Option	Description	Cost – Estimated (£ millions)				Predicted water level drop	Carbon (tCO2e)		
		Whole Life Cash Cost	Whole Life present value costs	Present Value benefits	Average benefit : cost ratio (BCR)		Capital Carbon	Estimated Operational carbon over next 100 years	Whole life carbon
1 Do Nothing	No work or maintenance at any existing structure or along the river channels.	0	0	0	0	Initially gates will remain closed leading to no change in water level in normal flow conditions. If the gates failed in a closed position, water levels throughout the scheme would be difficult to control with flood risk being increased. If the gates were to fail in an open position, there would likely be a reduction in water level on the Ember Loop, Royal Mills Loop and River Mole channels, depending upon the location of the gate failure.	0	0	0

Pros	Cons
No change in visual amenity or recreational use in non flood conditions until the gates fail.	Increased flood risk to over 1,200 properties if gates were to fail in closed position. No control of floating pennywort. As gates fail at Island Barn sluice, Ember Loop and River Mole channels will receive less flow and may dry out. As gates fail at Viaduct sluice, Royal Mills Loop will receive less flow and dry out. Further bank erosion likely. Fish passage likely to still be impeded at Island Barn and Viaduct due to a drop in river bed level at these sluices. Drop in water levels at Ember Loop, Royal Mills Loop and River Mole will impact on the existing species and habitat. Water levels throughout the scheme are difficult to control as gates fail. More regular flooding of riverside path around Molember Sluice affecting access for boating. If gates fail in the open position, there is likely to be a loss of water in the side channels including the Old Mole and Imber Court Loop, impacting on habitat and amenity.

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2 Do Minimum	Reactive maintenance and repairs as structures fail. Fish passes to be provided as structures are replaced.	118m	40m	313m	7.9	Water levels are maintained within the main Ember channel upstream of Molember Sluice and in the River Mole upstream of Zenith.	2,594	17,754	20,348

Pros	Cons
Current standard of protection levels will be maintained. No change to visual amenity or recreational use. When gates are replaced, fish passage solutions will be built to allow most species to bypass these barriers.	Limited opportunity to reduce spend on reactive maintenance. No change in floating pennywort. Reactive maintenance results in multiple disruptions to the river and for local residents. Prevents some of the objectives of the River Basin Management Plan being met as river still impounded. Habitats and wildlife will remain as they are, with no ability to improve them, or reduce floating pennywort.

Option	Description	Cost – Estimated (£ millions)				Predicted water level drop	Carbon (tCO2e)		
		Whole Life Cash Cost	Whole Life present value costs	Present Value benefits	Average benefit : cost ratio (BCR)		Capital Carbon	Estimated Operational carbon over next 100 years	Whole life carbon
3 Gate Replacement	**Molember**: Replace all radial* gates with a fixed crest weir (no change in upstream water level). Replace tilt** gate with new gate and automate operation. (*Radial gates lift up and water flows underneath. **Tilt gates are fixed at river bed level and water flows over the top). **Island Barn**: Replace all gates with new gates and automate operation. **Viaduct**: At one radial gate, install a new pier to divide the existing gate channel. On one side install a fixed crest weir and fish pass and on the other install a new gate. Replace all other gates with new gates and automate operation. **Zenith**: Remove existing gates, electrical equipment and walkway. Install new rock ramp fish pass on the existing structure. **Wilderness**: Remove existing gates and electrical equipment. Install new rock ramp fish pass on the existing structure. **Royal Mills**: Replace existing gate with a fixed crest weir at the same level. We may now be able to incorporate a fish pass at Royal Mills into our plans and our team will be looking at this over the coming weeks and months. **Flood channel**: Repair channel banks that were scoured in 2013/14 flood events.	69m	31m	314m	10.1	Water levels are maintained within the main Ember channel upstream of Molember Sluice and in the River Mole upstream of Zenith.	2,163	13,773	15,936

Pros	Cons
- Current 1:100 year standard of protection maintained, ensuring scheme stays resilient against predicted climate change - Reduction in carbon footprint compared to Option 2: Do Minimum, as less replacement and operation of gates in the future. - Fish passage will be possible via Zenith, Wilderness and Viaduct Sluices. There may be an improvement in species diversity along the channel. - Opportunity to remove some of the infrastructure such as the walkway and gate equipment at Molember allowing visual improvement. - No change to recreational use, potential to improve visual amenity. - At Zenith, the replacement of the existing sluice gates and walkway, with a rock ramp is considered a visual improvement. - Scour repairs will allow reinstatement of vegetation along the river banks ensuring the future stability of the banks and improving visual amenity. - Fish passage solutions at selected structures will enable most species to bypass these barriers.	- No improvement in habitat or species diversity at Molember or Island Barn. - No improvement in habitat or species diversity between Molember and Island Barn as this area will remain impounded upstream of gates and new fixed crest weir at Molember. - Gates that are replaced as part of this option will need replacing again in 30yrs. - No change in floating pennywort. - Fish fauna are at risk from invasive non-native species of fish from the Thames. - Ongoing maintenance is required to ensure gates remain operational. - Habitats and wildlife will remain as they are, with no ability to improve them, or reduce floating pennywort.

Option	Description	Cost – Estimated (£ millions)				Predicted water level drop	Carbon (tCO2e)		
		Whole Life Cash Cost	Whole Life present value costs	Present Value benefits	Average benefit : cost ratio (BCR)		Capital carbon	Estimated Operational Carbon over next 100 years	Whole life carbon
4 Molember gate replaced with fixed crest weir	**Molember:** Replace all gates with a fixed crest weir (fall in upstream water level). Changes at the following structures are the same as detailed in option 3: **Island Barn**: Replace all gates with new gates and automate operation. **Viaduct**: At one radial gate, install a new pier to divide the existing gate channel. On one side install a fixed crest weir and fish pass and on the other install a new gate. Replace all other gates with new gates and automate operation. **Zenith**: Remove existing gates, electrical equipment and walkway. Install new rock ramp fish pass on the existing structure. **Wilderness**: Remove existing gates and electrical equipment. Install new rock ramp fish pass on the existing structure. **Royal Mills**: Replace existing gate with a fixed crest weir at the same level. We may now be able to incorporate a fish pass at Royal Mills into our plans and our team will be looking at this over the coming weeks and months. **Flood channel**: Repair channel banks that were scoured in 2013/14 flood events.	67m	31m	313m	10.2	Water levels are maintained at Island Barn and Viaduct. There will be a drop in water level upstream of Molember.	2,047	12,718	14,765

Pros	Cons
- Current 1:100 year standard of protection maintained, ensuring scheme stays resilient against predicted climate change - Reduction in carbon footprint, compared to options 2 and 3, as less replacement and operation of gates in the future. - Fish passage will be possible via Zenith, Wilderness and Viaduct. There may be an improvement in habitat and species diversity along the channel. - Opportunity to remove some of the infrastructure such as the walkway at Molember allowing for some visual improvement. - No change in water levels at Island Barn and Viaduct, maintaining visual amenity and recreation at and upstream of these locations. - At Zenith, the replacement of the existing sluice gates and walkway, with a rock ramp is considered a visual improvement. - Scour repairs will allow reinstatement of vegetation along the river banks ensuring the future stability of the banks and improving visual amenity. - Fish passage solutions at selected structures will enable most species to bypass these barriers.	- Reduction in water level between Molember and Island Barn will impact on visual amenity, by exposing some hard engineered structures, and recreational use of this area. - The upstream water level drop at Molember may impact on visual amenity at this location and without mitigation could limit access to the water for boats from the riverside path. - No improvement in habitat or species diversity between Molember and Island Barn River as this area will remain impounded upstream of gates and new fixed crest weir at Molember. - No change in floating pennywort. - Gates that are replaced as part of this option will need replacing again in 30yrs. - Habitats and wildlife will remain as they are, with no ability to improve them, or reduce floating pennywort.

Option	Description	Cost – Estimated (£ millions)				Predicted water level drop	Carbon (tCO2e)		
		Whole Life Cash Cost	Whole Life present value costs	Present Value benefits	Average benefit : cost ratio (BCR)		Capital Carbon	Estimated Operational carbon over next 100 years	Whole life carbon
5 Remove all gates but replace Island Barn sluice gates	**Molember**: Remove all gates. **Viaduct:** Remove all gates. Provide rock ramp fish pass. **Royal Mills:** Royal Mills channel will become a backwater that flows during higher flow events. Existing gate removed as no longer required to impound water upstream. **Flood channel:** Repair channel banks that were scoured in 2013/14 flood events. Install berms and groynes to form a low flow channel where required. **Island Barn**: Replace all gates with new gates and automate operation. **Zenith**: Remove existing gates, electrical equipment and walkway. Install new rock ramp fish pass on the existing structure. **Wilderness**: Remove existing gates and electrical equipment. Install new rock ramp fish pass on the existing structure.	48m	28m	316m	11.4	Water levels are maintained at Island Barn and upstream of Zenith on the River Mole channel and on the Ember Loop. There will be a drop in water level upstream of Molember and Viaduct as gates are removed.	1,859	11,153	13,012

Pros

- Reduction in flood risk in severe events and greater resilience against climate change due to less impoundment and greater flow capacity in the river channel as a result of removing a number of sluice gates along the flood relief channel. Reduction in number of gates reduces also reduces risk to flooding should gates fail in a closed position.
- No change in visual amenity or recreational use around Island Barn, and along River Mole and Ember Loop.
- Reduction in carbon footprint, compared to options 2, 3 and 4, as less replacement and operation of gates in the future.
- Potential to remove significant barriers to fish and eels which is a priority of the Thames River Basin Management Plan and allow fish to access over 13 km of river. There is likely to be an increase in fish species diversity.
- This option, alongside inclusion of measures to encourage the development of a low flow channel, will improve the flow diversity and allow new habitat creation, such as reed beds in the River Ember channel.
- There will be no change to the flow regime in the River Mole and Ember Loop.
- Increased flows in the River Ember Channel will reduce the issues with floating pennywort but this will still be an issue at Island Barn and the River Mole and Ember Loop.
- Lack of future intervention would reduce disruption to local residents and also minimise temporary impacts on fish and eels during maintenance.
- All gate walkways and control buildings will be removed, reducing visual impact of structures, except at Island Barn.
- Removal of barriers to fish for approximately 13km. The restoration of natural processes, creating more diverse habitat along 6.5km of river, and the retention of existing features along the Old Mole and Imber Court Loop.

Cons

- This option would lead to the Royal Mills channel running dry during some periods, leading to the loss of some existing habitat.
- Reduction in water level upstream of Molember and Viaduct would impact would result in a drop in water levels along these sections of the River Ember. This would have an impact a negative impact on visual amenity by exposing some hard engineered structures. This could be partially mitigated with appropriate enhancements in the base of the channel. The reduction in water level would also impact on the recreation use in these areas of the Ember channel.
- Gates that are replaced would need to be replaced again in 30yrs.
- Due to the water level drop recreational use of the River Ember channel by residents for boating and canoeing is likely to be affected.
- Residents of riverside properties downstream of Esher Road would have difficulty accessing the river by boat without mitigation.
- Habitats and wildlife between Viaduct and Island Barn will remain the same, with no improvement.

Option	Description	Cost – Estimated (£ millions)				Predicted water level drop	Carbon (tCO2e)		
		Whole Life Cash Cost	Whole Life present value costs	Present Value benefits	Average benefit : cost ratio (BCR)		Capital Carbon	Estimated Operational Carbon over next 100 years	Whole life carbon
6 Remove all gates, passive flood relief channel with rock ramps	**Molember**: Remove all gates. **Island Barn**: Remove all gates. Provide rock ramp fish pass. **Viaduct**: Remove all gates. Provide rock ramp fish pass. **Zenith**: Remove existing gates, electrical equipment and walkway. Investigate potential for fish passage at Zenith. Work carried out to reduce future maintenance. **Wilderness**: Install new rock ramp fish pass at Wilderness. Works carried out to reduce future maintenance. **Royal Mills**: Existing gate removed. Channel will have low flows unless there is a higher flow event. **Flood channel**: Repair channel banks that were scoured in 2013/14 flood events. Install berms and groynes to form a low flow channel where required.	25m	21m	315m	15.1	Water levels will drop across the full length of the Ember channel. Immediately upstream of sluices this would be up to 1.5 - 3m but this would reduce upstream from these locations.	1,025	5,690	6,715

Pros	Cons
- Reduction in flood risk in severe events and increased resilience against climate change due to minimal impoundment and greater flow capacity in the river channel as a result of removing a number of sluice gates along the flood relief channel. Removal of sluice gates removes risk to flooding should gates fail in a closed position. - Reduction in carbon footprint as no replacement and operation of gates in the future. - Potential to remove significant barriers to fish and eels, which is a priority of the Thames River Basin Management Plan and allow fish to access over 13km of river. There will be an increase in fish species diversity, including game fish such as sea trout and salmon. - This option will improve flow diversity and allow new habitat creation, such as marginal reeds in the River Ember channel benefiting fish, particularly sea trout, salmon and other migratory species and aquatic invertebrates. - Increased flows in the River Ember Channel will reduce the issues with floating pennywort. - Lack of future intervention would reduce disruption to local residents and also minimise temporary impacts on fish and eels during maintenance. - All gate walkways and control buildings will be removed, reducing visual impact of structures.	- This option would lead to the River Mole, Ember Loop and Royal Mills channels experiencing lower flows and potentially running dry during some periods which could result in loss of connectivity between aquatic habitats and encroachment of drier riparian habitats. This option could include in channel mitigation measures which would help minimise lower flows. - Due to the water level drop recreational use of the River Ember channel by residents for boating and canoeing is affected. - Residents of riverside properties downstream of Esher Road would have difficulty accessing the river by boat without mitigation such as extended steps or ladders being put in place. - Fish fauna are at risk from invasive non-native species of fish from the Thames.

	Terms
Whole life cash costs	For each option these include the costs for design and construction of any changes that would happen to the scheme now and future operation and maintenance costs over a 100 year period. All options are assessed over a 100-year period as required by the appraisal guidance. Sluice gates such as those at Molember, Island Barn and Viaduct have a typical design life of 30 years, therefore options that involve replacement of gates allow for their replacement at the anticipated time in the future. All options include an allowance for risk and uncertainty as the design of any option develops, and as risks become better understood this allowance can change.
Present value (PV) benefits and costs	The present value of the benefits / costs are how much the benefits / costs are worth today. Present value uses an approach known as discounting and is used to convert costs over the 100 year appraisal period to a present value for each option. This will reflect the total value of all future costs in today's prices. Discounting is used to reflect peoples' preferences from benefits today rather than benefits tomorrow. The impact for appraisal is that future benefits and costs are worth less in present value terms than costs and benefits that occur today. Discounting is used to convert all costs and benefits into Present Values. This allows the timing of costs and benefits to be taken into account. As a result, options with very different interventions or that deliver benefits over different timescales can be compared. *Section 7 of the Flood and Coastal Erosion Risk Management appraisal guidance gives greater detail of the approach for estimating option costs (https://www.gov.uk/guidance/flood-and-coastal-erosion-risk-management-appraisal-guidance/7-describe-quantify-and-value-costs-and-benefits).* Calculating the present value benefits and costs enables us to calculate the benefit : cost ratio for each option.
Benefit : cost ratio (BCR)	is the ratio of the benefits of a scheme option or proposal, expressed in monetary terms, relative to its costs, also expressed in monetary terms. We can use the BCR to compare the options against one another.

	Terms
Capital carbon (tCO2e)	This is a measure of the impact of a scheme on the environment. Capital carbon includes carbon associated with the manufacture of components such as new gates, transportation of materials to the river and construction activities on the river such as removing and installing gates, construction of new weirs, construction of fish passes and repairing damage to the existing banks. Capital carbon does not include carbon associated with the final disposal of waste generated from the project.
River Basin Management Plan	River basin management plans (RBMPs) set out how organisations, stakeholders and communities will work together to improve the water environment. These are legal requirements under the Water Framework Directive. These plans can be found here**:** https://www.gov.uk/government/collections/river-basin-management-plans-2015#thames-river-basin-district-rbmp:-2015
Groynes	A groyne, built perpendicular to the river bank, is a rigid hydraulic structure built from a bank that interrupts water flow and limits the movement of sediment. It is usually made out of wood, concrete, or stone.
Berms	Berms are simply mounded hills of soil. They contain dense sediment materials that decrease water velocity, control flow rates and absorb excess water in the event of a flood.
Fixed Crest Weir	A weir is a barrier across a river that alters the flow characteristics of water, usually resulting in a change in height of the river level. There are a range of weir designs, but generally water flows freely over the top of a weir, before cascading down to a lower level. The top of the weir, where the water flows over, is also called the weir crest. A type of weir that is commonly seen is a fixed crest weir, meaning that the elevation or height of the weir does not change as it is designed and built to stay in a static position.