DREDGING FOR FLOOD-RISK REDUCTION UNDER CLIMATE CHANGE: A CRITICAL REVIEW OF HYDRAULIC, SEDIMENT AND ENVIRONMENTAL CONSIDERATIONS

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ABSTRACT

Dredging is widely used to restore channel capacity, but its contribution to climate-resilient flood-risk reduction depends on whether sediment-induced loss of conveyance is a principal flood mechanism. This critical narrative review synthesizes evidence on climate-driven flood hazards, channel hydraulics, sediment dynamics, riverine and coastal dredging, environmental impacts, beneficial sediment use and integrated flood-risk management. The review examines how channel geometry, flow conditions, downstream boundary levels, tributary inflows, floodplain connectivity, tidal processes and re-sedimentation influence the effectiveness and durability of dredging. Evidence indicates that targeted sediment removal can increase channel conveyance and reduce water levels for specified discharges where deposition constrains hydraulic performance. However, benefits are context-dependent, and extensive dredging may alter tidal propagation, redistribute flood risk or produce only temporary improvements where sediment rapidly accumulates. Environmental concerns include turbidity, habitat disturbance and contaminant remobilization, although suitable dredged material may support wetland restoration and shoreline nourishment. The review proposes an evaluation framework integrating baseline channel geometry, hydraulic modelling, flood levels and inundation, sedimentation rates, environmental indicators and life-cycle impacts. For Nigeria and comparable settings, dredging decisions should be based on the dominant flood mechanism, downstream consequences and long-term maintenance requirements. Dredging is therefore best treated as a targeted component of integrated flood-risk management rather than a universal standalone flood-control measure.

Keywords: *Channel conveyance; Climate adaptation; Dredging; Flood-risk management; Sediment dynamics; Sustainable sediment management*.

1.0 INTRODUCTION

Flood risk results from the interaction of hazard, exposure and vulnerability. Its severity depends not only on river discharge but also on channel conveyance, floodplain storage, drainage capacity and development within flood-prone areas. Climate change further complicates flood management by altering rainfall extremes, flood-generating processes and coastal conditions. Fowler et al. (2021) highlighted the intensification of short-duration rainfall extremes under anthropogenic warming, while Merz et al. (2021) emphasized the interacting atmospheric, hydrological, geomorphological and socioeconomic drivers of disastrous river floods. Effective interventions must therefore address the mechanisms responsible for flooding rather than assume universal effectiveness. Dredging removes accumulated sediment to restore channel geometry and potentially improve conveyance. However, its effectiveness depends on hydraulic radius, bed slope, channel roughness, downstream water levels and floodplain interactions. Sediment accumulation alone does not establish that

dredging will materially reduce flood risk. Ahrendt et al. (2022) demonstrated the importance of temporal changes in channel conveyance in explaining variations in flood hazard, reinforcing the need to consider channel adjustment and sediment dynamics.

These limitations are particularly important in low-gradient rivers and coastal transition zones, where river discharge interacts with tributary inflows, floodplain storage, tides and elevated coastal water levels. Using a hybrid one-dimensional and two-dimensional hydrodynamic model, Saad and Habib (2021) found that extensive dredging of the Vermilion River in southern Louisiana reduced flood stages under some scenarios but increased tidal-wave amplitude and inland propagation. Less extensive dredging provided more limited mitigation and increased downstream flood exposure under certain conditions. Local hydraulic improvements therefore do not necessarily produce equivalent reductions in flood risk across the wider watershed.

Dredging should consequently be assessed alongside floodplain restoration, wetland conservation, retention measures, drainage improvements and catchment management. Opperman and Galloway (2022) highlighted the potential of nature-based approaches to reduce flood risk while delivering wider environmental benefits. The appropriate intervention depends on the dominant flood mechanism, downstream consequences, environmental effects and long-term maintenance requirements.

This critical narrative review examines the hydraulic, geomorphological and environmental conditions governing dredging effectiveness under climate change. It evaluates changes in channel conveyance and water levels, sediment transport and channel stability, downstream flood-risk transfer, environmental impacts, beneficial sediment use and life-cycle implications. It also considers relevance to Nigeria and comparable developing-country settings, where project-level monitoring and hydraulic evidence may be limited. The review develops an evidence-based framework for determining when dredging is justified, emphasizing measurable flood outcomes, downstream consequences, environmental constraints and maintenance needs rather than assuming that sediment removal necessarily reduces flood risk.

2.0 REVIEW SCOPE AND METHODOLOGY

2.1 Review Design and Scope

This study adopts a critical narrative-review approach to examine when dredging can contribute to flood-risk reduction under climate change. It synthesizes evidence from hydraulic modelling, field observations, sediment-transport studies, environmental assessments and flood-management evaluations. It is neither a systematic review nor a meta-analysis, as no complete, reproducible search protocol, documented screening process or comprehensive study-selection dataset was available.

The review addresses five themes: changing flood hazards, channel hydraulics, sediment dynamics, environmental impacts and beneficial sediment use, and integration with wider flood-risk management. Riverine, urban drainage, coastal and estuarine settings are considered, with attention to implications for Nigeria and comparable developing-country contexts.

2.2 Literature Identification and Selection

The review draws on peer-reviewed studies of channel conveyance, flood-stage response, sediment dynamics, climate-related hazards, environmental impacts, beneficial sediment use and integrated flood management. Recent publications inform contemporary adaptation issues, while earlier studies provide evidence on established hydraulic mechanisms and sediment-management practices.

Studies were considered relevant where they addressed these themes and helped explain the conditions under which dredging may achieve meaningful, sustainable flood-risk reduction. Particular attention was given to

hydraulic modelling, field measurements and morphodynamical analyses, alongside research on turbidity, habitat disturbance, contaminant mobilization, sediment disposal and reuse.

Study findings were interpreted in relation to their geographical settings, methods, channel geometry, floodplain connectivity, sediment supply, tributary inflows and downstream conditions. Case-study results were not assumed to apply universally to other river systems.

2.3 Evidence Interpretation and Critical Synthesis

Evidence was synthesized thematically rather than statistically pooled. Hydraulic findings were examined using continuity, channel geometry, Manning-based conveyance relationships and boundary conditions. Modelled dredging scenarios were interpreted in terms of excavation extent, water-level changes, floodplain exchanges, tidal effects and downstream consequences.

Environmental evidence was assessed in relation to suspended sediment, water quality, aquatic habitats, sediment disposal and beneficial reuse. Treatment, transport, placement, maintenance and life-cycle impacts were also considered because improved local conveyance does not, by itself, demonstrate reduced overall flood risk or environmental sustainability.

The synthesis distinguished reported study findings from interpretations drawn across studies. Modelled outcomes were treated as scenario-dependent, and recommendations were assessed against the evidence and limitations identified.

2.4 Application to Nigeria and Developing-Country Contexts

International evidence was considered for its relevance to Nigerian rivers, urban waterways and coastal environments. Particular attention was given to baseline bathymetry, discharge and water-level records, sediment characterization, post-dredging monitoring and measured flood outcomes. These data are essential for distinguishing completion of dredging works from demonstrated reductions in flood hazard.

The Nigerian discussion therefore focuses on engineering requirements, evidence needs and management implications. International case studies inform the evaluation framework but do not constitute direct proof of flood-risk reduction from any specific Nigerian dredging project.

2.5 Limitations of the Review Method

The narrative design and absence of a documented, exhaustive search and screening protocol mean that the review cannot be assumed to cover all relevant publications. Evidence selection and interpretation may consequently reflect the availability and emphasis of published studies. No pooled effect size or universal percentage reduction in flood risk is estimated because the studies differ in hydraulic setting, intervention scale, modelling assumptions, outcome measures and sediment conditions.

Geographical representation is another limitation. Much of the evidence on dredging performance and long-term sediment management comes from regions with established monitoring programmes and extensive hydrological records. Comparable project-level evidence for Nigerian rivers and urban drainage systems is more limited in the literature considered. Accordingly, the review identifies evidence needs and research priorities rather than claiming direct empirical validation of dredging effectiveness across Nigeria.

3.0 CLIMATE CHANGE, CHANGING FLOOD HAZARD AND THE NEED FOR ADAPTATION

Climate change is altering flood hazards through changes in rainfall extremes, river discharge and coastal water levels. Fowler et al. (2021) highlighted the intensification of short-duration rainfall extremes under

atmospheric warming, while Merz et al. (2021) showed that disastrous river floods reflect interacting atmospheric, hydrological, geomorphological and socioeconomic processes. Flood-management interventions must therefore account for changing conditions and uncertainty rather than rely solely on historical flood records.

3.1 Changing Rainfall and River-Flood Hazards

Although warming can intensify extreme rainfall, flood responses also depend on rainfall distribution, antecedent soil moisture, catchment characteristics, drainage capacity and floodplain storage. Wasko et al. (2021) emphasized the need to account for uncertainty beyond natural hydrological variability when estimating future floods.

These factors determine whether dredging can provide meaningful benefits. Where sediment accumulation restricts conveyance, excavation may improve hydraulic performance. However, where flooding is driven primarily by extreme runoff, inadequate drainage or insufficient storage, dredging alone may offer limited relief. Its justification depends on whether sediment-related restriction materially contributes to flooding and whether removal produces a measurable improvement under relevant conditions.

3.2 Flood-Generating Mechanisms in African Catchments

Flood mechanisms vary across Africa with climate, topography, soil moisture, river morphology and human development. Using observations from 399 stream gauges and 11,302 flood events, Tramblay et al. (2021) demonstrated regional differences in flood drivers, including rainfall, soil moisture and flood seasonality. This variability supports location-specific assessment rather than universal reliance on a single intervention.

In Nigeria, flooding may result from excessive river discharge, overwhelmed urban drainage, sediment accumulation, floodplain encroachment or combinations of these factors. Dredging may be appropriate where surveys and hydraulic assessments establish sediment-related restrictions, but other mechanisms may require drainage improvements, catchment management, floodplain protection or additional storage.

3.3 Coastal Flooding, Sea-Level Rise and Compound Hazards

Coastal and estuarine flooding reflects interactions between river discharge, tides, storm surges and sea-level rise. Elevated coastal water levels can restrict river outflow, while coincident rainfall and coastal extremes may compound inundation.

Aziz et al. (2024) reviewed coastal urban flood-management challenges associated with climate change, sea-level rise, urbanization and human interventions. Vousdoukas et al. (2020) examined sandy-coastline vulnerability to erosion under rising sea levels, highlighting wider coastal changes relevant to adaptation.

In these settings, dredging may alter channel conveyance, sediment transport and tidal propagation but cannot eliminate downstream water-level controls. Hydraulic or hydrodynamic assessment must therefore consider river flows, coastal conditions and their interactions rather than infer flood benefits from increased channel depth alone.

3.4 Dredging within an Integrated Climate-Adaptation Strategy

Flood-risk management should combine appropriate engineering measures with catchment management, drainage improvements, floodplain restoration, wetland conservation, retention, forecasting and land-use planning. Opperman and Galloway (2022) highlighted the potential of nature-based approaches to reduce flood risk while providing wider environmental benefits. Azhar et al. (2025) examined adaptation portfolios and the trade-offs among technical performance, environmental effects, cost and implementation.

Within this portfolio, dredging is appropriate where sediment accumulation creates a demonstrable hydraulic restriction and excavation provides measurable benefits without unacceptable downstream or environmental consequences. Other measures may be more effective where flooding is dominated by runoff, inadequate storage or coastal boundary conditions; combined interventions may be needed where mechanisms interact. Dredging decisions should therefore consider baseline hydraulic conditions, expected changes in water levels and inundation, upstream and downstream effects, and long-term performance under plausible future hydrological and sedimentary conditions. These considerations lead to Section 4, which examines the hydraulic relationships governing channel conveyance and the conditions under which dredging may influence flood levels.

4.0 HYDRAULIC BASIS OF DREDGING FOR FLOOD-RISK REDUCTION

4.1 Channel Capacity and Continuity

The primary hydraulic justification for dredging is that removing accumulated sediment may restore part of the flow area lost through deposition and modify the relationship between discharge and water-surface elevation. Under steady-flow conditions, the continuity equation is expressed as:

$$Q = AV \qquad (1)$$

where (Q) is discharge (m^3/s), (A) is the wetted cross-sectional area (m^2), and (V) is the mean flow velocity (m/s).. For a given discharge, a change in cross-sectional area must be accompanied by a corresponding change in mean velocity, provided that the same discharge passes through the section without additional storage or lateral inflow. However, continuity alone cannot determine the resulting water level because flow area depends on water depth and channel geometry, while velocity is influenced by hydraulic resistance and energy slope. Sediment deposition can reduce the effective flow area and alter the wetted perimeter and hydraulic radius. Where accumulation occurs at a hydraulically controlling section, the resulting conveyance restriction may contribute to higher upstream water levels. Dredging may partly reverse this effect by increasing the available flow area and modifying the hydraulic properties of the section. The magnitude of the response depends on the original geometry, depth and extent of excavation, channel roughness, energy slope and downstream hydraulic boundary conditions. The continuity relationship therefore provides the physical basis for evaluating channel modification but does not, by itself, establish that dredging will reduce flood levels (Jobson & Froehlich, 1988).

4.2 Manning's Equation and Channel Conveyance

Manning's equation provides a practical means of relating discharge to channel geometry, roughness and energy slope under steady, uniform-flow conditions. In SI units, it is expressed as

$$Q = \frac{1}{n} A R^{2/3} S^{1/2} \qquad (2)$$

where (n) is Manning's roughness coefficient, (R) is the hydraulic radius (m), and (S) is the dimensionless energy slope. The hydraulic radius is defined as

$$R = \frac{A}{P} \qquad (3)$$

where (P) is the wetted perimeter (m). For uniform flow in a sufficiently regular channel, the energy slope is commonly approximated by the channel-bed slope. This approximation should not automatically be applied to natural rivers where backwater, rapidly varying flow, tidal influences or significant changes in channel geometry affect the water-surface profile (Federal Highway Administration [FHWA], 2001; Jobson & Froehlich, 1988).

For convenience, the conveyance term (K) can be defined as

$$K = \frac{1}{n} AR^{2/3} \qquad (4)$$

so that Equation (2) becomes

$$Q = KS^{1/2} \qquad (5)$$

Conveyance therefore represents the combined influence of cross-sectional geometry and channel roughness on the capacity to convey flow under a specified energy slope. Increasing the flow area does not necessarily produce an equal percentage increase in conveyance because the hydraulic radius also changes with depth and wetted perimeter. Moreover, the roughness coefficient and energy slope may differ between the pre-dredging and post-dredging conditions.

For a trapezoidal channel with bottom width (b), flow depth (y), and side slope (z) expressed as horizontal distance per unit vertical distance, the cross-sectional area and wetted perimeter are

$$A = by + zy^2 \qquad (6)$$

$$P = b + 2y\sqrt{1 + z^2} \qquad (7)$$

Equations (3), (4), (6) and (7) can be combined to estimate conveyance at different flow depths. A comparison of pre-dredging and post-dredging conveyance provides an initial indication of the potential hydraulic effect of excavation. However, demonstrating a change in flood stage requires consideration of the discharge and downstream boundary conditions, and may require a gradually varied flow calculation or a calibrated hydraulic model.

4.3 Worked Example: Removal of 0.5 m of Sediment from a Trapezoidal Channel

An illustrative calculation demonstrates how sediment removal can affect cross-sectional area and conveyance. The example represents an idealized trapezoidal channel in which deposition has reduced the available depth by 0.5 m. The numerical values are assumed for illustration and do not represent measurements from a specific river or dredging project.

The assumed channel parameters are a bottom width of 4.0 m, side slopes of 2 horizontal to 1 vertical, Manning's roughness coefficient of 0.030, and an energy slope of 0.0005. The available flow depth before dredging is 1.5 m. Removal of 0.5 m of deposited material restores the reference depth to 2.0 m. The comparison initially considers the same water-surface elevation relative to a fixed datum, so that the difference in depth results from the change in bed elevation.

Calculation of the pre-dredging condition

Using Equation (6),

$$A_1 = (4.0)(1.5) + 2(1.5)^2 = 10.50\ \text{m}^2$$

The wetted perimeter is

$$P_1 = 4.0 + 2(1.5)\sqrt{1+2^2} = 10.71\ \text{m}$$

The hydraulic radius is therefore

$$R_1 = \frac{10.50}{10.71} = 0.981\ \text{m}$$

Using Equation (4), the conveyance is

$$K_1 = \frac{1}{0.030}(10.50)(0.981)^{2/3} = 345.45\ \text{m}^3/\text{s}$$

The corresponding discharge capacity under the assumed uniform-flow slope is

$$Q_1 = 345.45\sqrt{0.0005} = 7.72\ \text{m}^3/\text{s}$$

Calculation of the post-dredging condition

After removing 0.5 m of deposited material, the available depth at the same water-surface elevation is 2.0 m. The cross-sectional area becomes

$$A_2 = (4.0)(2.0) + 2(2.0)^2 = 16.00\ \text{m}^2$$

The wetted perimeter is

$$P_2 = 4.0 + 2(2.0)\sqrt{1+2^2} = 12.94\ \text{m}$$

The hydraulic radius is

$$R_2 = \frac{16.00}{12.94} = 1.236\ \text{m}$$

The post-dredging conveyance is

$$K_2 = \frac{1}{0.030}(16.00)(1.236)^{2/3} = 614.27\ \text{m}^3/\text{s}$$

The corresponding discharge capacity is

$$Q_2 = 614.27\sqrt{0.0005} = 13.74\ \text{m}^3/\text{s}$$

The percentage change in conveyance is calculated as

$$\%\Delta K = \frac{K_2 - K_1}{K_1} \times 100 \qquad (8)$$

Substituting the calculated values give

$$\%\Delta K = \frac{614.27 - 345.45}{345.45} \times 100 = 77.8\%$$

The corresponding increase in calculated discharge capacity at the specified slope is also approximately 77.8%, because the same energy slope is used in both calculations.

Table 1. Illustrative hydraulic characteristics before and after sediment removal

Parameter	Before dredging	After dredging
Available flow depth (m)	1.50	2.00
Cross-sectional area (m²)	10.50	16.00
Wetted perimeter (m)	10.71	12.94
Hydraulic radius (m)	0.981	1.236
Conveyance, (K) (m³/s)	345.45	614.27
Calculated capacity at (S=0.0005) (m³/s)	7.72	13.74

Note. The values are calculated from the stated idealized geometry, roughness and slope. Conveyance is defined as ($K = AR^{2/3}/n$); its units are consistent with discharge when multiplied by the square root of the dimensionless energy slope.

The calculation illustrates that a 0.5 m increase in available depth can produce a proportionally different change in conveyance because both cross-sectional area and hydraulic radius change. The calculated increase in capacity is specific to the assumed trapezoidal geometry and uniform-flow conditions. It should not be interpreted as a prediction of the flood-reduction benefit of an actual dredging project.

To illustrate the corresponding water-level implication under the same idealized assumptions, consider a specified discharge of 10 m³/s. Solving Manning's equation for normal depth gives a depth of approximately 1.71 m for the assumed channel geometry, roughness and slope. If dredging lowers the bed by 0.5 m while leaving these hydraulic properties unchanged, the corresponding uniform-flow water-surface elevation relative to the original bed datum would also be approximately 0.5 m lower. This is a theoretical comparison under uniform-flow assumptions, not a general prediction that dredging will lower flood levels by 0.5 m. In an actual river, changes in bed slope, roughness, downstream control and floodplain interaction may substantially modify the response.

The hydraulic pathway through which dredging may influence flood-risk reduction is illustrated in Figure 1. The comparison highlights how sediment removal can increase the available flow area, while the resulting change in water level remains dependent on the prevailing hydraulic controls and downstream boundary conditions.

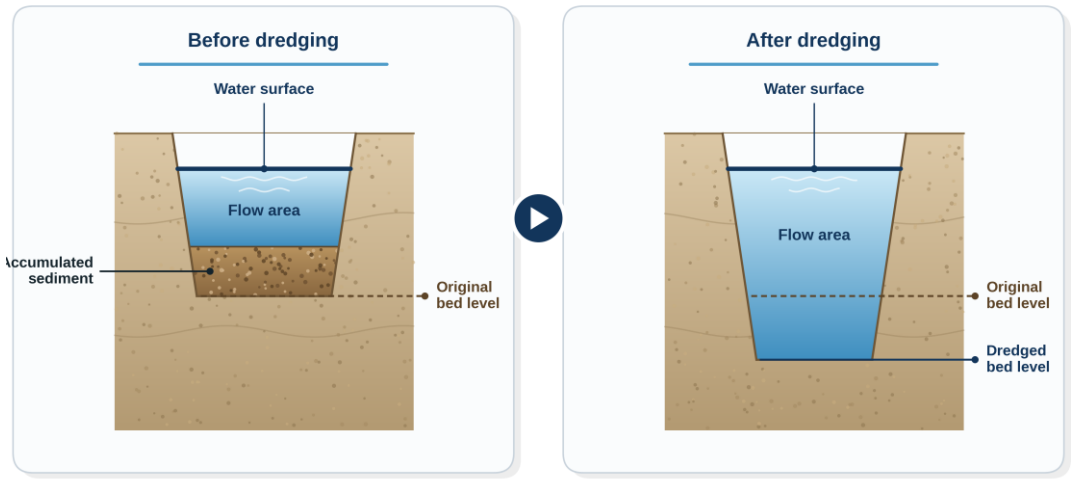


Figure 1: Conceptual hydraulic pathway linking sediment deposition, channel conveyance and potential flood-risk benefits of targeted dredging.

4.4 Backwater-Controlled Conditions and the Limits of Local Conveyance Improvement

The hydraulic benefit of dredging depends on whether local channel geometry controls water levels or whether downstream conditions dominate. High receiving-water levels, tides, constrictions and hydraulic structures can create backwater effects, whereby excavation increases local conveyance without proportionately lowering upstream water levels.

Manning's equation estimates conveyance under uniform-flow assumptions but cannot, by itself, determine water-surface profiles under backwater conditions. These require analysis of the energy and momentum relationships governing gradually varied flow, with appropriate upstream and downstream boundary conditions (Jobson & Froehlich, 1988; U.S. Army Corps of Engineers, n.d.).

For the illustrative trapezoidal channel, removing 0.5 m of sediment increases the available flow area. However, if a high downstream water level controls the profile, the upstream stage may change only slightly. The response depends on channel geometry, discharge, roughness, hydraulic losses and the location and strength of the downstream control; it cannot be quantified from cross-sectional area alone.

Consequently, a percentage increase in conveyance must not be interpreted as an equivalent percentage reduction in flood stage. Where backwater or tidal influences dominate, dredging may provide limited benefits or require complementary interventions. Site-specific water-surface profile calculations or hydraulic modelling are needed to establish the likely response.

4.5 Hydrodynamic Modelling and Demonstration of Flood Benefit

A defensible assessment must link channel modifications to measurable hydraulic and flood outcomes. Bathymetric surveys and channel cross-sections establish baseline geometry, while discharge and water-level observations support model calibration and evaluation of alternative dredging scenarios.

Models should represent relevant discharges, upstream inflows, downstream water levels, channel roughness, floodplain connectivity and plausible future conditions. In coastal and estuarine systems, tidal variation and elevated coastal water levels should also be included where they influence the water-surface profile. Sensitivity analysis should test whether predicted benefits persist under uncertain parameters and boundary conditions.

Performance should be assessed using water-surface elevation at specified discharges, flood depth, inundation extent and duration, overtopping frequency, and downstream water levels. Where risk transfer is possible, assessment should extend beyond the dredged reach to examine changes in flood timing and impacts elsewhere. Post-dredging surveys and monitoring are necessary to verify the achieved geometry and track sediment reaccumulation.

Dredging may reduce flood risk where sediment accumulation materially restricts conveyance and its removal produces a demonstrable hydraulic benefit. The magnitude and durability of that benefit depend on channel geometry, roughness, energy slope, downstream controls and floodplain interactions. These considerations establish the basis for examining sediment dynamics and the possibility that dredging may redistribute rather than uniformly reduce flood risk.

5.0 SEDIMENT DYNAMICS AND THE LIMITS OF DREDGING

5.1 Sedimentation, Channel Morphology and Flood Hazard

Sedimentation reflects the balance between sediment supply, transport, deposition and erosion. Accumulation can alter channel geometry, hydraulic radius and bed elevation, affecting water levels at a given discharge.

However, deposition does not necessarily cause flooding; its significance depends on its location, extent and effect on conveyance relative to other hydraulic controls.

Vázquez-Tarrío et al. (2024) showed that sediment transport, erosion, aggradation, channel instability and changing sediment supply influence channel morphology and flood stages, yet sediment dynamics remain insufficiently integrated into many flood-hazard assessments. Dredging removes deposited material but does not eliminate the processes that cause deposition. Where sediment supply remains high, channels may refill, diminishing initial conveyance gains and increasing maintenance needs. Long-term effectiveness therefore depends on sediment sources and transport pathways, channel morphology and post-dredging stability.

5.2 Effects of Dredging on Sediment Transport and Channel Stability

Dredging alters channel geometry, potentially changing flow velocity, bed shear stress and sediment transport. Depending on local conditions, these changes may cause erosion, bank instability or downstream deposition. Responses vary with sediment properties, channel confinement, bed material and upstream sediment supply.

Cox et al. (2022), drawing on scale experiments, empirical relationships and real-world examples, showed that dredging and sea-level rise can interact to increase channel migration, bank erosion and sediment import in some estuaries. Rapid sediment replenishment may undermine repeated channel deepening. Although these findings are specific to estuarine settings, they demonstrate the need to assess dredging under changing sedimentary and boundary conditions.

Dredging design should therefore consider grain-size distribution, cohesion, bulk density, organic content and contaminant concentrations, which affect sediment mobilization, handling, transport and placement. Repeated bathymetric surveys can establish whether the intended channel geometry persists and quantify subsequent sediment accumulation.

5.3 Upstream–Downstream Effects and Flood-Risk Transfer

Local improvements in channel conveyance do not necessarily reduce flood risk throughout a river system. Increasing capacity can alter floodwater routing and timing, potentially lowering local water levels while increasing downstream flows or peaks. Outcomes depend on the flood hydrograph, channel geometry, floodplain storage, tributary inflows and downstream boundary conditions.

Saad and Habib (2021), modelling the Vermilion River in southern Louisiana, found that substantial flood-stage reductions required extensive dredging and changes to the longitudinal channel slope. These scenarios also increased the amplitude and inland propagation of the Gulf tidal wave. Less extensive dredging provided more limited mitigation and increased downstream flood exposure under some scenarios, demonstrating that effectiveness depends on the wider hydraulic system.

Floodplains and connected wetlands also store water temporarily, influencing downstream flood peaks and timing. Dadson et al. (2017) discussed how channel modification can lower local water levels while increasing downstream flood hazard, emphasizing the importance of sediment transport and channel stability.

Dredging does not invariably increase downstream flooding; effects are site-specific and require hydraulic assessment. Nevertheless, evaluations should extend beyond the excavation site to compare baseline and post-dredging water levels, flood-wave timing and inundation at relevant upstream and downstream locations.

5.4 Lessons from River-Dredging Experience and Channelization

The United Kingdom's winter floods of 2013–2014 illustrate the difficulty of attributing flood outcomes to channel maintenance alone. Persistent rainfall, storms and coastal conditions contributed to the events and renewed debate about dredging and flood-defense investment. Thorne (2014) examined the geographical and

political dimensions of these floods, highlighting the need to consider multiple causes rather than attribute losses to a single management intervention.

Dadson et al. (2017) similarly discussed the hydraulic and sedimentary consequences of channel modification. Enlarging or straightening channels may lower local water levels but increase downstream hazards by accelerating floodwater passage. Such changes may also disrupt sediment continuity, initiate erosion or deposition, and increase maintenance requirements.

These findings do not exclude dredging from flood-management programmes. Where sediment accumulation at a controlling section materially raises flood stages, excavation may help. Where flooding is dominated by extreme runoff, downstream backwater or insufficient floodplain storage, dredging alone may offer limited relief or adversely affect other locations. A catchment-based assessment should therefore compare dredging with floodplain restoration, upstream storage, drainage improvements and other suitable interventions.

5.5 Identifying Where Dredging Is Hydraulically Justified

Sediment presence alone does not justify dredging. An intervention requires evidence that deposition materially contributes to flooding and that excavation can improve hydraulic performance without unacceptable consequences elsewhere.

Bathymetric surveys and channel cross-sections should establish the location, extent and geometry of sediment accumulation. Water-level and discharge observations can help determine its hydraulic significance, while modelling can compare dredging configurations under different channel depths, slopes, roughness values, downstream levels and floodplain connections. Tidal conditions and sediment import should also be represented in coastal and estuarine settings.

Post-dredging surveys are needed to determine whether the intended geometry persists and how quickly sediment returns. Where flood-risk transfer is plausible, assessment should include downstream water levels and flood-wave behavior, alongside comparisons with alternative interventions.

Dredging is most defensible when sediment-related conveyance loss is a demonstrated flood mechanism, excavation provides a measurable benefit, downstream consequences are acceptable and the resulting channel can be maintained under plausible future conditions. This evidence-based approach supports the integration of dredging with environmental protection; beneficial sediment use and wider flood-risk management.

6.0 EVIDENCE FOR DREDGING AS A FLOOD-MITIGATION INTERVENTION

6.1 Riverine Dredging

Dredging may reduce flood levels where sediment accumulation materially restricts channel conveyance. Its effectiveness depends on channel geometry, excavation extent, tributary inflows, floodplain connectivity and downstream conditions. Increased conveyance alone does not establish a reduction in flood risk across the catchment. Using a hybrid one-dimensional and two-dimensional hydrodynamic model, Saad and Habib (2021) found that extensive dredging of the Vermilion River in southern Louisiana reduced flood stages but increased the amplitude and inland propagation of the Gulf tidal wave. Less extensive dredging provided smaller water-level reductions and increased downstream exposure under some scenarios. Changes in peak inundation extent did not necessarily correspond to changes in water level, although inundation duration was substantially reduced. Flood stage, inundation extent and duration must therefore be assessed separately.

Following the United Kingdom's winter floods of 2013–2014, the House of Commons Environment, Food and Rural Affairs Committee (2014) concluded that dredging could assist flood management but was not a standalone solution. Dredging the Parrett and Tone rivers in Somerset might have accelerated drainage while

having limited effects on flood height and extent. Its justification consequently depends on demonstrated hydraulic benefits, downstream effects, environmental constraints and sediment reaccumulation.

6.2 Urban Drainage Channels and Canals

Dredging and desilting can restore the effective capacity of urban drains, canals and engineered waterways where sediment and obstructions restrict flow. However, benefits may be limited when flooding results from intense rainfall, impermeable surfaces, restricted culverts, inadequate drainage, pumping constraints or insufficient storage.

Mignot and Dewals (2022) highlighted interactions between drainage infrastructure and surface-flow pathways in urban flood modelling. Consequently, clearing one channel may provide limited relief if downstream outfalls remain restricted or runoff exceeds network capacity. Baseline and post-maintenance surveys, water-level records and observations during rainfall events can help establish whether drainage performance has improved.

Huang et al. (2020) reviewed nature-based solutions for urban pluvial flood management, including green infrastructure that reduces runoff and provides temporary storage. Combining channel maintenance with appropriate infiltration, retention and nature-based measures may offer a more comprehensive response than desilting alone, depending on local drainage conditions.

6.3 Coastal and Estuarine Dredging

Coastal and estuarine dredging must account for interactions among river discharge, tides, storm surges, sea-level rise and sediment exchange. Channel deepening may improve conveyance but can also alter tidal propagation, sediment import and exchanges with adjacent wetlands, affecting flood levels beyond the dredged reach.

Saad and Habib (2021) found that dredging in the Vermilion River reduced water-surface elevations while increasing tidal-wave amplitude and inland propagation, with changes also affecting river–swamp exchanges. Cox et al. (2022) showed that dredging and sea-level rise can interact to increase channel migration, sediment import and maintenance requirements under particular estuarine conditions.

Hydraulic or hydrodynamic assessments should therefore represent river flows, tides, downstream water levels and relevant sediment processes. Changes in river stage, tidal amplitude, inundation and downstream exposure should be evaluated separately. Greater channel depth alone does not demonstrate reduced coastal or estuarine flood risk.

6.4 Floodplain Management and Alternative Interventions

Dredging should be compared with measures that manage floodwater beyond the main channel, including floodplain restoration, wetland conservation, retention basins and catchment management. These interventions can influence runoff, storage and floodwater timing, complementing dredging where several mechanisms contribute to risk.

Opperman and Galloway (2022) discussed the environmental and societal benefits of nature-based flood-management solutions. Verweij et al. (2021), examining the Dutch Room for the River programme, highlighted the importance of integrating flood interventions with spatial planning and institutional coordination.

Neither dredging nor nature-based measures are universally superior. Options should be compared according to the dominant flood mechanism, expected hydraulic benefits, downstream effects, environmental consequences and maintenance requirements. Dredging may be appropriate where sediment is the principal

restriction, whereas runoff, downstream water levels or inadequate storage may require other or complementary interventions.

6.5 Distinguishing Demonstrated Benefits from Unverified Claims

Hydraulic calculations and modelling can establish potential changes in conveyance and water levels under specified conditions, but actual flood outcomes depend on downstream controls, floodplain exchanges, tributary inflows and the wider river system. Long-term performance also depends on sediment reaccumulation, environmental effects and maintenance.

A reduction in water-surface elevation does not necessarily represent an equivalent reduction in flood risk, which also depends on inundation extent and duration, exposure, vulnerability and flood-wave timing. Likewise, achieving a target dredging volume demonstrates work completed, not flood reduction.

Evaluation should compare baseline and post-dredging conditions using defined indicators, including water levels at specified discharges, peak flood depth, inundation extent and duration, downstream levels and sediment-reaccumulation rates. Modelled outcomes should be compared with observations where data permit. Without project-level hydraulic evidence, claims should be restricted to documented channel changes or plausible mechanisms.

Dredging can contribute to flood mitigation under suitable hydraulic and geomorphological conditions, but its effectiveness is not guaranteed. Site-specific assessment, comparison with alternatives and monitoring are essential to integrate dredging responsibly with environmental protection, beneficial sediment use and climate-resilient flood-risk management.

7.0 ENVIRONMENTAL IMPLICATIONS, BENEFICIAL USE AND LIFE-CYCLE IMPACTS OF DREDGING

7.1 Turbidity, Sediment Plumes and Water Quality

Dredging disturbs bed sediments and increases suspended sediment concentrations. Plume extent and duration depend on grain size, sediment cohesion, dredging technique, water depth, currents and settling rates; fine particles may remain suspended longer and affect areas beyond the excavation site.

Spearman (2015) reviewed sediment dispersion associated with aggregate dredging and showed that plume behaviour depends on sediment characteristics, release mechanisms and hydrodynamic conditions. Elevated turbidity can reduce light penetration, affect primary production and alter aquatic habitats. Deposition may smother benthic organisms, while resuspension of contaminated sediments can release pollutants. Impacts depend on their intensity, duration and the sensitivity of the receiving ecosystem. Environmental monitoring should therefore establish baseline turbidity and suspended sediment concentrations, measure changes during dredging, and assess recovery afterwards.

7.2 Benthic Habitats and Aquatic Ecosystems

Dredging can remove riverbed or seabed habitats, displace benthic organisms, deposit disturbed sediment and alter local hydrodynamic conditions. The extent of damage and recovery depends on habitat type, sediment properties, dredging intensity and ecosystem sensitivity.

Erftemeijer and Lewis (2006) identified direct habitat removal, burial, turbidity and sediment deposition as major pathways of dredging impacts on seagrasses. Erftemeijer et al. (2012) similarly showed that coral responses to dredging and sediment disturbance depend on exposure and local environmental conditions.

Although these studies concern marine ecosystems, they demonstrate the need to assess impacts in relation to the receiving habitat rather than the volume of sediment removed alone.

Environmental management should identify sensitive habitats before excavation and apply appropriate controls, including restrictions on dredging location and timing, plume monitoring and post-dredging ecological assessment. Where substantial habitat damage is likely, alternative methods or excavation boundaries should be considered.

7.3 Contaminated Sediments and Management of Dredged Material

Sediments in rivers, ports and estuaries may contain contaminants from industrial discharges, urban runoff and wastewater. Dredging can resuspend or redistribute these contaminants, depending on sediment chemistry, contaminant mobility, hydrodynamics and handling practices.

Manap and Voulvoulis (2015) highlighted the environmental-management challenges of dredged sediments, particularly in developing countries where data and management capacity may be limited. Carreira et al. (2025) further emphasized that beneficial use depends on sediment characteristics, contaminant concentrations and, where necessary, treatment.

Sediment quality should therefore be assessed before disposal, placement or reuse where contamination is plausible. Testing may include grain-size distribution, organic content and contaminant concentrations, selected according to sediment origin and intended use. Contaminated material may require treatment, restricted placement or alternative management. Reuse should not be considered environmentally beneficial if it exposes sensitive receptors to unacceptable risks.

7.4 Beneficial Use of Dredged Sediment

Where its physical, chemical and environmental properties are suitable, dredged sediment can support coastal nourishment, wetland restoration, habitat creation, land reclamation and selected construction applications. Such uses may reduce disposal requirements and demand for alternative raw materials, but their benefits depend on material suitability, treatment, transport and placement impacts.

Suedel et al. (2022) documented the use of dredged sediment for coastal-marsh restoration, while Carreira et al. (2025) reviewed beneficial-use options for marine dredged sediment, emphasizing sediment characteristics, treatment requirements, environmental conditions and regulatory constraints. Fratini et al. (2025) also reviewed beneficial uses across marine, river and lagoon environments, identifying resource-recovery opportunities alongside the need for further practical assessment.

Beneficial use should therefore follow sediment characterization and assessment of the intended application. Potential environmental gains must be weighed against processing, transport, placement and monitoring requirements. Material that is unsuitable for a proposed use should be directed to an appropriate alternative rather than reused solely to avoid disposal.

7.5 Life-Cycle Environmental and Economic Implications

The environmental footprint of dredging extends beyond excavation to include fuel and energy consumption, sediment transport, dewatering, treatment, temporary storage, placement and disposal. These activities contribute to emissions, resource use and costs. Consequently, a dredging project that improves channel conveyance may still have a substantial environmental footprint, particularly where frequent maintenance, long-distance transport or energy-intensive treatment is required.

Svensson et al. (2022) assessed dredged-sediment management options by combining life-cycle assessment with environmental and economic evaluation, demonstrating the importance of comparing complete

management pathways rather than excavation or disposal in isolation. Ferrans et al. (2022) similarly applied life-cycle assessment to dredged-sediment management scenarios, showing that treatment and placement choices influence environmental performance.

Life-cycle evaluation should therefore consider the entire sediment-management chain, including excavation, transport, treatment, reuse or disposal, and recurring maintenance. Comparing alternative scenarios can identify options that balance hydraulic performance, environmental impacts and cost over the intervention's useful life.

7.6 Integrating Environmental Protection with Dredging Decisions

Dredging decisions should integrate hydraulic objectives with sediment quality, ecological sensitivity, beneficial-use opportunities and life-cycle implications. The volume of sediment removed or the increase in channel capacity alone cannot establish whether an intervention is environmentally sustainable. Assessment should consider the effects of sediment disturbance, habitat impacts, contaminant mobilization, transport requirements and the likelihood of repeated excavation.

Where sediment is suitable, beneficial reuse may reduce disposal demand and support restoration or resource-recovery objectives. However, reuse must be supported by material characterization and assessment of the intended application. Where contamination or ecological sensitivity creates unacceptable risks, treatment, restricted placement, alternative methods or a different intervention may be more appropriate.

Environmental monitoring and post-dredging assessment should accompany hydraulic performance evaluation. This integrated approach allows decision-makers to determine whether dredging provides a defensible flood-management benefit without overlooking environmental costs or longer-term sediment-management requirements.

8.0 INTEGRATED FLOOD-RISK MANAGEMENT AND THE PROPOSED EVALUATION FRAMEWORK

8.1 Integrating Dredging with Wider Flood-Risk Management

Dredging should form part of an integrated flood-risk management strategy rather than be treated as a universal solution. Its suitability depends on whether sediment accumulation materially restricts conveyance, whether excavation improves hydraulic performance, and whether downstream and environmental consequences remain acceptable.

Opperman and Galloway (2022) highlighted the potential of nature-based solutions to reduce flood risk while providing wider environmental benefits. Verweij et al. (2021), examining the Dutch Room for the River programme, demonstrated the importance of coordinating flood management with spatial planning and institutional arrangements.

An integrated strategy comprises five interacting layers: catchment management to influence runoff, erosion and sediment supply; channel and sediment management to address conveyance restrictions; floodplain and storage management to accommodate floodwater; coastal boundary management to account for tides, storm surges and sea-level rise; and risk management through forecasting, early warning, land-use planning and emergency preparedness. Their combination should reflect local flood mechanisms, downstream controls and maintenance requirements.

Figure 2 presents the integrated flood-risk management framework developed from the preceding discussion. It positions dredging within a broader set of complementary measures, emphasizing that sustainable flood-

risk reduction requires coordination between channel and sediments management, catchment management, floodplain and storage management, coastal boundary and flood-risk- planning and management.



Figure 2: Integrated flood-risk management framework showing dredging within a coordinated portfolio of flood-management measures.

8.2 Minimum Evidence Requirements for Dredging Projects

Dredging projects require baseline data against which post-intervention performance can be assessed. Essential evidence includes channel geometry, sediment distribution and characteristics, water levels, discharge, and relevant rainfall and flood records. Bathymetric surveys should establish whether sediment accumulation coincides with a hydraulic restriction, while downstream water levels are particularly important in tidal and backwater-controlled systems.

Where feasible, hydraulic models should be calibrated using observations and applied to alternative dredging geometries, considering design discharges, roughness, downstream conditions, floodplain connectivity and plausible future hydrological conditions. Post-dredging surveys and subsequent monitoring should establish whether the intended geometry was achieved and whether sediment reaccumulation reduces the initial benefit. The minimum evidence framework is summarized in Table 2.

Table 2: Minimum evidence framework for evaluating dredging performance

Performance dimension	Minimum indicators	Preferred evidence	Purpose
Channel geometry	Bed elevation, cross-sectional area and dredged volume	Pre- and post-dredging bathymetric surveys and cross-sections	Establish whether the intended geometry was achieved
Hydraulic performance	Water-surface elevation at a specified discharge and relevant conveyance indicators	Calibrated hydraulic model supported by observed levels and discharge	Determine whether excavation changes the hydraulic response

Flood outcomes	Flood depth, inundation extent and duration, and overtopping where relevant	Event observations and/or modelled flood scenarios	Establish whether hydraulic changes translate into flood-risk benefits
Sediment dynamics	Bed-level changes, sediment characteristics and reaccumulation rate	Repeated bathymetric surveys and sediment sampling	Evaluate intervention durability
Environment	Turbidity, suspended sediment concentration (SSC), relevant contaminant levels and habitat indicators	Baseline, operational and post-dredging monitoring	Assess environmental disturbance and recovery
Sustainability	Fuel and energy use, transport distance, treatment requirements and beneficial-use rate	Project records and, where feasible, life-cycle assessment	Evaluate the wider environmental footprint
Maintenance	Frequency and volume of repeat dredging	Multi-year monitoring and maintenance records	Establish long-term operational requirements

Note. RTK means real-time kinematic positioning; MBES, multibeam echosounder; SBES, single-beam echosounder; and SSC, suspended sediment concentration. Survey methods should suit the channel dimensions, water depth, required accuracy and available equipment. Project-specific monitoring thresholds should be defined using baseline conditions, applicable environmental requirements and intended hydraulic targets.

The framework distinguishes completion of excavation from demonstrated flood-risk reduction. Achieving a target dredged volume does not establish that flood levels or inundation have decreased.

8.3 Decision Criteria for Selecting Dredging

Dredging should be selected through comparison with alternative interventions against hydraulic, environmental, economic and operational criteria. Sediment presence alone is insufficient justification; its contribution to the flood mechanism must first be established. Targeted excavation, broader dredging, no intervention and complementary measures should be compared using appropriate hydraulic assessments.

Evaluation should consider changes in water levels, flood depth, inundation extent and duration, downstream effects, future climate conditions, sediment reaccumulation, environmental disturbance, costs and monitoring feasibility. Azhar et al. (2025) highlighted the importance of assessing adaptation measures across different dimensions of performance and implementation.

No single indicator is sufficient. Reduced water levels may not translate into substantial flood-risk benefits, just as a large dredged volume does not demonstrate successful mitigation. The preferred option should address the dominant flood mechanism while providing the most defensible overall outcome under the relevant environmental and operational constraints.

8.4 Circular Sediment Management and Beneficial Use

Sediment management should be planned before excavation. Suitable material may support wetland restoration, habitat creation, shoreline nourishment and selected construction applications, reducing disposal requirements and potentially replacing newly extracted materials.

Carreira et al. (2025) emphasised matching dredged sediment characteristics to its intended use. Grain size, moisture content, organic matter, salinity, engineering properties and contaminant concentrations should be

assessed as relevant. Material that fails the requirements of a proposed application should not be reused without appropriate treatment and verification.

Transport distance, treatment, energy consumption and the availability of suitable receiving sites also influence the value of reuse. A sediment-management plan should identify the proposed placement or reuse route, applicable quality requirements and monitoring arrangements. Environmental or resource-recovery benefits should be demonstrated through comparison of realistic alternatives rather than assumed simply because reuse occurs.

8.5 Monitoring, Verification and Adaptive Management

Monitoring must continue beyond dredging to establish whether hydraulic benefits persist. Initial surveys should verify the achieved geometry, while subsequent surveys should measure bed-level changes and sediment accumulation. Where feasible, water-level and discharge observations during relevant flow events should test whether the expected hydraulic response has occurred.

Environmental monitoring should address relevant impact pathways, including turbidity, suspended sediment, contaminants and habitat recovery. Any thresholds should specify measurement methods, units, reference conditions and the responses required when limits are exceeded.

Monitoring results should guide maintenance and operational decisions. Rapid sediment reaccumulation may require addressing sediment sources, modifying the dredging design or adopting complementary measures. Where benefits are small or adverse downstream effects emerge, the intervention should be reconsidered rather than continued solely because excavation targets were achieved.

8.6 Proposed Eight-Stage Climate-Resilient Dredging Framework

A climate-resilient dredging programme can be organized into eight stages:

1. Diagnose the flood mechanism: Establish whether sediment-related conveyance loss materially contributes to flooding, alongside runoff, backwater and floodplain constraints.
2. Establish the baseline: Survey channel geometry, sediment characteristics, hydraulic controls, water levels, discharge and environmental receptors.
3. Define measurable performance targets: Specify intended changes in water level, flood depth, inundation extent or duration.
4. Test alternative interventions: Compare existing conditions with targeted dredging, broader excavation, no dredging and appropriate complementary measures.
5. Design sediment management: Determine sediment quantity and quality, suitable reuse or placement options, and treatment and disposal requirements.
6. Implement environmental controls: Establish operational restrictions, monitoring requirements, environmental thresholds and responses to unacceptable impacts.
7. Verify performance: Repeat bathymetric and hydraulic measurements and assess results against performance targets, downstream effects and environmental outcomes.
8. Adapt maintenance and management: Use monitoring to determine whether dredging should be repeated, modified, supplemented or replaced.

The eight-stage process is summarized in Figure 3, which links flood-mechanism diagnosis, baseline assessment, option appraisal, implementation and performance verification to adaptive management. The feedback connection indicates that monitoring results should inform subsequent assessment and maintenance decisions, allowing the intervention to be modified when its intended performance is not sustained.

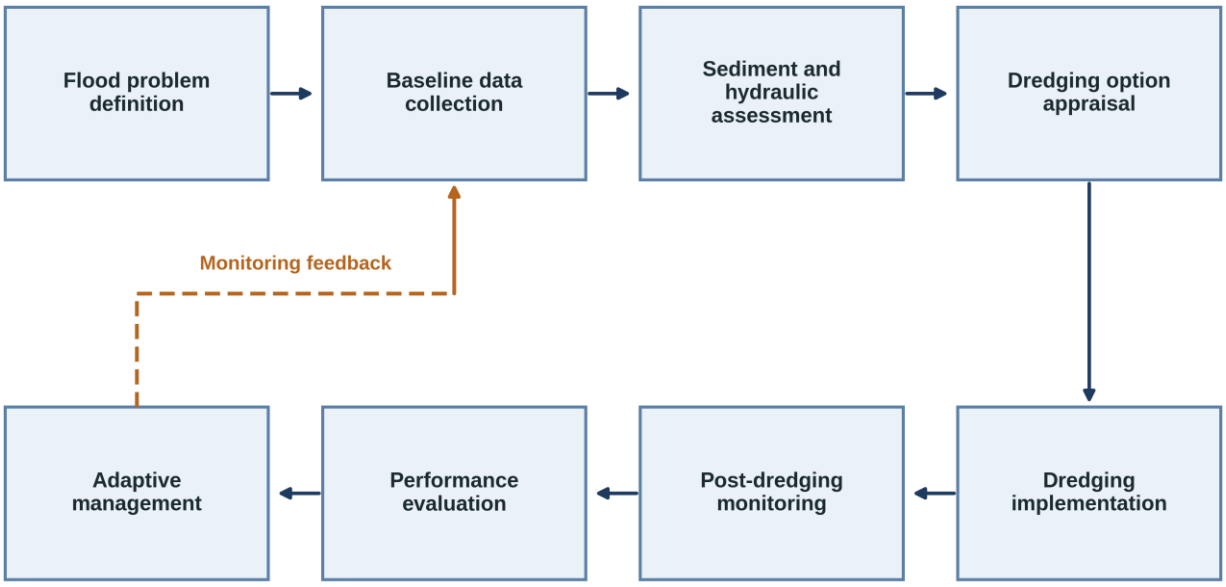


Figure 3: Eight-stage framework for planning, implementing, monitoring and adapting dredging interventions for flood-risk management.

The framework connects flood diagnosis, baseline assessment, option appraisal, sediment management, environmental protection and performance verification with adaptive management. It is a decision-support structure, not a universal prescription; implementation should reflect the river system, available data, intervention scale and institutional capacity.

8.7 Implications for Nigeria and Comparable Contexts

Nigerian rivers, urban drains and coastal waterways experience different combinations of rainfall-driven runoff, sediment accumulation, drainage constraints and downstream water-level influences. A single dredging strategy is therefore inappropriate across all settings.

Project monitoring should include georeferenced channel surveys, water-level observations, representative discharge measurements where feasible, sediment characterization, dredged-volume reconciliation and post-dredging assessment. Environmental observations and sediment-placement records should also be included where relevant.

Where evidence is insufficient to establish flood-risk reduction, claims should be limited to documented outcomes, such as sediment removal or restoration of a specified channel geometry. Claims of reduced flood risk require evidence connecting these activities to measurable changes in flood conditions. Dredging should consequently be planned as one component of integrated flood-risk management, justified by the local flood mechanism and evaluated through hydraulic, environmental and maintenance evidence.

9.0 IMPLICATIONS FOR NIGERIA, RESEARCH GAPS AND LIMITATIONS

9.1 Implications for Nigeria

Dredging for flood-risk reduction in Nigeria must reflect differences in river hydraulics, sediment dynamics, drainage infrastructure, floodplain development and coastal influences. These differences make a uniform dredging strategy inappropriate.

Umar and Gray (2023) highlighted limitations in Nigerian flood data and modelling, reinforcing the need for baseline channel surveys, water-level and discharge observations, and sediment characterization. Ani et al. (2024) demonstrated the value of spatially assessing flood susceptibility and exposure in the Lower Niger Basin. However, susceptibility mapping alone cannot establish dredging effectiveness; hydraulic measurements or modelling are needed to determine whether excavation changes water levels, inundation extent or flood duration.

Coastal and low-gradient waterways require particular attention to tides, downstream water levels and floodplain interactions. Saad and Habib (2021) showed that dredging outcomes in a low-gradient coastal river depended on excavation extent, channel slope and downstream conditions. Their findings identify mechanisms relevant to investigating comparable Nigerian settings, but do not establish that identical outcomes would occur there.

Dredging should therefore be justified through site-specific evidence. Where sediment accumulation materially restricts conveyance, excavation may be appropriate if downstream, floodplain and environmental effects are acceptable. Where runoff, inadequate drainage or backwater dominates, alternative or complementary measures may be necessary.

9.2 Research Gaps and Future Research Priorities

Sediment transport and channel adjustment remain insufficiently integrated into some flood-hazard assessments. Vázquez-Tarrío et al. (2024) and Hamidifar et al. (2024) highlighted the importance of sediment dynamics and fluvial processes in flood analysis. Further research should examine how sediment supply, erosion, deposition and channel adjustment influence both the initial benefits and long-term performance of dredging.

Research is also needed to establish when increased local conveyance reduces overall flood impacts and when it alters flood-wave timing or downstream exposure. Building on Saad and Habib (2021), comparative modelling should examine different channel gradients, geometries, floodplain connections, tributary inflows and downstream boundary conditions. Outcomes should include water levels, peak discharge, inundation extent and duration at upstream and downstream locations.

Longitudinal studies using repeated bathymetric surveys, sediment measurements and water-level observations are needed to quantify sediment reaccumulation, the persistence of hydraulic benefits and long-term maintenance requirements.

In Nigeria, project-level studies should connect dredging operations with measured flood outcomes through pre- and post-dredging surveys, discharge and water-level records, sediment characterization and flood-event monitoring. This would address data and modelling limitations identified by Umar and Gray (2023) and complement the spatial flood-risk assessment demonstrated by Ani et al. (2024).

Consistent performance indicators are also required. Dredged volume, excavation length and achieved bed elevation document project outputs but do not independently demonstrate reduced flood risk. Studies should report water levels at specified discharges, flood depth, inundation extent and duration, downstream effects and sediment reaccumulation. Finally, combining hydraulic assessment with ecological monitoring, life-cycle assessment and economic analysis would enable more comprehensive comparisons of dredging, beneficial sediment reuse and alternative flood-management measures.

9.3 Limitations of the Review

This critical narrative review is not a systematic review or meta-analysis; therefore, it may not cover all relevant publications and provides no pooled estimate of dredging effectiveness. The reviewed studies differ

in hydraulic conditions, sediment characteristics, modelling methods and performance measures, limiting direct comparison and transferability. In particular, Saad and Habib (2021) demonstrate possible hydraulic responses and trade-offs in a specific coastal river, not proven outcomes for Nigerian rivers.

The Section 4 calculations are illustrative and based on stated assumptions, not field measurements. The review presents no new field data, original hydraulic simulations, project-specific environmental assessment or quantitative life-cycle assessment. Its conclusions therefore identify the conditions and evidence needed to justify dredging rather than establish the effectiveness of a specific project. Site-specific monitoring and further empirical research, particularly in Nigeria, remain necessary.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

This review establishes that dredging can contribute to flood-risk reduction where sediment accumulation materially restricts channel conveyance and its removal produces a demonstrable hydraulic benefit. However, the magnitude of that benefit depends on channel geometry, roughness, energy slope, downstream controls and floodplain interactions. Increased channel depth or cross-sectional area alone does not establish reduced flood risk across the wider river system.

Hydraulic calculations demonstrate that excavation can increase theoretical conveyance under specified uniform-flow conditions, but backwater and tidal influences may limit reductions in upstream water levels. Sediment supply, erosion and deposition can also diminish initial benefits, alter flood-wave propagation and increase maintenance requirements.

Evidence from riverine, urban drainage, coastal and estuarine settings supports a conditional rather than universal role for dredging. Where flooding is dominated by extreme runoff, inadequate storage or elevated downstream water levels, complementary measures such as drainage improvement, floodplain management and catchment interventions may be necessary.

Environmental considerations are equally important. Dredging can disturb habitats, increase suspended sediment and mobilize contaminants, while appropriate beneficial reuse may reduce disposal demand and support resource recovery. Its overall value therefore depends on hydraulic performance, environmental acceptability and long-term maintenance.

The review's principal contribution is an evidence-based framework for deciding when dredging is justified and evaluating its hydraulic, environmental and long-term performance. Decisions should be guided by measurable outcomes rather than excavation targets alone.

10.2 Recommendations

1. Dredging projects intended to reduce flood risk should begin with a diagnosis of the dominant flood mechanism, supported by bathymetric surveys, channel cross-sections, water-level and discharge observations, and sediment characterization. Hydraulic assessments should compare existing conditions with alternative dredging configurations and suitable non-dredging interventions, using appropriate hydraulic or hydrodynamic modelling where backwater, tidal or floodplain interactions are significant.
2. Project performance should be evaluated using measurable flood outcomes, including water-surface elevation, flood depth, inundation extent and duration, and downstream conditions, rather than relying solely on dredged volume or achieved channel depth. Sediment quality, ecological sensitivity, transport, treatment, placement and beneficial reuse should be incorporated into project planning to minimize environmental impacts and improve resource recovery.

3. Post-dredging monitoring should establish whether the intended channel geometry is maintained, sediment reaccumulates and anticipated hydraulic benefits persist. Where benefits are limited or downstream consequences are unacceptable, the intervention should be modified or supplemented with appropriate measures. In Nigeria, priority should be given to long-term, project-level research linking dredging activities to measured flood outcomes across riverine, urban drainage and coastal settings, enabling more reliable comparisons with alternative flood-management strategies.

ACKNOWLEDGEMENTS AND DECLARATIONS

Funding: No external funding was received for this review.
Conflict of interest: The authors declare that they have no competing interests.
Data availability: No new primary dataset was generated. The review is based on published literature and secondary sources.
Ethics approval: Not applicable.
Author contributions: Tonbra Akina Ojujoh contributed to the conceptualization, literature identification and review, and manuscript drafting. MaryAnn O. Ezugwu contributed to literature identification and review, manuscript drafting, and proofreading. Both authors should confirm their contributions and approve the final manuscript before submission.

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