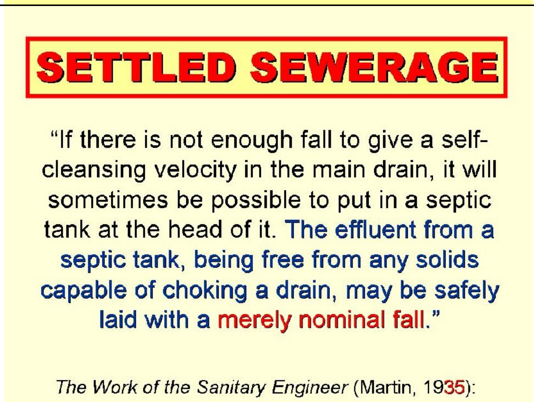
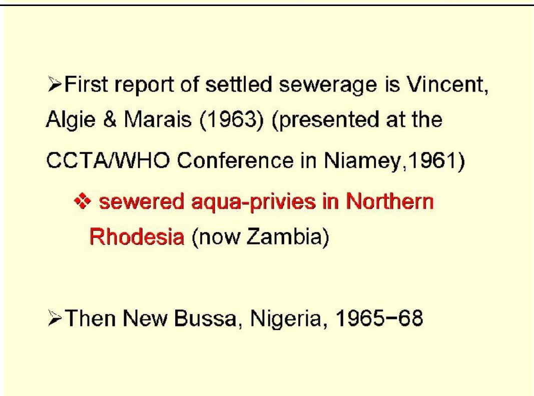
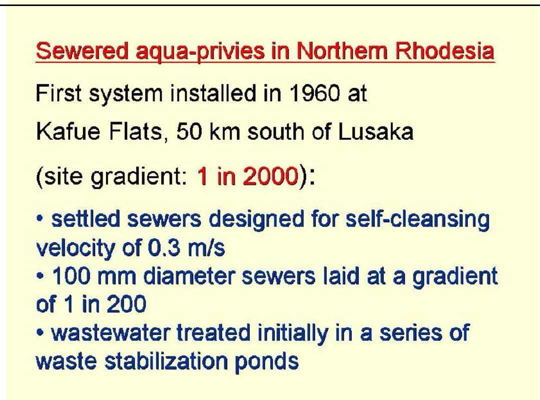
SETTLED SEWERAGE

Part 1 of 3

<table>
<tr><td>1.</td><td>
</td><td>This programme is about settled sewerage, sometimes called small-bore sewerage,</td></tr>
<tr><td>2.</td><td>
</td><td>and the first reference of this is in a book published in England in 1935, which said:

“If there is not enough fall to give a self-cleansing velocity in the main drain, it will sometimes be possible to put in a septic tank at the head of it, the effluent from a septic tank being free from any solids capable of choking a drain may be safely laid with a merely nominal fall.”</td></tr>
<tr><td>3.</td><td>
</td><td>The first report of an actual settled sewerage scheme was published in 1961 and this described sewered aqua-privies in what was then Northern Rhodesia, now Zambia, and this was followed in the mid-to-late 1960s by a scheme in New Bussa in Nigeria.</td></tr>
<tr><td>4.</td><td>
</td><td>The sewered aqua privies in Northern Rhodesia were first installed in 1960 in Kafue Flats, about 50 km south of Lusaka; and the site gradient was very flat: 1 in 2000.
This was the first sewered aqua-privy system, and the settled sewers were designed for a self-cleansing velocity of 0.3 m/s and the scheme used 100 mm diameter sewers laid at a gradient of 1 in 200, and the wastewater was treated, at least initially, in a series of waste stabilization ponds.</td></tr>
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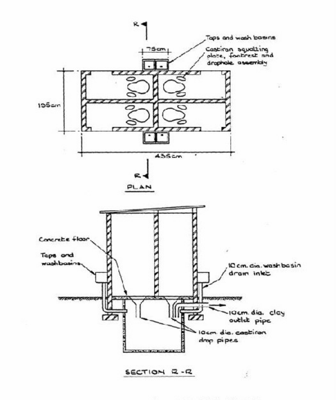
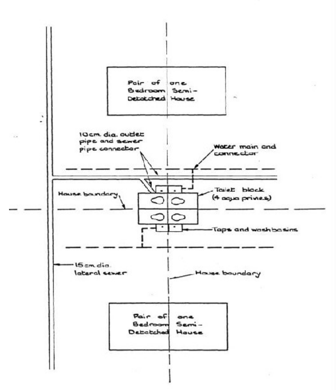
5.	 **Details of sewered aqua-privies in Zambia**	This slide shows a typical layout of an aqua-privy block as used in Zambia. There are four units shown at the top, one for each of four houses, and they sit above a common watertight tank which lies underneath them.
6.	 **Typical layout of houses & aqua-privy block in Zambia**	This slide shows the four-unit aqua-privy block and the four houses it serves. It also shows how the aqua-privy effluent is discharged into a 100-mm diameter sewer, and this discharges in turn into a street sewer of 150-mm diameter.
7.	**Sewered aqua-privies in Nigeria** New Bussa (resettlement town) • 256 compounds (15–40 people) • each compound has a sanitation block with aqua-privy, laundry area & shower; water tap in laundry area • sullage discharged into aqua-privy tank (ie, "self-topping aqua-privy") ❑ No information on hydraulic design, presumed to be same as in Zambia ❑ 100 mm dia. compound connection to lane junction box; 150 mm dia. lane sewers; treatment in WSP	In the mid-to-late 1960s sewered aqua-privies were installed in the resettlement town of New Bussa in Nigeria. There are 256 compounds, each serving an extended family of somewhere between 15 and 40 people. Each compound had a sanitation block with an aqua privy, a laundry area and a shower, with a water tap in the laundry area. Solids were discharged into the aqua-privy tank and so it is sometimes described as a self-topping aqua-privy. There was no information on the hydraulic design of the system and we presume it to be the same as in Zambia: 100-mm diameter compound connections to a lane junction box and then 150-mm lane sewers, with treatment in waste stabilization ponds.
8.	❑ Aqua-privies now a questionable sanitation facility: • expensive water-tight tank • 'crude' drop-pipe • difficulty of maintaining water seal ❑ Pour-flush toilets less expensive and more "sophisticated"	Aqua-privies are now a questionable sanitation technology. They require an expensive watertight tank, they have a fairly crude drop pipe, and it is difficult to maintain the water seal; and pour-flush toilets are really much less expensive and also more sophisticated, at least to the users.

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<td>But sewered aqua-privies gave us settled sewerage, first installed in Zambia in 1960, then in Australia in 1962, Nigeria in 1965, in the United States in 1975, in Colombia in the very early 1980s, and in South Africa in 1990.</td>
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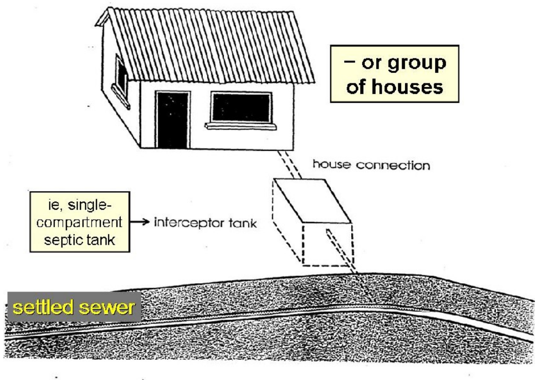
<td>10.</td>
<td>
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<td>This slide shows the basic components of a settled sewerage scheme: a house or a group of neighbouring houses discharge their wastewater into an interceptor tank, which is basically a single-compartment septic tank. In the tank the settleable solids settle and the solids-free effluent is then discharged into the settled sewer running outside.</td>
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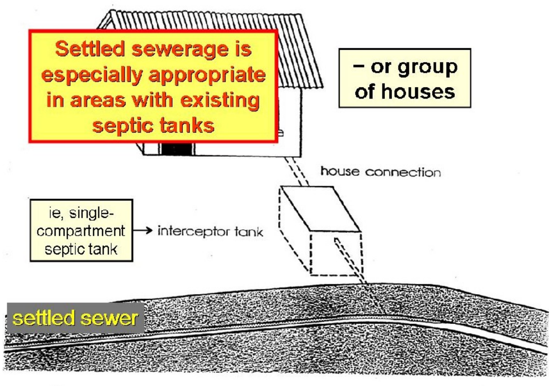
<td>11.</td>
<td>
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<td>Clearly, settled sewerage is really very appropriate in areas which already have septic tanks as the cost then is much less.</td>
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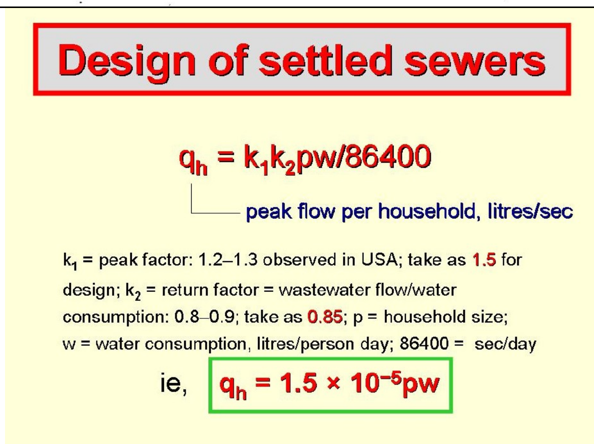
<td>12.</td>
<td>
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<td>Now we move to the design of settled sewers and the first thing we have to establish is the peak flow per household in l/s, and this is equal to:
$$\frac{k_1\, k_2\ p\, w}{86{,}400}$$
k_1 is the peak factor. In the United States they have observed values of the peak factor of between 1.2 and 1.3, but for design purposes we would normally use 1.5.
k_2 is the return factor, that is to say, the percentage of water consumption which ends up as wastewater, and that is usually between 80 and 90%, and so we would use a k_2 value for design of 0.85.
p is the household size, the number of people in the household; w is their water consumption in litres per person per day; and 86,400 is the number of seconds in a day. So, using those values for k_1 and k_2, the peak flow per household is:
$$1.5 \times 10^{-5} pw$$</td>
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13.	➢ Flow can be either **open channel flow** or, in sections below the hydraulic grade line, **full-bore pressure flow.** ➢ Make separate analysis for each section of sewer in which the type of flow (open channel or pressure) does not vary & the hydraulic gradient is reasonably uniform	A really important feature of settled sewers is the flow can be either open channel flow, that is to say with a free water surface, or in sections of the sewer which lie below the hydraulic gradient, full-bore pressure flow; and we make a separate analysis for each section of sewer in which the type of flow, either open channel or pressure flow, does not vary and over which the hydraulic gradient is reasonably uniform.
14.	**Use Manning's equation** $v = (1/n)r^{2/3}i^{1/2}$ velocity of flow, m/s sewer gradient, m/m (strictly, hydraulic gradient) pipe roughness coefficient (usually taken as 0.013) hydraulic radius (= area of flow ÷ wetted perimeter)	The basic equation we use for the design of settled sewers is Manning's equation. This states that the velocity of flow in m/s is equal to: $$\left(\frac{1}{n}\right) \times r^{2/3} \times i^{1/2}$$ *n* is Manning's pipe roughness coefficient; it is dimensionless and has a value normally of 0.013. *r* is the hydraulic radius, that is to say the area of flow divided by the wetted perimeter, so it has units of metres; and *i* is the sewer gradient in m/m (so dimensionless) − strictly speaking it is the hydraulic gradient.
15.	When the sewer is flowing just full: r = R and R is given by $R = (\pi D^2/4)/\pi D = D/4$ sewer diameter, m Now velocity = flow/area, so Manning's 'flow' eqn is: $Q = 24D^{8/3}i^{1/2}$ D in m or $Q = (2.4\times10^{-4})D^{8/3}i^{1/2}$ D in mm	When the sewer is flowing just full, *r* the hydraulic **radius**,[*] equals *R*, the hydraulic **radius**[*] at full flow; and *R* is given by $\pi D^2/4$ (where *D* is the sewer diameter in metres) divided by πD, and that is equal to $D/4$. Velocity is equal to flow over area, so Manning's 'flow equation' becomes: $$Q = 24D^{8/3}i^{1/2}$$ when D is in m; or, when D is in mm: $$Q = (2.4 \times 10^{-4})D^{8/3}i^{1/2}$$
[*] *Note: the audio track erroneously says 'hydraulic gradient; it should say 'hydraulic radius'.*		
16.	When the sewer is flowing just full: r = R and R is given by $R = (\pi D^2/4)/\pi D = D/4$ sewer diameter, m Always be *very* careful with units Now velocity = flow/area, so Manning's 'flow' eqn is: $Q = 24D^{8/3}i^{1/2}$ D in m or $Q = (2.4\times10^{-4})D^{8/3}i^{1/2}$ D in mm	In these sorts of hydraulic calculations we always have to be very careful with units.

17.	When the sewer is flowing just full: r = R and R is given by $R = (\pi D^2/4)/\pi D = D/4$ sewer diameter, m Always be *very* careful with units Now velocity = flow/area, so Manning's 'flow' eqn is: $Q = 24D^{8/3}i^{1/2}$ D in m or $Q = (2.4\times10^{-4})D^{8/3}i^{1/2}$ D in mm ❖ DESIGN CONCEPT: The value of Q given by this eqn. must be greater than estimated peak flow in section of sewer being considered ❑ if not, use next larger pipe diameter	The **basic design concept** is that the value of *Q* given by this equation has to be *greater* than the estimated peak flow in the section of sewer we are designing. If not, then we have to use the next larger available pipe diameter.
18.	**Inflective Gradient Design Method (USA)** • sewer profile closely follows ground profile – flow conditions change as required from open channel flow to pressure flow, and back to open channel flow • self-cleansing velocity not required as sewer only conveys settled wastewater	Workers in the United States developed for settled sewerage the inflected gradient design approach. In this design procedure the sewer profile closely follows the ground profile so that flow conditions change as required from open channel flow to pressure flow and back to open channel flow, and so on. This method was the first method to realise that a self-cleansing velocity in a settled sewer was not required as the sewer only conveys settled wastewater, as all the solids have been retained in the interceptor tank.
19.	• The design *must* ensure that: (1) an overall fall exists across the system and (2) the hydraulic grade line does not rise above level of outlet invert of any interceptor tank – otherwise wastewater would flow from the sewer to the interceptor tank	There are two things that the design has to ensure. Firstly, that there is an overall fall across the system and, secondly, that the hydraulic grade does not rise above the level of the invert of the outlet of any interceptor tank; otherwise wastewater would flow from the sewer back into the interceptor tank and cause local flooding
20.	**CRITICAL POINTS** • establish maximum sewer elevation at: – high points where flow changes from open channel to pressure flow – points at end of long flat sections	In relation to the second point, we have to consider critical points where we establish the maximum sewer elevation, and the critical points are high points where the flow changes from open channel flow to pressure flow, and points at the end of long, flat sections.