

Category 1 Standard

S1052 Civil Engineering - Gravity Drainage Systems

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1 Purpose

- 1.1 The purpose of this Standard is to define the life cycle requirements for gravity drainage system assets in performance terms.
- 1.2 This standard also covers hydraulic and structural design of internal and external building gravity drainage systems (foul and surface water - including roof drainage). It should be noted that buried drainage assets are generally designated as Civil assets and non-buried drainage as Premises assets (except pump drainage assets which are also generally designated as Civil assets).
- 1.3 Standards for pumped drainage systems are given in London Underground (LU) Standard 1-056.
- 1.4 In defining requirements specifically applicable to gravity drainage system assets, this Standard complements LU Standard 1-050 that defines mandatory requirements generally applicable to all Civil Engineering assets including gravity drainage system assets.
- 1.5 A supporting Manual of Good Practice G-052 gives guidance and information specific to LU gravity drainage system assets.

2 Scope

- 2.1 This standard applies to *new* and *rehabilitated* gravity drainage system assets (*foul and surface water*) owned by LU as part of the following drainage systems:
 - a) Track and off-track gravity drainage systems (*surface water only*).
 - b) Stations, depots and other operational buildings gravity drainage systems (*foul and surface water*).
 - c) Other gravity drainage systems (*foul and surface water*).
- 2.2 This Standard defines the responsibilities involved during the life cycle of the assets and sets out the requirements for:
 - a) Design
 - b) Construction
 - c) Maintenance (*including Inspection and Assessment*)
 - d) Decommissioning
- 2.3 This Standard should be read in conjunction with *LU Technical Specification T0001 Civil Engineering – Track and Off-track Gravity Drainage Systems* and any relevant site-specific application of the National Building Specification (NBS) (*in relation to Stations, Depots and other operational buildings gravity drainage systems*) by the Premises team. The aforementioned specifications state the generic and site-specific materials and workmanship LU requirements.
- 2.4 This Standard also covers flood protection requirements to LU assets.



3 Requirements

3.1 Design

3.1.1 General

- 3.1.1.1 The inception and design of works to gravity drainage system assets shall ensure that the assets meet their *Required Duty*.

Note: The *Required Duty* for Gravity Drainage System assets is as follows:

- 1 Meet railway operating requirements (*within the performance specification at system installation or at the most recent system upgrade*).**
 - 1.1 Maintain inherent structural integrity (*support itself so as not to suffer complete or partial collapse*).
 - 1.2 Maintain the ability to carry any permitted applied static and dynamic design loads without restriction.
 - 1.3 Allow adequate clearance to ensure the safe passage of rail vehicles.
 - 1.4 Operate without risk of blockage or failure to minimise the risk of flooding or disruption to railway operations.
 - 1.5 Provide sufficient hydraulic capacity to convey the flow requirements.
 - 1.6 Provide appropriate access and egress for all planned uses, and for reasonably anticipated emergency uses (*including Maintenance*).
 - 1.7 Sustain a Condition and state so as not to cause unplanned interruption to, or restriction of, any aspect of the operating railway.
- 2 Ensure support at asset interfaces without undue wear and tear.**
 - 2.1 Minimise the degradation of all interfacing assets (*e.g. as evidenced through Maintenance cycles*). This includes interfaces with the railway and adjacent infrastructure, e.g. track, structures, stations and premises.
- 3 Match LU policy in respect of realistic user perceptions.**
 - 3.1 Ensure pumping and gravity drainage systems collect, convey and discharge their content without undue degradation to interfacing assets, disruption to railway operations, unacceptable environmental nuisance, or risk to the health and safety of passengers, employees and members of the general public.
- 4 Provide resistance against external interference and events.**
 - 4.1 Provide a drainage system which minimises the likelihood and consequence of asset abuse. Asset abuse encompasses vandalism, damage due to external events, etc.
- 5 Present acceptable environmental impact.**
 - 5.1 Provide an acceptable societal environmental impact (*including adverse weather management, outfalls, toxicity, public health, odours, etc.*).
 - 5.2 Protect receiving waters from pollution (*within statutory limits*).
- 6 Minimise environmental impact throughout lifecycle.**



6.1	Minimise environmental impact and demands at all stages in the asset lifecycle; this includes effects now and in the future, including successive refurbishment, final decommissioning, and disposal routes.
7	Function within the legal and standards framework.
7.1	Ensure the asset functions within the framework defined by legislation (<i>including environmental legislation</i>), regulatory guidance, standards (<i>including LU and applicable National, European & International standards</i>), and LU policies.
8	Ensure safe operation as defined by LU.
8.1	Ensure safe operation and Condition as specified by LU requirements; this includes passengers, employees and members of the general public.
8.2	Ensure safe access/egress by passengers, employees, general public and emergency services (<i>in planned and reasonably anticipated emergency scenarios</i>). Appropriate access/egress shall be provided for Maintenance purposes.
8.3	Safeguard the health and safety of passengers, employees and members of the general public.
9	Provide above within reliability and availability targets.
9.1	Meet all aspects of the <i>Required Duty</i> within the defined LU requirements.
10	Ensure Required Duty is performed without incurring excessive or prohibitive costs.

- 3.1.1.2 An holistic approach to the design and construction of new and rehabilitated gravity drainage systems shall be adopted. Designs shall conform to the principles of *Whole Life Asset Management*.
- 3.1.1.3 LU supports the use of Sustainable Drainage Systems (SuDS) and a statement justifying the extent of their employment shall be made in the CDS for the work (*in accordance with the relevant assurance process*). Relevant technical requirements are given in Clause 3.1.2.
- 3.1.1.4 Appropriate pollution control measures shall be designed within LU gravity drainage systems. They shall comply with current statutory requirements *and* best practice. In particular, reference shall be made to the CIRIA publication *C643 The potential for water pollution from railways*.
- 3.1.1.5 Only materials which meet the requirements of the current version of LU Category 1 Standard *1-085 Fire Safety Performance of Materials*, in respect of flammability, smoke emission and toxic fume emission shall be used in Sub-surface Railway areas, shafts and tunnels (*both bored tunnel and cut & cover tunnel forms*).

Note: The use of solid-walled polyethylene pipes (*for Track and Off-track Drainage*) in the above context are the subject of two specific and mutually exclusive concessions. These are concession references CR03003 and CR05565, which are a matter of record and are explained in more detail within the LU Technical Specification T0001.

- 3.1.1.6 Gravity drainage system designs shall be approved by the *Professional Head (Pumps and Drainage)* through the relevant assurance process, in accordance with LU Category 1 Standard 1-538 Assurance.

Conceptual Design Statements (CDS) shall be produced and approved (*prior to the commencement of detailed design*) in accordance with the requirements of LU



Standard 1-538 and the relevant specific requirements for drainage CDS's set out in LU Manual of Good Practice G-052.

- 3.1.1.7 Each chamber asset shall be equipped with a Radio-frequency Identification (RFID) tag and a plate displaying its unique identification number. Refer to LU Technical Specification T0001 for materials and workmanship requirements associated with these items.
- 3.1.1.8 Permanent access provision within drainage chambers (*i.e. step irons and/or ladders*) is generally not required unless the designer has sound engineering reasons for adopting a contrary arrangement (*which must be detailed within the CDS for the work in accordance with the relevant assurance process*).
- 3.1.1.9 New discharges to Public Sewers require the agreement of the Sewerage Undertaker and (*in the case of surface water and groundwater discharges*) can only be made subject to approval of the drainage system by the SuDS Approving Body under the Flood and Water Management Act 2010.

Note: Existing surface water and groundwater discharges to Public Sewers should either be the subject of an existing agreement with the Sewerage Undertaker under the Water Industry Act 1991, or be covered by existing 'prescribed' rights under the relevant Railway Act.

LU sewers and lateral drains are exempt from adoption (by relevant sewerage undertakers) under The Water Industry (Schemes for Adoption of Private Sewers) Regulations 2011 regardless of whether such sewers and drains are within railway land or not.

- 3.1.1.10 The Design Life of drainage assets shall be in accordance with Table 3.1.1.1.

Drainage asset	Design life
Drainage assets (<i>unless stated otherwise</i>)	60 years
Pipes and chambers made from hydrocarbon-based materials e.g. High Performance Polyethylene (HPPE); and CIPP lining systems.	40 years
Pipes and chambers made from non hydrocarbon-based materials e.g. clay, concrete, masonry, etc.	100 years
Chamber covers and gratings	20 years

Table 3.1.1.1 – Design Life of Drainage Assets

- 3.1.1.11 LU maintains a Products Register (<http://www.lu-apr.co.uk>); only products appearing on that register may be incorporated into the works. Should a supplier or contractor wish to use a product not on the register then special approval from the LU Professional Head (*Pumps and Drainage*) will need to be sought and granted before it can be incorporated in to the works. The product shall then be submitted for formal approval and entry on to the Products Register as soon as practicable thereafter.
- 3.1.1.12 Pipes passing beneath tracks ('*under-track crossings*' (*UTX's*)) shall be carrier drains, i.e. imperforate pipes.

UTX's shall generally cross perpendicular to the tracks, but where this isn't possible the length of the UTX shall be minimised.



Note: In the vicinity of points and crossings, where Track Drainage in the six-foot may pass beneath the crossing, it is acceptable for the pipe asset between chambers to transition from filter drain to carrier drain part way along its length. The carrier drain section shall be appropriately positioned beneath the sleepered zone. Bedding, surround and trench backfill details shall conform to the relevant LU Technical Specification T0001 requirements.

3.1.1.13 Drainage system access points (e.g. *chambers*) shall have internal plan dimensions, clear opening plan dimensions and sump depths that are appropriate for the maintenance regime applied to the drainage system concerned.

3.1.2 Track and Off-track Gravity Drainage Systems (Open Track Sections)

3.1.2.1 Location of drainage systems

3.1.2.1.1 Unless there is a sound engineering reason for adopting a contrary arrangement (*which must be detailed within the CDS for the work in accordance with the relevant assurance process*) and subject to the exceptions stated in sub-Clause 3.1.2.1.2, appropriate positive drainage shall be provided in the following positions:

- a) In one side Cess only on single-track lines (*including between platforms*).
- b) In both side Cesses on two-track lines.
- c) In both side Cesses and between adjacent pairs of tracks (*i.e. in the 'Ten Foot' zones*) on lines with four or more tracks. (*Thus, for example, on a six-track line there would be four drains, one in each of the two side Cesses and one in each of the two 'Ten Foot' zones.*)
- d) In the 'Six Foot' if the side Cesses are unavoidably obstructed or insufficient.
- e) Off-track Drainage shall be provided as required, to convey track formation and earth structure surface water runoff to a suitable discharge point.

3.1.2.1.2 Omission of positive drainage

3.1.2.1.2.1 Positive drainage may not be required in the positions listed in sub-Clause 3.1.2.1.1 if the following conditions are *all* met:

- a) The overlying *and* underlying geology in the side Cesses and 'Ten Foot' zones is sufficiently free-draining, as to permit compliance with the hydraulic design performance criteria stated in sub-Clause 3.1.2.3.4 through infiltration.
- b) The prevailing groundwater level during its seasonal high is at least 2m below the apex of the track formation.
- c) The absence of positive drainage is considered *not* to have a long term detrimental impact on track formation stability. This point shall be agreed with a competent Geotechnical Engineer.

3.1.2.1.2.2 Irrespective of the overlying and underlying geology, positive drainage shall always be provided at vertical alignment low points within cuttings, where there is an implicit risk of flood water accumulating. Such drainage provision may be localised at the geometric low point but shall be designed to ensure compliance with the hydraulic design performance criteria stated in sub-Clause 3.1.2.3.4. Pumped drainage solutions may need to be considered in such locations (*refer to LU Category 1 Standard 1-056 Civil Engineering – Pumping Systems*).

3.1.2.1.2.3 Unless there is a sound engineering reason for adopting a contrary arrangement (*which must be detailed within the CDS for the work in accordance with the relevant assurance process*), track drainage is not usually provided in the side Cesses of lines on embankment unless it is as carrier drainage to convey non-embankment flows to a remote outfall.

3.1.2.1.3 Depots and sidings areas

- 3.1.2.1.3.1 Where it is impracticable to meet the requirements of sub-Clause 3.1.2.1.1 or where it gives rise to excessive or prohibitive cost, and subject only to the content of sub-Clause 3.1.2.1.2, alternative drainage locations may be considered following an assessment of the associated risks (*including any implications for maintenance operations*) and provision of any appropriate mitigation measures.

The assessment of such risks and any mitigation proposals shall accompany the CDS and/or DDR (*Detailed Design Report*) for approval under the relevant assurance process.

3.1.2.1.4 Location of access points

- 3.1.2.1.4.1 Track and off-track filter gravity drainage systems shall generally have access chambers positioned at intervals no greater than 30m and at all other positions where good engineering design demands them. Such chambers shall be catchpit chambers designed to capture and permit the removal of suspended solid debris.

This maximum spacing may be increased if the proposed maintenance regime supports it (*e.g. high pressure jetting as opposed to manual rodding*) and the strategy has been presented in the CDS or DDR for approval under the relevant assurance process.

- 3.1.2.1.4.2 It may not be possible to achieve the interval between chambers of no greater than 30m in the vicinity of points and crossings. Under these circumstances chambers should be sited on either side of the points or crossing but as close together as it is practicable to place them.

If the closest distance that can be achieved is greater than 45m, then additional measures to ensure future maintainability shall be considered within the design and be presented in the CDS and/or DDR for approval under the relevant assurance process.

3.1.2.2 Hydrological and hydrogeological parameters

- 3.1.2.2.1 The time of entry for track filter gravity drainage systems shall be selected by the designer based on the specific catchment characteristics, but generally within the range 30 to 45mins. Selection of values outside this range shall be justified within the CDS for the work (*in accordance with the relevant assurance process*).

- 3.1.2.2.2 Runoff coefficients assumed in the design of gravity drainage systems accepting surface water shall be selected by the designer based on the site specific surface treatment, underlying geology and topography.

- 3.1.2.2.3 Subject only to the requirements of sub-Clause 3.1.2.2.4, an allowance shall be made for groundwater infiltration (*where groundwater is accepted into the drainage system*) as a base flow in the drainage system (*where it is believed to be hydraulically significant*), which shall be based on the advice of a competent Geotechnical Engineer or Hydrogeologist.

- 3.1.2.2.4 Where it is possible to measure the actual groundwater infiltration rate at a site, then the measured value shall be used (*for drainage system hydraulic design purposes*) after it has been adjusted to allow for any increases likely over the design horizon as a result of structural or hydrogeological changes. The *adjusted* measured value shall then be multiplied by two to yield the design value.

- 3.1.2.2.5 Unless there is a sound engineering reason for adopting a contrary arrangement (*which must be detailed within the CDS for the work in accordance with the relevant*

assurance process), geotextile fabric compliant with LU Technical Specification T0001 shall always be employed as a trench liner in connection with filter gravity drainage systems, to ensure that fines from the adjacent subgrade cannot migrate into the drainage system.

LU requires that the geotextile fabric lining the filter gravity drainage trench be left open at the top of the trench (see *standard details in LU Manual of Good Practice G-052 Civil Engineering – Gravity Drainage Systems*) to permit the migration of ballast fines into the filter gravity drainage system, so that they can be removed during routine maintenance.

Note: However, recent research (*appended to G-052*) indicates that where track and drainage renewal is happening simultaneously (*or within a reasonably short time of one another*) or in the case of new railway, that there is merit in closing and lapping the geotextile filter gravity drainage trench liner at the top of the trench, to minimise future maintenance requirements. Such proposals shall be detailed in the CDS for the work (*in accordance with the relevant assurance process*).

3.1.2.2.6 Special requirements for trenchless conduit rehabilitation techniques

3.1.2.2.6.1 Where filter gravity drainage systems are rehabilitated using trenchless techniques, the infiltration rate of the existing material above the pipe shall be measured in accordance with the procedure defined in LU Technical Specification T0001. If the existing material has a measured infiltration rate lower than 1×10^{-3} m/sec, then it shall be replaced either, completely or, in discrete 'lenses' in accordance with the requirements of LU Technical Specification T0001.

3.1.2.3 Hydraulic design criteria

3.1.2.3.1 General

3.1.2.3.1.1 Hydraulic design shall be undertaken using industry standard hydraulic modelling software capable of carrying out full hydrodynamic unsteady flow analysis, *unless* the gravity drainage system involved is simple and it has been agreed via a CDS and/or DDR (*approved under the relevant assurance process*) that the design can be reliably progressed manually or using less sophisticated software.

3.1.2.3.1.2 The designer shall select the type of drainage system most appropriate for the site under consideration.

The design of gravity drainage systems shall include consultation with Track and Geotechnical disciplines, to establish whether there is a technical requirement for the drainage system to permanently draw-down the groundwater level below the track formation or earth structure (*for the purpose of ensuring that the design life of the asset is achieved*). If such a requirement exists, then the minimum cover depth for the drainage shall be increased over the designated area in line with the technical advice of a competent Geotechnical Engineer or Hydrogeologist.

3.1.2.3.1.3 Pipe roughness coefficients for use in hydraulic design shall be Colebrook-White linear roughness values, selected by the designer based on pipe material and assuming the worst conditions likely to prevail during the design life of the asset.

Channel roughness coefficients for use in hydraulic design shall be Manning's roughness values, selected by the designer based on conduit material and assuming the worst conditions likely to prevail during the design life of the asset.

3.1.2.3.1.4 Conduits shall be designed with a minimum 0.75m/s flow velocity for self-cleansing purposes. However, this value may be reduced to 0.6m/s where there is a significant

base flow within a system or where upstream pumping mains provide regular flushing. This minimum flow velocity applies to the design flow (*which is generally a part-full pipe flow*), i.e. not the theoretical pipe-full flow velocity.

It is acceptable to further reduce the minimum flow velocities stipulated above, at the heads of pipe branches, where design flows may be small in comparison to pipe hydraulic capacities as a result of compliance with minimum pipe size requirements.

3.1.2.3.1.5 Gravity drainage systems shall be protected against back flow from receiving third party drainage systems (*including open watercourses*) through the use of engineered solutions.

3.1.2.3.2 Conduit sizing

3.1.2.3.2.1 Pipe and channel sizing (*if required - see sub-Clause 3.1.2.1*) shall be undertaken in accordance with the Modified Rational Method (*published as Volume 4 of the Wallingford Procedure for design and analysis of urban storm drainage by HR Wallingford Ltd.*).

Conduits shall be sized to convey (*without surcharge*) the peak flow generated by the 1 in 5 year return period storm event of critical duration (*i.e. the Critical Storm*).

In the case of improvement works to existing systems where it may impracticable to meet this requirement, or where it gives rise to excessive or prohibitive cost, an alternative storm return period may be used for conduit sizing following an assessment of the associated risks (*including any implications for maintenance operations*) and provision of any appropriate mitigation measures.

The assessment of such risks and any mitigation proposals shall accompany the CDS and/or DDR for approval under the relevant assurance process.

3.1.2.3.2.2 The minimum pipe size is 150mm internal diameter.

3.1.2.3.2.3 If a base flow is included within the hydraulic design, then conduits shall be sized such that the base flow is confined to a maximum of half the conduit cross sectional flow area.

3.1.2.3.3 Full hydrodynamic unsteady flow analyses

3.1.2.3.3.1 Hydraulic modelling to prove compliance with the design criteria stated in sub-Clause 3.1.2.3.4, shall be full hydrodynamic unsteady flow analysis. It shall employ design rainfall hyetographs generated in accordance with both of the following methodologies (*i.e. separate model runs shall be undertaken to determine which yields the critical result*):

- a) Flood Studies Report (FSR) (*published by the Institute of Hydrology, 1975*), rainfall-runoff method, assuming both 75% winter and 50% summer storm profiles.
- b) Revitalised Flood Hydrograph (RefH) model using Flood Estimation Handbook (FEH) based hydrology (*published by the Centre for Ecology and Hydrology, 2007*), assuming both winter and summer storm profiles.

3.1.2.3.3.2 All rainfall hyetographs used for full hydrodynamic unsteady flow analyses shall have 20% added to them (*throughout the hyetograph*) to account for the potential impact of climate change through to year 2085 (*i.e. consistent with the approximate expected life of the drainage system*), in line with guidance in Planning Policy Statement 25 (PPS25) (*published by HMSO, 2006*).

3.1.2.3.4 The hydraulic design criteria to be adopted for *new* and *rehabilitation* works shall be as follows.

Gravity drainage system designed, such that when it is subjected to the critical storm event with a return period of 1 in 50 years, the following criteria are met:

- a) The maximum water level generated shall be *no higher* than 50mm below underside of sleeper (*i.e. surcharging of pipes and chambers and specified limited flooding from the system is permitted*) for ballasted track and tube track with shingle-filled channels.
- b) For slab track, no flooding of the slab shall occur.

3.1.2.3.5 The voidage available for temporary storage of water within the pipe bedding, trench backfill and track support ballast shall be assessed and a value adopted that will represent the worst case condition over the Design Life of the system.

3.1.2.3.6 Chamber headloss coefficients appropriate for the types of chambers proposed shall be adopted for use within hydraulic modelling software.

3.1.2.3.7 *Special requirements for trenchless conduit rehabilitation techniques*

3.1.2.3.7.1 Localised Cured In Place Repair (CIPR) systems (*known as 'Patch Repairs' in the WRc Sewer Rehabilitation Manual*) and Cured In Place Pipe lining (CIPP) for making structural repairs to drainage conduits shall be checked to ensure that the liner does not significantly reduce the conduit cross-sectional flow area and that it yields an approximately equivalent theoretical hydraulic flow capacity - due to its improved roughness coefficient.

3.1.2.3.8 *Designing for event exceedence*

3.1.2.3.8.1 New and rehabilitated gravity drainage system hydraulic designs shall be checked using full hydrodynamic unsteady flow analysis (*in accordance with sub-Clause 3.1.2.3.3*) against the effects of the critical storm event with a return period of 1 in 100 years (+ *climate change allowance as detailed in sub-Clause 3.1.2.3.2*), to ensure that excess water can be safely stored on, or conveyed from, LU land without unacceptable adverse impacts.

3.1.2.3.8.2 During the critical storm event with a return period of 1 in 100 years (+ climate change allowance) the developed rate of runoff into a watercourse, or other receiving body of surface water, shall be no greater than the existing rate of runoff for the same event (*designers should make efforts to reduce runoff rates from previously developed sites as close as practicable to the Greenfield runoff rate*). Volumes of runoff should also be reduced wherever possible using infiltration techniques.

3.1.2.4 **Structural Design Criteria**

3.1.2.4.1 *General pipeline structural design*

3.1.2.4.1.1 In-trench pipeline structural design shall consider temporary and permanent loading conditions. Design shall be progressed assuming the most critical combination of live and dead loads, in accordance with BS EN 1295-1 and its supporting standard BS 9295.

3.1.2.4.1.2 Pipelines subject to railway live loading shall generally be designed for the Rail London (RL) load condition as defined in LU Standard 1-051. However, where Train Operating Companies (TOC) have operating rights they shall be designed for *BS EN 1991-2 Load Model 71* with an α factor of 1.0 (*this is equivalent to the now superseded BS 5400-2 Type RU loading*).