Multi-use Channels with Dedicated Rail Tracks

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Abstract

Many metropolitan regions face three major challenges: traffic congestion, poor air quality, flooding and/or water shortage. To address these issues, this article presents a conceptual design of multi-use channels that utilize reinforced concrete conduits (RCCs) to create multiply pathways immediately below ground level for the combined functions of transportation and water conveyance. Precast RCCs can be installed using open trench excavation methods and provide robust and long-last platforms for public transit at relatively low cost. Under normal weather conditions, the upper level of the channel is used for light-rail transit, while the lower level is dedicated to water conveyance. During heavy rainfall events, the transit services are suspended and the entire channel space is utilized for flood control. Three different configurations of multi-use channels are discussed and their conveyance capacities are evaluated. The results indicate that these multi-use channels not only provide dedicated tracks for safe light-rail operation, but also serve as an effective flood-control measure by making the full channel space available for water conveyance, resulting in up to a fourfold increase in conveyance capacity.

Keywords: multi-use channel; water conveyance; flood control; public transit; light rail; dedicated track

1. Introduction

As population grows, many metropolitan regions face three challenges: traffic congestion, poor air quality, flooding and/or water shortage. Taking transportation as an example, an increasing number of cities are adopting light rail systems to ease congestion and improve air quality. Light rail systems are typically installed at three levels: at ground level along streets, underground as subways, or above ground as sky-trains.

In addition to traffic flow, potable water must be supplied to cities, while wastewater and storm water must be safely conveyed away. Open channels, rivers or bayous, and large conduits are commonly used for these purposes. In regions with high rainfall, storm water often causes natural rivers/bayous to meander extensively, consuming large amounts of land.

Due to the limited availability of public space, it is reasonable to consider multi-use infrastructure as an alternative solution. The SMART Tunnel in Kuala Lumpur [1] is a successful example that combines automobile traffic with water conveyance. The tunnel has three levels: the bottom level is dedicated to water conveyance, while the middle and upper decks are used for automobile traffic during normal weather conditions or minor storms. As water levels rise, the middle deck is converted for water conveyance. During severe storms, all traffic is evacuated, and the entire tunnel is used to convey storm water. The tunnel was completed in 2007 and, by the end of 2020, had been fully utilized for water conveyance seven times. The SMART Tunnel has significantly reduced flooding risk in Kuala Lumpur's city center and prevented billions of dollars in flood damage [2].

2. Multi-use Channels

Multi-use channels utilize reinforced concrete conduits (RCC) to retain surrounding soils, and create pathways below the ground level. Figure 1 shows a single RCC channel with water flowing inside RCC and light rail vehicles running on the top of RCC during normal weather conditions [3].

During extreme precipitations, the light rail vehicles are evacuated from the channel and the entire space is available for water conveyance as a flood control measure.

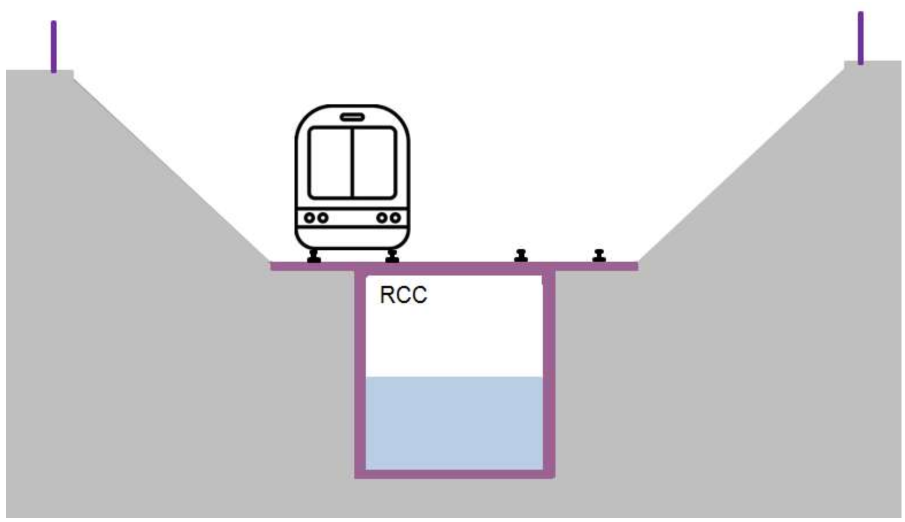

Figure 1. Single RCC Channel with Rail Tracks on Top

Train stations are preferably located at ground level, offering several advantages:

- Easy access for passengers boarding and alighting from trains.
- Enhanced safety, as trains can remain at elevated stations in the event of an unexpected rise in water levels within the channel.

- Energy efficiency, as trains can store potential energy when approaching a station and regain kinetic energy when departing the station and moving to a low elevation.

- On-site charging, allowing batteries or super-capacitors to be recharged while trains are stopped at the station.

The configuration illustrated in Figure 1 is particularly suitable for regions with existing creeks or bayous that have relatively gentle curves. This arrangement avoids interference with surface traffic.

A double RCC channel can be designed with an open drainage path between the two RCCs. Figure 2 presents an example of a multi-use channel along a street, where the median is converted into a drainage path. Under normal weather conditions, water flows through the central path while light-rail vehicles operate inside the RCCs and automobiles travel on the top of RCC structures. When severe weather approaches, trains within the RCCs can be evacuated, making the entire below-ground space available for flood control purposes

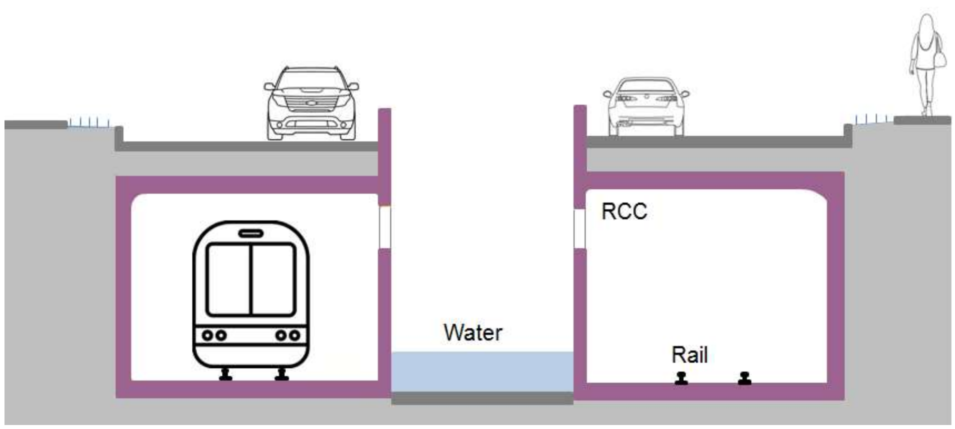

Figure 2. Shallow Double RCC Channel with Rail Tracks Inside

In both examples of multi-use channels, the space immediately below ground level is utilized for public transit during normal weather conditions and for water conveyance during heavy rain storms.

These multi-use channels do require bridges at street crossings; however, such bridges can be constructed at relatively low cost using reinforced concrete structures. For instance, in the single RCC channel illustrated in Figure 1, two rows of deep group piles and precast double T slabs may be used to build a bridge. For the double RCC channel in Figure 2, precast double T slabs can be supported on the adjacent walls of two RCCs to form an intersection for street traffic.

3. Synergy and Safety of Multi-use Channel

3.1. Synergy

By using reinforced concrete conduits (RCC) of appropriate sizes, separated pathways can be created within a confined space to accommodate public transit as well as the conveyance of storm water, sanitary sewage or portable water. Under normal operating conditions, lower levels are typically designated for water conveyance while upper levels are used for public transit.

In metropolitan areas, public transit and storm water conveyance can share the same space because minimum traffic is expected during severe storms. Residents are generally advised to remain at home when severe weather is approaching. Under such conditions, it is feasible to suspend transit services and allocate the entire channel space to convey large volumes of storm water.

Public transit systems are well suited to integration with water conveyance infrastructures, as both favor the following characteristics:

- a straight route that minimize distance between Point A and Point B, maximizing efficiency;
- below-grade corridors that avoid interference with surface street traffic;
- robust reinforced concrete structures and slabs that support public transit loads and stabilize channel banks;
- gentle slope and smooth surfaces that facilitate steady flow of both water and vehicles.

In addition, transit tracks within a multi-use channel can provide convenient access for inspection and maintenance of the channel.

3.2. Safety

Two common safety concerns are addressed here: the risk of drowning and the risk of electrocution. There are occasional reports of fatalities caused by flooding during severe storms. However, the public transit operating within a multi-use channel incorporates two layers of safety protection.

The first layer of protection is weather forecasting. When a severe weather is anticipated, train service cancellation can be announced several days in advance and all trains are evacuated at least one hour before the arrival of the storm. Even in case of unexpected storms, there is a minimum delay of 15 minutes between the onset of heavy rainfall and the water level in the channel reaching a critical threshold. This provides sufficient time for the trains to reach higher ground such as stations.

The second layer of protection is real-time monitoring of water level within the channel. When the critical level is reached, an alarm is triggered as a final warning, prompting trains to proceed immediately to the nearest station and remain there.

The risk of electrocution is a legitimate concern when high-voltage DC or AC power is supplied through a third rail or overhead catenary system. To mitigate this risk, the light rail vehicles operating within the multi-use channel rely on onboard energy sources. These onboard energy options include:

- diesel fuel, which has been used to power passenger trains worldwide for decades [4];
- rechargeable batteries, which have powered streetcar in Dallas along the Houston Street Viaduct crossing the Trinity River since 2015, and fully powered train services in Split, Croatia, since December 15, 2025 [5].
- hydrogen-powered passenger rail systems, which have been operating in San Bernardo county, California, since September 2025 [6]. To further enhance the safety, ammonia may be stored onboard and catalytically cracked into hydrogen and nitrogen to supply fuel cell for continuous electricity generation [7].
- super-capacitors, which can be charged at the ground-level stations in less than 1 minute and used to power the trains between stations [8].

Accordingly, multi-use channels can be designed to safely operate under wet conditions while restricting the use of high-voltage electricity to the stations located above-ground. By selecting appropriate onboard energy sources and following pre-determined operating procedures, passenger safety can be ensured.

During severe storms, water levels may rise and submerge rail tracks. Before transit service is resumed, post-storm cleaning and inspection are required. Any debris can be removed using maintenance vehicles operating along the rail tracks within the channel.

4. Comparison with Subway and Skytrain

Subway tunnels have been in service for more than a century, originating as underground corridors for heavy rail systems. With advances in tunnel-boring machine (TBM) technology, many media- to large- sized cities have adopted underground rail systems as a form of urban rapid transit [9]. The skytrains represent another alternative, in which light rail vehicles operate on elevated tracks using modern, often driverless, technology. Table 1 lists the comparison of these two systems with light rail services operating in multi-use channels located near the ground level. Trams running along city streets are excluded from the comparison as they share space with cars and pedestrians.

Table 1. Comparison among Three Types of Rail Services with Dedicated Tracks

Item	Subway (Tunnel)	Sky-train	Fig.1 multi-use channel
Description	Trains run through two separated deep tunnels underground made by TBM	Light rail vehicles on tracks elevated aboveground	Light rail vehicles on the top of RCC while water flowing inside RCC below
Project Example	Los Angles Purple D-Line Extension (USA)	Surrey-Langley Extension(Canada)	To be implemented
Construction Materials for track support	Precast reinforced concrete segments bolted onsite	Reinforced concrete structure	Precast reinforced concrete conduits assembled onsite
Elevation (m)	-100 to -10	8 to 16	-15 to 0 (ground level)
Cost (millions)	\$620/km \$1000/mile [10]	\$310/km \$500 /mile [11]	\$60-90/km \$100-150/mile
Time to Build	>5 years (14.5km)	>4 years (16.5km)	<2 years(assume 20km)
Accessibility	Pedestrian tunnel and elevator/stair (long)	Elevator/stair (short)	Easiest access with station at ground level
Power Source	600-1000 volts DC through overhead wire attached to tunnel ceiling	Up to 750 volts DC by a third rail on track through contact [12]	Diesel onboard; Batteries onboard; Super-capacitor; or Fuel cell onboard
Benefit-Cost Ratio	>1	>1	>5

All three approaches can provide efficient and environmentally friendly services of light rails. Each uses dedicated tracks that enable safe and driverless operation. In addition, all three rely on reinforced concrete structures to support the rail tracks. The key distinction is that the reinforced concrete structures used in multi-use channels are positioned just below ground level, allowing for easier access and construction.

Multi-use channels can be installed with open-trench excavation methods and conventional construction equipment, such as excavators, bulldozers, and deep-trench boxes. When precast reinforced concrete components are delivered and assembled on site at multiple locations simultaneously, a single RCC channel could be completed within months rather than years.

The subway tunnels generally cause the least interruption to surface street traffic but are associated with very high construction costs. In contrast, the multi-use channels can reduce construction costs by 75% while simultaneously providing water conveyance, resulting in an exceptionally high benefit-cost ratio.

5. Highlights of Advantages and Variations

The following sections discuss the significant impacts of the multi-use channels in metropolitan areas.

5.1. Flexible and Long-lasting Infrastructure

Each RCC segment is precast with continuous steel reinforcement, taking advantage of the high tensile strength of steel and the high compressive strength of concrete. A typical RCC segment is 2-3 m long and includes a bell end and a spigot end. With rubber gasket rings at each joint, adjacent RCC segments can be rapidly assembled on site. Owing to the flexibility at the joints, RCC systems can accommodate up to 0.025 m (1 in) of ground movement caused by ground cracking, differential settlement, or earthquake wave propagation [13]. In addition, the RCCs are uniformly supported on the surrounding soil and can achieve a service life exceeding 100 years with minimum maintenance.

5.2. Stabilizing Banks and Minimizing Soil Erosion

Many megacities are built on alluvial plains, where soils are particularly susceptible to erosion by fast-moving storm water. For example, Hurricane Harvey in 2017 caused severe soil erosion and deposited up to 1.5m (5 ft) of sediment in the Houston Shipping Channel [14]. RCC installations help stabilize the banks of natural creeks and bayous, thereby minimizing soil erosion at its source. Although the multi-use channels incorporating RCCs have higher initial costs than conventional streets or natural bayous and creeks, they can save millions of dollars over time by reducing the need for sediment removal and bank restoration.

5.3. Alleviating Traffic Congestion

Light rail systems operating within multi-use channels avoid interference with surface street traffic and provide high-capacity transit during normal weather conditions. These services can significantly reduce traffic congestion in metropolitan areas during peak hours while operating at a low cost through autonomous technologies.

During construction, the multi-use channels can be completed in as little as one year using open-trench methods and precast RCC segments. Once installed, the RCC pathway within the channel can serve as an access road for transporting additional RCC segments, thereby minimizing disruption to surface street traffic.

5.4. Reducing Air Pollution and Protecting Environment

Unlike vegetation, concrete surfaces absorb and re-radiate heat under direct sunlight. By combining transportation and water conveyance functions, multi-use channels reduce the total concrete and pavement surface area required. Moreover, light rail systems are among the most energy-efficient transit modes and can remove millions of cars from roadways. When properly designed, such systems can reduce the need for private vehicle ownership, particularly for seniors and teenagers. These benefits contribute to improved air quality and overall environmental protection.

5.5. Easy Maintenance

The author has examined common causes of frequent urban flooding. While increased rainfall and municipal expansion are major factors, insufficient access and maintenance also play a critical role. Over time, soil erosion generates sediment that reduces the capacity of detention ponds and drainage channels, while vegetation growth along banks further impedes flow. Maintenance is often delayed due to limited access. When intense rainfall coincides with reduced system capacity, bank overflow and flooding become inevitable. With access inside the multi-use channel, any defects can be identified earlier before any further damage is developed and any maintenance action can be carried out easily.

5.6. Flood Control

Flow capacity can be increased by enlarging the size of the RCC in a single RCC channel configuration (Figure 1) or by widening the spacing between two RCCs in a shallow double-RCC channel configuration (Figure 2). However, such modifications typically increase capacity by no more than 50%. To achieve greater conveyance capacity, the RCCs can be installed at greater depth with traffic on the top of double RCCs, as shown in Figure 3 [3]. This arrangement can quadruple conveyance capacity by allowing water to flow both inside RCCs and outside RCCs, making it suitable as a primary outlet channel for reservoirs or lakes.

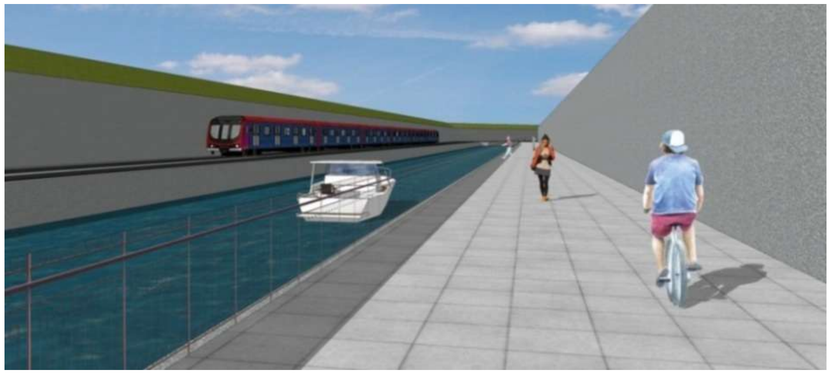

Figure 3. Deep Double RCC Channel with Traffic on Top

Table 2 lists the features and water conveyance capacity of multi-use channel configurations in Figure 1 through Figure 3.

Table 2. Water Conveyance Capacity of Multi-use Channel Configurations

Item	Single RCC Channel (Figure 1)	Double RCC Channel - Shallow (Figure 2)	Double RCC Channel -Deep (Figure 3)
RCC size(WxH) *	5m x 4m	5m x 5m	5m x 4m
Open channel W*	18m(ground level)	3m (in the middle)	18m (total)
Open channel H*	5m(from RCC top)	6m (total)	10m (total)
Normal water flow area	inside RCC	between two RCCs	inside & between two RCCs
Normal flow rate	30 m^3/s (1060 cfs)	17 m^3/s (600 cfs)	120 m^3/s (4300 cfs)
Max flow rate	145 m^3/s (5100 cfs)	170 m^3/s (6000 cfs)	465 m^3/s (16500 cfs)

* W- Width; H- Height

These flow capacities are calculated using the Manning equation [15] assuming a slope of 0.04%. For each configuration, the full conveyance capacity is quadrupled compared to normal flow limit.

6. Potential Application

6.1. Existing City

Multi-use channels are particularly well suited for regions where transportation corridors and water conveyance routes are closely aligned. For example, downtown Houston serves as a central traffic hub from which highways and streets radiate outward. It is also a primary convergence point for several bayous that discharge into the Houston Ship Channel. The multi-use channel concept could be implemented along existing bayous, streets or a combination of both.

The 2017 Hurricane Harvey storm highlighted the vulnerability of Houston's bayou-based drainage system. Notably, the Barker and Addicks reservoirs, which were designed to protect downtown Houston, ultimately contributed to flooding both upstream and downstream communities during this unprecedented storm.

As the sole outlet for both reservoirs, Buffalo Bayou has a maximum flow capacity of 110 m^3/s (4000cfs) at Piney Point, largely due to its narrow and meandering channel [16]. To double the discharge capacity, a single RCC channel as shown in Figure 1 could be constructed along the creek south of Clay Road, and then extended along Hempstead Road and Allen Street, or alternatively along White-Oak Bayou, before reconnecting with Buffalo Bayou in downtown Houston.

To further increase conveyance capacity, a shallow double RCC configuration, as illustrated in Figure 2, could be implemented along Westheimer Street and Kirby Drive to divert water from Barker reservoir to a wider segment of Buffalo Bayou. Alternatively, a deep double RCC configuration, shown in Figure 3, could be constructed primarily along Brays Bayou, supplemented by a short tunnel connecting Barker Reservoir to Brays bayou and another short tunnel linking the Barker and Addicks reservoirs.

Given that many transportation corridors and waterways converge toward downtown Houston, additional alignments and configurations for implementing the multi-use channel concept are also feasible.

6.2. New City

Many large cities face similar challenges such as flooding and traffic congestion because their infrastructure was originally designed for small populations and limited budgets. As populations grow, these cities are forced to invest increasing amounts of money to upgrade their infrastructure within constrained urban spaces. This multi-use channel concept offers a feasible and attractive alternative due to its affordability, flexibility, and efficient use of space. When incorporated during the early planning stages, city's infrastructure can be systematically organized as illustrated in Figure 4.

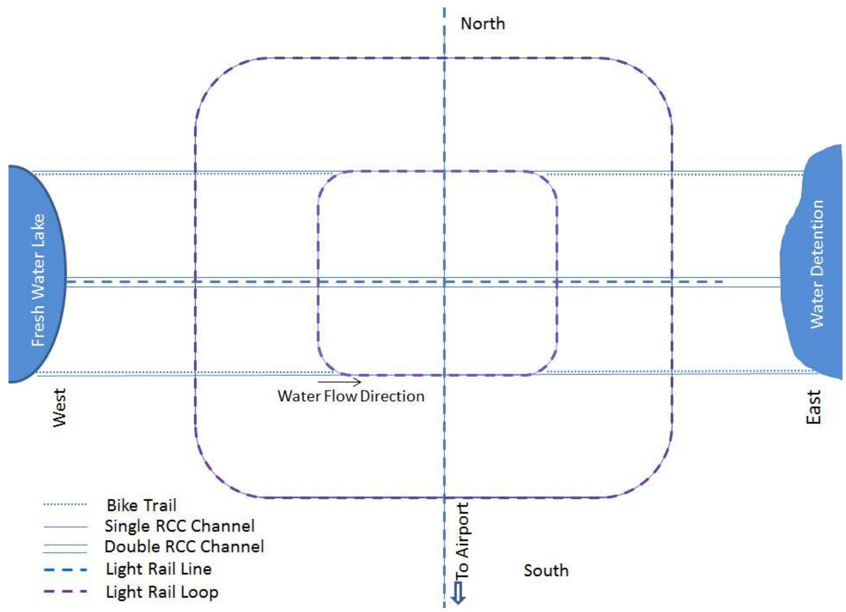

Figure 4. Example of Multi-use Channels with Light Rail in a New City (not to scale)

The infrastructure of such a city may include the following features:

- **Freshwater reservoirs** located on one side of the city (assuming to be the west) at a higher elevation. These lakes collect runoff from surrounding areas and supply portable water to residents.
- **Detention lakes** on the opposite side (east side) to store storm water and waste water. Alternatively, this side may border a coastline, or a major river.
- **A deep double RCC channel**, as shown in Figure 3, located between the two sides of the city and serving as the primary outlet for freshwater reservoirs with flow-control gates to regulate discharge rates.
- **An airport and logistics district** located on the south side of the city, along with supporting facilities such as hotels, forming a primary north-south transportation corridor.
- **At least two single RCC channels**, as shown in Figure 1, laid parallel to the west-east axis, with two additional channels perpendicular to the axis to divert storm-

water during heavy rainfall. These channels support two interconnected light rail loops that form the core of the city's transit system. To avoid interference, the light rail tracks in one orientation (e.g., north-south) are elevated at a station aboveground right at the intersection of two channels, allowing the trains in the other orientation (e.g., east-west) to pass underneath.

- **Street networks** oriented parallel or perpendicular to the RCC channels with freeways crossing at least one of the light rail lines or loops.
- **Utility corridors** integrated within the RCCs: major communication cables placed near the upper corners for easy access and repair, while portable water pipelines and electricity cables are installed below ground level along the channel banks.

As additional drainage capacity is required, pedestrian trails or bicycle lanes can be incorporated atop RCC in a single RCC configuration similar to Figure 1.

With freshwater sources located at higher elevations and detention facilities positioned at lower elevations, water supply and wastewater drainage can function efficiently throughout the city. In an environment friendly and convenient urban setting, light rail systems are often preferred by residents, particularly seniors or young people. By living in a city designed around multi-use infrastructure, residents can spend less time in traffic and more time enjoying a higher quality of life.

7. Conclusions

Multi-use channels are a feasible and safe solution for urban areas that require the combined functions of transportation and water conveyance at an affordable cost. Municipalities in coastal regions or near large lakes, particularly those subjected to occasional heavy rainfall, can benefit significantly from multi-use channel systems as an effective flooding control measure. These channels can be constructed within a short period of time with minimal disruption to surface street traffic and an exceptionally high benefit-cost ratio.

Using precast reinforced concrete conduits, the multi-use channels are structurally robust, long-lasting and easy to maintain. When incorporated into the planning of new cities, they can operate with high efficiency while minimizing environmental impact. As a result, residents can enjoy cleaner air, convenient public transit, and enhanced protection against flooding.

8. Abbreviations

The following abbreviations are used in this manuscript:

SMART	Stormwater Management And Road Tunnel
RCC	Reinforced Concrete Conduit
AC/DC	Alternating Current/Direct Current
TBM	Tunnel Boring Machine

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