1906

Plans and estimates for the disposal of sewage and storm water for the city of Rolla, Mo.

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THESIS

FOR THE

Degree of Bachelor of Science

IN

CIVIL ENGINEERING.

SUBJECT:

"Plans and Estimates for the Disposal of Sewage and Storm Water for the City of Rolla, Mo."

TRACY IRWIN PHELPS.

ROBERT ARTHUR BARTON

JUNE, 1906.

Plans and Estimates

for the

DISPOSAL OF SEWAGE AND STORM WATER

for the

City of Rolla, Missouri.

June 1906.

T.I.Phelps. R.A.Barton.

Introduction.

The City of Rolla is the county seat of Phelps County, situated 111 miles southwest of St.Louis, on the St.Louis and San Francisco R.R.

This thriving city of 2000 inhabitants already owns the electric lighting system, and has engineers working upon plans for a deep well water supply system.

Since the sanitary conditions are not the best and a water supply is to be installed, we submit these plans and estimates for a "Disposal of Sewage and Storm Water."

After making a topographical survey of the city and adjacent water sheds,it was found advisable to divide the city into three districts,each having a main branch,one on the western outskirts, termed "West" another on Rolla St. termed "Rolla" and the third on Oak St. termed "Oak."

From these main branches laterals are run through the more important streets. (see topographical map,showing districts,main branches and laterals).

There being no near by waterway into which to discharge the sewage,it becomes necessary to treat the same,consequently a separate system was decided upon.

CONSIDERATION OF "SEPARATE SEWER".

Since an allowance of 25 gallons per capita per day was made for water supply and the quantity of sewage depends,to a certain extent on the water supply,we therefore take this quantity as the basis for disposal. The maximum rate may exceed this amount at certain times by 100 % therefore the maximum rate of flow taken is 50 gallons per capita per day.

The average number of persons for a city block was found to be 20. The enrollment at the Rolla Public School is 400 pupils. At the Missouri School of Mines the enrollment is 250.

Ground water is assumed to leak into the main branches at the rate of two gallons per day per foot of pipe.

DATA FOR SEPARATE SEWER.

Branch.	Number of Blocks	Number of Persons	Sewage in Gals.	Length of Branch	Groundwater in Gallons.	Cal.	Total Sewage in Cu.ft/min
West.	16	320	16000				
		* 100	1500	2380	4760	22260	2.97
Rolla.	27	540	27000				
		* 150	2250				
		** 400	6000	3700	7400	42650	5.69
Oak.	36	720	36000	3090	6180	42180	5.91
Trunk ***			88750	1120	20580	109330	10.15
Total	79	2230		10290			

* Students at Missouri School of Mines.

** Pupils at Rolla Public School.

*** Line from junction of Rolla and Oak to Septic Tank.

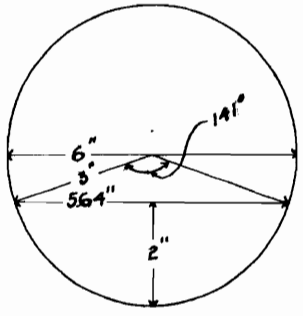
After the location of the main branches was decided upon, profile levels were run, plotted and grade lines established. (see plates 1,2,3,4 and 5).

After making calculations for velocities and discharges a 6 inch sewer pipe was decided upon for the "Trunk" line, and also for the other branches, it not being thought advisable to use smaller size on account of probability of clogging. A four inch sewer pipe was considered sufficient for the laterals.

Following are the calculations for (a) the maximum velocity and discharge for the greatest flow, (b) the minimum velocity and discharge for the least flow.

(a)

"TRUNK LINE".
Sewer flowing half full (3")



$V = c\sqrt{R\,S}$

V = Velocity feet per sec.

c = constant = 85

R = Hydraulic radius = $\frac{\text{area}}{\text{wetted perimeter}}$

S = Grade = .01

$$\text{Area} = 1/2\ \frac{\pi d^2}{4} = \frac{1}{2} \times \frac{3.1416}{4} \times .25 = .0982 \text{ sq.ft.}$$

$$\text{Wetted perimeter} = \frac{1}{2} \times \frac{2\pi r}{} = \frac{2 \times 3.1416 \times .25}{2} = .786 \text{ ft.}$$

$$R = \frac{.0982}{.786} = .125 \qquad \sqrt{R} = .353$$

$$V = c\sqrt{R\,S} = 85 \times .353 \times .1 = 2.81 \text{ ft per sec.}$$

$$Q = 60\ A\ V = 60 \times .0982 \times 2.81 = 16.55 \text{ cu ft per min.}$$

Sewer Flowing 2 inches deep.

Area = area of sector - area of triangle.

$$= \frac{14.1}{360} \times \frac{\pi d^2}{4} - \frac{\text{base} \times \text{altitude}}{2}$$

$$= \frac{141}{360} \times \frac{3.1416 \times .25}{4} - \frac{5.64 \times 1}{2 \times 144} = .0574 \text{ sq ft.}$$

$$\text{Wetter perimeter} = \frac{141}{360} \times 2\pi r = \frac{141}{360} \times 2 \times 3.1416 \times .25 = .612 \text{ ft.}$$

$$R = \frac{.0574}{.612} = .0938 \qquad \sqrt{R} = .306$$

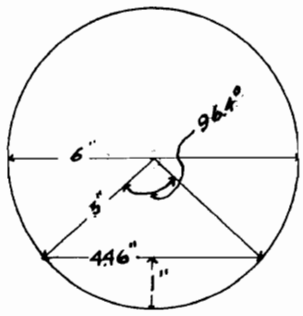
$$V = c\sqrt{RS} = 85 \times .306 \times .1 = 2.60 \text{ ft/sec.}$$

$$Q = 60\ AV = 60 \times .0574 \times 2.60 = 8.95 \text{ cu ft / min.}$$

The estimated discharge of this sewerbeing 10.15 cu.ft/min, the velocity will range between 2.60 and 2.81 ft/sec.

(b)

"WEST LINE."



Sewer flowing 1 inch deep

Grade = .008

Area = area sector - area of triangle

$$= \frac{96.4}{360} \times \frac{\pi d^2}{4} - \frac{\text{base} \times \text{altitide}}{2}$$

$$= \frac{96.4 \times 3.1416 \times .25}{360 \quad 4} - \frac{4.46 \times 2}{2 \times 144}$$

= .0216 sq.ft.

$$\text{Wetted Perimeter} = \frac{96.4 \times 2\pi r}{360} = \frac{96.4}{360} \times 2x3.1416x.25$$

= .420 ft.

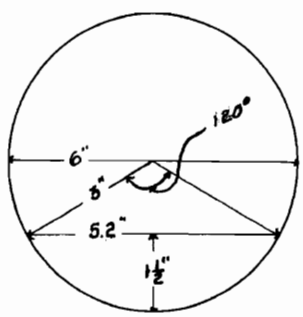
$$R = \frac{.0216}{.420} = .051 \qquad \sqrt{R} = .227$$

$V = c\sqrt{RS}$ = 85 x .227 x .089 =1.72 ft/sec.

Q = 60 AV = 60 x.0216 x 1.72 = 2.22 cu ft/min.

Estimated discharge is 2.07 cu ft/ min,calculated discharge being 2.22 cu ft/ min. The velocity will closely approach 1.72 ft/sec.

"RCLLA AND OAK LINE."



Sewage flowing 1 1/2 inches deep.

Grade = .01

Area = area sector - are of triangle

$$= \frac{120}{360} \times \frac{\pi d^2}{4} - \frac{\text{base} \times \text{altitude}}{2}$$

$$= \frac{120}{360} \times \frac{3.1416 \times .25}{4} - \frac{5.2 \times 1.5}{2 \times 144}$$

= .0384 sq.ft.

$$\text{Wetted Perimeter} = \frac{120}{360} \times 2\pi r = \frac{120}{360} \times 2x3.1416 \times .25$$

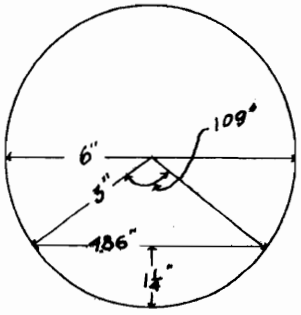
= .523 ft.

$$R = \frac{.0384}{.523} = .0734 \qquad \sqrt{R} = .27$$

$V = c\sqrt{RS}$ = 85 x .27 x .1 = 2.295 ft/sec.

Q = 60 AV = 60 x .0384 x 2.295 = 5.28 cu.ft/min.

Sewers flowing 1 1/4 inches deep.



Area = area sector - area triangle.

$$= \frac{109}{360} \times \frac{3.1416}{4} \times .25 - \frac{4.86 \times 1.75}{2 \times 144}$$

= .0304 sq. ft.

Wetted perimeter = $\frac{109}{360} \times 2 \times 3.1416 \times .25$

= .475 ft.

$R = \frac{.0304}{.475} = .0619 \quad \sqrt{R} = .249$

$V = c\sqrt{RS} = 85 \times .249 \times .1 = 2.12$ ft/sec

$Q = 60\ AV = 60 \times .0304 \times 2.12 = 3.87$ cu ft/min.

Estimated discharges for these lines are 3.96 and 3.91 cu.ft/min respectively. The velocities will range between 2.295 and 2.12 ft/sec

SUMMARY OF VEOLCITIES AND DISCHARGES.

Branch	Grade. Minimum	Depth of flow in inches	Velocity in ft/sec.	Discharge Estimated cu.ft.per min.	Discharge Calculated cu.ft.per min.
West	.8%	1	1.72	2.07	2.22
Rolla.	1%	1 1/4 - 1 1/2	2.12 - 2.295	3.96	3.87 - 5.28
Oak	1%	1 1/4 - 1 1/2	2.12 - 2.295	3.91	3.87 - 5.28
Trunk.	1%	2 - 3	2.60 - 2.81	10.15	8.95 -16.55

MANHOLES AND FLUSH-TANKS.

Manholes and flush-tanks of approved design shall be placed along the lines, the dimensions specified on plans and the locations upon maps and profiles (Plan of manholes see Plate VIII)

TREATMENT OF SEWAGE.

On account of total disappearance of the water in the streams during the summer months it beccmes necessary to treat the sewage to prevent the creation of a nuisance. This will be done by use of a septic tank.

The number of inhabitants using the sewer, at first, is assumed to be 1400. Average rate of flow per day is 25 gallons per capita. Ground water is assumed to have an average flow of 10000 gallons per day.

Total flow in gallons per day = 44000

" " " cu.ft. " " = $\frac{44,000}{7.5}$ = 5863

Sewage should remain in the tank from 12 to 24 hours.

A tank 6'x 12' x 40' will handle 5760 cu ft., discharging twice in 24 hours.

This size of tank will be installed. Should it prove inadequate another tank can be added, thereby allowing the sewage to remain in the tank 24 hours. (For plans, see Plate IX)

CONSIDERATION OF DISPOSAL OF STORM WATER.

On account of the unsanitary condition of the two creeks heading in Rolla and Oak Streets, respectively and the erosion of the streets it becomes necessary to control these waters.

Because of the fluctuation in the discharge of the streams we have designed a cross-section which gives a greater hydraulic radius, and consequently a greater velocity for shallow flows than a circular section.

The cost of these concrete sewers is less than vitrified pipe.

The following table was compiled from the records of precipitation, kept by Mr.P.J.Wilkins for the U.S.Weather Bureau.

TABLE OF RAINFALL IN INCHES.

Months	1900 Total.	Max.for	Hrs.	1901 Total	Max.for	Hrs.	1902 Total.	Max.for	Hrs.
January	1.39			.87	. 65	24	1.31		
February	4.43	1.96	48	1.70	. 48	15	1.31	.60	12
March	1.53	1.05	48	3.32	1.78	18	4.15	1.23	20
April	5.25	2.76	48	2.99	1.14	24	2.61	.62	24
May	2.78	1.25	72	.73	.25	4	5.96	2.28	12
June	3.67	1.79	24	2.30	1.11	10	3.15	3.30	30
July	4.46	1.29	6	1.64	.53	4	3.11	1.70	7
August	3.61	2.85	48	1.59	-		3.20	2.65	20
September	3.04	1.30	12	.92			2.59	.69	6
October	3.13	1.36	15	2.29			2.46	1.68	24
November	3.33	1.45	24	1.66	.69	24	4.06	1.52	24
December.	.89	.27	24	4.80	2.56	18	4.82	1.64	24

Table Continued.

Months.	1903 Total	1903 Max for	1903 hrs.	1904 Total	1904 Max.for	1904 hrs.	1905 Total	1905 Max.for	1905 Hrs.
January	1.83			4.84	3.43	24	3.19	2.10	40
February	3.08	1.12	24	.85			1.64		
March	4.92	1.94	36	4.47	2.54	24	3.89	1.01	15
April	3.11	.89	6	7.11	3.10	24	3.25	2.08	24
May	7.27	2.66	24	6.32	2.32	30	4.81	2.16	12
June	4.24	1.79	24	7.86	3.09	18	2.51	.74	3
July	.78			3.19	1.58	18	6.97	1.17	3
August	5.75	2.51	5	6.06	1.39	9	3.76	1.26	10
September	7.67	2.24 *	2	4.31	1.38	12	9.51	4.40	15
October	2.84	2.07	12	1.13			5.45	2.04	24
November	.41			.38			1.99	1.02	24
December.	1.62			.89			1.31		

* From the above table maximum rain fall occurred in September 1903 and is found to be 2.24 inches in 2 hours. This is a rate of .001555 feet per minute.

Drainage area was taken from topographical map.

ESTIMATED DRAINAGE AREA AND DISCHARGE.

District	Drainage Area. In acres	In sq.ft.	Discharge Cu ft/min.
Rolla	53.04	2,310,300	2724
Oak.	56.51	2,342,150	2841
Junction	22.90	997,550	1210
			6775 Total.

Discharge was computed by taking .001555 feet per minute rain fall and considering 78 per cent imperviousness.

Profiles were run, grades established and cross sections determined. (See Plates 6,7 and 10)

In order to keep within the velocity limits it was necessary to put in drops as located on profiles 6 and 7.

Inlets to be placed at the intersection of cross streets and other places necessary. Drops and inlets to be approved by Engineer.

Rolla storm sewer will have two sections, the upper one having a radius of 1'9" the lower 2'5".

Oak Street Storm Sewer to have a radius of 2'3".

The Junction Storm Sewer (below junction of Oak and Rolla) to have a radius of 3'8" as per the following calculations:

ROLLA ST. STORM SEWER. (from 10th Street -100' south of 6th St.)

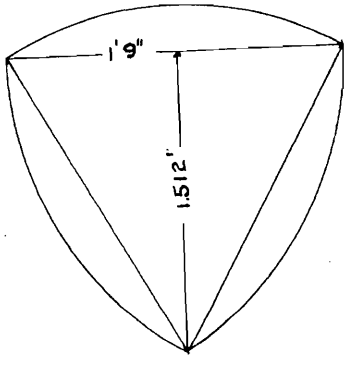
Section 1. Plate X

Grade = .02, (for 1:5 cement morter) N = .011

$V = c\sqrt{RS}$ $\qquad Q = 60\ AV.$

By Kutter's formula $\quad c = \dfrac{41.6 + \frac{.00281}{S} + \frac{1.811}{N}}{1 + (41.6 + \frac{.00281}{S})\frac{N}{\sqrt{R}}}$

Depth of Flow = 1.512 ft.



Area equi. $\triangle$ $= \frac{1.512}{2} \times 1\ 3/4 = 1.323$ sq.ft.

" sector $= \frac{3.1416}{6 \times 4} \times (3.5)^2 = 1.604$ " "

" segment $= 1.604 - 1.323 = .28$ " "

Total Area $= 1.323 + 2x\ .28 = 1.883$ " "

Perimeter of sector $= 2 \times \frac{3.1416 \times 1.75}{6}$

$= 1.83$ feet.

Wetted perimeter = 1.83 x 2 = 3.66 ft.

$R = \frac{1.883}{3.66} = .5136 \qquad \sqrt{R} = .716$

$$c = \frac{41.6 + \frac{.00281}{.02} + \frac{1.811}{.011}}{1 + (41.6 + \frac{.00281}{.02})\frac{.011}{.716}} = 126.$$

$V = 126 \times .716 \times .141 = 12.72$ feet per sec.

$Q = 60 \times 1.883 \times 12.72 = 1435$ cu ft. per min.

Depth of Flow. = 4 inches.

Surface width 10 inches

$$\text{Area} = \frac{20}{144} \text{ sq ft.}$$

$$\text{Wetted Perimeter} = \frac{12.8}{12} \text{ ft.}$$

$$R = \frac{20}{144} \times \frac{12}{12.8} = .1307 \qquad \sqrt{R} = .36$$

$$C = \frac{41.6 + \frac{.00281}{.02} + \frac{1.811}{.011}}{1 + (41.6 + \frac{.00281}{.02})\frac{.011}{.36}} = 90.5$$

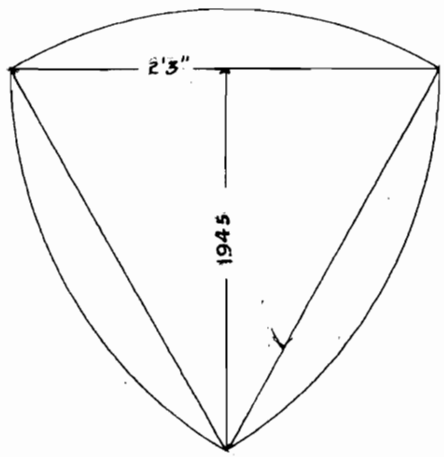
$V = 90.5 \times .36 \times .141 = 4.59$ ft per sec.

Rolla Street Storm Sewer (from 100' south of 6th St to Junction)

Oak " " " " 7th St. to Junction)

See Sec.11 . Plate X

Depth of Flow = 1.945 ft.



Grade = .02

Area of Equi.$\triangle$ $= \frac{1.945}{2} \times 2\ 1/4 = 2.19$sq ft.

" sector $= \frac{3.1416}{6 \text{ X } 4} \times (4.5)^2 = 2.65$" "

" segment $= 2.65 - 2.19 = .46$ sq.ft.

Total area $= 2.19 + 2\text{x } .46 = 3.11$ " "

Perimeter sector $= \frac{2\text{x } 3.1416 \times 2.25}{6} =$

$= 2.356$ ft.

Wetter perimeter $= 2\text{x } 2.356 = 4.71$ ft.

$$R = \frac{3.11}{4.71} = .658 \qquad \sqrt{R} = .81$$

$$C = \frac{41.6 + \frac{.00281}{.02} + \frac{1.811}{.011}}{1+\left(41.6 + \frac{.00281}{.02}\right)\frac{.011}{.81}} = 132$$

$V = 132 \times .81 \times .141 = 15.06$ ft/ sec.

$Q = 60 \times 3.11 \times 15.06 = 2810$ cu.ft. per min.

Depth of Flow = 4 inches.

Surface width 10.8 inches.

Area = $\frac{2.16}{144}$ sq.ft.

Wetted Perimeter = $\frac{13.5}{12}$ ft.

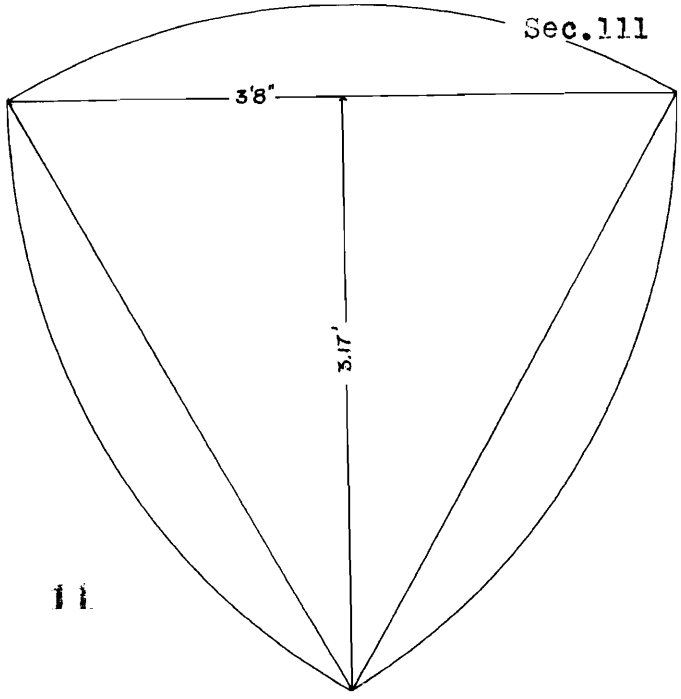
$$R = \frac{2.16}{144} \times \frac{12}{13.5} = .133 \qquad \sqrt{R} = .365$$

$$C = \frac{41.6 + \frac{.00281}{.02} + \frac{1.811}{.011}}{1+\left(41.6 + \frac{.00281}{.02}\right)\frac{.011}{.365}} = 91.5$$

$V = 91.5 \times .365 \times .141 = 4.71$ feet per sec.

JUNCTION STORM SEWER. (from Rolla and Oak Sewers to City limits)

Sec.111 Plate X.



Grade = .01

Depth of Flow = 3.17 ft.

Area equi. $\triangle = \frac{3.17}{2} \times 3\ 2/3 = 5.81$ sq.ft.

" sector $= \frac{3.1416 \times (7\ 1/3)^2}{6 \times 4} = 7.04$ " "

" segment $= 7.04 - 5.81 = 1.23$ " "

Total Area $= 5.81 + 2(1.23) = 8.27$ " "

Perimeter of Sector $= \frac{2 \times 3.1416 \times 3\ 2/3}{6} =$ 3.84 ft.

Wetted Perimeter = 2 x 3.84 = 7.68 ft

$$R = \frac{8.27}{7.68} = 1.07 \qquad \sqrt{R} = 1.03$$

$$C = \frac{41.6 + \frac{.00281}{.01} + \frac{1.811}{.011}}{1 + \left(41.6 + \frac{.00281}{.01}\right)\frac{.011}{1.03}} = 142.5$$

V = 142.5 x 1.03 x .1 = 14.68 feet per sec.

Q = 60 x 14.68 x 8.27 = 7284 cu ft. per min.

Depth of Flow = 4 inches.

Surface width = 11.5 inches.

Area $= \frac{23}{144}$ sq. ft.

Wetted Perimeter $= \frac{14.1}{12}$ ft.

$$R = \frac{23}{144} \times \frac{12}{14.1} = .136 \qquad \sqrt{R} = .37$$

$$C = \frac{41.6 + \frac{.00281}{.01} + \frac{1.811}{.011}}{1 + \left(41.6 + \frac{.00281}{.01}\right)\frac{.011}{.37}} = 91.5$$

V = 91.5 x .37 x .1 = 3.39 ft. per sec.

It will be noticed that the velocities in the above calculations are within the allowable limits, giving the dischargesrequired.

SUMMARY OF DATA FOR STORM SEWER.

District	Section	Length	Grade	Velocity in ft/sec.	Discharge cu.ft/min Calculated	Estimated
Rolla	Upper	1100	.02	12.72	1435	
	Lower	1100	.02	15.06	2810	2724
Oak		1200	.02	15.06	2810	2841
Junction		650	.01	14.68	7284	6775

—— ESTIMATES.——

FOR SEPARATE SYSTEM:-

Excavation and Back Filling ..... $ .35 per cu,

Portland Cement(Carload lots) ..... 2.10 per Bbl.

Sand .....(delivered) ..... 1.50 cu.yd.

Gravel....(") ..... 1.25 " "

Barrels of Cement (1:1 mortor)required for laying 100 ft standard sewer pipe (3' lengths)

Size of Pipe in inches 4 6 (From Gillette's Hand Bock of Cost Data)

Barrels of Cement rqd..0533 .096

For Concrete prportioned by volumne 1:3:5

Barrels of Cement per cu. yd. concrete .96

" " sand .47

" " gravel .78

Cost of Laying Sewer Pipe.

Size of Pipe in Inches 4 6

Cents per linear foot 3/4 1

Bill of Sewer Pipe for West Branch and Laterals.

Length	Pieces	Articles	Cost.
2466	822	6" pipe @ $ .08 4/10 per foot	$207.14
1077	359	4" " " .05 6/10 " "	60.26
180	60	4" " for house connections	10.08
72	36	4"to 6" Y's at $.38 each	13.68
24	12	4"to 4" " " .25 "	3.00
	3	6" 1/4 curve @ .28 "	.84
	1	4"to 6" increaser.25 "	.25
			$ 295.25

Bill of Sewer Pipe for Rolla Branch and Laterals.

Length	Pieces	Articles		Cost.
3573	1191	6" pipe	$ .08 4/10 per ft.	$300.14
1644	548	4" "	.05 6/10 " "	92.06
48	16	4" " for house connection	.05 6/10 " "	2.67
136	68	4" to 6" Y's	.38 each	25.84
56	28	4" to 4" "	.25 "	7.00
	5	6" 1/4 curve	.28 "	1.40
	2	6" 1/8 curve	.28 "	.56
	2	4" to 6" increasers	.25	.50
				$430.17

Bill of Sewer Pipe for Oak Branch and Laterals.

Length	Pieces	Articles		Cost.
2988	996	6" Pipe	$ .08 4/10 per ft.	$250.99
4305	1435	4" "	.05 6/10 " "	241.08
102	51	4" to 6" Y's	.38 each	19.38
166	83	4" to 4" Y's	.25 "	20.75
	8	6" 1/4 curve	.28 "	2.24
	3	6" 1/8 "	.28 "	.84
	7	4" to 6" increaser	.25 "	1.75
				$537.03

Bill of Sewer Pipe for Trunk.

Length	Piece	Article		Cost.
1122	374	6" Pipe	$ .08 4/10 per foot.	$94.25

Bill of Sewer Pipe for Septic Tank.

Length	Pieces	Article		Cost.
42	14	6" Pipe	$ .08 4/10 per foot	$3.55

Total Cost of Pipe Used.....$1360.25

Cement in Barrels Required to Lay Sewer Pipe.

	Branch	Laterals	Cost.
West	2.41	.67	$ 6.47
Rolla	3.56	.94	9.45
Oak	2.98	2.39	11.28
Trunk	1.08		2.27
		Total	$29.47

Cost of Laying Sewer Pipe.			Excavation and Back Filling in cu yds.		
	Branch	Laterals	Branch	Lateral	Cost.
West	$25.35	$ 9.45	1636	555	$ 766.85
Rolla	37.09	13.10	1501	998	874.65
Oak	30.90	33.45	1157	1725	1108.70
Trunk.	11.22		489		171.15
	$104.56	$ 56.00			$2821.35

SEPTIC TANK. Concrete required. 82.74 cu.yds.

		Cost.	
Cement required	86.2 bbls.	$ 181.00	
Sand "	176. cu yds.	264.00	
Gravel "	106. " "	132.50	$577.50
(Sewer Pipe "	42 ft)		
Lumber for Cover 1310 BM. $20.			26.20
Cost of Placing Concrete $1.65 per cu.yd.			136.52
Cast Iron Pipe.			
15 ft. 6" pipe $ .38 per ft.		$5.70	
2 valves $3.00 each		6.00	
4 - 1/4 curve $.90 each		3.60	
1 - T $.90 "		.90	16.20
			$ 756.42

MANHOLES. For 4 foot Manholes $17.50, $2.20 for each additional foot.

	Number	Cost.	
West	4	$147.00	
Rolla	7	166.50	
Oak	11	243.10	$556.60

FLUSH TANKS at $26.00 each.

	Number	Cost.	
West	2	$ 52.00	
Rolla	3	78.00	
Oak.	4	104.00	$ 234.00

TOTAL COST OF SEPARATE SYSTEM.

Branch	Pipe	Cement	Laying.	Excavation Backfilling	Manholes	Flush-Tanks	Septic Tank	Total
West	295.25	6.47	34.80	766.85	147.00	52.00		1302.37
Rolla	430.17	9.45	50.19	874.65	166.50	78.00		1608.96
Oak.	537.03	11.28	64.35	1008.70	243.10	104.00		1968.46
Trunk.	94.25	2.27	11.22	171.15				278.89
Septic Tk.	3.55						756.42	759.97
	$1360.25	29.47	160.56	2821.35	556.60	234.00	756.42	5918.65

FOR STORM SEWER.

Cost of Placing Concrete $3.50 per cu.yd.

Cost of Excavation and Backfilling .35 per cu. yd.

ROLLA.

From Station 0+00 to Sta. 11+80 (Sec.1. Plate X)

Area of section 2.194 square feet.

Contents. 2.194 x 1180 = 2588.9 cu ft. = 95.88 cu.yds.

From Sta. 11+80 to Sta. 22+85(Sec.11 Plate X)

Area of Section 2.71 sq.ft.

Contents 2.71 x 1105 = 2994.55 cu.ft.= 110.90 cu.yds.

JUNCTION.

From Sta. 22+85 to Sta. 28+85(Sec.111 Plate X)

Area of Section = 4.21 sq.ft.

Contents. 4.21 x 600 = 2526 cu. ft. = 93.55 cubic yds

OAK.

From Sta. 0+00 - Sta. 13+20(Sec.11.Plate X)

Contents. 2.71 x 1320 = 3604.3 cu ft. = 133.49 cu.yds.

1 inlets- 1/2 cu.yds.each. 8.00 " "

Total Concrete. 441.82 " "

Number of barrels of cement required 441.82 cu.yds. concrete = 424.15

Cu. Yds.Sand " for " " = 207.56

" " Gravel " " " " = 344.62

COST. 424.15 Bbls Cement $2.10 per BBl = $890.75

207.56 cu.yds.sand 1.50 " cu.yd. = 311.50

344.62 " " gravel 1.25 " " " = 430.75

Total Concrete. $1633.00

Brought Forward.

Total Concrete.	$1633.00
16 gratings for inlets at $ .75 each	12.00
Placing Concrete, 442.82 cu. yds. at $3.50 cu.yd. =	1546.37
Excavation and Backfilling.-	
Oak 862 cu.yds. $.35 = $301.75	
Rolla and Junction 1963.9 cu.yds .35 = 687.35	= 989.10
Total Cost of Storm Sewer System	$4180.47

S P E C I F I C A T I O N S .

SPECIFICATIONS FOR MATERIALS.

Sec.1. Sewer-pipe. All pipe and specials shall be the best quality, salt-glazed, vitrified clay sewer pipe of the hub and spigot pattern: both body and bell shall be of standard thickness. Hub shall of sufficient diameter so as to have a space around spigot of not less than 1/2 inch for cement mortar joint: it shall also have a depth from its face to sholder of at least 2 inches greater than the thickness of the pipe. Pipe shall be furnished in three foot lengths. Branches may be in two foot lengths. All pipes and specials shall be well glazed, smooth on the inside and free from broken blisters, lumps and flakes which are thicker than 1/6 the normal thickness of the pipe, and whose largest diameters are greater than 1/8 the inner diameter of said pipe. Pipes and specials having broken blisters, lumps and flakes of any size shall be rejected unless the pipe can be so laid as to bring all these defects in the top half of the sewer. Pipes or specials, having fire cracks or cracks of any kind extending through the thickness shall be rejected.

No pipe shall be used which, designed to be straight, varies from a straight line, more than 1/8 inch per foot of length; nor shall there be a variation between any two diameters of the pipe greater than 1/24 the nominal diameter.

Sec.2. **Brick.** For all brick-work none but the best quality of sound, hard-burned, perfect-shaped bricks, presenting a regular and smooth surface shall be used. After being thoroughly dried and immersed in water for 24 hours they shall not absorb more than 10 percent by weight of water.

Sec.3. Sand. All sand shall be clean,sharp,coarse,and free from loam, clay or vegetable matter.

Sec.4. Cement. Unless otherwise specified all cement shall be of the best quality of Natural cement and when tested in briquettes (American Soc.C.E.standard) shall show a tensile strength of at least 75 pounds after 1 hour in air and 23 hours in water and of at least 150 pounds after one day in air and 6 days in water.

When specified Portland cement shall be used,This shall show a tensile strength of at least 400 pounds per square inch in a 7 day test made as above.

The engineer shall be allowed to test all cements and notice of its receipt by the contractor must be made to the engineer at least 48 hours in advance of its use on the work. Any cement not satisfactory to him shall be at once removed from the work.

Sec.5. Timber. All timber and planking used in cradles,platforms and foundations shall be of spruce,or timber equally as good,straight,sound, free from sap,shakes,large,loose,or decayed knots,worm holes or other imperfections which may impair its strength or durability.

EXCAVATION.

Sec.6. Classification of materials. All materials excavated shall be classified as either earth or rock. No material shall be classified as rock which cannot be removed more cheaply by drilling and blasting than by picking,except that any boulder measuring 1/2 cubic yard or more shall be so classified,whether blasted or removed bodily; but such boulders shall not be returned to the trench without being first broken up.

Sec.7. Excavation of Trench. The trench shall be excavated along the line designated by the engineer and to the depth necessary for laying the sewer at the grade given by him. In case of pipe sewers it shall be 1 foot wider at the bottom than the outside diameter of the pipe,and

for a concrete sewer as wide as the greatest external horizontal width of the structure placed therein,without any undercutting on the banks. Where,in the opinion of the engineer,the original earth is sufficiently compact and solid for the foundation of the work the contractor shall excavate the bottom of the trench to conform to the external form and dimensions of the invert or foundation as ordered.For pipe sewers the bottom of the trench under each bell shall be so hollowed out as to allow the body of the pipe to have a bearing throughout on the trench bottom and permit of making the joint.In case the trench be excavated at any place,except at joints,below the proper grade they shall be refilled to grade with sand or loam thoroughly rammed,without extra compensation unless the extra excavation was ordered by the engineer.

The engineer shall have the right to limit the amount of trench which shall be opened or partly opened at any time in advance of the completed sewer,and also the amount of trench left unfilled.

Sec.8. The Contractor shall remove any water which may be found or shall accumulate in the trenches and shall perform all work necessary to keep them clear of water while the foundation and masonry are being constructed or the sewer laid. In no case,unless by special permission of the engineer,shall water be allowed to run over the invert or foundation or through the sewer until the cement is satisfactorily hardened.

Sec.9. Shoring and Sheathing. Whenever necessary the sides of the trench shall be braced and rendered secure and either open or closed sheathing shall be used,to the satisfaction of the engineer; such sheathing and bracing to be left in until the trench is refilled,all such bracing and sheathing being done at the contractor's expense.

Sec.10. Railway-crossing. When any railway-lines are to be crossd or interfered with specific directions as to the time and manner of doing this work will be given by the engineer,and the contractor shall conform to such directions.

Sec.11. In excavating and back-filling trenches and laying sewer care must be taken not to move or injure water pipes.

At street-crossings and other points as may be designated by the engineer the trenches shall be bridged in a secure manner so as to prevent any interruption of travel upon the roadway and sidewalks. The cost of all such work must be included in the regular price bid for the sewer.

Sec.12. Rock Trenches. When the excavation for a sewer is made through rock or other material too hard to be readily or conveniently removed for admitting the hubs of the pipe the trench shall be excavated at least four inches deeper than the grade of the outside bottom of the sewer. When rock is encountered in the trench it shall be stripped of earth and the engineer notified and given proper time to measure the same before blasting. All rock removed which has not been measured by the engineer,will not be estimated as rock excavation. Measurement for rock excavation will be limited to 6 inches on either side of the sewer,and trench-slopes of 8 verticals to 1 horizontal. In all cases of blasting the blast shall be carefully covered with heavy timber chained together,and the engineer may limit the number of simultaneous discharged. No blasting shall be done within forty feet of the finished sewer and the end of the finished sewer shall be covered or stopped with planks or earth during each blast.

CONSTRUCTION.

Sec.13. Concrete shall be composed of 1 part, loose by bulk of Portland cement three parts of sand and 5 parts of gravel of approved quality. In mixing, the sand shall be spread upon a single platform or box and the cement deposited upon this; these shall then be thoroughly mixed dry until the whole is of an even, uniform color, when sufficient clean water shall be added to form a thick paste. The gravel which has previously been thoroughly wet, shall then be added and the whole shall be quickly and thoroughly mixed. Concrete must not be mixed in quantities greater than required for immediate use and any which has begun to set shall not be retempered or used in any way. One course shall follow another as rapidly as possible. When fresh concrete is to be placed in contact with that already set or partly set all loose stone or concrete not thoroughly compacted shall be removed from the surface of the latter, which shall be washed clean of all dirt and given a thin coat of mortor. If such a surface be hard set it shall previously be water-soaked. When concrete is in place all wheeling, working or walking on it must be prevented until it is firmly set and until such time it shall be kept damp and protected from the sun.

Such forms and centers as may be necessary to give the finished concrete the desired form shall be furnished by the contractor without extra charge. These shall be sufficiently stiff and substantial to retain the concrete firmly in place, and shall not be withdrawn until the same has set to the satisfaction of the engineer.

Sec.14. Brick Masonry, unless otherwise specified shall be laid with mortor composed of one part by measure of natural cement, two of sand, mixed as specified for concrete mortor. No mortor shall be used after it has set or partiallt set. For manholes, flush-tanks, and similar work a limited number of half bricks may be used, not to exceed one third of the whole in any case. Unless the engineer direct otherwise each

brick shall be throughly wetted immediately before being laid. It shall be laid with a full, close joint of cement mortor on its bed, edds, and side at one operation. In nc case is mortor to be slushed in afterwards. Special care shall be taken to make the face of the brick work smooth, and all joints on the interior of the sewer shall be carefully struck with the point of a trowel or pointed to the satisfaction of the engineer. Where pipe connections enter a manhole "bull's-eyes" shall be constructed by laying rowlock courses of brick around them, the cost of such construction being included in the regular price bid for the appurtenance. All brick-work shall be thoroughly bonded, adjacent courses breaking joints at least 1/3 the exposed length of the brick.

Sec.15. Laying Pipe Sewers. Previous to being lowered into the trench, each pipe shall be carefully inspected and those not meeting the foregoing specifications shall be rejected, and either destroyed or removed from the work within ten hours. No pipe shall be laid except in the presence of the engineer or his authorized inspector, and the engineer may order the removal and relaying of any pipe not so laid. Trench shall be excavated in accordance with Section 7 and 12. No sewer shall be laid within 10 feet of the excavation or 40 feet of the blasting. Pipes having any defects which do not cause their rejection shall be so laid as to bring these in the top half of the sewer.

The pipes and specials shall be so laid in the trench that after the sewer is completed the interior surface thereof shall conform accurately to the grades and alignments fixed and given by the engineer. All adjustments to line and grade of pipes laid directly upon the

bottom must be done by scraping away or filling in the earth under the body of the pipe,and not by blocking or wedging up.Special care must be taken to properly fill with mortor the annular space at the bottom and sides as well as at the top of the joints. The interior of the joint shall be wiped clean of cement by wad made of a sack filled with hay,large enough to tightly fill the pipe and attached to a rod or cord,which shall at all times be kept in the sewer and pulled ahead past each joint as soon as it is cemented. Mortor used shall be composed one part Portland cement to one of sand wet to a thick paste.

As soon as the cementing of any joint has been completed the bell hole under the hub must be carefully and compactly filled with sand,loam,or fine earth so as to hold external mortor finish of said joint securely in its place. Refilling shall also be made with selected materials free from stones carried half way up the sides or circumferance of the entire length of pipe and compacted with a proper tamping-tool. The trench shall then be filled to a point at least 2 feet above the top of the pipe with material containing no stone larger than two inches in any dimension.

At such places as shall be directed by the engineer,branches will be inserted in the sewer for future connections.Each branch thus inserted shall be closed by a thin vitrified stone ware cover or plug,which shall be placed before the special pipe is lowered into the trench. The entire cost of furnishing and setting such covers shall be included in the regular price bid for branches.

Any omission of the required branches,manholes or other special constructions indicated upon the plans,or that may be specially ordered beforehand by the engineer,shall be corrected by the contractor at his own expense.

Before leaving the work for the night or at any other time the end of the sewer shall be securely closed with a tight fitting plug.

Sec.16. Manholes of Various kinds- line,intersection,drop,etc.-flush -tanks, inlets,and other appurtenences shall be built where the engineer may direct,in size,form,thickness and all other respects in accordance with the plans. All appurtenances shall be brought accurately to the grade given by the engineer. Great care shall be taken to make the channels in manhole conform accurately to the sewer grade.

Flush-tanks and inlets shall be plastered on the outside with 1/2 inch cement mortor;and on the inside shall be given three poats of thin Portland-cement grout,without sand,applied with a brush,each coat being allowed to set before the next is applied.

All concrete or brick-masonry shall conform to specifications given in Section 13 and 14. Each appurtenence shall be begun within 24 hours of the time it is reached in the laying of the sewer and shall be completed and excavation closed as expeditiously as possible.

BACK-FILLING.

Sec.17. Back-filling.- In back-filling sewer trenches loose,fine earth,free from stone,shall be used up to a point 2 feet above the sewer,and shall be thoroughly compacted in 6 inch layers with hand-rammers. The remainder of the trench may be composed of 1/3 broken rock and no stone of this shall weigh more than 50 pounds. The filling shall be crowned 6 inches above the street surface.

Sec.18. Final Inspection. Upon notification by the Contractor of the completion of the work herein contracted for the engineer will carefully inspect all sewers,appurtenences and all other work done by the contractor. In each stretch of pipe sewer intended to be straight light shall be visible from one end to the other.Any broken or cracked pipe shall be replaced with sound ones. Any deposits found in the sewers,

or protruding cement,shall be removed and the sewer-bore left clean and free throughout its entire length. All man-holes and other appurtenences shall be of the specified size and form and of a neat appearance ,and their tops shall be set to the proper grade. In general the work shall comply with these specifications,and if found not to do so in any respect shall be brought to proper condition at the expense of the contractor.

GENERAL PROVISIONS,PAYMENTS,ETC.

Sec.19. General Provisions. If any alterations in plan directed by the Engineer diminish the quantity of work to be done they shall not constitute a claim for damages nor for anticipated profits,and any increase or decrease shall be paid for or deducted according to the quantity actually done,and at the price established for such work under this contract.

The contractor will be furnished with a set of drawings,showing the details and dimensions necessary to carry out the work,dimensions in figures thereon having precedence over the scale.The plans submitted to the contractors for proposals are to be interpreted in conjunction with the specifications and descriptions of the character of the work appearing on the plan are made a part of these specifications.

The contractor shall provide suitable stakes,plank,and forms,and render such assistance to the engineer at his own expense,as may be necessary to establish lines and grades for the guidance of his work and shall carefully preserve said points at all times.

Sec.20. Responsibility for Injuries. The Contractor shall be responsible for injuries to persons and property inflicted during the construction of the work and the city may at its discretion withhold the amount of such injury or damage from any estimate due him which may be needed to make good such damages or injuries,and the city shall not in any wise be liable therefor.

The contractor shall place sufficient lights on or near the work and keep them burning from twilight to sunrise.

Sec.21. Extra Work. If any work of the general nature herein contracted for,but for doing which a bid has not been specially made,shall need be done the contractor shall do the same under the direction of the engineer,and shall receive therefore the actual cost of labor and material used plus ten percent (10%) for superintendence and use of tools,but he shall not be entitled to receive payment for any work as extra work unless ordered by the engineer to do the same as such. No claim for extra work will be allowed if not made before the payment of the next following monthly estimate.

Sec.22. Time of Commencement and Completion. The party of the second part agrees to begin the work herein contracted for within two weeks of the awarding of the contract and to fully complete the work herein specified on or before the ..... day after the awarding of said contract,but the party of the first part may extend the time of completion should they deem it for the best interests of the city.

Sec.23. Position of the Engineer. The engineer shall have the final decision on all matters of dispute involving the character of the work, the compensations to be made thereof,or any question arising under this contract. He shall as representing the city,have the option of making any changes in the line,grade,plan,form,position,dimensions,or material of the work therein contemplated either before or after construction has begun,and all explanations or directions necessary for carrying out and completing satisfactorily the different descriptions of work contemplated and provided for under this contract shall be given bym said engineer.

Sec.24. Duties of the Contractor. The Contractor must perform the work contracted for strictly in accordance with these specifications,and follow at all times,without delay,all orders or instructions of the engineer in the prosecution and completion of the work and every part thereof, and constantly be on the grounds or be represented by a duly qualified person to look after the work and receive instructions.

Sec.25. Measurements and Payments. Measurements of sewers shall be taken from the center of uppermost manhole or flusk-tank on each line to the center of the manhole at its junction with a main or lateral,or to the center line of such main or lateral at the junction,including all branches,manholes,or other appurtenences along the line. The depth by which sewer prices will be graded will be measured from the surface of the ground to the underside of the sewer pipe or concrete. The price bid for sewers shall include furnishing all materials and labor for excavating,shoring,constructing the sewers in accordance with the specifications and plans,back-filling,restoringnthe street surface as previously specified, for all matters in connection therewith heretofore specified as being so included. Branches shall be paid f
for By the piece at the price bid,which shall include the cost of furnishing and fixing plugs in said branches where necessary.

Flush tanks shall be paid for at the price bid for each tank,this to include the tank complete as set forth by drawings and specifications,including the excavation and back-filling,ventilation pipe and iron head.

Ordinary manholes shall be paid for on the basis of a depth of 4 feet with an additional amount for each foot exceeded,price bid to include excavation and back filling,furnishing and setting iron casting and steps,and completing the whole as set forth in the plans and specifications. The depth of flush tanks and manholes shall be measured

from the invert of a pipe sewer to the top of the iron head when properly set.

The price of brick or concrete not otherwise provided for shall be per cubic yard by actual measurement in place,provided such dimensions do not exceed those indicated or implied in the plans or instructions of the engineer.

Iron work,both cast and wrought,shall be paid for by the pound. No payment for iron work as such shall be made for the heads or steps or other divices included in the manholes and other appurtenences as shown in the plans and specifications.

The price of timber in foundations shall include the furnishing and setting of the same.

The engineer at the first of each month,or within five days thereafter,during construction will estimate approximately the amount of work completed during the preceeding month according to the specifications,and eighty-five percent (85%) of the amount due beyond the reservation herein made will be paid the contractor on or before the 15th day of each month for the work of the preceeding month.

When the contract shall have been completely performed on the part of the contractor the engineer shall proceed to make final measurements and estimates of the same,and shall certify the same to the City Council,who shall,except for cause herein specified,pay to the concontractor,on or before the 15th day after such completion of the contract,the balance which shall be found due,excepting therefrom such sum as may be lawfully retained under any provision of this contract.