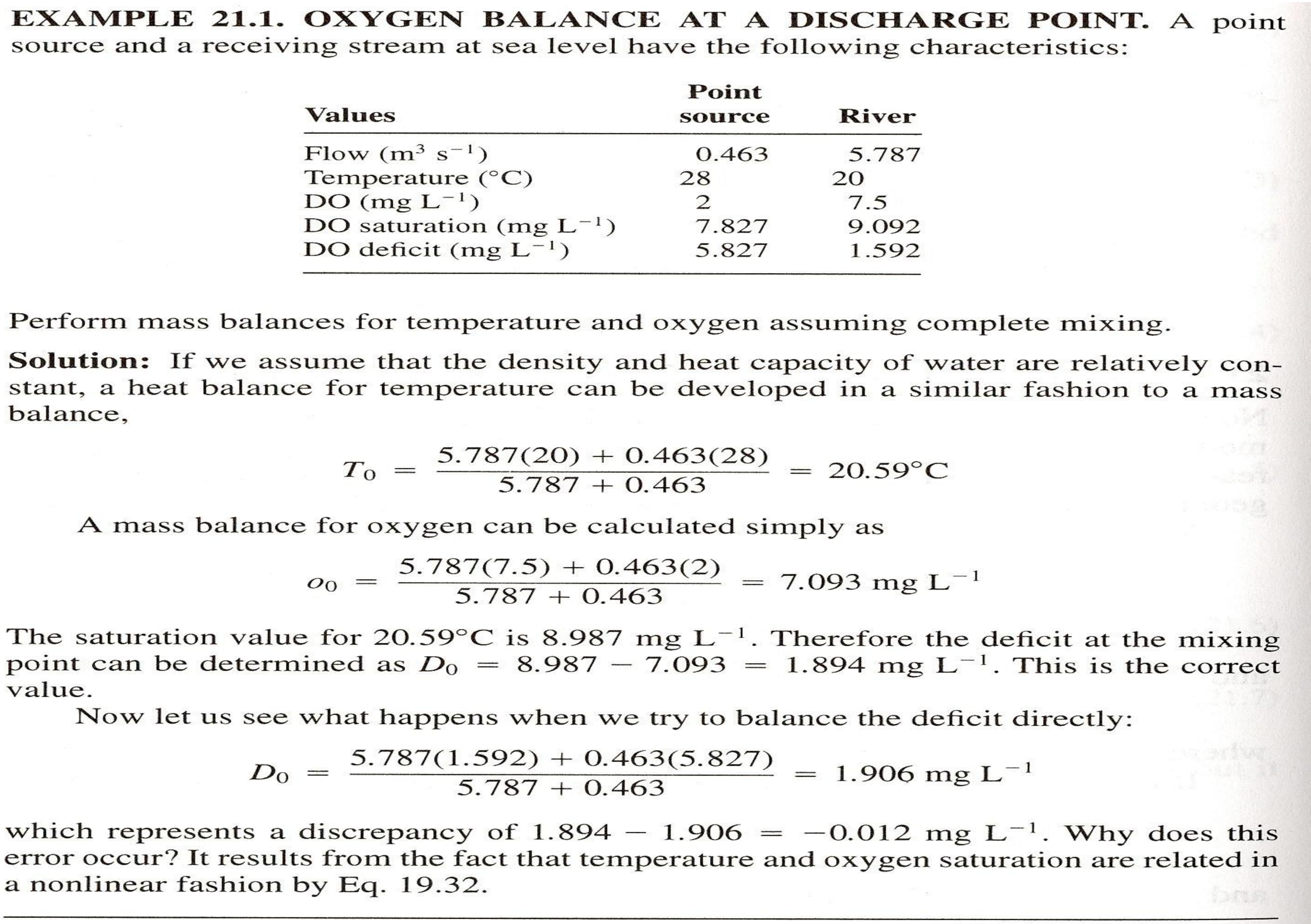
21.3 Deficit balance at the discharge point



EXAMPLE 21.1. OXYGEN BALANCE AT A DISCHARGE POINT. A point source and a receiving stream at sea level have the following characteristics:

Values	Point source	River
Flow ($m^3\ s^{-1}$)	0.463	5.787
Temperature (°C)	28	20
DO ($mg\ L^{-1}$)	2	7.5
DO saturation ($mg\ L^{-1}$)	7.827	9.092
DO deficit ($mg\ L^{-1}$)	5.827	1.592

Perform mass balances for temperature and oxygen assuming complete mixing.

Solution: If we assume that the density and heat capacity of water are relatively constant, a heat balance for temperature can be developed in a similar fashion to a mass balance,

$$T_0 = \frac{5.787(20) + 0.463(28)}{5.787 + 0.463} = 20.59°\text{C}$$

A mass balance for oxygen can be calculated simply as

$$o_0 = \frac{5.787(7.5) + 0.463(2)}{5.787 + 0.463} = 7.093\ \text{mg L}^{-1}$$

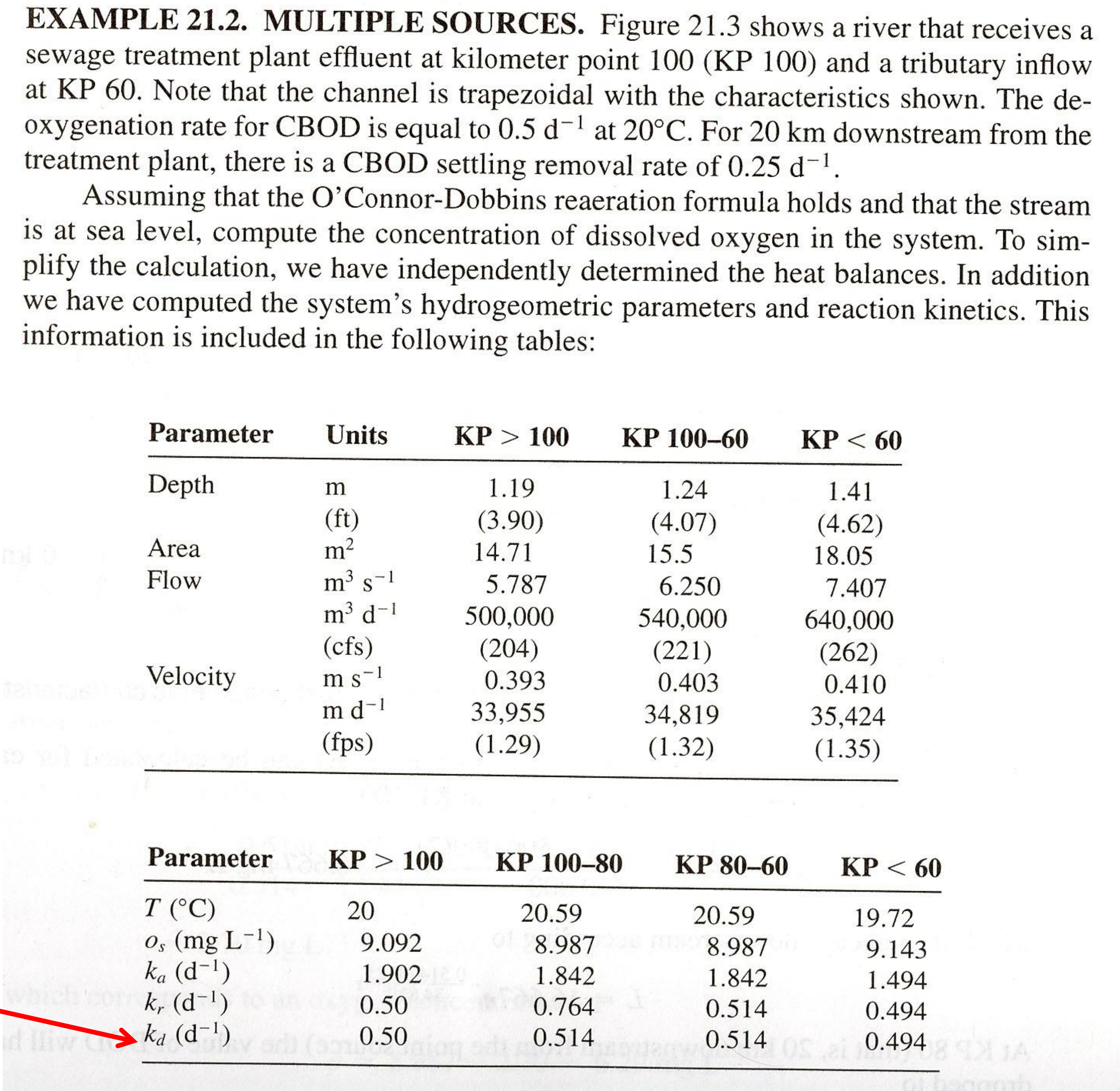
The saturation value for 20.59°C is 8.987 mg L^{-1}. Therefore the deficit at the mixing point can be determined as $D_0 = 8.987 - 7.093 = 1.894\ \text{mg L}^{-1}$. This is the correct value.

Now let us see what happens when we try to balance the deficit directly:

$$D_0 = \frac{5.787(1.592) + 0.463(5.827)}{5.787 + 0.463} = 1.906\ \text{mg L}^{-1}$$

which represents a discrepancy of $1.894 - 1.906 = -0.012\ \text{mg L}^{-1}$. Why does this error occur? It results from the fact that temperature and oxygen saturation are related in a nonlinear fashion by Eq. 19.32.

21.4 Multiple point sources



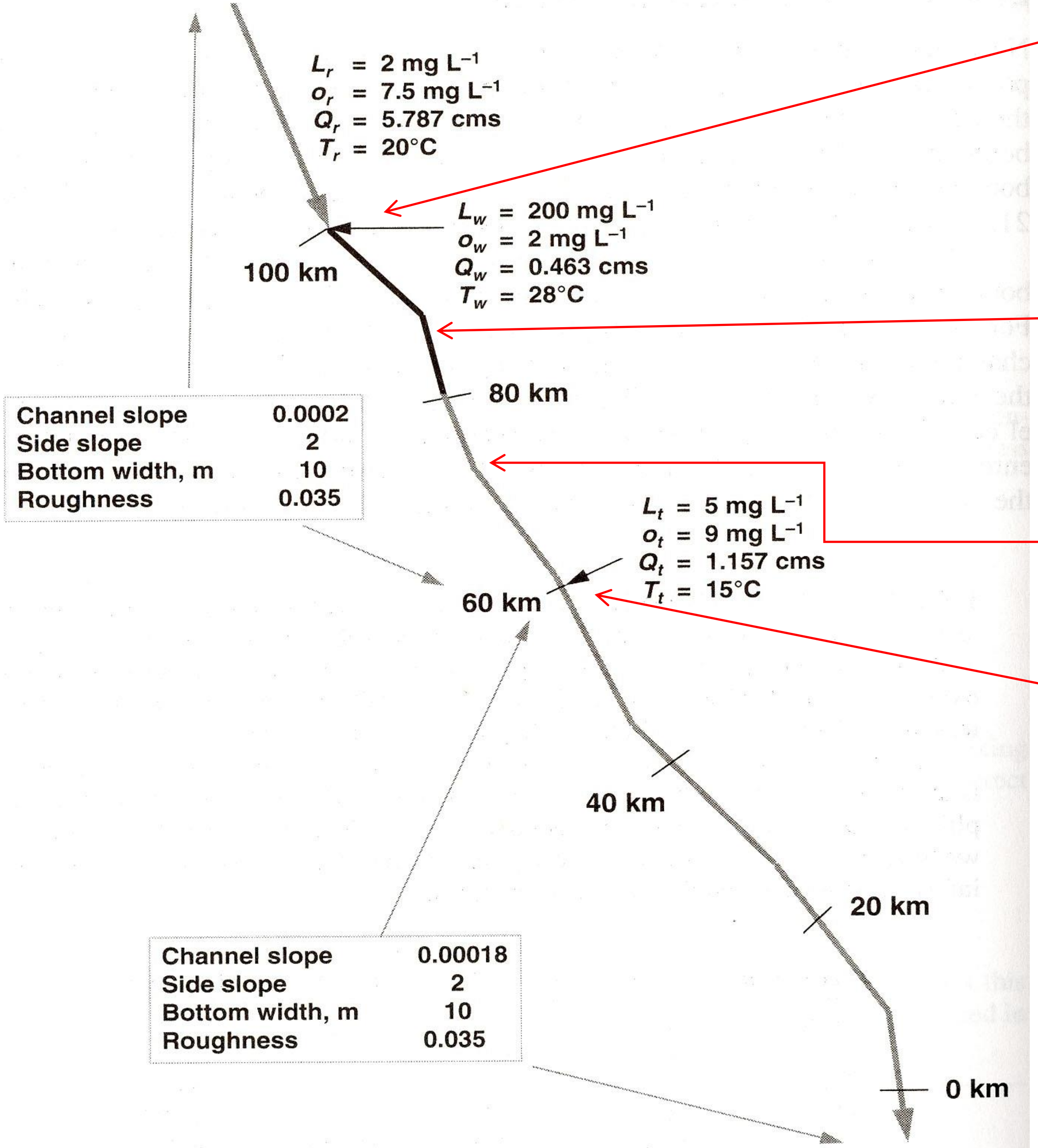
EXAMPLE 21.2. MULTIPLE SOURCES. Figure 21.3 shows a river that receives a sewage treatment plant effluent at kilometer point 100 (KP 100) and a tributary inflow at KP 60. Note that the channel is trapezoidal with the characteristics shown. The deoxygenation rate for CBOD is equal to 0.5 d^{-1} at 20°C. For 20 km downstream from the treatment plant, there is a CBOD settling removal rate of 0.25 d^{-1}.

Assuming that the O'Connor-Dobbins reaeration formula holds and that the stream is at sea level, compute the concentration of dissolved oxygen in the system. To simplify the calculation, we have independently determined the heat balances. In addition we have computed the system's hydrogeometric parameters and reaction kinetics. This information is included in the following tables:

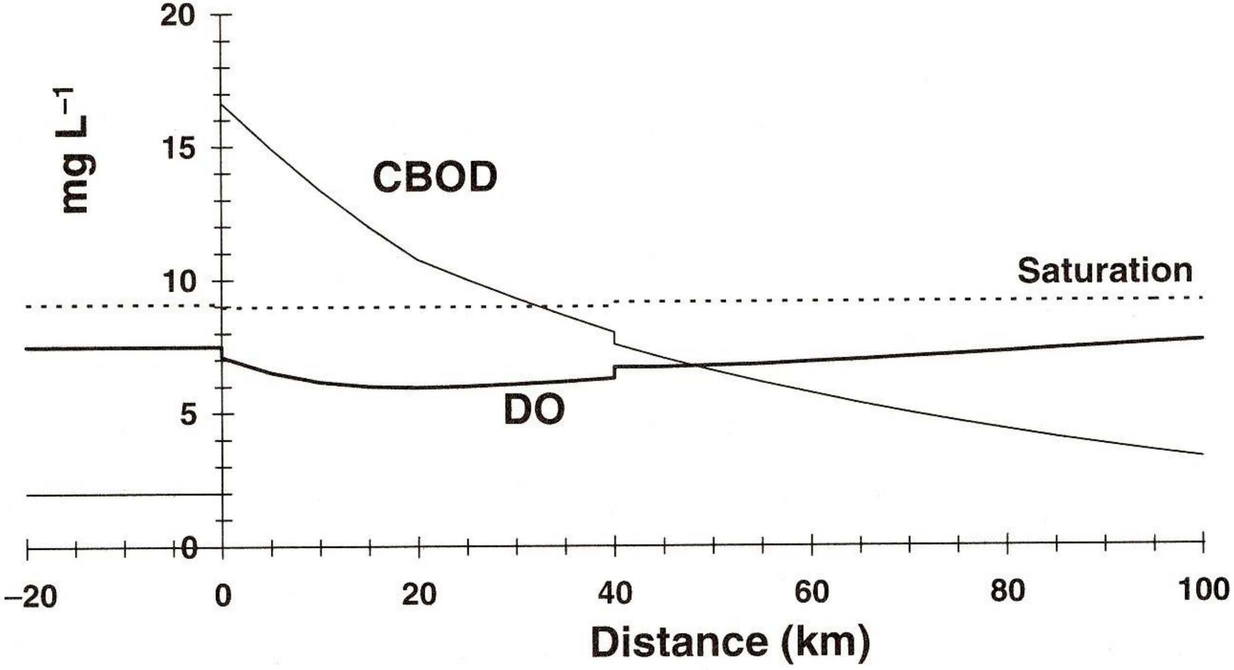
Parameter	**Units**	**KP > 100**	**KP 100–60**	**KP < 60**
Depth	m	1.19	1.24	1.41
	(ft)	(3.90)	(4.07)	(4.62)
Area	m^2	14.71	15.5	18.05
Flow	$m^3\ s^{-1}$	5.787	6.250	7.407
	$m^3\ d^{-1}$	500,000	540,000	640,000
	(cfs)	(204)	(221)	(262)
Velocity	$m\ s^{-1}$	0.393	0.403	0.410
	$m\ d^{-1}$	33,955	34,819	35,424
	(fps)	(1.29)	(1.32)	(1.35)

Parameter	**KP > 100**	**KP 100–80**	**KP 80–60**	**KP < 60**
T (°C)	20	20.59	20.59	19.72
o_s (mg L^{-1})	9.092	8.987	8.987	9.143
k_a (d^{-1})	1.902	1.842	1.842	1.494
k_r (d^{-1})	0.50	0.764	0.514	0.494
k_d (d^{-1})	0.50	0.514	0.514	0.494

Temperature correction on k_d



- Discharge from wastewater treatment plant
- Have settling velocity (removal rate)
- No more settling
- Additional flow from a tributary



- Q_w = 0.463 cms = 40,000 m^3/day
- Q_t = 1.157 = 100,000 m^3/day

KP	CBOD (mg L^{-1})	Deficit (mg L^{-1})	DO (mg L^{-1})
−10	2.000	1.592	7.500
0	16.667	1.894	7.093
10	13.384	2.814	6.173
20	10.748	3.022	5.965
30	9.274	2.918	5.997
40	7.532	2.433	6.710
50	6.553	2.391	6.752
60	5.700	2.260	6.883
70	4.959	2.085	7.059
80	4.314	1.891	7.252
90	3.753	1.696	7.447
100	3.265	1.509	7.635