concentration of Total Phosphor	us (Oct 2022 - Oct 2023)				
C*m	mg/l	0.022	Background concentration of Total Phos	aborus				
- 1P	m/ur	10	Pate coefficient for reduction of Total Ph	osphorus				
NTP 0	ing yi	10		ospiloi us				
0 _{-TP}	-	0.986	Median Temp coefficient for Total Phose	norus				
	÷Ľ	8	Average operating temperature					
No. of treatment stages	-	3	en anticipation de la construction de la Maria de la					
P	-	6	For one treatment stage i.e. 1 cell in seri	es/three treatment stages i.e 3	cells in series - P is 2 or 6 respec	tively (conservative value)		
Design Flow	m3/d	239	Input flow rate into here					
I otal annual hydraulic	m ³ /yr	87235						
throughput	2							
Total wetland area	m	7,500	Active cell area (i.e. excluding diving ber	ms, spreader channels and leve	el control structures)			
q	m/yr	11.63133333						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	1.05 44.78 55.22	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the backgro	ound concentrations, as it is not p	ossible to achieve i.e. backgro	ound conc will always be	2 present
reachent endelity of wetland	/0	33.22	78 of containing it removed					

6 ^			PROJECT No:	3019260)2	
/-	ARUADIS	CALCULATIONS	GBA:	Resilienc	ce - Water	
CLIENT:	Corodigion County Co	uncil	REVISION:	P01		
Ceredigion County Co		dici	AUTHOR:	RG		
PROJECT:	Wotland Sitos Toifi V	Votlands	CHECKER:	EBP		
	Wetianu Sites - Tein V	vetialius	APPROVER:	0		
SUBJECT:	Brocoss Design Calcul	ations Cilgorran	DATE:	45254		
	Process Design Calcul		DOC. No:	0		
SECTION:	References		SHEET:	4	OF	4

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (in the weathing watch column) (
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

					PROJECT No:	30192602		
JADIS		CALCUI			GBA:	Resilience -	Water	
Ceredigion Cou	inty Council				REVISION:	P01		
					AUTHOR:	RG		
Wetland Sites -	 Teifi Wetland 	IS			CHECKER:	EBP		
					APPROVER:			
Process Design	Calculations -	Cilgerran			DATE:	24/11/2023		
Estimated Flow	v, Orthophosph	hate Sep 202:	1 - Sep 2022		DOC. No:			
Front Sheet					SHEET:	1	OF 4	
TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS	
4	RG	29/11/23	EBP	30/11/23	LV	12/01/23		
				<u> </u>				
FATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	Iculations)			
	Ceredigion Cou Wetland Sites - Process Design Estimated Flow Front Sheet TOTAL SHEETS 4 Image: Construction of the second structure TATEMENT (Inc.	Ceredigion County Council Wetland Sites - Teifi Wetland Process Design Calculations - Estimated Flow, Orthophospil Front Sheet TOTAL AUTHOR 4 RG	CALCUI Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Estimated Flow, Orthophosphate Sep 202 Front Sheet Image: TOTAL SHEETS AUTHOR DATE 4 RG 29/11/23 Image: Design Calculation of Simple Sep 202 Front Sheet	CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Estimated Flow, Orthophosphate Sep 2021 - Sep 2022 Front Sheet Image: TotTAL SHEETS AUTHOR DATE CHECKED BY 4 RG 29/11/23 EBP	CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Estimated Flow, Orthophosphate Sep 2021 - Sep 2022 Front Sheet 1 AUTHOR DATE 4 RG 29/11/23 EBP 4 RG 29/11/23 EBP 4 RG 29/11/23 EBP 4 RG 29/11/23 EBP 4 RG 100 100 1 100 100 100 1 100 100 100 1 100 100 100 100 1 100 100 100 100 1 100 100 100 100 1 100 100 100 100 1 100 100 100 100 1 100 100 100 100 1 100 100 100 100 1 100 100 100 100 <t< td=""><td>XDIS CALCULATIONS PROJECT No: GBA: Ceredigion County Council REVISION: AUTHOR: AUTHOR: Vetland Sites - Telfi Wetlands CHECKER: APPROVER: Process Design Calculations - Cilgerran Estimated Flow, Orthophosphate Sep 2021 - Sep 2022 DATE: DOC. No: SHEET: TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY 4 RG 29/11/23 EBP 30/11/23 LV</td><td>XDIS CALCULATIONS PROJECT No: 30192602 GBA: Restilience - Ceredigion County Council REVISION: P01 Wetland Sites - Teifi Wetlands REVISION: P01 Wetland Sites - Teifi Wetlands CHECKER: EBP Process Design Calculations - Cilgerran DATE: 24/11/2023 Estimated Flow, Orthophosphate Sep 2021 - Sep 2022 DOC. No: SHEET: 1 TOTAL AUTHOR DATE CHECKER SHEET: 1 TOTAL AUTHOR DATE CHECKER Y DATE 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4</td><td>CALCULATIONS PROJECT No: 30129202 Geredigion County Council Resilience - Water Resilience - Water Wetland Sites - Teiff Wetlands HEVISION: RG AUTHOR: RG AUTHOR: RG Process Design Calculations - Cilgerran DATE: 24/11/2023 Estimated How, Orthophosphate Sep 2021 - Sep 2022 DCC. No: </td></t<>	XDIS CALCULATIONS PROJECT No: GBA: Ceredigion County Council REVISION: AUTHOR: AUTHOR: Vetland Sites - Telfi Wetlands CHECKER: APPROVER: Process Design Calculations - Cilgerran Estimated Flow, Orthophosphate Sep 2021 - Sep 2022 DATE: DOC. No: SHEET: TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY 4 RG 29/11/23 EBP 30/11/23 LV	XDIS CALCULATIONS PROJECT No: 30192602 GBA: Restilience - Ceredigion County Council REVISION: P01 Wetland Sites - Teifi Wetlands REVISION: P01 Wetland Sites - Teifi Wetlands CHECKER: EBP Process Design Calculations - Cilgerran DATE: 24/11/2023 Estimated Flow, Orthophosphate Sep 2021 - Sep 2022 DOC. No: SHEET: 1 TOTAL AUTHOR DATE CHECKER SHEET: 1 TOTAL AUTHOR DATE CHECKER Y DATE 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4	CALCULATIONS PROJECT No: 30129202 Geredigion County Council Resilience - Water Resilience - Water Wetland Sites - Teiff Wetlands HEVISION: RG AUTHOR: RG AUTHOR: RG Process Design Calculations - Cilgerran DATE: 24/11/2023 Estimated How, Orthophosphate Sep 2021 - Sep 2022 DCC. No:

ARCADIS		CALCULATIO	INS	PROJECT No:	30192602		
KEY	CLIENT			GBA: REVISION:	PO1		
	CEIEINT.	Ceredigion County Council		AUTHOR	RG		
Input values	PROJECT:			CHECKER:	EBP		
Calculated values		Wetland Sites - Teifi Wetlands		APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	24/11/2023		
Assumed values		Frocess Design Calculations - Cligerran		DOC. No:	0		
Iterated values	SECTION:	P-k-c		SHEET:	2	OF	4
Process Calculations Parameter	Unit	Value	References/Comments				
C _{i-TP}	mg/l	2.48	Influent concentration of Total Phosphore	us (Sep 2021 - Sep 2022)			
С* тр	mg/l	0.022	Background concentration of Total Phosp	horus			
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Pho	osphorus			
θ.π	-	0.986	Median Temp coefficient for Total Phosph	norus			
т	°C	8	Average operating temperature				
No. of treatment stages	-	3	0 · 0 ·				
Р	-	6	For one treatment stage i.e. 1 cell in serie	s/three treatment stages i.e	3 cells in series - P is 2 or 6 respec	ively (conservative value)	
Design Flow	m3/d	239	Input flow rate into here				
Total annual hydraulic throughput	m³/yr	87235					
Total wetland area	m²	15,000	Active cell area (i.e. excluding diving bern	ns, spreader channels and le	vel control structures)		
q	m/yr	5.815666667					
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	0.54 22.05 77.95	NB. treated discharge from the wetland c % of contaminant removed	annot be less than the back	ground concentrations, as it is not p	oossible to achieve i.e. backgro	ound conc will always be present

			NS	PROJECT No:	30192602			
		CALCOLAIN		GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Calculated values				APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	24/11/2023			
Assumed values	CECTION .			DUC. No:	0			
	SECTION:	P-k-c		SHEET:	3	OF	4	
Process Calculations Parameter	Unit	Value	References/Comments					
Cim	mg/l	2.48	Influent concentration of Total Phospho	rus (Sep 2021 - Sep 2022)				
C*	mg/l	0.022	Background concentration of Total Phos	nhorus				
5 p	m (ur	10	Bate coefficient for reduction of Total Nos	acabarus				
K _{TP}	11/yi	10						
0 _{-TP}	-	0.986	Median Temp coefficient for Total Phose	phorus				
T	°C	8	Average operating temperature					
No. of treatment stages	-	3						
P	-	6	For one treatment stage i.e. 1 cell in seri	es/three treatment stages i.e	3 cells in series - P is 2 or 6 respe	ctively (conservative value)		
Design Flow	m3/d	239	Input flow rate into here					
Total annual hydraulic throughput	m³/yr	87235						
Total wetland area	m²	7,500	Active cell area (i.e. excluding diving ber	ms, spreader channels and le	vel control structures)			
q	m/yr	11.63133333						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	1.10 44.78 55.22	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the back	round concentrations, as it is not	possible to achieve i.e. back	ground conc will always be preser	ıt

			PROJECT No:	3019260)2	
/-	ARUADIS	CALCULATIONS	GBA:	Resilienc	ce - Water	
CLIENT:	Corodigion County Co	uncil	REVISION:	P01		
	Cerealgion County Co	dici	AUTHOR:	RG		
PROJECT:	Wotland Sitos Toifi V	Votlands	CHECKER:	EBP		
	Wetianu Sites - Tein V	vetialius	APPROVER:	0		
SUBJECT:	Brocoss Design Calcul	ations Cilgorran	DATE:	45254		
	Process Design Calcul		DOC. No:	0		
SECTION:	References		SHEET:	4	OF	4

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

						PROJECT No:	30192602		
	UADIS		CALCUI			GBA:	Resilience -	Water	
CLIENT:	Ceredigion Cou	unty Council				REVISION:	P01		
						AUTHOR: RG			
PROJECT:	Wetland Sites	- Teifi Wetland	ls			CHECKER:	EBP		
						APPROVER:			
SUBJECT:	Process Design	Calculations -	Cilgerran		DATE:	24/11/2023			
	Estimated Flow, Assumed Backstop TP								
SECTION:	Front Sheet					SHEET:	1	OF	4
ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	СОМІ	MENTS
P01	4	RG	29/11/23	EBP	30/11/23	LV	12/01/23		
DESIGN BASIS	STATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	liculations)			

			ากร	PROJECT No:	30192602			
		CALCOLAIR	5115	GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Calculated values				APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	24/11/2023			
Assumed values				DOC. No:	0			
Iterated values	SECTION:	P-k-c		SHEET:	2	OF	4	
Process Calculations Parameter	Unit	Value	References/Comments					
Ci-TP	mg/l	5	Influent concentration of Total Phosphor	us (Assumed Backstop TP)				
С*тр	mg/l	0.022	Background concentration of Total Phose	phorus				
	m/vr	10	Rate coefficient for reduction of Total Ph	osnhorus				
Ĥ		0.986	Median Temp coefficient for Total Phose	horus				
с. ₁ р т	°C	0.500		10103				
No of treatment stages	e	2	Average operating temperature					
P		5	For one treatment stage i.e. 1 cell in seri	es/three treatment stages i e	3 cells in series - P is 2 or 6 respe	ctively (conservative value)		
, Design Flow	m3/d	239	Input flow rate into here	es/ three treatment stages he				
Total annual hydraulic throughput	m³/yr	87235						
Total wetland area	m²	15,000	Active cell area (i.e. excluding diving ber	ms, spreader channels and le	vel control structures)			
q	m/yr	5.815666667						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	1.10 22.05 77.95	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the back	round concentrations, as it is not	possible to achieve i.e. back	ground conc will always be pr	esent

			NS	PROJECT No:	30192602	
- AROADIS		CALCOLAIR	115	GBA:	Resilience - Water	
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01	
				AUTHOR:	RG	
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP	
Calculated values				APPROVER:	0	
Linked values	SUBJECT:	Process Design Calculations - Cilgerran	-	DATE:	24/11/2023	
Assumed values	SECTION:			DUC. NO:	0	
iterated values	SECTION.	P-k-c		SHEET.	3 OF 4	
Process Calculations						
Parameter	Unit	Value	References/Comments			
C _{i-TP}	mg/l	5	Influent concentration of Total Phosphorus	s (Assumed Backstop TP)		
C* _{TP}	mg/l	0.022	Background concentration of Total Phosph	iorus		
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Phos	sphorus		
θ _{-TP}	-	0.986	Median Temp coefficient for Total Phosphe	orus		
Т	°C	8	Average operating temperature			
No. of treatment stages	-	3				
Р	-	6	For one treatment stage i.e. 1 cell in series	/three treatment stages i.e 3 ce	ells in series - P is 2 or 6 respectively (conservative value)	
Design Flow	m3/d	239	Input flow rate into here			
Total annual hydraulic throughput	m³/yr	87235				
Total wetland area	m²	7,500	Active cell area (i.e. excluding diving berm	s, spreader channels and level c	control structures)	
q	m/yr	11.63133333				
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	2.23 44.78 55.22	NB. treated discharge from the wetland ca % of contaminant removed	innot be less than the backgrour	und concentrations, as it is not possible to achieve i.e. background conc will always be present	

6 ^			PROJECT No:	3019260)2	
/-	ARUADIS	CALCULATIONS	GBA:	Resilienc	ce - Water	
CLIENT:	Corodigion County Co	uncil	REVISION:	P01		
	Cerealgion County Co	dici	AUTHOR:	RG		
PROJECT:	Wotland Sitos Toifi V	Votlands	CHECKER:	EBP		
	Wetianu Sites - Tein V	vetialius	APPROVER:	0		
SUBJECT:	Brocoss Design Calcul	ations Cilgorran	DATE:	45254		
	Process Design Calcul		DOC. No:	0		
SECTION:	References		SHEET:	4	OF	4

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (in the weathing watch column) (
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

					PROJECT No:	30192602		
JADIS		CALCUI			GBA:	Resilience -	Water	
Ceredigion Cou	inty Council				REVISION:	P01		
					AUTHOR:	RG		
Wetland Sites -	 Teifi Wetland 	S			CHECKER:	EBP		
					APPROVER:			
Process Design	Calculations -	Cilgerran			DATE:	24/11/2023		
Permitted Q, O	rthophosphate	e Oct 2022 -	Oct 2023		DOC. No:			
Front Sheet					SHEET:	1	OF 4	
TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS	
4	RG	29/11/23	EBP	30/11/23	LV	12/01/23		
				<u> </u>				
FATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	Iculations)			
	Ceredigion Cou Wetland Sites - Process Design Permitted Q, O Front Sheet TOTAL SHEETS 4 Image: Construction of the second structure TATEMENT (Inc.	Ceredigion County Council Wetland Sites - Teifi Wetland Process Design Calculations - Permitted Q, Orthophosphate Front Sheet TOTAL AUTHOR 4 RG	CALCUI Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Permitted Q, Orthophosphate Oct 2022 - Front Sheet Image: TOTAL SHEETS AUTHOR DATE 4 RG 29/11/23 Image: Design Calculation of Sile XHEETS AUTHOR A RG 29/11/23 Image: Design Calculation Image: Design Ca	CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Permitted Q, Orthophosphate Oct 2022 - Oct 2023 Front Sheet ITOTAL AUTHOR A RG 29/11/23 EBP Image: All of the state of the s	CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Permitted Q, Orthophosphate Oct 2022 - Oct 2023 Front Sheet 1 1 AUTHOR 0 DATE 4 RG 29/11/23 EBP 30/11/23 1 DATE	XDIS CALCULATIONS PROJECT No: GBA: Ceredigion County Council REVISION: AUTHOR: Vetland Sites - Telfi Wetlands AUTHOR: CHECKER: APPROVER: Process Design Calculations - Cilgerran Permitted Q, Orthophosphate Oct 2022 - Oct 2023 DOC. No: SHEET: Front Sheet SHEET: TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY 4 RG 29/11/23 EBP 30/11/23 LV	XDIS CALCULATIONS PROJECT No:: 30192602 GBA: Restilience - Restilience - Restilincon - Restilincon - Restilincon - Restilience - Restil	CALCULATIONS PROJECT No:: 3019202 GRA: Resilience - Water GBA: Resilience - Water Greedigion County Council Revision: RG

			ากร	PROJECT No:	30192602		
		CALCOLAIN	5115	GBA:	Resilience - Water		
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01		
		·····		AUTHOR:	RG		
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP		
Calculated values				APPROVER:	0		
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	24/11/2023		
Assumed values	CECTION .			DOC. No:	0		
Iterated values	SECTION:	P-k-c		SHEET:	2	OF	4
Process Calculations	linit	Value	Rafarances (Commants				
Parameter	mg/l	2 37	Influent concentration of Total Phosphor	116			
C*	mg/l	0.022	Rackground concentration of Total Phase	aborus			
C TP	ilig/i	0.022	Background concentration of Total Phos	priorus			
Ктр	m/yr	10	Rate coefficient for reduction of Total Pr	iosphorus			
θ _{-TP}	-	0.986	Median Temp coefficient for Total Phose	horus			
Т	°C	8	Average operating temperature				
No. of treatment stages	-	3					
Р	-	6	For one treatment stage i.e. 1 cell in seri	es/three treatment stage	es i.e 3 cells in series - P is 2 or 6 respe	ctively (conservative value)	
Design Flow	m3/d	408	Input flow rate into here				
Total annual hydraulic throughput	m³/yr	148920					
Total wetland area	m²	15,000	Active cell area (i.e. excluding diving ber	ms, spreader channels ar	nd level control structures)		
q	m/yr	9.928					
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % 1 %	0.93 39.41 60.59	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the b	background concentrations, as it is not	possible to achieve i.e. backg	round conc will always be present

			NS	PROJECT No:	30192602			
		CALCOLATIC		GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Calculated values	CUDIFOT			APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	24/11/2023			
Assumed values	SECTION			DUC. NO:	0			
	SECTION.	P-k-c		SHEET.	3	OF	4	
Process Calculations	11-14	Value	Difference (Conservation					
Parameter	Unit	Value	References/Comments					l
CI-TP	liig/i	2.37		lus				
Стр	mg/i	0.022	Background concentration of Total Phos	pnorus				
K _{TP}	m/yr	10	Rate coefficient for reduction of Total Pr	losphorus				
θ-τρ	-	0.986	Median Temp coefficient for Total Phose	phorus				
Т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
Р	-	6	For one treatment stage i.e. 1 cell in seri	es/three treatment stages	i.e 3 cells in series - P is 2 or 6 respe	ectively (conservative value)		
Design Flow	m3/d	408	Input flow rate into here					
Total annual hydraulic throughput	m³/yr	148920						
Total wetland area	m ²	7,500	Active cell area (i.e. excluding diving ber	ms, spreader channels an	d level control structures)			
q	m/yr	19.856						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	1.45 61.66 38.34	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the ba	ickground concentrations, as it is not	possible to achieve i.e. back	kground conc will always be present	

			PROJECT No:	3019260)2	
- 1-	ARUADIS	CALCULATIONS	GBA:	Resilienc	ce - Water	
CLIENT:	Corodigion County Co	uncil	REVISION:	P01		
	Cerealgion County Co		AUTHOR:	RG		
PROJECT:	Wotland Sitos Toifi M	latlands	CHECKER:	EBP		
	Welland Siles - Tent V	venanus	APPROVER:	0		
SUBJECT:	Process Design Calcul	ations Cilgorran	DATE:	45254		
	Process Design Calcula	ations - Cigerran	DOC. No:	0		
SECTION:	References		SHEET:	4	OF	4

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (m/yr)
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

ARCADIS C				PROJECT No:	30192602				
		CALCUI			GBA:	Resilience - Water			
Ceredigion Cou	inty Council				REVISION:	P01	P01		
Ā						RG			
Wetland Sites -	 Teifi Wetland 	S			CHECKER:	EBP			
					APPROVER:				
Process Design	Calculations -	Cilgerran			DATE:	24/11/2023			
Permitted Q, O	rthophosphate	e Sep 2021 - S	Sep 2022		DOC. No:				
Front Sheet					SHEET:	1	OF	4	
TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMN	/IENTS	
4	RG	29/11/23	EBP	30/11/23	LV	12/01/23			
ATEMENT (Inc.	high level des	cription of sit	te/process and p	urpose of ca	Iculations)				
	Ceredigion Cou Wetland Sites - Process Design Permitted Q, O Front Sheet TOTAL SHEETS 4 A	Ceredigion County Council Wetland Sites - Teifi Wetland Process Design Calculations - Permitted Q, Orthophosphate Front Sheet TOTAL SHEETS AUTHOR 4 RG Image: Content of the system of the syst	CALCUI Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Permitted Q, Orthophosphate Sep 2021 - S Front Sheet TOTAL AUTHOR DATE 4 RG 29/11/23 Image: Control of the strength of the strengt of the strengt of the strength of the strengt of the strengt of th	CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Permitted Q, Orthophosphate Sep 2021 - Sep 2022 Front Sheet TOTAL AUTHOR SHEETS AUTHOR 4 RG 29/11/23 EBP	CALCULATIONS Ceredigion County Council Wetland Sites - Teifi Wetlands Process Design Calculations - Cilgerran Permitted Q, Orthophosphate Sep 2021 - Sep 2022 Front Sheet TOTAL AUTHOR DATE CHECKED BY DATE 4 RG 29/11/23 EBP 30/11/23 L L AUTHOR L CHECKED BY DATE 4 RG 29/11/23 EBP 30/11/23 L L L L L L AUTHOR DATE CHECKED BY DATE 4 RG 29/11/23 EBP 30/11/23 L L L L L L AUTHOR L L L L L AUTHOR L L L L L 4 RG 29/11/23 EBP 30/11/23 CHECKENT (Inc. high level description of site/process and purpose of calculations and the sinterval of the sintery of the site site site sinterval of the sin	XDIS CALCULATIONS PROJECT No: GBA: Ceredigion County Council REVISION: AUTHOR: AUTHOR: AUTHOR: CHECKER: APPROVER: Wetland Sites - Teifi Wetlands CHECKER: APPROVER: APPROVER: Process Design Calculations - Cilgerran Permitted Q, Orthophosphate Sep 2021 - Sep 2022 DOC. No: Front Sheet SHEETS AUTHOR TOTAL SHEETS AUTHOR DATE CHECKED BY 4 RG 29/11/23 EBP 30/11/23 LV	ADIS CALCULATIONS PROJECT No: 30192602 GBA: Resilience - Ceredigion County Council REVISION: R0 Wetland Sites - Teifi Wetlands CHECKER: EDP Process Design Calculations - Cilgerran DATE: 24/11/2023 Permitted Q, Orthophosphate Sep 2021 - Sep 2022 DOC. No: PETE: Front Sheet SHEET: 1 TOTAL AUTHOR DATE CHECKED BY 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29	ADIS CALCULATIONS PROJECT No: 30192602 GBA: Resilience - Water Resilience - Water Wetland Sites - Telfi Wetlands POI RG Process Design Calculations - Cligerran DATE: 24/11/2023 Permitted Q, Orthophosphate Sep 2021 - Sep 2022 DOC. No: Process Design Calculations - Cligerran Permitted Q, Orthophosphate Sep 2021 - Sep 2022 DOC. No: Process Design Calculations - Cligerran Front Sheet SHEET: 1 OF TOTAL AUTHOR DATE CHECKER BY DATE AUTHOR DATE CHECKED BY DATE AUTHOR 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 4 RG 29/11/25 EBP	

			NS	PROJECT No:	30192602			
		6,12602,111		GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
				AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Calculated values				APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	24/11/2023			
Assumed values	SECTION			DUC. NO:	0			
	SECTION:	P-k-c		SHEET:	2	OF		4
Process Calculations								
Parameter	Unit	Value	References/Comments					
C _{i-TP}	mg/l	2.48	Influent concentration of Total Phospho	rus (Sep 2021 - Sep 2022)				
C* _{TP}	mg/l	0.022	Background concentration of Total Phos	phorus				
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Pl	nosphorus				
θ. _{тр}	-	0.986	Median Temp coefficient for Total Phos	phorus				
т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
Р	-	6	For one treatment stage i.e. 1 cell in ser	ies/three treatment stages i.e	3 cells in series - P is 2 or 6 resp	ectively (conservative value)		
Design Flow	m3/d	408	Input flow rate into here					
Total annual hydraulic throughput	m³/yr	148920						
Total wetland area	m²	15,000	Active cell area (i.e. excluding diving be	rms, spreader channels and lev	vel control structures)			
q	m/yr	9.928						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % d %	0.97 39,41 60.59	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the backg	round concentrations, as it is no	: possible to achieve i.e. back	ground conc will alway	ys be present

	CALCULATIONS			PROJECT No:	30192602			
		6,12602,111		GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council	F	REVISION:	P01			
		AUTH AUTH			RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Calculated values			A	APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	24/11/2023			
Assumed values	SECTION		L	JUC. NO:	0			
iterateu values	SECTION:	P-k-c	5	DHEET	3	OF		4
Process Calculations								
Parameter	Unit	Value	References/Comments	(2021 2022)				
C _{I-TP}	mg/i	2.48	Initiation of Total Phosphorus	(Sep 2021 - Sep 2022)				
C* _{TP}	mg/I	0.022	Background concentration of Total Phospho	orus				
k _{TP}	m/yr	10	Rate coefficient for reduction of Total Phos	phorus				
θ _{-тр}	-	0.986	Median Temp coefficient for Total Phospho	orus				
Т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
Р	-	6	For one treatment stage i.e. 1 cell in series/	/three treatment stages i.e	3 cells in series - P is 2 or 6 respe	tively (conservative value)		
Design Flow	m3/d	408	Input flow rate into here					
Total annual hydraulic	m ³ /vr	148920						
throughput	.,							
Total wetland area	m	7,500	Active cell area (i.e. excluding diving berms	s, spreader channels and lev	el control structures)			
q	m/yr	19.856						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	1.52 61.66 38.34	NB. treated discharge from the wetland car % of contaminant removed	nnot be less than the backgr	round concentrations, as it is not	oossible to achieve i.e. backg	round conc will always l	be present

ARCADIS			PROJECT No:	3019260	2	
		CALCULATIONS	GBA:	Resilienc	e - Water	
CLIENT:	Corodigion County Co	uncil	REVISION:	P01		
	Cerealgion County Co		AUTHOR:	RG		
PROJECT:	Wotland Sitos Toifi M	latlands	CHECKER:	EBP		
	Welland Siles - Tent V	venanus	APPROVER:	0		
SUBJECT:	Process Design Calcul	ations Cilgorran	DATE:	45254		
	Process Design Calcula	ations - Cigerran	DOC. No:	0		
SECTION:	References		SHEET:	4	OF	4

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_{e} - C^{*}}{C_{i} - C^{*}} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-t}$$

 C_i = Influent concentration of contaminant (mg/l)

- $\label{eq:ce} C_e = \text{Effluent concentration of contaminant (mg/l)} \\ C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)}$
- k = Rate coefficient for reduction of contaminant (in the weathing watch column) (
- P = Apparent no. of tanks in series (PTIS dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C:: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- Co: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.

CLUCKTIC CERCUICING GBA: Resilience - Water CLUENT: Ceredigion County Council ALTHORS: RG PROJECT: Wetland Sites - Telf Wetlands CHECKER: EBP JUBJECT: Process Design Calculations - Cligerran DATE: 24/11/2023 Permitted Q, Backstop TP DOC. No: Permitted Q, Backstop TP DATE: 1 OF 4 ISSUE TOTAL AUTHOR DATE CHECKED BY DATE APPROVED BY DATE COMMENTS P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 P01 4 RG 29/11/23 EBP 10 10 10					PROJECT No:	30192602					
CLIENT: Ceredigion County Council REVISION: P01 AUTHOR: RG AUTHOR: RG PROJECT: Wetland Sites - Teifi Wetlands CHECKER: EBP SUBJECT: Process Design Calculations - Cligerran DATE: 2/4/11/2023 Permitted Q, Backstop TP DOC. No: DOC. No: DOC. No: SECTION: Front Sheet SHEET: 1 OF 4 ISSUE TOTAL SHEETS AUTHOR DATE COMMENTS P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 P01 4 RG P01 CHECKED RY DATE COMMENTS P01 4 RG P01 CHECKED RY DATE COMMENTS P01 4 <					GBA:	Resilience -	Water				
AUTHOR: RG PROJECT: Wetland Sites - Teifi Wetlands CHEKKER: EBP SUBJECT: Process Design Calculations - Cilgerran DATE: 24/11/2023 Permitted Queschop TP DCC. No: POCOL No: POCOL No: SECTION: Front Sheet SHEET: 1 OF 4 ISSUE TOTAL AUTHOR DATE CHECKED BY DATE APPROVED BY DATE COMMENTS P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 Image: Comment of the process and purpose of calculations (Comment of the process and	CLIENT:	Ceredigion Cou	inty Council				REVISION:	P01			
PROJECT: Wetland Sites - Telf Wetlands CHECKRE: EPP SUBJECT: Process Design Calculations - Cligerran DATE: 24/11/2023 Permitted Q. Backstop TP DOC. No: SHEET: 1 OF 4 ISSUE TOTAL AUTHOR DATE CHECKED BY DATE APPROVED BY DATE COMMENTS P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 COMMENTS P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 COMMENTS P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 COMMENTS P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 COMMENTS ISSUE I						AUTHOR:	RG	RG			
APPROVER: APPROVE: APPROVE:	PROJECT:	Wetland Sites -	Teifi Wetland	S			CHECKER:	EBP			
SUBJECT: Process Design Calculations - Cligerran Permitted Q, Backstop TP DATE: 24/11/2023 SECTION: Front Sheet Image: Construction of Stepse Ste							APPROVER:				
Permitted Q, Backstop TP DOC. No: Permitted Q, Backstop TP SECTION: Front Sheet SHEET: 1 OF 4 ISSUE TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY DATE COMMENTS P01 4 R6 29/11/23 EBP 30/11/23 LV 12/01/23 Image: Comment State Sta	SUBJECT:	Process Design	Calculations -	Cilgerran			DATE:	24/11/2023			
SECTION: Front Sheet SHEET: 1 OF 4 ISSUE TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY DATE COMMENTS P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 <td></td> <td>Permitted Q, B</td> <td>ackstop TP</td> <td></td> <td></td> <td></td> <td>DOC. No:</td> <td></td> <td></td> <td></td>		Permitted Q, B	ackstop TP				DOC. No:				
ISSUE TOTAL SHEETS AUTHOR DATE CHECKED BY DATE APPROVED BY DATE COMMENTS P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 Image: Commentation of the state	SECTION:	Front Sheet					SHEET:	1	OF	4	
P01 4 RG 29/11/23 EBP 30/11/23 LV 12/01/23 Image: Second state s	ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMM	VENTS	
Image: State of the state o	P01	4	RG	29/11/23	EBP	30/11/23	LV	12/01/23			
DESIGN BASIS STATEMENT (Inc. high level description of site/process and purpose of calculations)											
DESIGN BASIS STATEMENT (Inc. high level description of site/process and purpose of calculations)											
	DESIGN BASIS S	TATEMENT (Inc.	high level des	cription of si	te/process and p	urpose of ca	lculations)				

ARCADIS	CALCULATIONS			PROJECT No:	30192602		
KEY	CLIENT			GBA:	Resilience - Water		
KEI	CLIENT:	Ceredigion County Council	edigion County Council		POI BG		
Input values	PROJECT			CHECKER.	FBP		
Calculated values	Wetland Sites - Teifi Wetlands		APPROVER.	0			
Linked values	SUBJECT:	Presses Design Calculations Cilconne		DATE:	24/11/2023		
Assumed values		Process Design Calculations - Cligerran		DOC. No:	0		
Iterated values	SECTION:	P-k-c		SHEET:	2	OF	4
Process Calculations		Volue					
Cim	mg/l	value 5	Influent concentration of Total Phospho	rus (Backston TP)			
C*_		0.022	Background concentration of Total Phos	nborus			
k	mbr	10	Pate coefficient for reduction of Total Pho	priorus			
κ _{τρ}	iny yi	0.0%6	Madian Town coefficient for Total Phoe	horus			
U-TP	-	0.960		norus			
No of treatment stages	C -	8	Average operating temperature				
P	-	6	For one treatment stage i.e. 1 cell in seri	es/three treatment stages i e	3 cells in series - P is 2 or 6 respec	tively (conservative value)	
Design Flow	m3/d	408	Input flow rate into here	es/ three treatment stages he			
Total annual hydraulic throughput	m³/yr	148920					
Total wetland area	m ²	15,000	Active cell area (i.e. excluding diving ber	ms, spreader channels and le	vel control structures)		
q	m/yr	9.928					
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % %	1.96 39.41 60.59	NB. treated discharge from the wetland % of contaminant removed	cannot be less than the back	ground concentrations, as it is not	possible to achieve i.e. backgro	ound conc will always be present

			NS	PROJECT No:	30192602			
		0,12002,1110		GBA:	Resilience - Water			
KEY	CLIENT:	Ceredigion County Council		REVISION:	P01			
		, ,		AUTHOR:	RG			
Input values	PROJECT:	Wetland Sites - Teifi Wetlands		CHECKER:	EBP			
Calculated values				APPROVER:	0			
Linked values	SUBJECT:	Process Design Calculations - Cilgerran		DATE:	24/11/2023			
Assumed values				DOC. No:	0			
Iterated values	SECTION:	P-k-c		SHEET:	3	OF	4	
Process Calculations	•							
Parameter	Unit	Value	References/Comments					
C _{i-TP}	mg/l	5	Influent concentration of Total Phosphor	us (Backstop TP)				
C* _{TP}	mg/l	0.022	Background concentration of Total Phose	ohorus				
k _{τP}	m/yr	10	Rate coefficient for reduction of Total Ph	osphorus				
θτρ	-	0.986	Median Temp coefficient for Total Phosp	horus				
т	°C	8	Average operating temperature					
No. of treatment stages	-	3						
Р	-	6	For one treatment stage i.e. 1 cell in serie	es/three treatment stages	i.e 3 cells in series - P is 2 or 6 respe	ctively (conservative value)		
Design Flow	m3/d	408	Input flow rate into here					
Total annual hydraulic throughput	m³/yr	148920						
Total wetland area	m²	7,500	Active cell area (i.e. excluding diving ber	ms, spreader channels and	level control structures)			
q	m/yr	19.856						
Total Phosphorus Amount of remaining contaminant, Ce - C* Treatment efficiency of wetland	- % 1 %	3.07 61.66 38.34	NB. treated discharge from the wetland of % of contaminant removed	cannot be less than the bac	ckground concentrations, as it is not	possible to achieve i.e. backg	round conc will always be pre	isent

ARCADIS			PROJECT No:	3019260	2		
		CALCOLATIONS	GBA:	Resilienc	e - Water		
CLIENT:	Corodigion County Co	uncil	REVISION:	P01			
	Cerealgion County Co		AUTHOR:	RG			
PROJECT:	Wotland Sitos Toifi V	latlands	CHECKER:	EBP			
	Wetland Siles - Tenry	Vetialius	APPROVER:	0			
SUBJECT:	Process Design Calcul	ations Cilgorran	DATE:	45254			
	Process Design Calcul		DOC. No:	0			
SECTION:	References		SHEET:	4	OF	4	

bnstructed Wetland Design & Specification.pdf

The 'Tanks In Series' (TIS) model assumes that the wetland behaves like a treatment plant with a number of completely mixed tanks connected in series, whereby the contaminant is reduced in each tank. This model considers the concentration of the contaminant (C), the background concentration (C*), the rate of reduction of the contaminant over time (rate coefficient 'k', m/d) and the hydraulic parameter (N = no. of tanks in series). It is an improvement on the PFD model, as N is considered to be a finite number (for plug flow, N = ∞ which is not achievable). However, the TIS model assumes the reduction of a single compound through a treatment wetland, whereas many contaminants such as TN and TP are mixtures of contaminants that break down at different rates. The mixture becomes *weathered*, which is a term used to describe the selective stripping of light volatile materials upon exposure to outdoor environments. Observed weathering behaviour in real wetland situations may be represented by the TIS model, wherein the parameter values are relaxed to become fitting parameters. This 'relaxed' TIS model is known as the P-k-C* model and is defined to be as follows (Kadlec & Wallace 2009):

$$\frac{C_e - C^*}{C_i - C^*} = \begin{bmatrix} 1 + \frac{k}{Pq} \end{bmatrix}^{-1}$$

 C_i = Influent concentration of contaminant (mg/l)

Ce = Effluent concentration of contaminant (mg/l)

 $\label{eq:calibration} C^* = \text{Background concentration of contaminant (in the wetland water column) (mg/l)} \\ k = \text{Rate coefficient for reduction of contaminant (m/yr)}$

P = Apparent no. of tanks in series (PTIS – dimensionless)

q = Hydraulic loading rate (m/yr)

k - C* modelling *Wetland Feasibility, Design and Offsetting (1).pdf

Plug-flow k-C* Model

The plug-flow k-C* model is based on the below equation; large constructed p-control wetlands have been found to fit this description (Kadlec 2016¹¹):

A=(0.0365*Q/k)*In[(Ci-C*)/Ce-C*)]

Where A= Area (ha), Q=design flow (m₃/d), k: apparent rate coefficient (m/year/1), C_i: inlet TP concentration (gP/m3); C*: background Concentration (mgP/I); Ce=Target Effluent Concentration (mg/I)

- (Flows and TP levels modelled are outlined in table 2).
- C_o: The target TP concentration for the wetland is 1mg/l.
- C*: The wetland background concentration is estimated at 0.05mg/l.
- k: The apparent rate coefficient used was 12 m/year.



Arcadis (UK) Limited

80 Fenchurch Street London EC3M 4BY United Kingdom

T: +44 (0)20 7812 2000

arcadis.com