A Review of Modular Temporary Road Dividers with Integrated Rainwater Harvesting and Storage

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***Abstract*—Temporary Road dividers are widely employed to guide vehicles and pedestrians in work zones and controlled environments. Separately, rainwater harvesting uses engineered catchments, filtration and storage to conserve runoff. This review examines the feasibility of combining these functions in a lightweight, interlocking divider that collects rainfall and stores it as supplementary water ballast. Government guidance and documented water-filled channelizers are compared with rainwater-harvesting principles to identify design requirements for structural stability, collection efficiency, maintenance and safe use. A preliminary example based on a 0.30 m² catchment, 50 mm rainfall and an assumed 0.80 collection coefficient yields 12 L, illustrating both the potential and the small scale of capture. The synthesis suggests that an integrated divider merits prototype testing in low-speed controlled settings, while its rainwater collection cannot be assumed to deliver impact protection or potable water. No experimental performance is claimed.**

***Index Terms*—Modular Road divider, rainwater harvesting, temporary traffic channelization, water ballast, water storage.**

I. INTRODUCTION

Temporary traffic-control equipment must be visible, portable and adaptable to changing road layouts. Concrete dividers are durable but heavy, while hollow polymer channelizers can be transported empty, linked at their ends and filled on site. The Federal Highway Administration (FHWA) describes longitudinal channelizing devices (LCDs) as connected delineation devices, rather than automatically crashworthy traffic barriers [1], [2].

Rainwater harvesting generally involves a catchment, conveyance path, pretreatment and storage. The Central Ground Water Board (CGWB) identifies site conditions, hydraulic design and maintenance as central considerations [3]. A small infrastructure element such as a road divider offers a much smaller catchment than a roof, but it may still intercept some rainfall and store the water within an existing hollow enclosure. The present review evaluates the proposed combination of a modular road divider and rainwater-storage chamber. Its purpose is to synthesize documented practice, explain design trade-offs and identify measurable research gaps. The concept is intended for traffic guidance in controlled, low-speed environments, not as an independently approved highway impact barrier.

II. REVIEW OF EXISTING SYSTEMS

A. Temporary traffic channelization

Temporary traffic channelization is an important element of work-zone management because it establishes recognizable vehicle movement paths and separates traffic from areas undergoing maintenance or construction. The Federal Highway Administration (FHWA) describes longitudinal channelizing devices as interconnected, highly visible and deformable traffic-guidance elements. The Manual on Uniform Traffic Control Devices (MUTCD) permits the use of hollow water-ballasted units while distinguishing their channelization function from the protective performance of crash-tested temporary barriers [1].

The FHWA's technical publication on longitudinal channelizing devices identifies modular continuity, field installation flexibility and improved delineation as important operational characteristics [2]. Nevertheless, its guidance highlights the possibility of vehicle penetration, water release during an impact and complications associated with the removal or disposal of ballast water. These observations indicate that increasing the mass of a lightweight divider does not independently establish its ability to safely resist vehicle impact. Finley and colleagues [3] examined

the operational effectiveness of longitudinal channelizing devices under different work-zone configurations. Their investigation considered merging tapers, exit ramps and urban access locations. The findings show that a channelizing arrangement's effectiveness depends on roadway geometry, device placement, driver visibility, and the specific traffic-control application. Consequently, you cannot determine a modular divider's suitability solely from its physical dimensions or interlocking configuration.

FHWA guidance on roadside safety hardware [4], together with implementation guidance concerning the Manual for Assessing Safety Hardware [5], further emphasizes the distinction between an ordinary traffic channelizer and an impact-tested protective system. For the present application, a hollow polymer divider incorporating rainwater storage should therefore be considered a temporary channelizing device unless its complete configuration undergoes the necessary safety evaluation.

B. Water-ballasted modular constructions

Rainwater harvesting represents a decentralized approach to managing localized water availability and reducing uncontrolled surface runoff. The Central Ground Water Board [6] identifies rainfall assessment, catchment characteristics, conveyance, storage and maintenance as essential considerations in designing harvesting arrangements. These principles provide a technical basis for evaluating small infrastructure-based collection systems, although they were primarily developed for established harvesting and groundwater-recharge applications.

Campisano and colleagues [7] presented a comprehensive review of urban rainwater harvesting practices, examining technical performance, implementation challenges and opportunities for multifunctional systems. Their synthesis indicates that rainwater harvesting should be evaluated beyond volumetric water savings by considering stormwater management and broader infrastructure performance. This approach is particularly relevant to a road divider in which stored rainwater would serve both as a supplemental water resource and as ballast.

Zabidi and colleagues [8] evaluated roof- and pond-based rainwater harvesting systems, identifying collection efficiency, storage capacity, site conditions and operational maintenance as important determinants of system effectiveness. Similarly, Bañas and colleagues [9] reviewed the design and sustainability of roof-catchment stormwater harvesting arrangements, demonstrating the need to integrate collection-system geometry, water-quality control and downstream storage requirements. Although these studies focus on larger or conventional catchments, their principles can be adapted to the substantially smaller collection surface available on a modular road divider.

C. Rainwater harvesting and pretreatment

Fewkes [10] investigated the performance of rainwater collection systems using behavioural modelling approaches that account for variations in rainfall and storage conditions. Fewkes and Butler [11] subsequently examined the influence of time-step selection, storage capacity and operating rules on model accuracy. Their analyses suggest that the prediction of usable rainwater yield requires more than a simplified estimate based on average annual rainfall. Fewkes and Wam [12] extended performance modelling across different geographical locations and storage-demand configurations. These investigations collectively establish that rainfall distribution, dry intervals, storage capacity and water demand influence the operational reliability of harvesting systems. For a small road-divider reservoir, event-based calculations are particularly relevant because storage may be filled during an intense rainfall event while remaining partly empty during prolonged dry periods.

Amos, Rahman and Gathenya [13] reviewed the economic and technical feasibility of rainwater harvesting systems across different geographical and developmental contexts. Their findings indicate that project viability depends on local rainfall conditions, storage requirements, intended water applications and implementation cost. Their subsequent economic comparison [14] demonstrates the importance of evaluating system performance under location-specific constraints rather than assuming that harvesting arrangements provide equivalent benefits in all environments.

Ali, Zhang and Chandio [15] investigated the sensitivity of rainwater harvesting performance to changes in rainfall patterns. Their findings show that stormwater-control efficiency and water-supply reliability respond differently to rainfall variation, with system configuration and demand influencing the resulting performance. Research on dual-use

harvesting systems [16] similarly emphasizes the importance of considering both water-supply and event-based runoff-control metrics. These studies indicate that a rainwater-storing divider should be assessed through actual rainfall-event responses and storage behaviour rather than through nominal chamber capacity alone.

D. Rainwater Quality, Filtration and Storage Maintenance

The collection of rainwater from exposed infrastructure surfaces introduces additional concerns related to sediment, debris and water-quality deterioration. Gikas and Tsihrintzis [17] evaluated first-flush runoff and harvested rainwater quality through monitored collection installations. Their investigation established the practical importance of runoff-quality assessment and first-flush management within rainwater harvesting arrangements. Maniquiz-Redillas and colleagues [18] reviewed first-flush pollution in urban catchments, highlighting the relationship between surface contamination and the initial runoff generated during rainfall. Maykot, Vaz and Ghisi [19] further investigated first-flush characteristics and examined variations in water-quality parameters under different rainfall and antecedent weather conditions.

These findings support the integration of accessible debris screens, sediment-removal arrangements and appropriate inlet-maintenance procedures into the proposed divider. Lepcha and colleagues [20] reviewed rooftop harvesting as a supplementary water resource while recognizing the importance of water-quality management. For a roadside harvesting application, additional assessment is necessary because the collection surface may be exposed to traffic-related particulate matter and other pollutants. The presence of filtration components should therefore not be interpreted as evidence of potable water quality. Stored water should be restricted to suitable non-potable applications unless its quality is independently assessed against the requirements of the proposed use.

E. Sustainability and Integrated Infrastructure Performance

Research on rainwater harvesting sustainability has increasingly considered environmental, economic and operational benefits together rather than evaluating only the quantity of collected water. Studies of integrated harvesting systems demonstrate that decentralized storage can contribute to water conservation and localized runoff control, although the magnitude of these benefits is strongly dependent on system scale and operating conditions [21], [22].

Campisano and Lupia [23] introduced a dimensionless approach for evaluating water savings from urban rainwater harvesting systems.

Their methodology illustrates the importance of relating catchment area, storage provision and water demand when assessing system performance. Such relationships are relevant to an integrated road-divider design, where the available collection area is constrained by the divider geometry and traffic-guidance requirements. Reviews of urban stormwater management [24] also emphasize the importance of evaluating water quantity and quality together. In the present application, an integrated performance assessment should consider the amount of water captured, the operational effect of added ballast, overflow management, filtration requirements and maintenance effort. The engineering value of the proposed system therefore lies in its potential multifunctionality rather than in maximizing harvested water volume independently.

III. INFERENCES DRAWN FROM THE REVIEWED LITERATURE

The reviewed studies and technical guidelines establish several important relationships between traffic channelization, structural stability, rainfall collection and operational sustainability. The following inferences are derived from the combined literature rather than from completed experiments on the proposed prototype.

A. Functional integration and traffic safety

The findings of [1] [5] indicate that modular traffic-guidance systems provide advantages in portability, installation and configuration flexibility. However, their structural and impact performance must be evaluated separately. Integrating rainwater storage into a channelizing device may introduce a supplementary functional benefit, but the resulting system cannot be assumed to provide equivalent protection to a certified traffic safety barrier.

B. Influence of stored water on static stability

The literature on water-ballasted channelizers [2], [4] indicates that adding water increases the mass of a hollow unit. From a static mechanical perspective, water retained near the base may improve resistance to sliding or overturning, depending on the mass distribution, support geometry, interface friction and external loading. However, this benefit cannot be quantified without considering the position of the resultant centre of gravity and the forces acting on the complete assembly. Water-induced changes in static stability also do not demonstrate crashworthiness.

C. Effect of limited catchment area

The harvesting studies [7] [12] suggest that collection performance is strongly dependent on effective catchment area, rainfall characteristics and system losses. Since a road divider possesses a comparatively small horizontal projected area, rainwater harvesting is more appropriately considered a supplementary function than a primary water-supply application.

D. Dependence on rainfall distribution

Studies [10] [16] indicate that storage performance depends not only on total rainfall but also on rainfall intensity, event frequency, dry intervals and chamber capacity. Therefore, evaluating a divider using a single design rainfall event would be insufficient to establish year-round harvesting performance. A more representative assessment should account for multiple rainfall conditions and differences between collection, retention and overflow volumes.

E. Importance of filtration and maintenance

The investigations in [17] [20] indicate that runoff quality is affected by the accumulation and subsequent transport of contaminants from exposed surfaces. An integrated filtration assembly can reduce the entry of relatively large particles, but its effectiveness depends on the type of filter, sediment loading and maintenance interval. Consequently, the divider design should incorporate removable filtration elements, accessible cleaning points and controlled drainage. Water-quality testing is necessary before selecting reuse applications.

F. Sustainability and practical viability

The economic and environmental investigations [13], [14], [21] [24] show that technical functionality does not automatically establish financial or environmental sustainability. For the proposed system, the added costs of collection channels, fittings, filters, water storage and maintenance must be assessed against the potential benefits of temporary traffic guidance, reduced ballast-water requirements and limited rainwater recovery. Accordingly, evaluation should consider the combined performance of these functions rather than treating the stored water volume as the sole indicator of success.

IV. RESEARCH GAP IDENTIFICATION

The existing literature provides substantial technical information on temporary traffic channelization and rainwater harvesting as independent engineering systems. However, the reviewed sources provide comparatively limited evidence concerning the combined implementation of deliberate rainwater capture, internal storage and modular temporary traffic channelization within a single small-scale unit.

The principal research gaps identified from this review are described below.

A. Limited Evaluation of Integrated Dual-Function Divider Configurations

Existing studies on longitudinal channelizing devices [1] [5] primarily address traffic guidance, visibility, modular deployment and safety performance. Conversely, rainwater harvesting studies [6] [16] principally investigate catchment efficiency, storage behaviour and water-use potential.

The literature examined does not establish a validated performance framework specifically addressing a compact road divider designed to collect rainwater for storage and ballast. This represents an opportunity for a prototype-level investigation rather than evidence that no equivalent system has previously been developed.

B. Insufficient Experimental Evidence on Small-Catchment Harvesting

Most rainwater harvesting studies reviewed use roof surfaces, ponds or other dedicated collection areas. The hydraulic performance of a narrow, inclined divider surface may differ because of restricted projected area, runoff concentration, splash losses and inlet geometry.

Specific experimental relationships between rainfall intensity, surface inclination, inlet capacity and retained water volume require investigation for the proposed configuration. The resulting information would help establish whether harvesting performance is sufficient to justify the additional components.

C. Limited Characterization of Variable Water-Ballast Stability

Although water-filled channelizers are established traffic-management products, the reviewed research does not quantify the static stability of the proposed geometry under varying rainwater-fill levels.

The relationship between chamber fill level, centre-of-gravity position, base geometry and resistance to sliding or overturning therefore remains an important design-specific research requirement. Testing should examine the empty, partially filled and fully filled conditions without extrapolating static stability results to vehicle-impact protection.

D. Need for Integrated Water-Quality and Maintenance Assessment

Existing first-flush and runoff-quality studies [17] [20] demonstrate the significance of surface contamination and filtration. However, these findings cannot be applied directly to roadside storage chambers without considering localized dust deposition, traffic-related contaminants, sediment accumulation and stagnant storage conditions.

Evaluation of filter performance, cleaning accessibility, sediment deposition and water-quality suitability is therefore necessary before considering practical water reuse.

E. Absence of Validated Combined Performance and Feasibility Assessment

The literature establishes separate methods for assessing water harvesting, economic viability and traffic-control performance. However, their integration into one evaluation framework for the proposed divider remains insufficiently developed. A combined assessment should quantify water collection efficiency, storage retention, leakage, static stability, connection integrity, installation practicality and maintenance requirements. Such an approach would allow the benefits and limitations of the system to be evaluated in a technically defensible manner. The central research gap is the lack of configuration-specific experimental evidence and integrated evaluation methods for modular temporary traffic channelizers that deliberately collect and store rainwater while using the retained water as ballast.

The proposed work aims to address this gap through design development and controlled prototype-level assessment. Its contribution should be evaluated in terms of technical feasibility, measurable hydraulic performance, static stability, maintenance and suitability for low-speed traffic-guidance applications, rather than as a crash-protection system.

V. COMPARATIVE ANALYSIS

Conventional dividers and water-storage units solve different engineering problems. Table I summarizes the principal distinctions relevant to integrating both functions in a modular product.

Table I. Comparison of related approaches

System	Principal benefit	Key limitation
Concrete divider	Durability and mass	Difficult relocation
Plastic channelizer	Lightweight deployment	May need ballast
Water-filled LCD	Increased installed mass	Filling/drainage needs
Rainwater tank	Dedicated water retention	No traffic guidance
Integrated proposal	Two functions in one unit	Small capture; testing needed

The review indicates a conceptual opportunity, not proof of commercial novelty: the sources examined do not describe a directly equivalent small-scale rainwater-harvesting LCD, but other designs may exist. Integration also introduces trade-offs: the inlet creates potential leakage points, the filtration path needs upkeep, and rainfall-dependent ballast varies over time.

IV. PROPOSED DESIGN FRAMEWORK

A. Components and working principle

The proposed module consists of a hollow high-density polyethylene (HDPE) or comparable polymer body, a widened base, interlocking end joints and retroreflective markers. Rain falling on the inclined top travels through a collection channel and removable debris filter to an internal storage chamber. A lower outlet controls withdrawal, and a higher overflow

prevents overfilling. The chamber should be accessible for inspection and sediment removal.

A low water-storage position can reduce the centre of gravity, provided chamber geometry and filling conditions are appropriate. Compatibility of seals, fittings and the divider body must be assessed across expected weather and handling cycles. The design must not obstruct vehicle lanes, create unintended discharge across pedestrian routes or conceal leaks.

B. Rainwater collection estimate

A preliminary runoff estimate follows the common catchment relationship

$$V = R \times A \times C, \quad (1)$$

where V is collected volume in litres, R is event rainfall in millimetres, A is effective horizontal catchment area in square metres and C is a dimensionless collection coefficient. For R = 50 mm, A = 1.0 × 0.30 = 0.30 m² and an assumed C = 0.80, the estimated volume is 12 L. These are illustrative design assumptions from the project concept, not measured results. Splashing, blocked screens, evaporation, overflow and leakage may lower the collected quantity.

C. Evaluation requirements

The prototype should be evaluated at different water fill levels using repeatable tests. Water collection can be assessed by applying known rainfall volumes and comparing recovered volume with the theoretical estimate. Leak testing should monitor the chamber and joints over a specified duration. Static lateral-load tests should document sliding and overturning thresholds, while joint tests should record connection security during repeated assembly. Filter obstruction, outlet discharge, visibility and installation time are also relevant performance measures.

V. RESEARCH GAPS AND DISCUSSION

First, the rainfall catchment is modest. A practical design must establish whether the annual or event-level water yield justifies adding inlets and maintenance duties.

Second, runoff and ballast cannot be treated as independent functions: varying rainfall affects water mass, which influences static stability. An empty or partly filled module may behave differently from a completely filled one.

Third, water quality, drainage and stagnant storage require explicit controls. A documented reuse plan should define the intended non-potable application, minimum inspection frequency and criteria for rejecting contaminated water.

Fourth, a water-tight chamber and readily replaceable filter may conflict with the desire for simple, inexpensive manufacturing.

Lastly, no inference of crashworthiness should be drawn from the preliminary design. Indian Roads Congress guidance on traffic safety barriers [6] is relevant to broader roadway safety assessment but is not evidence of approval of this prototype.

Accordingly, future work should compare measured collection efficiency, storage losses, unit mass, stability and total lifecycle cost against ordinary water-ballasted channelizers. A multi-unit pilot in a controlled location would help evaluate operational durability, while any proposed public-road installation must be considered by the responsible road authority.

A. Engineering performance indicators

A useful performance framework should distinguish rainfall collection from stored volume. The former is the actual water transferred past the inlet during an event; the latter is the water remaining after losses and withdrawal. Measuring only the final tank level may mask overflow, pre-existing water or leakage. Collection tests should therefore report rainfall input, catchment area, initial storage, filtered inflow, final storage and any measured discharge. Repeated trials under simulated light and heavy rainfall would establish whether the screen or inlet restricts flow. Recording sediment accumulation would also reveal whether collection efficiency declines after repeated exposure.

For stability, an empty-module baseline is essential. Comparison should include dry, partial and full conditions, and should report applied lateral force, application height, base movement and visible deformation. A simple increase in mass need not produce proportional improvement in overturning resistance if the centre of gravity or supporting surface changes. Similarly, adjacent units must remain aligned without assuming that their connection has vehicle-restraint capability. Repeatable procedures and a clear loading arrangement are required to support meaningful comparison.

B. Maintenance and environmental implications

Operational feasibility is partly a maintenance issue. A divider placed near loose soil or construction debris may collect substantial sediment during the first rainfall. The top channel should be inspectable without disassembling neighbouring units, the debris screen should be replaceable using ordinary tools, and the drain valve should be accessible without placing an operator in active traffic. Stored water should be inspected for odour, discoloration and stagnation; appropriate drainage should be provided where reuse is not justified. No untreated roadside runoff should be described as suitable for drinking.

Potential sustainability advantages must also be tested against added material and labour requirements. Additional piping, screens and seals create manufacturing costs and replacement needs; a unit that stores only small quantities during isolated rain events may deliver limited water conservation. Lifecycle comparison with a standard channelizer should include expected service life, transportation burden, water needed for initial ballast, cleaning frequency and safe disposal. These factors will ultimately determine whether rainwater integration provides an operational benefit beyond its educational demonstration value.

C. Suggested experimental reporting protocol

For a controlled demonstration, investigators should record the actual prototype length, width, height, chamber volume and mass before adding water. The projected catchment footprint should be measured directly instead of being inferred from the inclined surface length. Rainfall input may be simulated using a calibrated container and distributed sprinkler, with the applied volume recorded independently. Trials should begin with the chamber empty and clean, and measurements should be repeated to assess variability. The resulting dataset should distinguish water reaching the screen, water admitted to the chamber and water lost via the overflow. A photograph or drawing of each experimental arrangement would help other researchers reproduce the conditions. Structural measurements should be reported separately from hydraulic measurements. A horizontal force applied at a known height allows comparison of sliding onset, visible tilt and joint separation at defined water levels. Repetition on more than one surface type can illustrate sensitivity to surface friction, but the loading apparatus and boundary conditions must be documented. These observations represent static behaviour only; they cannot be extrapolated into predictions of collision injury, crash-energy absorption or vehicle redirection. The interpretation should be limited to the forces, geometry and operating conditions that were actually evaluated.

For maintenance trials, the investigators may introduce a defined quantity of representative debris at the intake and observe whether rainfall collection drops, whether the screen is accessible, and whether cleaning restores flow. Drainage and overflow should be checked to ensure released water does not create an avoidable slip or skidding hazard. A short cost statement should distinguish initial fabrication expenses from recurring cleaning and repair costs. Presenting uncertainty, test repetitions and negative findings would make the final study more useful than reporting a single favourable trial.

VI. CONCLUSION

The reviewed literature demonstrates that modular traffic-channelizing devices and decentralized rainwater harvesting systems are established engineering technologies with distinct functional requirements. Longitudinal channelizers offer portability and configuration flexibility, while rainwater harvesting principles support controlled runoff collection and supplementary water storage. Integrating these functions within a hollow road-divider module represents a potential approach to developing multifunctional temporary infrastructure.

The literature further indicates that engineering performance is strongly influenced by geometric configuration, rainfall variability, storage capacity, mass distribution, filtration effectiveness and maintenance conditions. Although retained water may provide supplementary ballast, improvements in static stability must be demonstrated experimentally. The system's small catchment area also restricts the quantity of water that can reasonably be recovered.

The proposed research consequently requires an integrated assessment covering hydraulic collection efficiency, leakage resistance, water retention, structural stability and operational practicality. Such investigations can establish whether the combined arrangement offers a technically and economically feasible alternative for selected low-speed temporary channelization applications. Any use involving

vehicle-impact protection or public-road deployment would require separate safety assessment and applicable regulatory approval.

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