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Guidelines for the Design of Intermediate Faecal Sludge Transfer Systems (IFSTS) using Pressurized and Gravity Sewers in Urban Slum or Large Refugee Camp Contexts in Bangladesh.

UNHCR, Oxfam

(Version: 28th June 2020)

GLOSSARY

FSTS	Faecal Sludge Treatment System.
IFSTN	Intermediate Faecal Sludge Transfer Network
FSTP	Faecal Sludge Treatment Plant
FoS	Factor of Safety.
PTN	Primary Transfer Node
PCT	Primary Collection Tank
SCT	Secondary Collection Tank
MCT	Main collection tank
PS	Pumping station
TS	Transfer Station

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1.0 INTRODUCTION

To date, in relation to the Rohingya refugee response, a considerable amount of work has been done to reach consensus on faecal sludge treatment technologies, with general agreement being reached on system selection with relation to context, though this yet needs to be formalized with the WASH Sector and the Government.

The concept of full chain sanitation is now generally agreed and based on this a faecal sludge treatment system (FSTS) comprises six technologically separate, functionally distinct but entirely dependent and overlapping systems, and one operational system;

1. Point of Use
2. Containment
3. Emptying
4. Transmission (or Conveyance)
5. Treatment
6. Re-use/Disposal.
7. Operation or management.

A FSTS must include all elements from latrine to safe discharge back to the environment. If one element is missing, then the system is not fully functional. This also includes the operation or management of the system.

This document will therefore specifically look at “4. Transmission”, but out of necessity will refer to aspects of 1, 2, 3 and 5. If you are not able to transfer the product (sludge) safely and efficiently to the treatment plant (FSTP), then the system or chain is not complete or fully operational.

There are four (or more) distinct design philosophies for faecal sludge treatment systems; Fully-centralized, semi-centralized, de-centralized and localized. The final selection of technology depends on context, specifically; population, population density, topography, geology, social and operational. The first three share a lot of design parameters in common and will be the main focus for this document. It will deal with the situations we have in the Rohingya refugee settlements in Bangladesh; high absolute population numbers, high population density, lack of space, often low infiltration and weak operational capacity.

There are components of the containment system that can also be categorized as *downline* or *decentralized* treatment (infiltration latrines, composting latrines, septic tanks, biogas digesters, biofil latrines, etc). Clearly the two components are intrinsically linked and entirely interdependent. This document will therefore assist in defining the design process for the centralized transfer elements (IFSTS), though out of necessity will make reference to aspects of downline or decentralized treatment.

The core principle of a centralized IFSTS is to “get the dangerous waste away from the vulnerable population. Then treat it.” The main key advantages of centralized FSTS’s are;

- The ability to ensure better quality control.
- Removal of danger from populated areas.
- Lower per capita CAPEX.
- Lower OPEX.
- Smaller per capita land requirements.

The transmission system of any centralized FSTS will itself be composed of a number of discreet elements comprising “sections” (or “reaches”).

All design work must be within capacity of local partners to conceptualize and repeat. Don’t over intellectualize the problem, meet the capacities of the operators, designers and partners.

2.0 PREPARATORY PHASE.

The preparatory phase is the time taken before any field work takes place and is the most important of the design process. Taking time at this stage to gather data, interview people and develop a comprehensive picture of the context will save multiple issues later in the process.

No individual element of the IFSTS is technically complex in itself, however when developing large networks with potentially hundreds of tanks and pumps as well as many kilometers of pipelines it is important to follow clear procedures to avoid overly complex and expensive solutions.

The final network will be an aggregation of many discrete small systems which consist of tank (or node) an optional pump and a length of pipe. In this document these discreet systems will be referred to as a ***“section”.***

2.1 Define the Problem.

The first stage in any design process is to define the problem. This relates to;

1. Area: define the area of the community to be served and more importantly what areas are available for elements of the FSTS.
2. Define the total population (including mapping), by as small an area as possible (by DSZ if possible).
3. Establish the population density, (again for the smallest areas).
4. Map any free space (see 1.)
5. Plot all existing FSM infrastructure. (latrines (type, size), collection tanks, FSTPs, networks etc…)
6. Locate all existing other infrastructure, present and planned. (roads, power, institutions, water etc)
7. Collect data on soil (and sub-soil) conditions.
8. Investigate the surface aquifer and its use.
9. Study social considerations.
10. Investigate Operational capacities.
11. Detailed analysis of resource availability (materials, skills, financing)

Obtain detailed maps of areas to be covered showing; shelters, roads (including planned), common facilities, services, streams/drains, agricultural land, contours and topographic relief.

Obtain locations of redundant or obsolete infrastructure such as;

- Nonfunctional hand pumps,
- BioFil latrines,
- Biogas plants,
- Emergency latrines.

These can all potentially be decommissioned to create space for the elements of the IFSTS

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Ensure CiCs (camp leaders) and RRRC (government oversight body) are fully aware and approve of project. Their assistance can be invaluable, especially in selecting sites for storage tanks and FSTPs.

2.2 Design Parameters

- Designers should take into account strong seasonal variations; therefore, sludge generation is taken as 0.75 l/c/d (dry season) to 1.5 l/c/d (wet season).
- Sludge is planned as 1.8% solids (FoS 1.2 on head losses)with the network capable of functioning at 4%. (FoS 1.5 on head losses)
- Specific gravity of fecal sludge can be taken as 1.2.

2.3 Design Order

1. Define logical desludging areas (DSZs).
2. Place the storage tanks based on guidelines mentioned below. Within those areas, locate tanks in best most central and accessible location using 100m as a guide, from the furthest containment.
3. Define potential routes for mainlines to the FSTPs based upon maximizing gravity flow and minimizing the use of pumps.
4. Review options and variations to optimize.
5. Calculate detailed BoQs.

2.3 Design Principals

The design, construction, expansion, and operation of the system must be within the technical and operational capacity of the eventual system managers to sustainably operate in terms of technical complexity, recurrent costs and quality control; probably an NGO or the government (through a contractor). These operators and managers must me fully engaged in the design phase of the programme.

It is a key design principle that ease and cost of O&M is prioritized over CAPEX. Capital and expertise are available during the immediate period of the crisis but the longer-term operations will require to be done by government and national NGOs for whom funding and consequently expertise may be hard to mobilise.

This should include;

- Functioning under variations in loading (seasonal, maintenance and breakdown)
- Minimizing labour and management requirements in all phases,
- Ensuring the maximization of locally available materials and spare parts
- Avoiding sensitive biological processes.
- Avoiding complex mechanic al processes.

Longer gravity reaches are better than shorter pumped reaches, pipelines that are not immediately using the most direct or shortest route should not be ruled out. If the system is flat from source to FSTP then the head-losses will tend to skew to majority pumping due to system and head losses. Shortest routes are desirable but ease of construction, access, availability of services (electricity) and operational considerations should also have a high priority.

The larger a system becomes with increasing numbers of sections the number of gravity vs pumped sections will tend towards a mild skew towards pumping if reaches are designed with as flat a profile as possible. The number of pumped sections will always tend to be larger than gravity due to tank inlet heights, residual heads and head losses in pipelines.

- Make a separate comparison of electric pumps and diesel pump operational cost.
- Wherever possible pipelines should have a flat profile and follow contours, (often this is not practicable or possible). Designers must draw a balance between good location and correct energy (head) balance.
- When calculating head losses in sections, design should be done for water with simple pre-calculated factors of safety added for sludge being factored in at the later stages. Make it easy.
- The FSTP should be located as low as possible without compromising on potential flood risks. This maximizes the benefit of gravity as the full system mass-volume will be delivered to this point.
- The number of gravity sections should be maximized. Operational cost effectiveness will be directly dependent on overall fuel consumption.
- Gravity sections of pipes should be self-cleaning.
- Nodes (or tanks) should be located on elevated positions to maximize the potential for gravity transmission but should also be located to preserve energy i.e. not sited at the top of hills unless that elevation is required for gravity flow or at the bottom of valleys unless part of a wider efficiency plan.
- Nodes should generally be connected by the shortest practical route from point to point which has the required slope, accessibility and stability, but taking the issues of maintaining a flat pipeline profile, ease of construction, use of existing roads and pathways, and maintaining access into consideration.
- The network should be able to respond to a range of pre-determined emergency scenarios i.e. pipe diameter, additional storage, interconnection of branches, access and trucking points etc.
- Sludge should not be left in the network where it could settle and clog.
- Tanks should be designed to not have to be de-sludged.
- Pipes should run full, flat and have few if any inflections.
- Gravity sections should maintain a minimum slope of 0.5% between any two given points and minimize all sumps and inflections.
- Pipes should follow roads, paths or cross open areas, avoiding existing and potential future infrastructure and housing unless absolutely necessary.
- Tanks and nodes should be placed in empty/available space with full consultation with and permission of existing communities, considering community facilities other religious and social concerns.
- Overall storage capacity of system (not including FSTP) should equal two days sludge production for the entire coverage area and is related to estimated maximum downtime of FSTP in emergency. This shows advantage of building modular FSTPs, if one becomes un-operational it is not critical.
- Where possible, in downhill grades, use nodes (connection boxes) rather than tanks. These preserve the energy/pressure from the de-sludging pumps and allow the sludge to immediately pass down the main lines to the next storage location.
- Nodes can also be used for small uphill grades depending on the remaining pumping head at the inlet compared to the required residual head at the next tank.
- For collection tanks or nodes, if possible design for emergency access for vacutugs, therefore these should be on roads wherever possible.
- Design for back-flow of sludge from full pipes in uphill sections, to nearest pit/tank.
- Caking is a design issue, use decommissioned boreholes for water supply for wash outs, discharge into pits or tanks.

- Nodes location should be based on an estimated 100m sludge collection radius, though this is not rigorous and final selection depends on ground-truthing and advice of de-sludging managers and teams.
- Avoid overlaps of de-sludging zones unless required by the topography.
- Existing FSM infrastructure (including ‘septic tanks’) and pipelines should be used where possible.
- Where possible, road and river crossings should utilize existing bridges and culverts.
- Only keep the existing tanks and pipelines where its proven to be economic and appropriate and match with new DSZs.
- A project is never final, individual tanks or nodes or pipeline alignments can and should be moved to optimize operation based on improving knowledge.

3.0 Design & Operation Criteria.

Design using standardized sections and elements, these sections will vary only according to their required storage capacity, estimated flow rates, difference in elevation and the reach or distance between nodes or tanks.

1. Primary Transfer Node: with return flow bypass.
2. Primary Transfer Node: without return flow bypass.
3. Primary collection tank (pumped sections only) (with or without bypass)
4. Secondary collection tank(s) (with pump) (with or without bypass)
5. Secondary collection tank (gravity)
6. Wash out. (outlet) (with connection to disposal)
7. Wash out (inlet) (with water source)
8. Valve chambers.
9. Rodding access points.

3.1 Calculating Total Network Storage Capacity

The “network” is defined as all elements of the IFSTN before any buffer tanks at the FSTP itself. The required storage capacity in the IFSTN will be defined by a risk analysis of any possible downtime of the FSTP caused by catastrophic failure of any major elements or by destruction by natural causes (cyclone, flood etc). This storage capacity will therefore be dependent on the criteria and variables agreed upon by the designers and operators. How many days will one or more of the modules or critical shared elements require for repair? Therefore, the total storage capacity (in the entire system, not including latrines and septic tanks) is calculated as; days of down time x maximum operational capacity of the non-functional module/element. An example of this would be assuming the entire Camp 4 FSTP was non-functional for seven days and assuming a 100 m3 per day treatment capacity;

7 x 120,000 = 840 m3,

but if only 33% of the system was non-functional for an estimated two days to return the elements to functionality then the required volume would be;

2 x 33,000 = 66 m3

This shows the importance of built-in redundancy, simplicity and modular design.

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This overall storage capacity should be placed within the IFSTN at locations and branches according to the proportion of sludge being produced upstream from that area. It is best practice to place larger storage tank units at low points where the following "section" or reach has a positive head difference and will require pumping, or at an elevated collection location from where multiple pipelines meet and the following section is by gravity.

3.2 Selection of Primary Transfer Nodes (PTN) vs Primary Collection Tanks (PCT)

To transfer the product into the main transmission and storage system there are two available options, primary transfer tanks (PTTs) and primary transfer nodes (PTNs). Their selection, use and function are significantly different. Primary transfer tanks are only selected under two conditions;

- Where storage capacity is required on a system or branch level and there is no place further down the branch to locate sufficient capacity.
- Where there is a high positive head difference in the following section and the next tank is elevated beyond the capacity of the sludge pump being used at the pit-side to reach. This will therefore require a second, or transmission pump at the PTT.
- Or a combination of the two.

In all other cases a ***primary transfer node*** should be used, for direct pressure connections to the pumping or transmission main.

All transmission tanks or transfer nodes should be marked as "dangerous" and "not for drinking water" with warnings written and in pictures or symbols.

3.3 Primary Transfer Node Design. (PTN)

A primary transfer node is essentially;

- A "tee" junction in a transfer pipeline contained in a valve box with gate valves on the upstream inlet and on the 2" pumping inlet. The downstream outlet will not need a gate valve unless in an uphill section and/or a non-return bypass is fitted. (see Annex 3)
- A direct connection to the start/end of a transmission line or branch.

The purpose of these are to transfer the sludge directly into the transfer system without the use of a collection tank and whilst maintaining the pressure head generated by the sludge pump. Nodes must be located on secure ground, not liable to slope instability and protected from significant erosion. Where there is an uphill section PTNs should have a non-return valve on outlet.

Given the reduced requirement for land, a number of nodes can be installed in larger DSZs creating mini-networks, reducing the requirement

Mainlines (secondary to secondary) should be sized based upon:

- The volume a model desludging team can remove in a day.
- The number of desludging teams required for a mainline
- Assumed that all desludging teams are simultaneously creating flows from primary collection tanks to the same part of the mainline
- Sludge should not be left in the network where it could settle and clog.
- Tanks should not have to be de-sludged and accommodate regular desludging.

Ease of O&M is prioritized over Capex. O&M includes functioning under variations in loading, using minimal labour and management in transfer, locally available and easily installed spare parts and avoiding sensitive biological processes wherever possible.

3.4 Tank Design

Tanks have one of four designations;

1. Primary Transfer Tank (PTT)
2. Secondary Transfer Tank (STT)
3. Primary Collection Tanks (MCT)
4. Secondary Collection Tank (SCT)

The selection and sizing of networked tanks is heavily dependent on the required function. Tanks are not required in every de-sludging zone, in fact probably only in those which require a mass lift in order to get the sludge to the following section. When installed, PTTs and STTs will be an integral part of a standardized “section” for which the standard design should be followed. This will define all materials, fittings, sizes and requirements.

Ensure tanks are located on secure ground, not liable to slope instability and protected from significant erosion.

Tanks will generally be of either Plastic or reinforced concrete design.

Reinforced concrete will be used in the following circumstances.

- There is an existing septic or collection tank that whose use is being converted to that of collection tank or transfer station.
- An underground tank is deemed to be necessary due to space constraints, volume requirements, head requirements or danger of slope instability.
- One inlet of tank will be used for vent, to prevent the accumulation of sewer gases that may be explosive and corrosive.

Otherwise plastic “Gazi” tanks of 5 m3 and 10 m3 volumes will be used. (see standard designs)

4.0 "Section" Design

1. Pipeline design starts at the final section entering the FSTP. This can be designed with two (or more) parallel pipelines to allow for seasonal variations, FSTP modular design, and FSTP operational considerations.
2. Section design then moves progressively along each branch to source, using calculated volume and flow requirements.
3. All transmission pipelines must be watertight and protected against traffic, erosion and footfall, especially if laid above ground.
4. Pipelines should be laid at minimum 90cm depth under footpaths and 90cm under roads, unless emergency conditions require otherwise.
5. Pipelines should be routed on the side of the road with the most connections.
6. Pipe route should not run through dense areas of community households unless completely unavoidable.
7. Pipelines should be laid vertically and horizontally separated from drinking water pipes. If these lines are within 2m horizontally they should be rerouted or sleeved.
8. Junction bends should be at maximum 45 degrees and otherwise use snaked flexible pipe.
9. For all pipeline reaches install inspection chambers at double the length of the longest unblocking tool (i.e. 50m total) and at all junctions.
10. Airlocks added as required and on every high point, before and after inflected sections and ventilated caps on all flushing/wash-out points.
11. Ensure there is provision for the flushing or cleaning of all main lines and storage tanks.

4.1 Head-loss and sizing

Head losses should be calculated using the coefficients for water, then a Factor of Safety (FoS) used to compensate for the estimated increased density and viscosity of the wastewater due to increasing percentages of solids; (FoS = 1.2 for 1.8% solids up to FoS = 1.5 for 4% solids.)

All pipelines should be a minimum of 63mm (2") until such time as field testing demonstrates that smaller diameters are not prone to blockages due to debris passing through the de-sludging pumps.

Residual heads at tank inlets should be a minimum of 1m unless otherwise specified due to local conditions.

4.2 Head Loss in a Gravity Section.

The head loss in a gravity section (see Annex 1) is calculated using the following formula.

HL_T	Total head loss in section
GL (T1)	Ground level of Tank 1
H (Out T1)	Outlet height of Tank 1 above ground level
L	Total length of pipeline
%	Head loss in pipeline for given flow as %.
GL (T2)	Ground level of Tank 2.
H (In T2)	Height of inlet to tank 2.
HL_F	Head loss in pipeline fittings.
H_R (In T2)	Residual Head at tank 2 inlet.

$$H_R\,(T2) = GL_{T1} + H\,(Out\,T1) - GL\,(T2) - (\%\times L) - H\,(In\,T2) - HL_F$$

4.3 Head Loss in a Pumped Section.

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The head loss in a pumped section (see Annex 2) is calculated using the following formula.

$H_{R\ T2}$ (in)	Residual Head at tank 2 inlet.
HL_T	Total head loss in section
H_{PT}	Pumping head of transfer pump.
GL_{T1}	Ground level of tank 1
GL_{T2}	Ground level of tank 2.
H_{T1} (out)	Outlet height of Tank 1 above ground level
L	Total length of pipeline
%	Head loss in pipeline for given flow as %.
H_{T2} (in)	Height of inlet to tank 2 above ground level.
HL_F	Head loss in pipeline fittings.

$$H_{R\ T2}\text{ (in)} = H_{PT} - (GL_{T1} - GL_{T2}) - HL_F - (\%\times L) - H_{T2}\text{ (in)}$$

4.4 Head Loss in a Transfer Node Section.

The head loss in a pumped section (see Annex 3) is calculated using the following formula.

HL_T	Total head loss in section
ΔH	Elevation difference between desludging pump and ground level at node.
L	Total length of pipeline
%	Head loss in pipeline for given flow as %.
GL_T	Ground level of tank.
GL_N	Ground level of node.
H_T (in)	Height of inlet to tank above ground level.
HL_F	Head loss in pipeline fittings.
H_R (in T)	Residual head at tank inlet.

$$H_R\text{ (in T)} = H_P - \Delta H - (GL_T - GL_N) - HL_F - H_T\text{ (In)} - (\%\times L)$$

In all equations above all parameters are fixed except for % (Head loss in pipeline for given flow as %) As the flow is fixed the only variable is pipe size. Head loss % will assume 2% solids, unless site-specific considerations apply.

4.5 Sludge Return

Care must be taken to compensate for "sludge return" in designing uphill sections. When pumping stops, all the sludge remaining in the transfer main will tend to flow back into the transfer pump or into the PCT. Where this is calculated to be a problem, a sludge diversion teen should be fitted with appropriate control valve to divert this volume of sludge (250 liters in a 63mm pipe over 100m uphill section). This amount should be diverted through a fixed pipe to the nearest septic tank, collection tank or latrine pit.

4.6 Tank Bypass

All transfer tanks, except those at the beginning of a transfer line should be constructed with a bypass system, to allow for the maintenance of pumping head when passing sludge along main lines, and to allow the transfer tanks to be used for zone de-sludging and storage at the same time. (see Annex)

4.7 Wash-Outs

All main transfer lines will be fitted with wash-outs at low points/upward inflections in the profile, or sumps, to enable cleaning and to avoid caking. Transfer lines will be regularly cleaned as part of the regular maintenance programme. These wash-outs will be connected by a fixed or temporary pipe to the closest septic tank, collection tank or latrine pit.

4.8 Rodding Points

For pumped sections of pipes install Y's every 50m (where rodding/flushing is possible in both directions, otherwise 25m between washouts / inspection chambers) and nodes will serve as the inspection chambers.

5.0 Pump Selection

Pumps will be designated by the following categories;

1. De-sludging pump.
2. Transfer pump (small)
3. Transfer pump (medium)
4. Transfer pump (large)

1. Mainline pumps (Transfer pumps, small, medium and large) should where possible be operated on grid electric. As an alternate option diesel engine should be considered and properly designed for power, head and flow.
2. Inlet should be minimum 90mm and outlet with minimum 63mm

3. Pump features for pit to tank transfer
   - Portable,lightweight
   - Higher flowrate, Trash (Preferable)
   - Maximum delivery distance and head

4. Pump features for secondary to secondary
   - Long range pumping and high delivery head
   - Noise control System as the pumps will be place inside the blocks .

5.1 Keeping the system free from grit and coarse particle

Foreign particles can break the pump shaft and impeller which will result in frequent repairing and breakdown of pumps. To avoid this issue -

Always use pump float valve (Max opening-20 mm)

6.0 De-Sludging Zones.

De-sludging zones will be the primary unit or area for the management and design of the entire FSTS. These will determine de-sludging programmes and will be reported on by the DS teams for tracking purposes.

DS zones will be defined and designed logically based on actual ground context, considering natural topography, existing communities, canals, drains, streams, ponds, power supply, existing/planned roads, camp/area political/organizational divisions, etc.

They will be based on the 100m guide radius mentioned above, though the reality of the zone boundaries will be based on social and topographical criteria as well as interview and documentation of the experience to date of active desludging teams in the affected area. They will take into account what de-sludging programmes are ongoing, and who (individuals) is implementing them. Interview must be held with the desludging teams, and it is imperative for the designers to spend some days with these teams walk through camps with them, asking questions on scope.

They will also be derived from data and surveys, identifying all latrines requiring desludging in each DSZ. Each zone will then have its population and number of households identified and consequently its projected maximum and minimum sludge production estimates.

Within those areas, find available locations for either a primary collection tanks (PCTs), or a primary transfer node (PTN), ensuring all latrines are within range of the available desludging pumps available. For initial planning purposes 100m can be used to estimate maximum pumping distance, though the actual maximum pumping distance will be determined by the ground realities as identified by the existing desludging teams.

DSZs should cover the full area of each camp, therefore capturing 100% of the shelters and public facilities. These zones will also be used to calculate the requirements for new or upgraded latrines.

6.1 De-sludging Strategy

The strategy for de-sludging the DSZs is critical to the design of the storage requirements and pipeline sizing for any IFSTS.

The de-sludging strategy (and teams) are seen as unskilled, unmanaged and the lowest in the sanitation chain. This is not the case and this aspect of the work must be professionalized.

At the moment latrines are not emptied systematically and are generally not recorded in terms of location or volume. They are usually emptied only when full and overflowing and they are reported as such leaving others in same area (DSZ) partially full. This is inefficient.

De-sludging zones must be de-sludged in their entirety, detailed and recorded; including the type, location, condition and volume. Also, to which FSTP the sludge was sent and by what means.

Each DSZ has a known and identified number of latrines, these should be emptied regularly and according to a fixed schedule. All latrines in the DSZ above 50% full should be emptied systematically.

One skilled DST should be estimated to remove 20 m3 per day. Therefore, this amount needs to enter the network from this location, through a PTT or a PTN. This determines that the flow in the primary transmission main will be either;

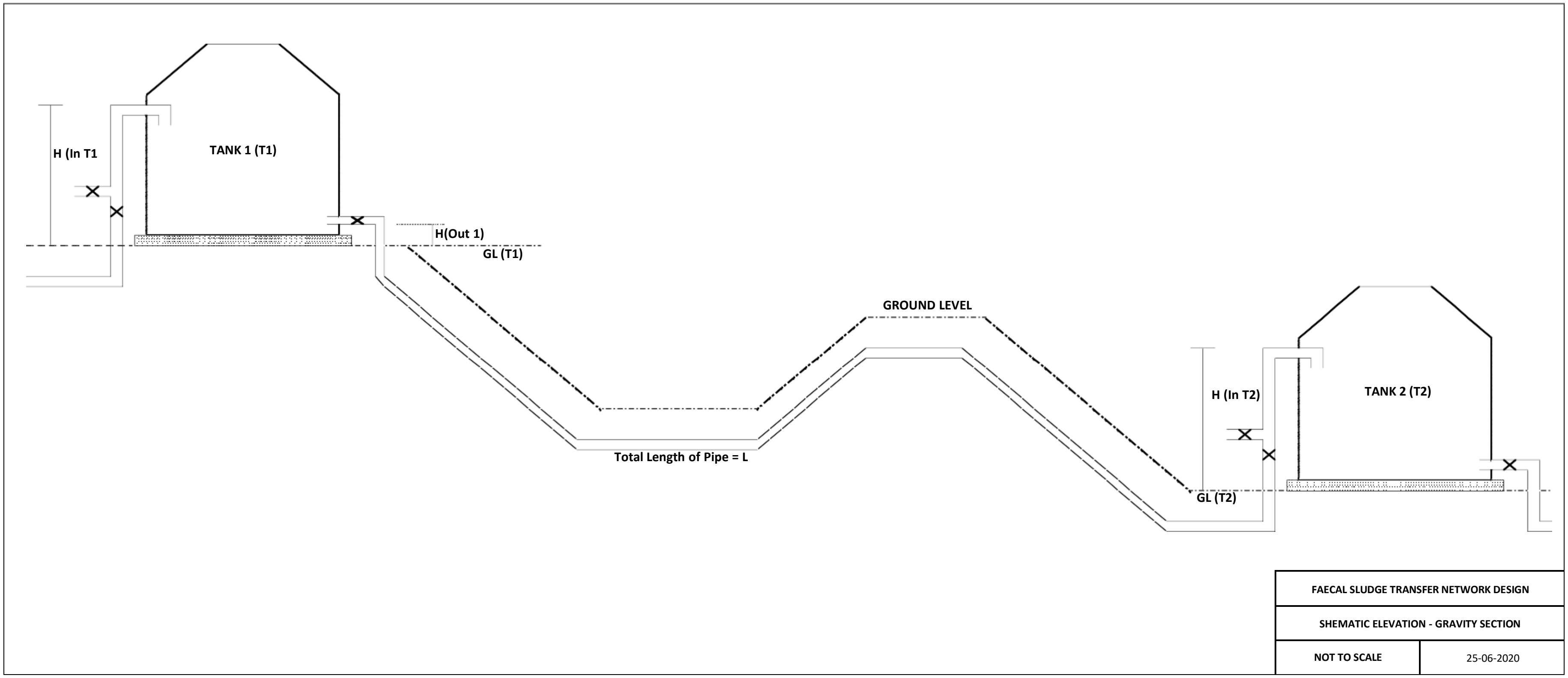
- Equal to the pumping capacity of the de-sludging pump (in the varying head conditions of a PTN) or
- Equal to the pumping capacity of the PTP (in the case of a pumped PCT) or
- Equal to the free gravity flow of the PT Main section (in the case of a gravity P/SCT)

Assuming 20 m3 being transferred over 4 hours of pumping, this would give an average design flow of 1.4 l/s. If it assumed a 63mm OD HDPE pipe is used then the average heads loss will be 0.62%.

The number of desludging teams required should be equal to the daily average treatment capacity of the FSTP divided by the daily capacity of a de-sludging team (estimated to be 20 m3 in this document).

Therefore if the capacity of the FSTP is 120 m3/day then six DSTs will be required. (Plus one emergency/specialist). Each DST will have a fixed area and number of DSZs in which to operate.

Annex 1: Gravity Section Schematic



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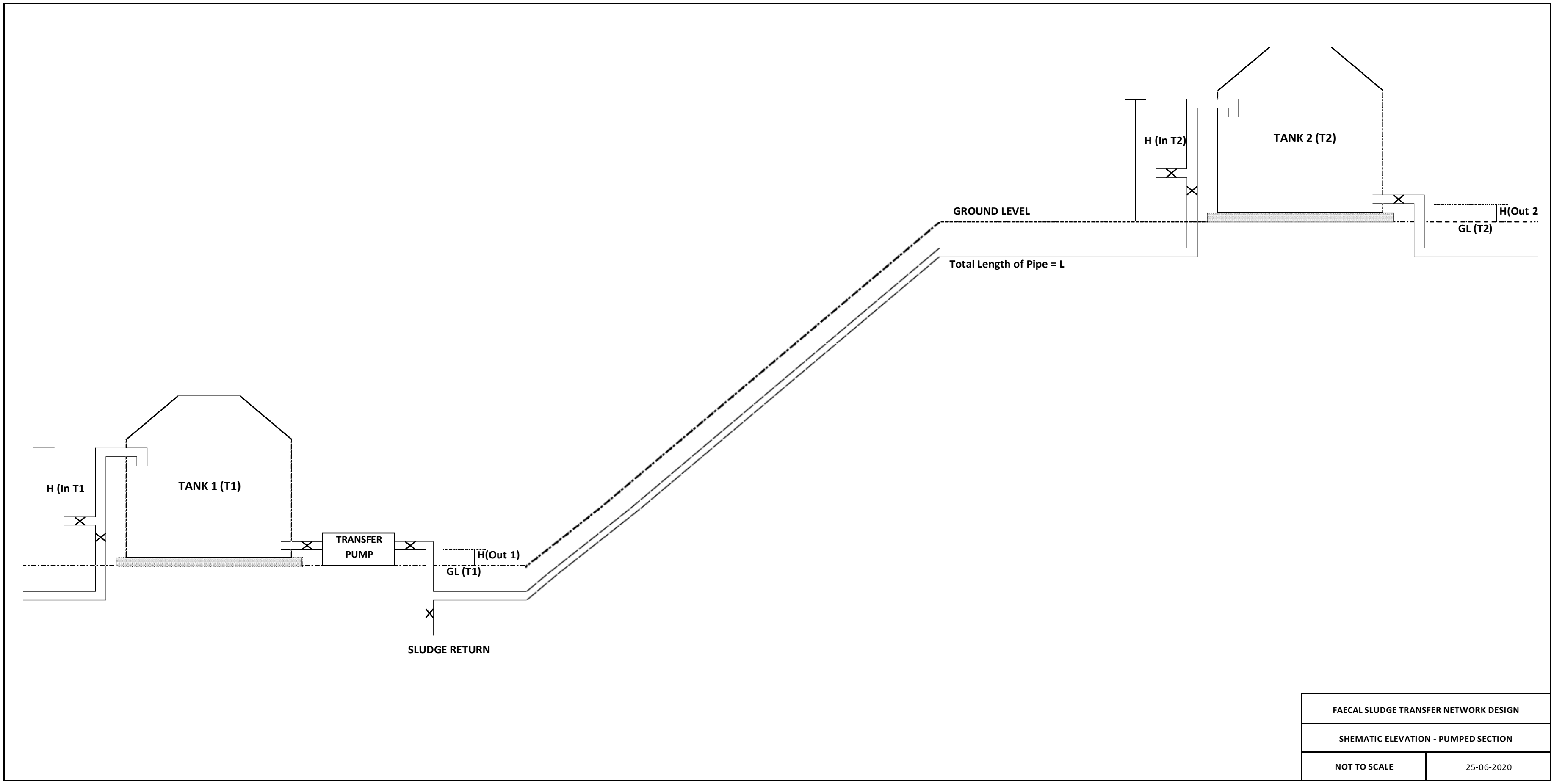
Annex 2: Pumped Section Schematic



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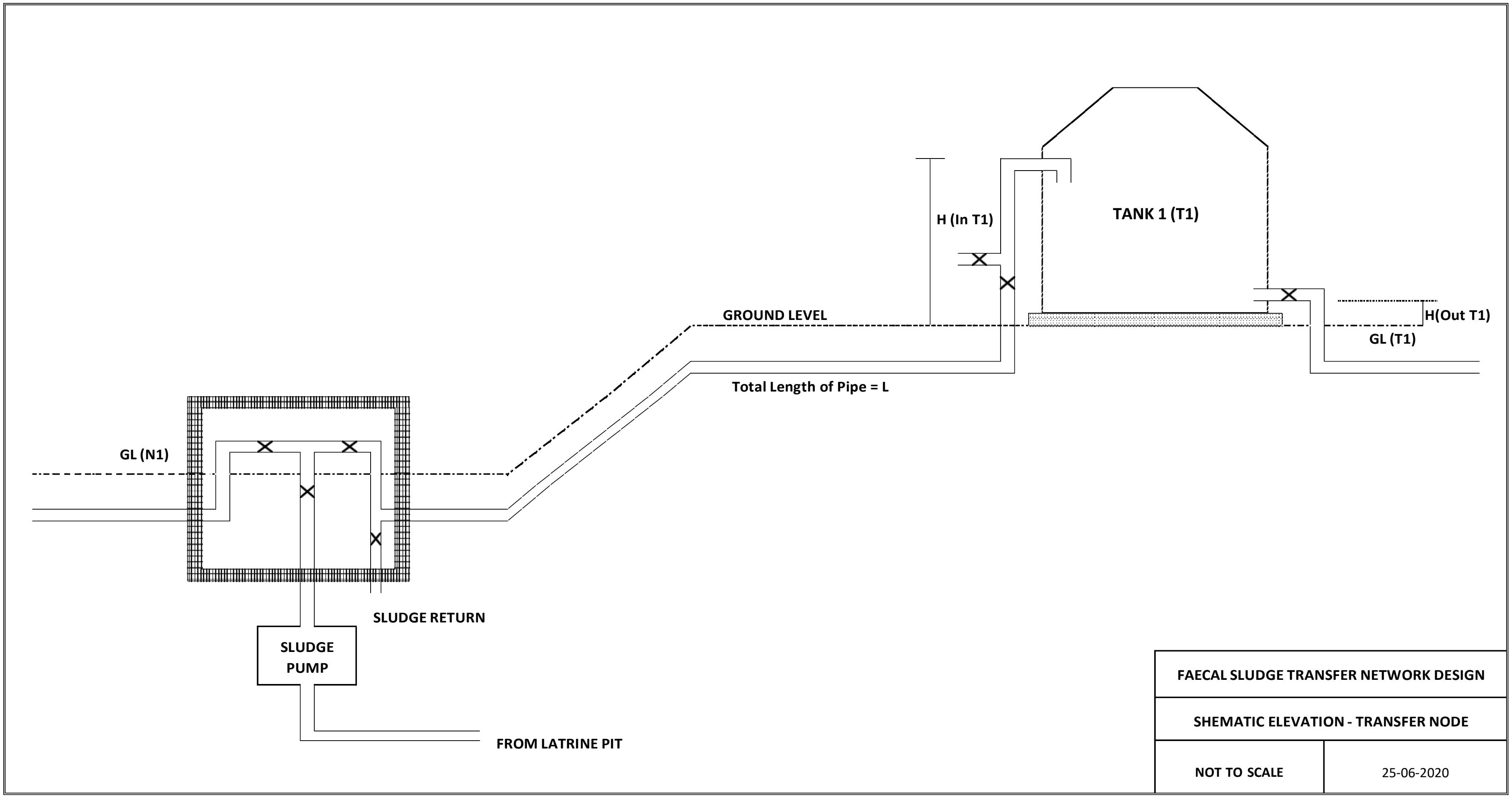
Annex 3: Transfer Node Section Schematic



ANNEX 4: HEAD LOSS CHARTS FOR FAECAL SLUDGE

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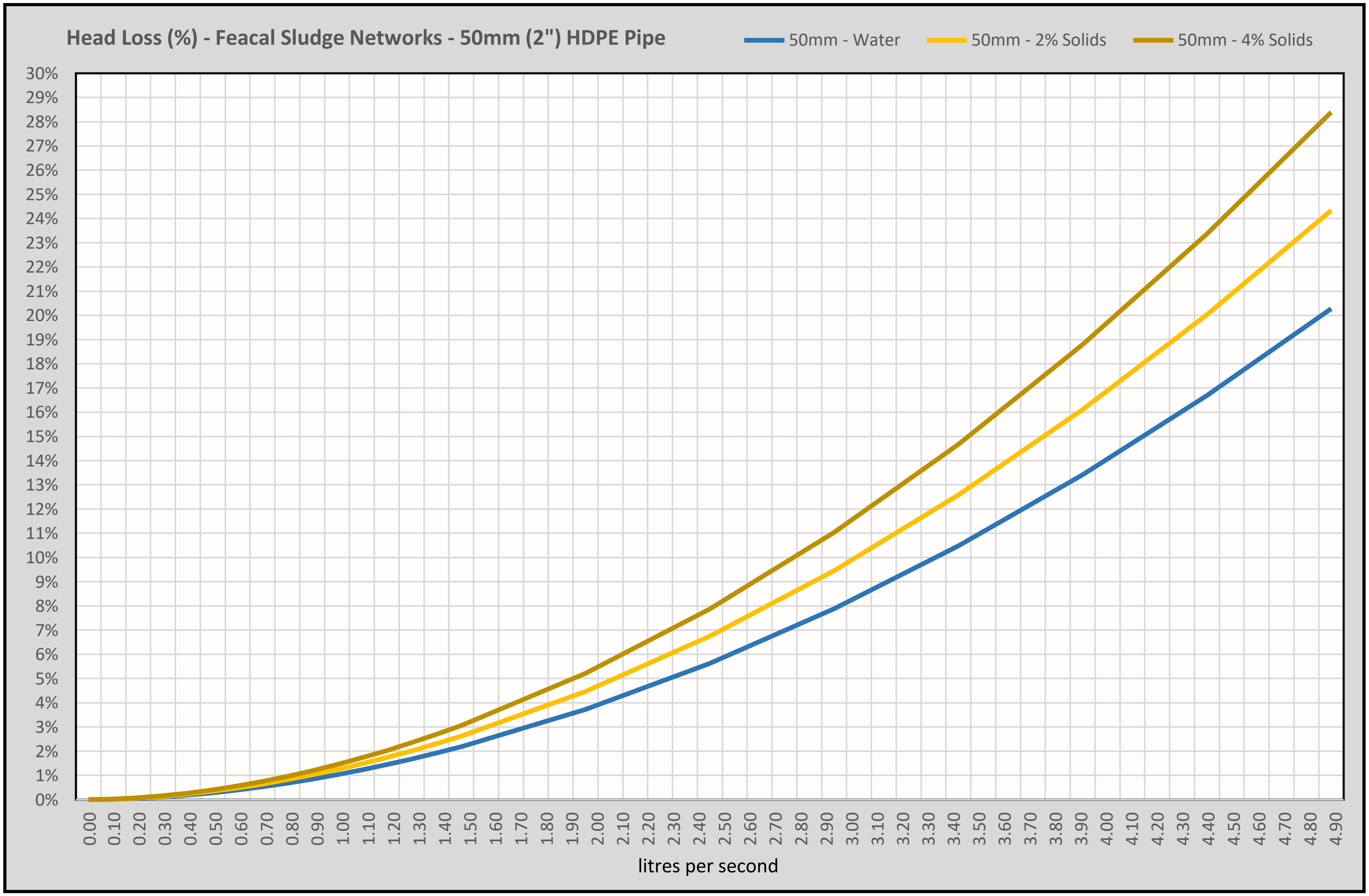
ANNEX 4A: 50mm (2”).



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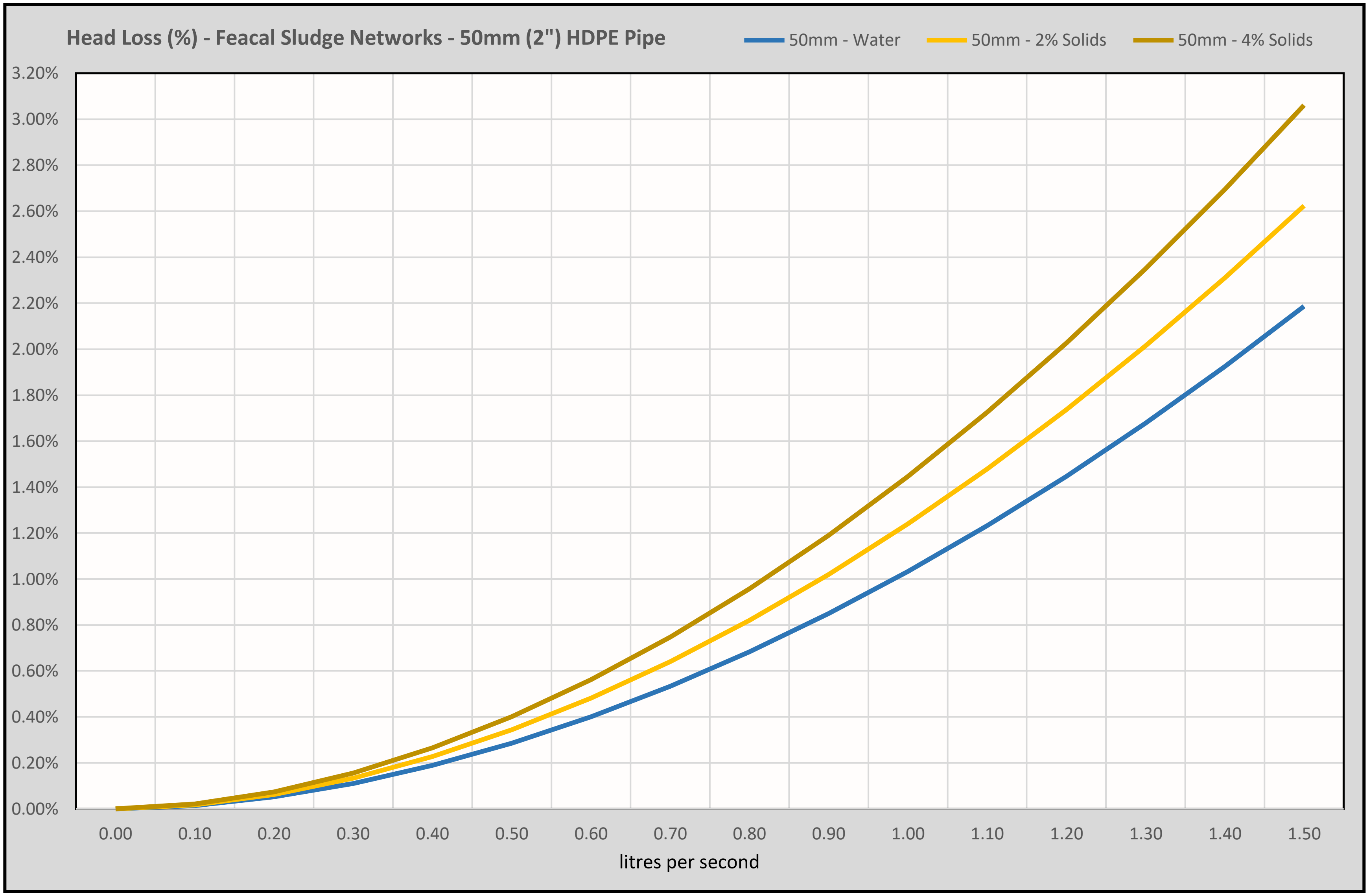
ANNEX 4B: 50mm (2”) Low Flow Detail.



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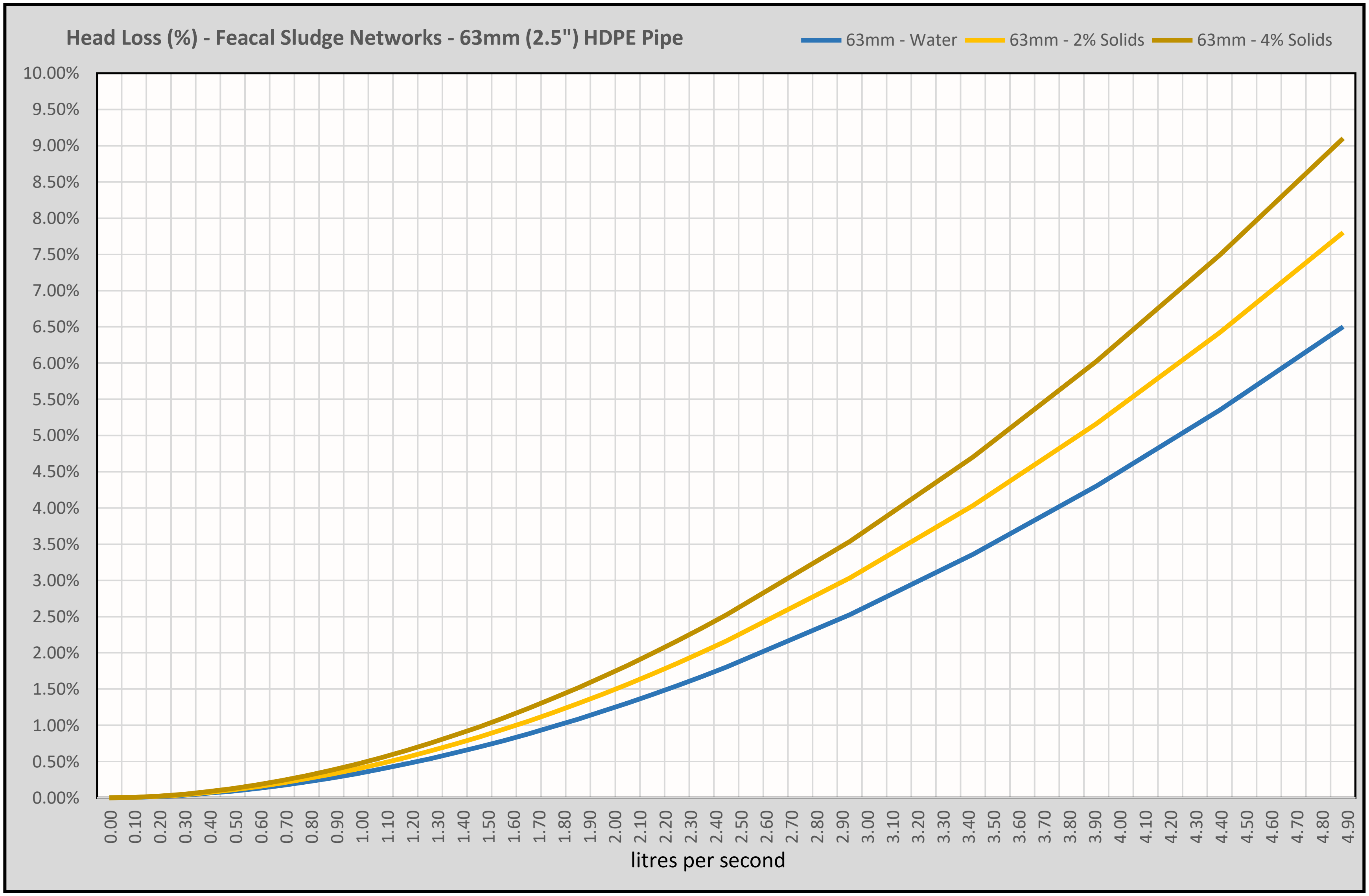
ANNEX 4C: 63mm (2.5”)



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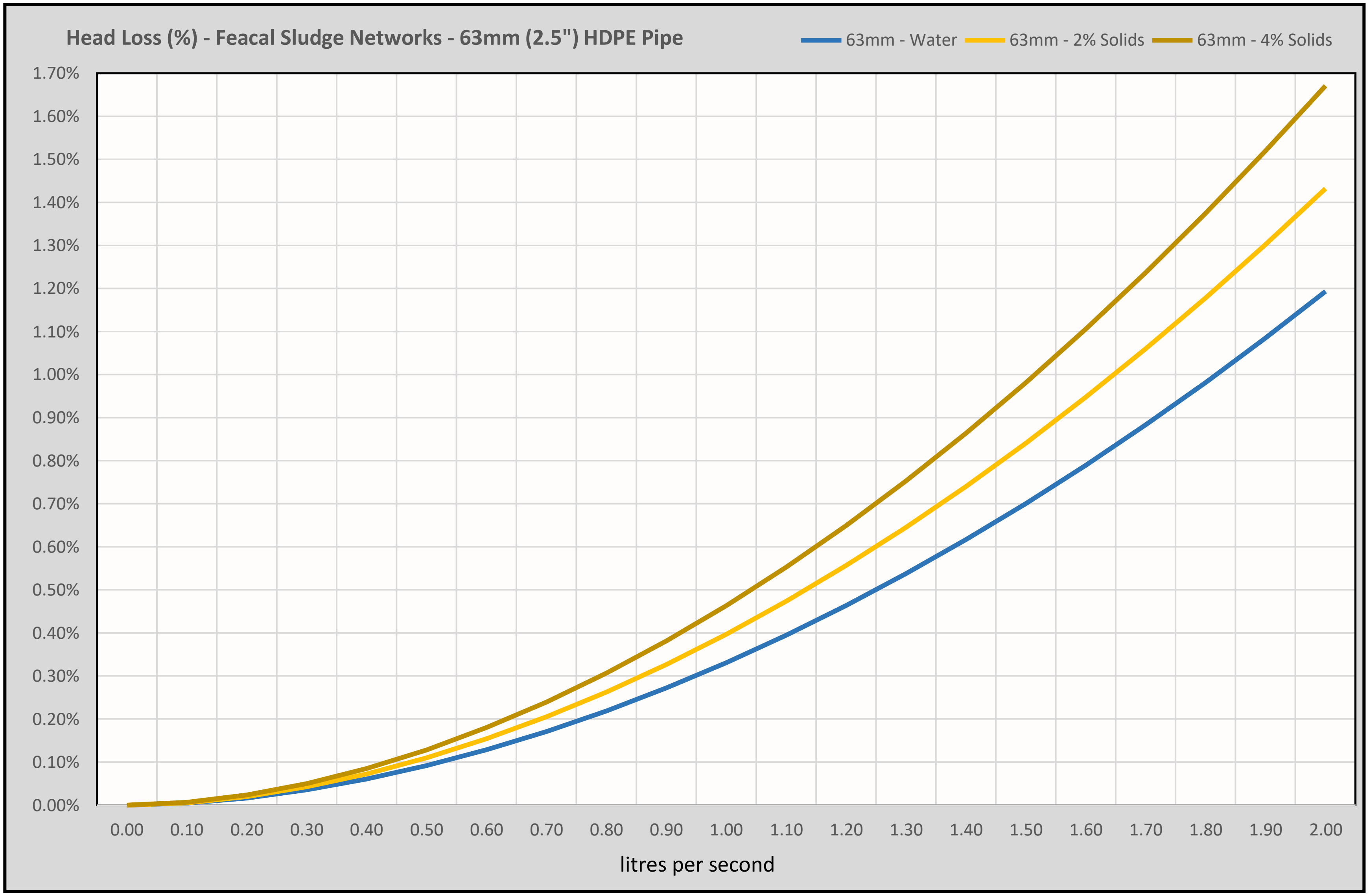
ANNEX 4D: 63mm (2.5”) (Low Flow Detail).



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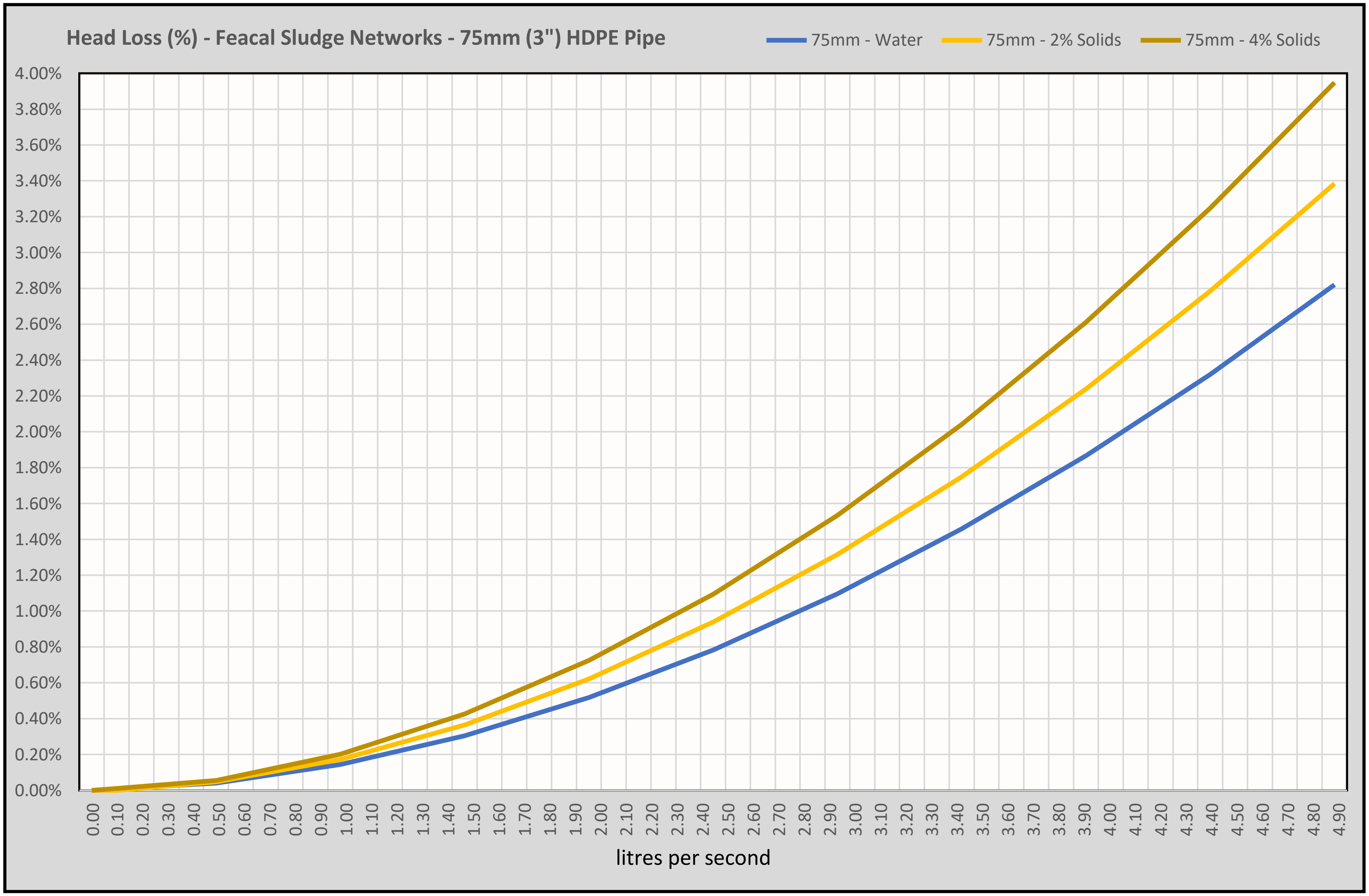
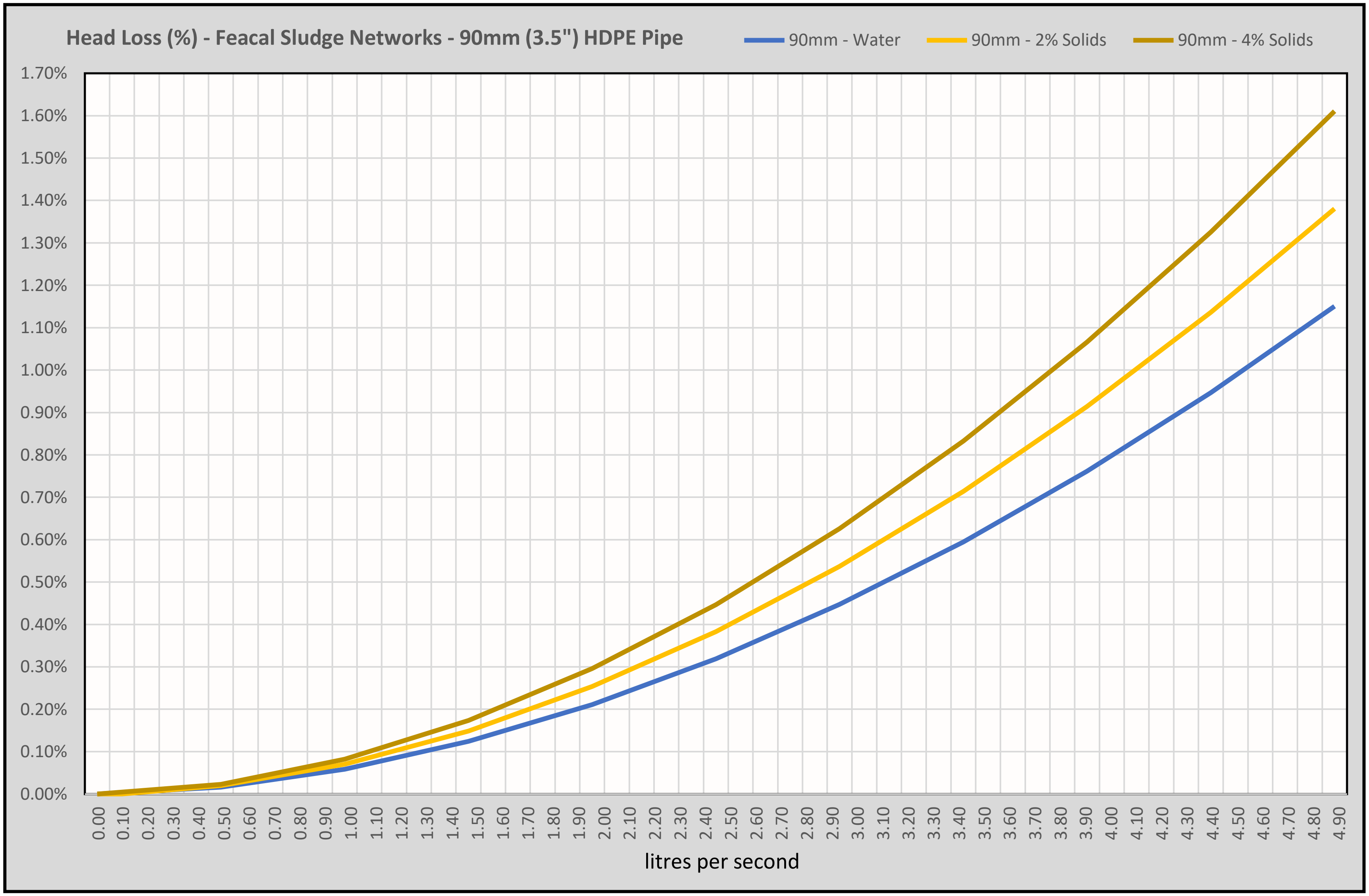
ANNEX 4E: 75mm (3”)



ANNEX 4F: 90mm. (3.5")



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ANNEX 4G: 110mm. (4")