City of Whitehorse

Marwell Water System

Hydraulic and Thermal Assessment Summary

Prepared by:

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Quest Engineering Group

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1.0 Background

In Sept./2002, David Nairne & Associates (DNA) completed the Marwell Area Preliminary Engineering Study for the City of Whitehorse. The report addressed the future land development and servicing for the remaining developable lands in the Marwell area.

DNA provided recommendations for future watermain sizing and system layout along existing and proposed rights-of-way in the existing and future development areas. DNA provided recommendations for pipe sizing, depth of bury, and recirculation requirements, assuming bare pipe installations @ 3 m bury, utilizing the existing Transit Station recirc pump and boiler, and the existing YECL recirculation pump.

The City of Whitehorse retained Quest Engineering Group to review the existing DNA recommendations, and provide more detailed assessment of the proposed water system, to determine if the YECL circ pump could be eliminated from the City system, and to determine if the existing Transit Station circ pump and boiler requires upgrading. The detailed assessment resulted in recommendations for the proposed watermain improvements to be installed on Industrial Rd. and Platinum Rd. this season.

Quest Completed the initial assessment as requested, and provided a summary report to the City on February 11, 03. As a result of some of the findings in the report, the City requested Quest to complete additional assessment work with respect to the overall Marwell water network, fire flows and future requirements. This second summary details the additional assessment work completed.

1.1 Hydraulic Assessment of Existing and Future Watermains

1.1.1 Review of Previous Reports and Findings

In 1990 Stanley completed an overall water study to look at existing and future water system improvements. They modeled the entire water system, and concluded that Marwell could be adequately serviced using the existing single supply source from Two Mile Hill. They assumed that recommended industrial fire flows of up to 228 l/s could be provided to the Marwell area if the existing PRV's were by-passed during a fire condition. They recommended future system expansion using 250 mm loops in expansion areas, but did not identify any upgrading requirements for the existing single source supply on Industrial Rd. Although by-passing of the PRV's could supply adequate fire flows, it should be noted that the system pressures would exceed 1100 kPa at the pumphouse, and would be even higher in the lower areas of Marwell, which could cause high pressure damage in hot water tanks and older pipes.

In 1995 Stanley completed the Crosstown Watermain Pre-design study, and subsequent Two Mile Hill Booster Station Predesign. In these studies it was recognized that Marwell could be serviced from the low pressure suction side of Two Mile Hill to provide more efficient system operation, however, this would require changes to the servicing of the

Trail of 98 RV Park, which would have insufficient pressure, due to its elevation above Two Mile Hill Booster. To deal with the problem, the Two Mile Hill Booster was designed with two parallel PRV's to supply Marwell from the high pressure outlet side in the short term, with provision for a future low pressure supply connection provided in the internal pipe network. At present the PRV's are set at 480 kPa for the 75 mm PRV for low flow conditions, and 450 kPa for the 200 mm PRV for high flow situations. The PRV settings maintain maximum pressures in Marwell below 700 kPa in the lowest areas, which are some 16 m lower than the Two Mile Hill Booster elevation.

In 2002 David Nairne and Associates completed the Marwell Area Preliminary Engineering Study which reviewed existing and proposed water network requirements. DNA modeled the local Marwell area using a truncated version of the City's overall water model. In their assessment, DNA concluded that the existing water network could provide fire flows in the order of 150 l/s for most of the existing and expansion area, and concluded that this would be adequate fire flow for the proposed development. The DNA model used a fixed grade source at the Two Mile Hill Booster, with a hydraulic grade line of 700.80 m, and did not accurately model the existing PRV operation. The DNA model also used a simplified method to check fire flows at nodes, and did not use the fire flow sub-routine in the City overall model. DNA did not recommend any existing system upgrading to the single supply source on Industrial Road.

1.1.2 Current Analysis of Existing and Proposed Future Pipe Network

The City of Whitehorse obtained a copy of the water model used by DNA for their predesign modeling review. The model was a truncated version of the City's overall model, and did not include node coordinates for the proposed network. The DNA model also used a fixed grade supply source at Two Mile Hill, in place of the actual PRV. The fixed grade source was given a hydraulic grade line of 700.80 m. Quest felt more comfortable using the City's overall water model, and updated the City's current model to include the proposed pipe network as recommended in the DNA report. Quest modeling was completed using the updated City model, with a PRV setting of 450 kPa at the PRV, based on operational data obtained from the Two Mile Hill Booster Station maintenance manual, and field verification. The PRV setting of 450 kPa is set to control maximum pressures in the lower Marwell area below 700 kPa., while still maintaining adequate pressure to the Trail of 98 RV Park, which is at the highest point on the local water system.

Using the existing and proposed planning information from the DNA report, Quest updated the water model for the Marwell area, using the existing City of Whitehorse Waterworks model. Nodal demands were reviewed and updated based on the proposed future land use plans developed by DNA. An Average Day Demand of 25 cu.m./hectare was used as an average commercial/industrial water use, as recommended in the DNA report.

During model analysis, it was evident that the available fire flows obtained using the City model, were lower than the results stated in the DNA predesign report. In reviewing the differences Quest discovered that DNA had not used the fire flow subroutine in the City model. Instead, they simply applied a nodal demand, and increased the demand until the residual pressure dropped to 140 kPa. While this method works, it does not take into account the pressure drop associated with an actual fire hydrant, and provides higher flow values, when compared to the fire flows achieved using the model subroutine. We believe the model subroutine provides more accurate results, as it was created to reflect the actual pressure drop through a fire hydrant, and was previously calibrated to actual flow measurements. Therefore, we concluded that the fire flows suggested by DNA are actually higher than would be expected in the Marwell area.

DNA considered that the available fire flows they modeled, in the order of 150 l/s in the Marwell area, were suitable for existing and proposed development. Therefore, they did not recommend any upgrading of the existing pipe network in the area.

1.1.3 Discussion of Fire Flow Requirements

The 1990 Stanley study suggested fire flow requirements for industrial areas should be in the order of 228 l/s.

The 2002 DNA study noted that 1991 IAO guidelines suggested fire flows of 250 l/s for industrial areas, but noted that actual building requirements were usually significantly lower than this. They concluded that fire flows in the order of 150 l/s could be obtained in most of the Marwell area, and concluded that this was sufficient, therefore no upgrading of the existing piped network was recommended.

Quest also calculated fire flow requirements, based on FUS recommendations, to determine what the available fire flows should be for the Marwell area. Based on the calculations, the following results were obtained:

- Maximum requirements (1500 sq.m. bldg, no sprinklers) 267 l/s
- Average requirements (750 sq.m.bldg, no sprinklers) 167 l/s
- Minimum requirements 33 l/s

These requirements were calculated for typical non-combustible buildings with hazardous contents, which is similar to the warehouse type structures containing flammable products, that are common in Marwell. FUS guidelines do not deal with bulk fuel storage requirements, or recommendations for fire protection for these facilities. It is assumed that special fire protection, including foam, or other retardants would be required for these facilities, and should be treated as a special situation.

1.1.4 Water Network Options Review

The existing water network was checked, and it was found that the system cannot provide the suggested average fire flows to the areas east of Quartz and Copper Road, or along Copper Road. The flow restrictions were found to be the single supply source along Industrial Road, from Two Mile Hill to Galena Road.

In order to achieve suggested average and greater fire flows, Quest reviewed various network improvements to arrive at a recommended network which provided the best overall fire flows through the existing and proposed system. The recommended improvements included upgrading on Industrial Road from 250 to 400 mm from Two Mile Hill to Quartz Rd, and upgrading from 250 to 300 mm from Quartz Rd to Galena Rd.

Other network options were also modeled to assess their suitability as follows:

- An alternate 250 mm supply main was provided along Quartz Rd., from Chilkoot Way to Industrial Rd, with an additional future connector between Quartz and Gold, as recommended by DNA. This option provided only marginal benefits, due to the lower pressures on the Chilkoot Way supply side. This option could provide greater benefit if all of Marwell was supplied from the low pressure side of Two Mile Hill Booster, as recommended by Stanley, but this would require changes to the supply pressures for the Trail of 98 RV Park.
- An alternate 250 mm supply main was provided from Range Rd, to the intersection of Copper and Tlingit Rd. This option provided greater fire flows in the immediate area of the connection, but was restricted by the 200 mm main on Copper Rd, and the small 150 mm bypass size at the Transit Station. Upgrading the bypass size from 150 mm to 250 mm provided improvements to the eastern area of Marwell.

In 1995, Stantec prepared the Cross Town Watermain predesign study. In this report it was recommended that Marwell should ultimately be serviced from the low pressure inlet side of Two Mile Hill. This would result in more efficient operation, and reduce pumping costs by not having to pump Marwell water to Valleyview reservoir. The downside is that the Trail of 98 RV Park would not have adequate pressure without modifications to their supply. If this option was chosen in the future, the upgrading of the existing 150 mm main along Quartz Rd. from Wal-Mart to Industrial would be required, as well as the upgrading on Industrial from Quartz to Galena. The provision of the proposed link from Quartz to Gold Rd. would also be required to provide suggested average fire flows throughout the proposed Marwell expansion area.

The cost of these alternate options would be significantly higher than upgrading the existing Industrial Rd. main, therefore, the most cost effective short term solution to improving fire flows in the Marwell area, is to upgrade the Industrial Rd. watermains as recommended in this study. Water supply would still be limited to a single supply source from Two Mile Hill.

Fire flows are currently limited to approx. 100 l/s in the extremities of the proposed future water system, and at the north end of Copper Rd., due primarily to the single supply main along Industrial Rd., and the long run of 200 mm main on Copper Rd. The bypass in the transit station has only a marginal impact on fire flows at nodes close to the transit station. This is due to the long runs of pipe on either side of the transit station, which are fed from a single supply source on Industrial Rd. Twinning or upgrading the Industrial Rd. supply main, from Two Mile Hill Booster to Copper Rd., would provide significant fire flow improvements in the existing and proposed future network.

1.1.5 Discussion of Recirculation Flow Improvements

The proposed DNA pipe network was adjusted slightly to provide better circulation flows in the future network along Platinum, Gold and Gypsum roads. The increased recirculation flows were obtained by increasing the pipe on Industrial Rd. from 200 to 250 mm, between nodes 5130 and 6010, and on Tlingit Rd., between nodes 6045 and 6050; and decreasing the pipe size from 200 to 150 mm, between nodes 6020 and 6050. The upgraded pipe along Industrial Road allowed greater flows between Galena, and Platinum and Gold Rd. These adjustments provided more balanced recirculation flows, and provided better overall fire flows in the extreme limits of the system, along Gypsum Rd. The improved recirculation flows result in higher return water temperatures at the Transit Station.

1.2 Thermal Assessment of Existing and Proposed Network

Using the flow information generated by the hydraulic water model, the thermal characteristics of the proposed ultimate network were assessed. A worst-case recirculation flow was determined by turning off all node demands, and assuming only the recirculation flow provided by the Transit Station recirc pump was available for night time and week end flows. The YECL circ pump was turned off for the assessment.

The existing Transit station boiler and circ pump can provide 9.7 l/s flow with a starting water temperature of +4 Celcius. Based on these flows and temperatures, the return water temperature was found to be 0.68 Celcius with the ultimate system in use. The coldest temperature occurs at the end of Galena Rd., which is a bare 250 mm pipe, just prior to mixing at node 5120, and was calculated to be 0.16 Celcius. After mixing at node 5120, the temperature rises to 0.78 Celcius, and the return temperature at the Transit Station was calculated to be 0.68 Celcius. All calculations assume insulated pipe will be installed for all new pipe extensions. The existing circ pump and boiler are adequate to protect the existing and proposed pipe network, as long as insulated watermains are installed for all future network extensions. The existing boiler and circ pump could not provide enough circulation or heat input to adequately protect a bare pipe network. Significant improvements would be required to both the circ pump and boiler capacities. If, during actual future operations, the return temperatures are found to be lower than 0.5 Celcius, the recirc pump could be upgraded to provide slightly more recirc flow. A pump capable of 12 l/s would provide minimum velocities of 0.15 m/s in bare pipes, resulting in higher return temperatures.

The YECL circ pump is not required to provide adequate network circulation once the network is complete. The existing pump should be retained to protect the YECL service only.

If a new link is constructed from Quartz to Gold in the future, as proposed by DNA, the recirculation flow and start temperatures may have to be increased due to the extra flow length and splitting of flow through the new link. This should be reassessed in the future.

1.3 Conclusions and Recommendations for 2003 Construction

The Marwell water network can be extended to service Platinum, Gold and Gypsum Roads, with restricted fire flows of approximately 100 l/s. This fire flow is adequate to protect an unsprinklered building of approx. 280 sq.m., which is smaller than many of the existing industrial buildings in the area. Suggested fire flows for the industrial area should be in the order of 167 to 267 l/s based on FUS guidelines.

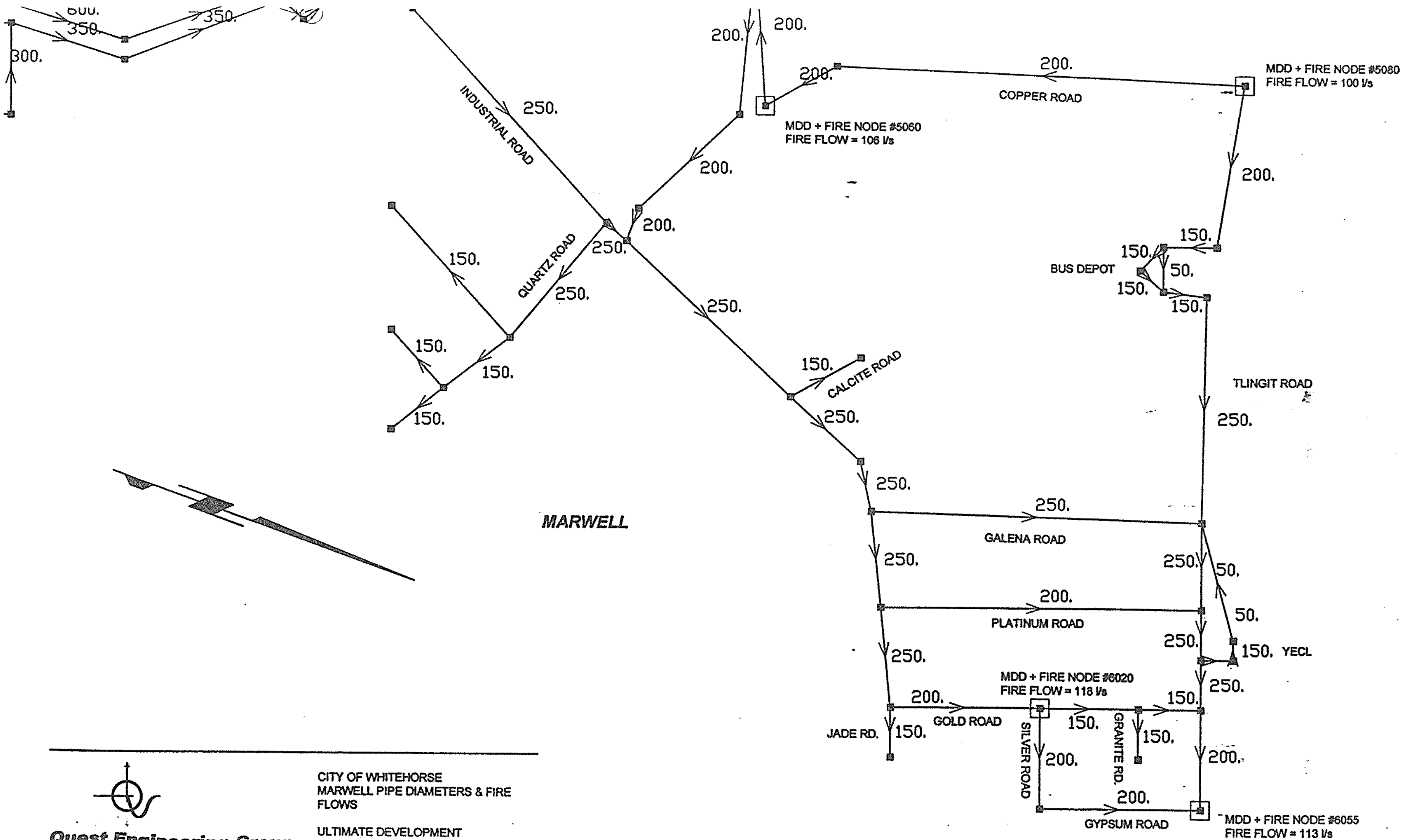
The watermain size recommended for Industrial Rd. between Galena and Platinum is 250 mm. This upgraded link will provide better recirculation flows in the proposed future loops on Gold and Gypsum Roads. The watermain size recommended for Platinum Rd. is 200 mm.

The existing recirculation pump and piping at YECL is not required for the future recirculation system, if the new mains installed are insulated. The YECL pump and piping should be retained to protect the YECL service connection form the main to the building.

All new watermain should be insulated with 50 mm UIP insulation. We believe the cost of pipe insulation will be offset by reduced trenching and dewatering costs. It would be very difficult to dewater trenches at 3.0 m depth of bury in the Marwell area.

Appendix:

Water Network Options Analysis



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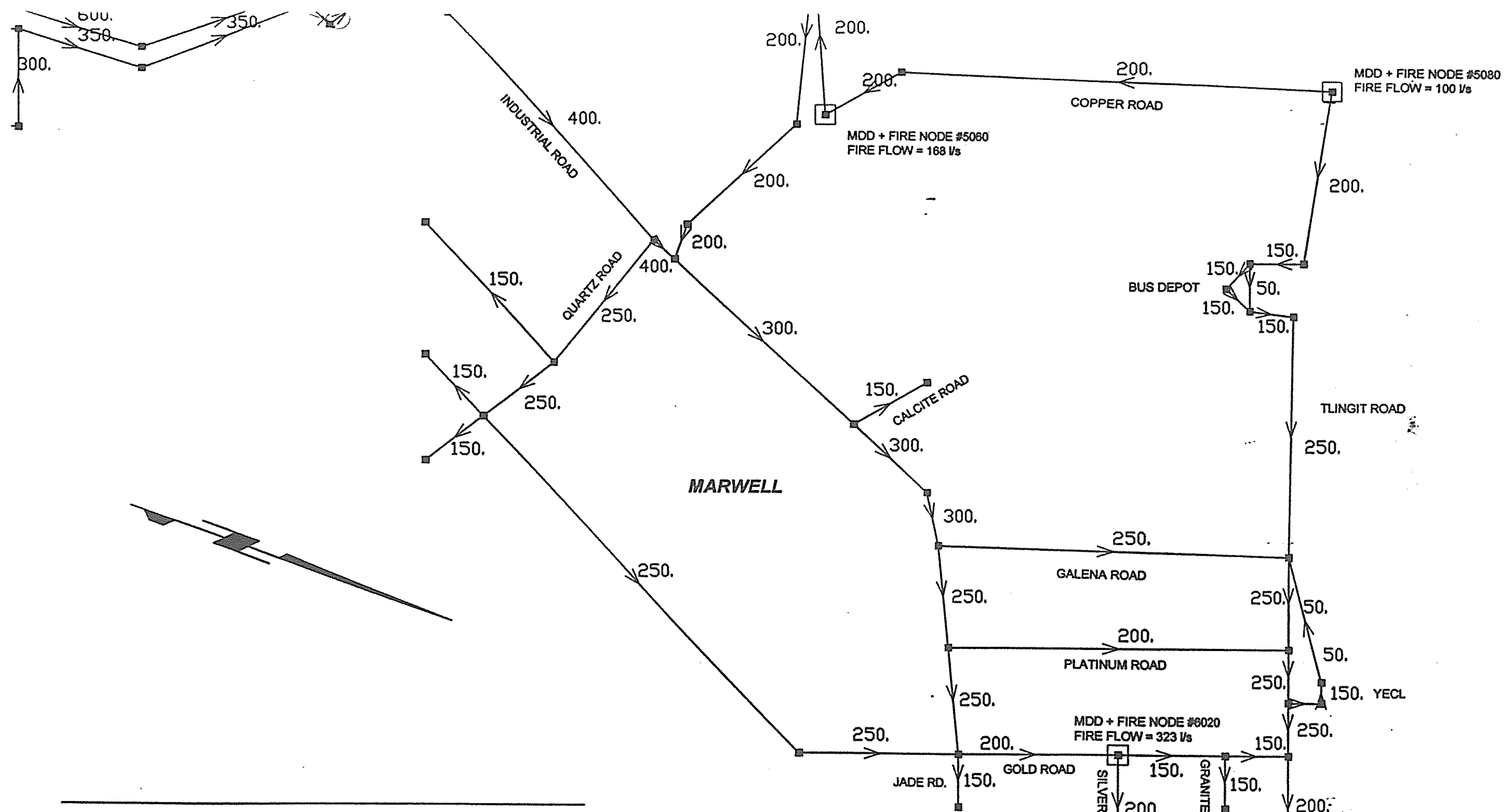
CITY OF WHITEHORSE
MARWELL PIPE DIAMETERS & FIRE FLOWS

ULTIMATE DEVELOPMENT
SCENARIO 1. - STATUS QUO



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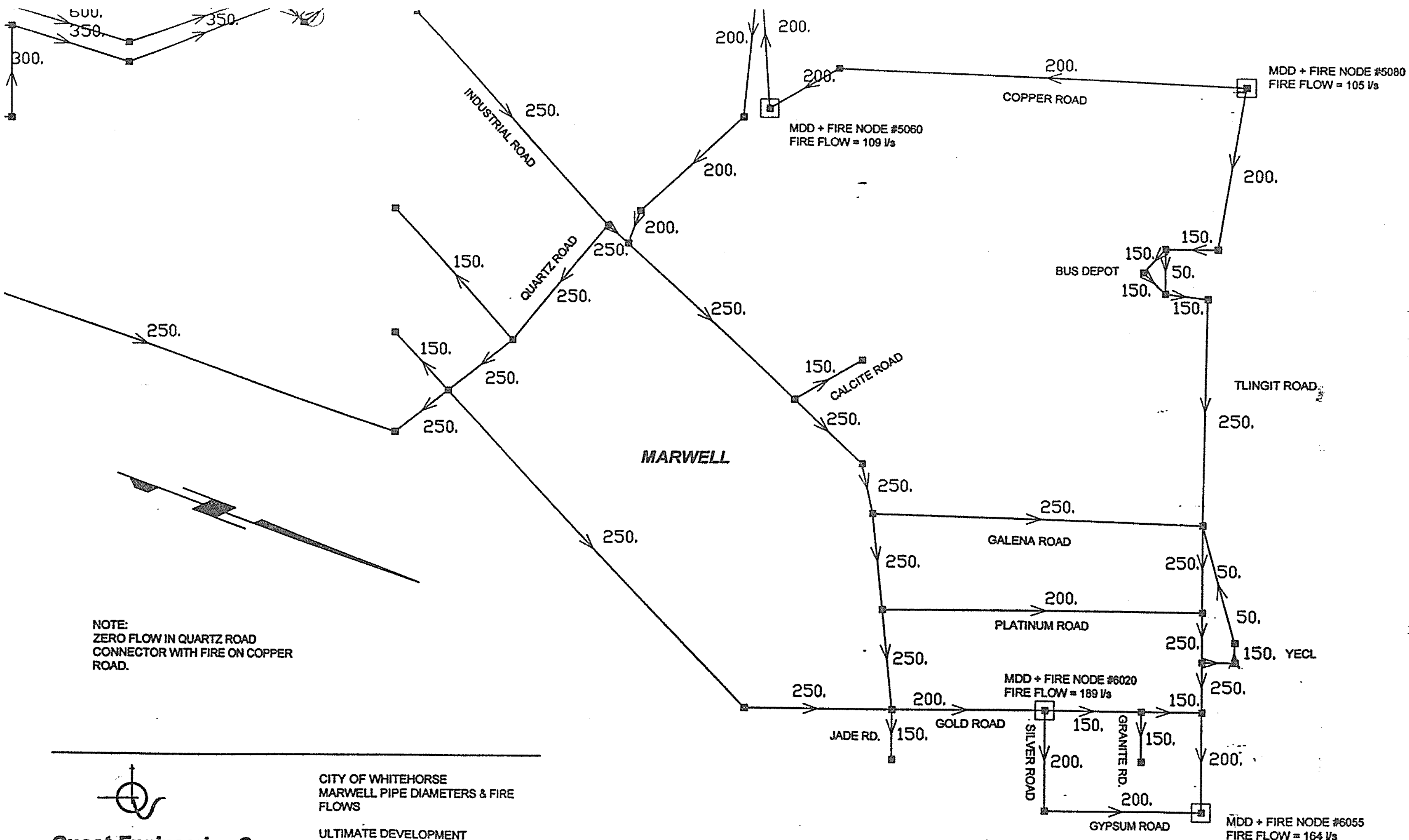
MARWELL PIPE DIAMETERS & FIRE FLOWS

ULTIMATE DEVELOPMENT
SCENARIO 2. - INDUSTRIAL ROAD UPGRADES



NOTE:
ZERO FLOW IN QUARTZ ROAD CONNECTOR WITH FIRE ON COPPER ROAD.

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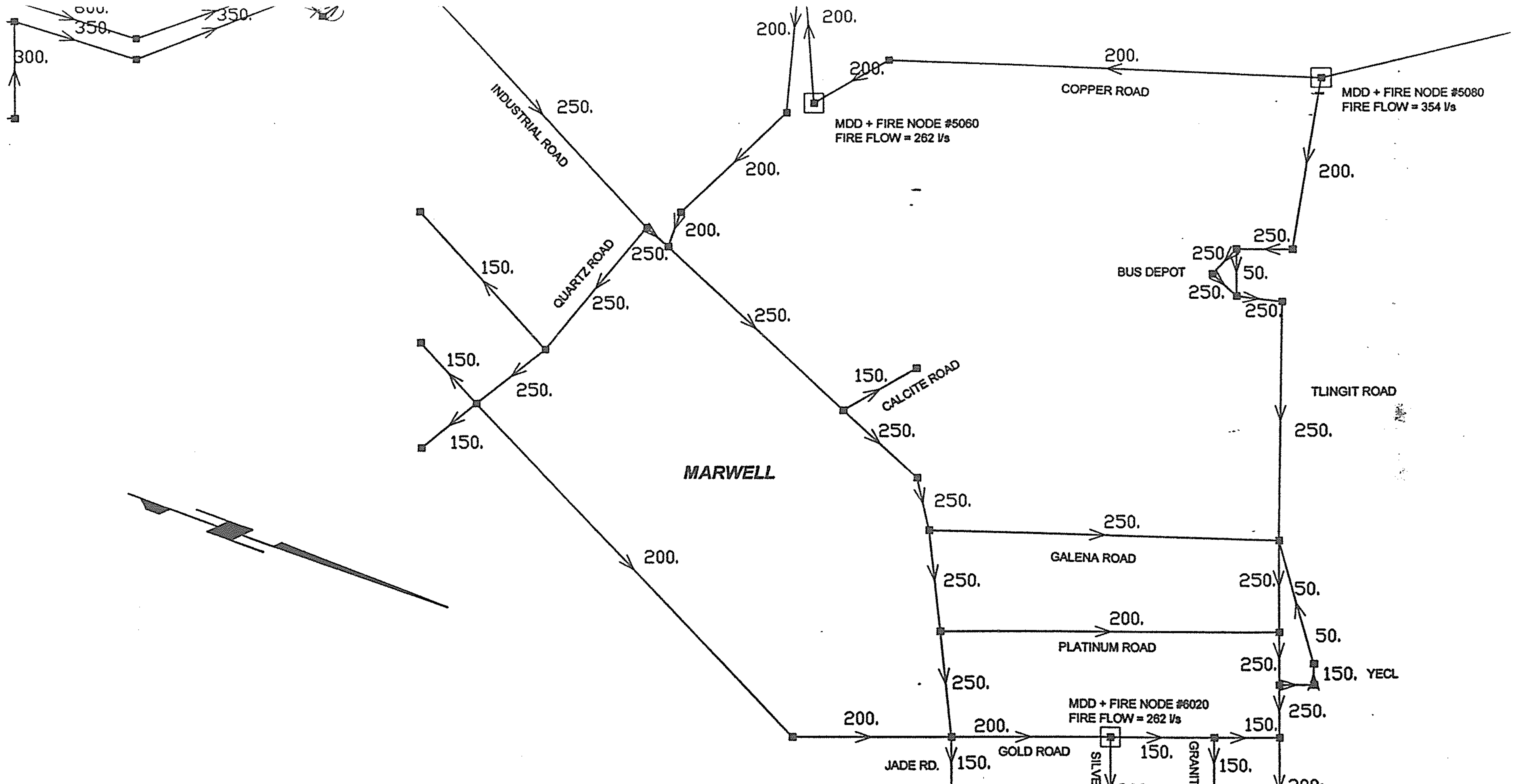
MARWELL PIPE DIAMETERS & FIRE FLOWS

ULTIMATE DEVELOPMENT
SCENARIO 3. - QUARTZ ROAD CONNECTOR



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CITY OF WHITEHORSE
MARWELL PIPE DIAMETERS & FIRE FLOWS

ULTIMATE DEVELOPMENT
SCENARIO 4. - TAKINI CONNECTOR

400 mm upgrade to Quartz Rd.	400 mm upgrade to Galena Rd.	400 / 350
6055 185	6055 273	6055 257
5080 148	5080 160	5080
350 mm upgrade to Quartz Rd.	350 mm upgrade to Galena Rd.	350 / 300
6055 179	6055 243	6055 219
	5080	5080
300 mm upgrade to Quartz Rd.	300 mm upgrade to Galena Rd.	400/300
6055 165	6055 198	6055 230
	5080	5080 155

250 dia Quartz/Platinum link - 300 dia Quartz main with CV - 300 dia Quartz Galena upgrade

			Node
	164	l/s	6055
	106	l/s	5080

300 dia upgrade Ind Rd to Quartz - 250 dia Quartz/Platinum link - 300 dia Quartz main with CV - 300 dia Quartz Galena upg

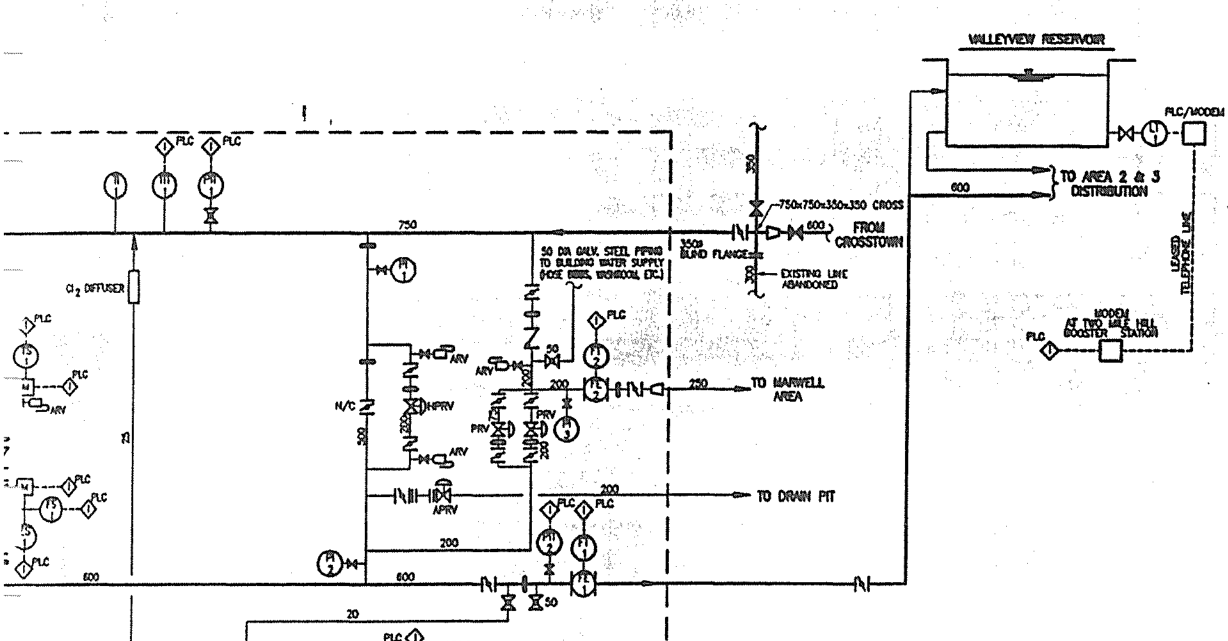
			Node
	205	l/s	6055
	133	l/s	5080

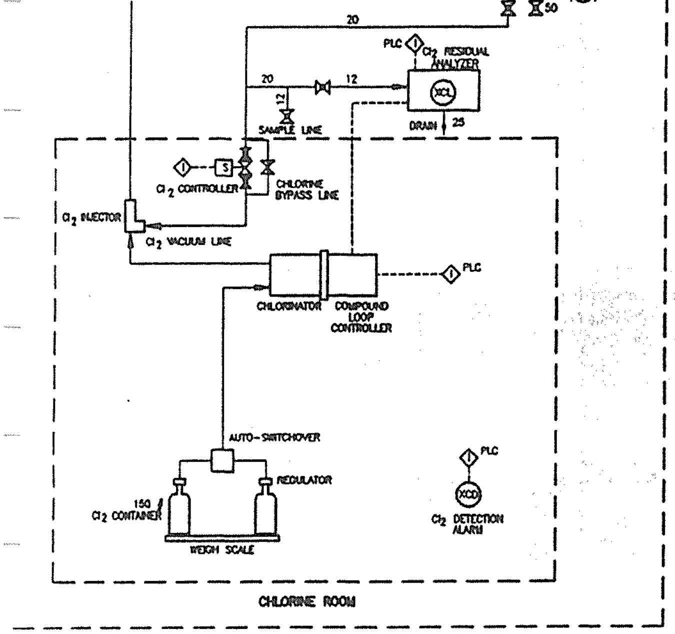
350 dia upgrade Ind Rd to Quartz - 250 dia Quartz/Platinum link - 300 dia Quartz main with CV - 300 dia Quartz Galena upg

	229	l/s	6055
0 l/s through Quartz CV main	147	l/s	5080

400 dia upgrade Ind Rd to Quartz - 250 dia Quartz/Platinum link - 300 dia Quartz main with CV - 300 dia Quartz Galena upg

0 l/s through Quartz CV main	248	l/s	6055
0 l/s through Quartz CV main	154	l/s	5080





RESERVOIR LEVEL CONTROL

WATER LEVEL	DEPTH(m) (N. END)	FUNCTION
759.8	5.9	OVERFLOW
759.7	5.8	FLYGT BULB
759.6	5.7	HIGH LEVEL ALARM
759.3	5.4	P1 STOP
759.1	5.2	P2 STOP
758.9	5.0	P3 STOP
758.3	4.4	P1 START
758.0	4.1	P2 START
757.7	3.8	P3 START
756.6	2.7	LOW LEVEL ALARM
756.6	2.7	FLYGT BULB
754.2	0.3	RESERVOIR FLOOR (S. END)

PUMP OPERATION (AUTOMATIC MODE)

1. LEAD PUMP STARTS ON LOW RESERVOIR LEVEL
2. AS THE LEVEL DROPS FURTHER THE SECOND (LAG) AND THIRD (FOLLOW) PUMPS WILL START ON STANDBY GENERATOR IN PEAK SHAVING MODE.
3. ONLY ONE PUMP IS ALLOWED TO RUN ON UTILITY POWER.

PUMP OPERATION (MANUAL MODE)

1. ALL PUMPS WILL BE OPERATED MANUALLY BYPASSING PLC CONTROL.

PLAN OF RECORD
CONTRACTOR: KETZA CONSTRUCTION LTD.
CONST. DATE: JULY 1996 – AUGUST 1997
SIGNATURE:
DATE: JUL. 09, 1998

NOTE:
SUBMIT SPOOL DRAWINGS FOR ENGINEER'S REVIEW

REFERENCE DRAWINGS

LEGEND

- PROCESS PIPE
- AIR LINE
- CONTROL/ELECTRICAL SIGNA
- VICTAULIC COUPLING
- PLUG VALVE
- BUTTERFLY VALVE
- BALL VALVE
- GATE VALVE
- HYDRAULICALLY OPERATED CONTROL VALVE
- CHECK VALVE
- EXISTING VALVE
- CONTROL INTERLOCK
- MOTOR
- SOLENOID
- PNEUMATIC ACTUATOR
- ARV AIR RELEASE VALVE
- PRV PRESSURE REDUCING VALVE
- HPRV HIGH PRESSURE RELIEF VALVE
- APRV ANTICIPATING PRESSURE RELIEF VALVE
- PI PRESSURE INDICATOR
- PT PRESSURE TRANSMITTER
- PIT PRESSURE INDICATING TRANSMIT
- PS PRESSURE SWITCH
- LI LEVEL INDICATOR
- LT LEVEL TRANSMITTER
- FE FLOW ELEMENT
- FT FLOW TRANSMITTER
- FIT FLOW INDICATING TRANSMITTE
- TI TEMPERATURE INDICATOR
- TIT TEMPERATURE INDICATING TRANS
- TS TEMPERATURE SWITCH
- ZS LIMIT SWITCH
- N/C NORMALLY CLOSED
- N/O NORMALLY OPEN

No.	DATE	DESCRIPTION
D		MICROFILMED
D	1998 01/01	RECORD DRAWING
C	1996 07/11	FOR CONSTRUCTION
B	1996 05/27	TENDER
A	1996 04/19	CLIENT REVIEW

REVISIONS & ISSUES

PROFESSIONAL ENGINEER — YUKON TERRITORY — STEVEN S. CHO — 27 MAY 96
Revision: 0 - Issue: B
P. ENG. SEAL

DESIGN: S.C
DRAWN: B.W.E
DATE: 96/03/
CHECKED: S.C.
APP'D BY CONSULTANT — DATE
APP'D BY CITY — DATE

SCALE
HOR. N.T.S.
VER.

City of Whitehorse
ENGINEERING

Stanley Associates

TWO MILE HILL BOOSTER STATION

PROCESS SCHEMATIC AN INSTRUMENTATION DIAGRA

SHEET 20 OF 47
CONSULTANT DWG. No. P1
CITY DWG. No.
REV. D

Thermal Analysis for Platinum Rd Development

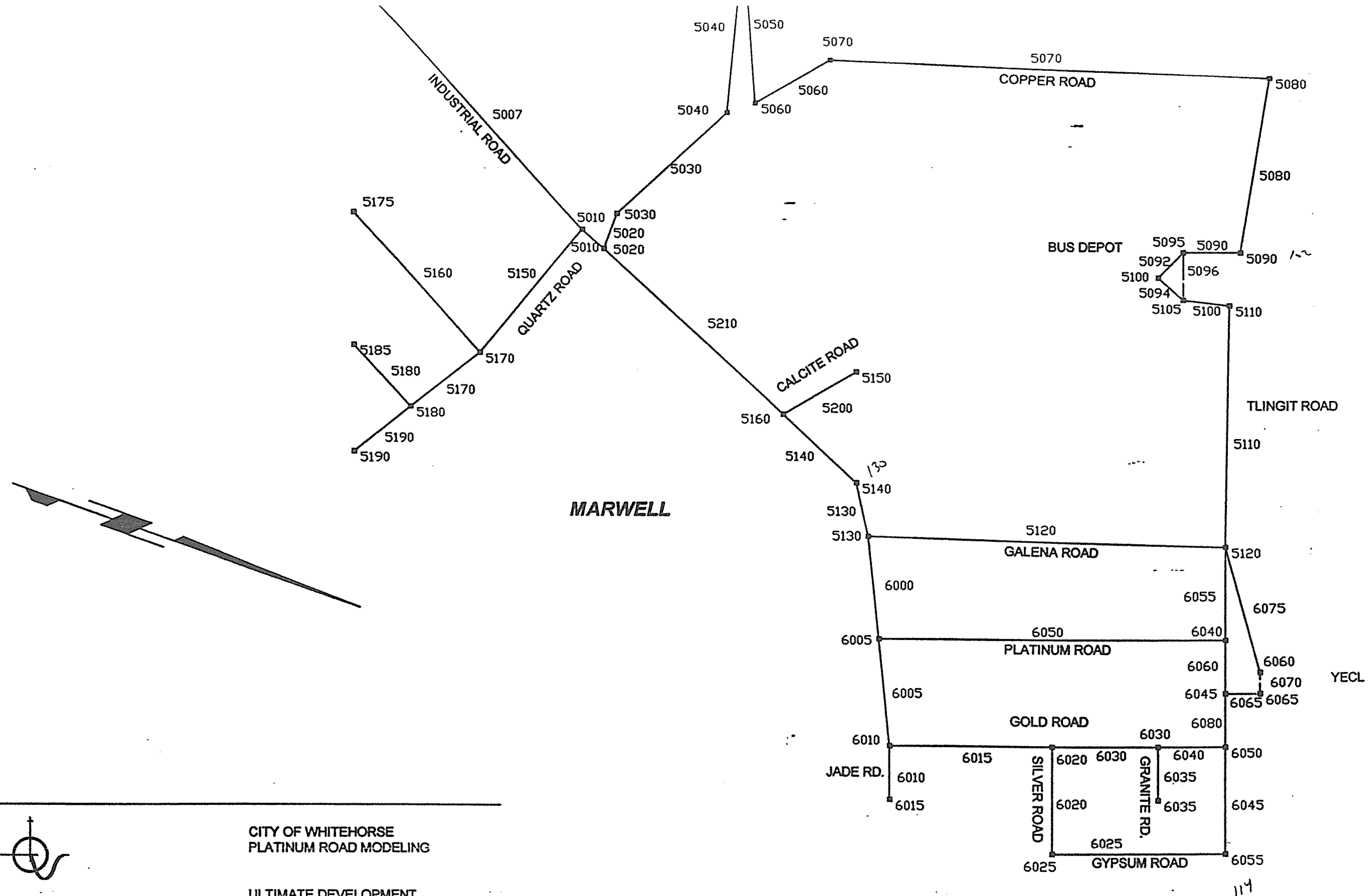
HYDRAULIC MODELING ANALYSIS RESULTS

Marwell Ultimate Design
Platinum Road 200mm Dia. Main
North end Industrial Rd 250 Dia. main

NFD factor = 0

Max Flow		Max Velocity		Min Residual Pressure		
Entire syste	New Mains	Entire syster	New Mains	Entire system	New Mains	
181.9	71.81	3.71	2.29	549.71	169.57	
-123.8	-74.2	-2.52	-1.51	188.24	217.21	67.6

LOCATION	RUN CONDITION	FIRE FLOW AT NODE (L/S)	MARWELL SYSTEM MAXIMUM FLOW (L/S)	MINIMUM FLOW (L/S)	MAXIMUM VELOCITY (m/s)	MINIMUM VELOCITY (m/s)	MINIMUM RESIDUAL PRESSURE (kPa)	COMMENTS
	ADD		33.8 7.4	0.3 0.1	0.69 0.18	0.02 0.01	550 647	Max flow pipe # 5000 / #6005 Min flow pipe # 5200 / #6035 Max velocity pipe # 5000 / #6015 Min velocity pipe # 5200 / #6035 Min pressure at node #5000 / #all System Demand = 33.8 l/s
	MDD		67.6 12.3	0.4 0.2	1.38 0.3	0.01 0.01	550 600	Max flow pipe # 5000 / #6005 Min flow pipe # 5050 / #6035 Max velocity pipe # 5000 / #6005 Min velocity pipe # 5050 / #6035 Min pressure at node #5000 / #all System Demand = 67.6 l/s
	PHD		101.5 17	0.8 0.3	2.07 0.36	0.05 0.02	507 532	Max flow pipe # 5000 / #6005 Min flow pipe # 5200 / #6035 Max velocity pipe # 5000 / #6015 Min velocity pipe # 5200 / #6035 Min pressure at node #5175 / #all System Demand = 101.5 l/s
	NFD		9.7 2.2	0 0	0.55 0.07	0 0	550 668	9.7 l/s Copper/Quartz/Tlingit Loop - 1.8 l/s #6015 Min flow Quartz & Ind. Rd Pipes / #6035 & #6010 Max velocity pipe # 5090 / #6015 Min velocity Quartz & Ind. Rd Pipes / #6035 & #6010 Min pressure at node #5000 / #all System Demand = 0 l/s
		Bypass Closed	Bypass Open					
5060	MDD + Fire	99.1	106.8					Flow exceeds recirc pump capacity at bus depot
5090	MDD + Fire	84.6	101.8					
5110	MDD + Fire	101.3	113					
5140	MDD + Fire	122	130.7					
5190	MDD + Fire	59.9	59.9					
6015	MDD + Fire	90.5	97.5					
6035	MDD + Fire	82.7	89.5					
6055	MDD + Fire	106	114.3					



CITY OF WHITEHORSE
PLATINUM ROAD MODELING

ULTIMATE DEVELOPMENT
PIPE & NODE NUMBERS

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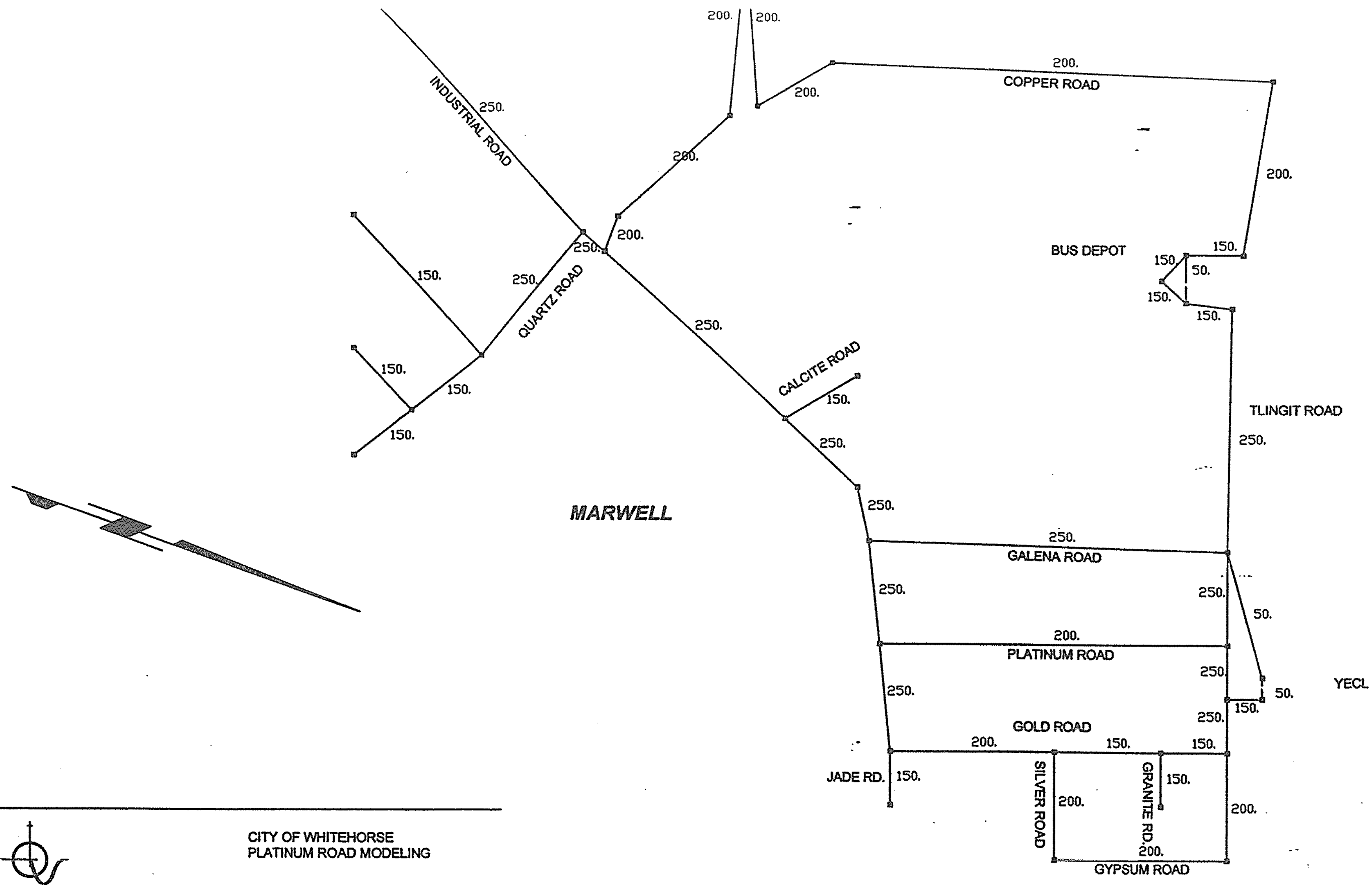

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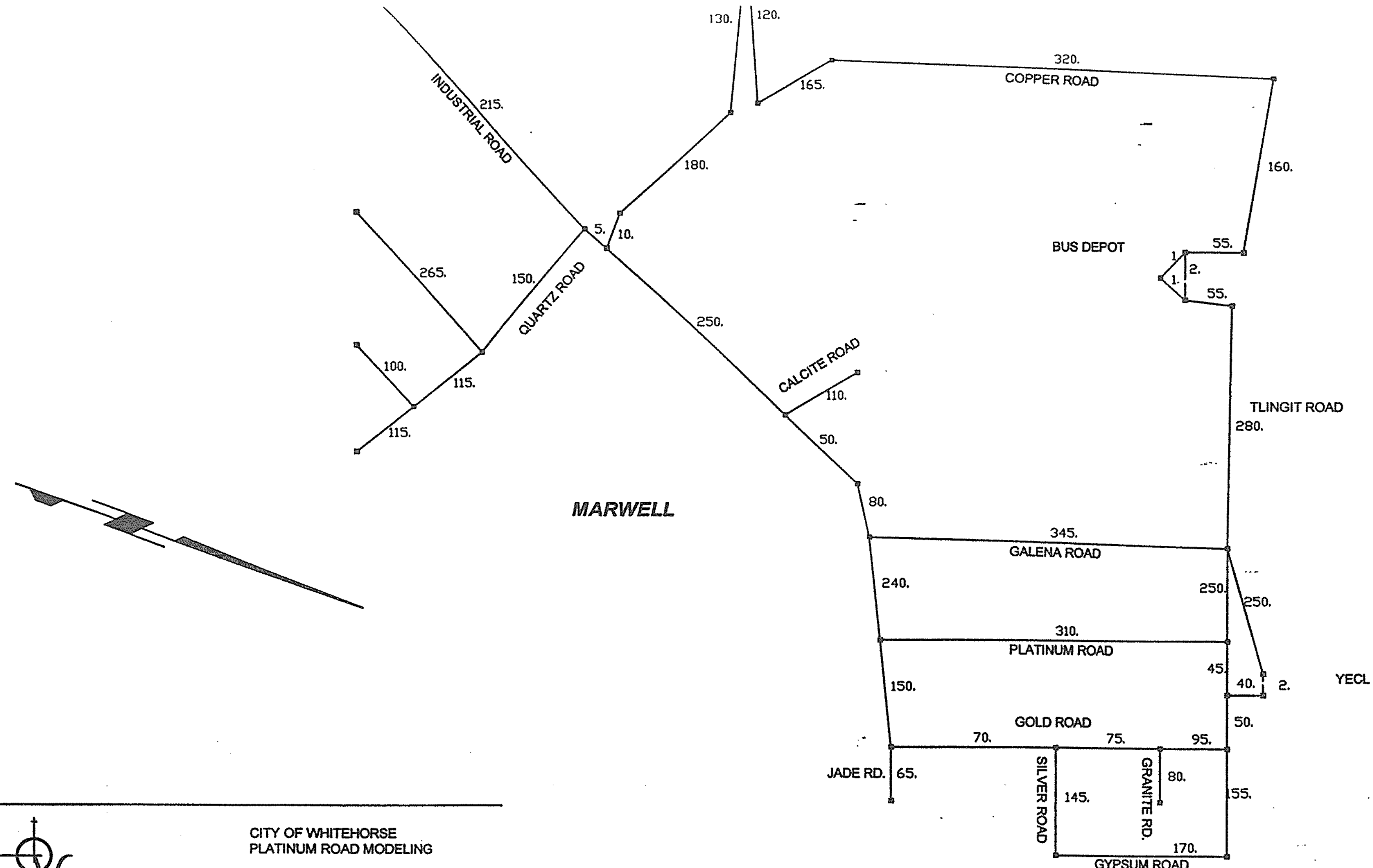
CITY OF WHITEHORSE
PLATINUM ROAD MODELING

ULTIMATE DEVELOPMENT
PIPE DIAMETER (mm)



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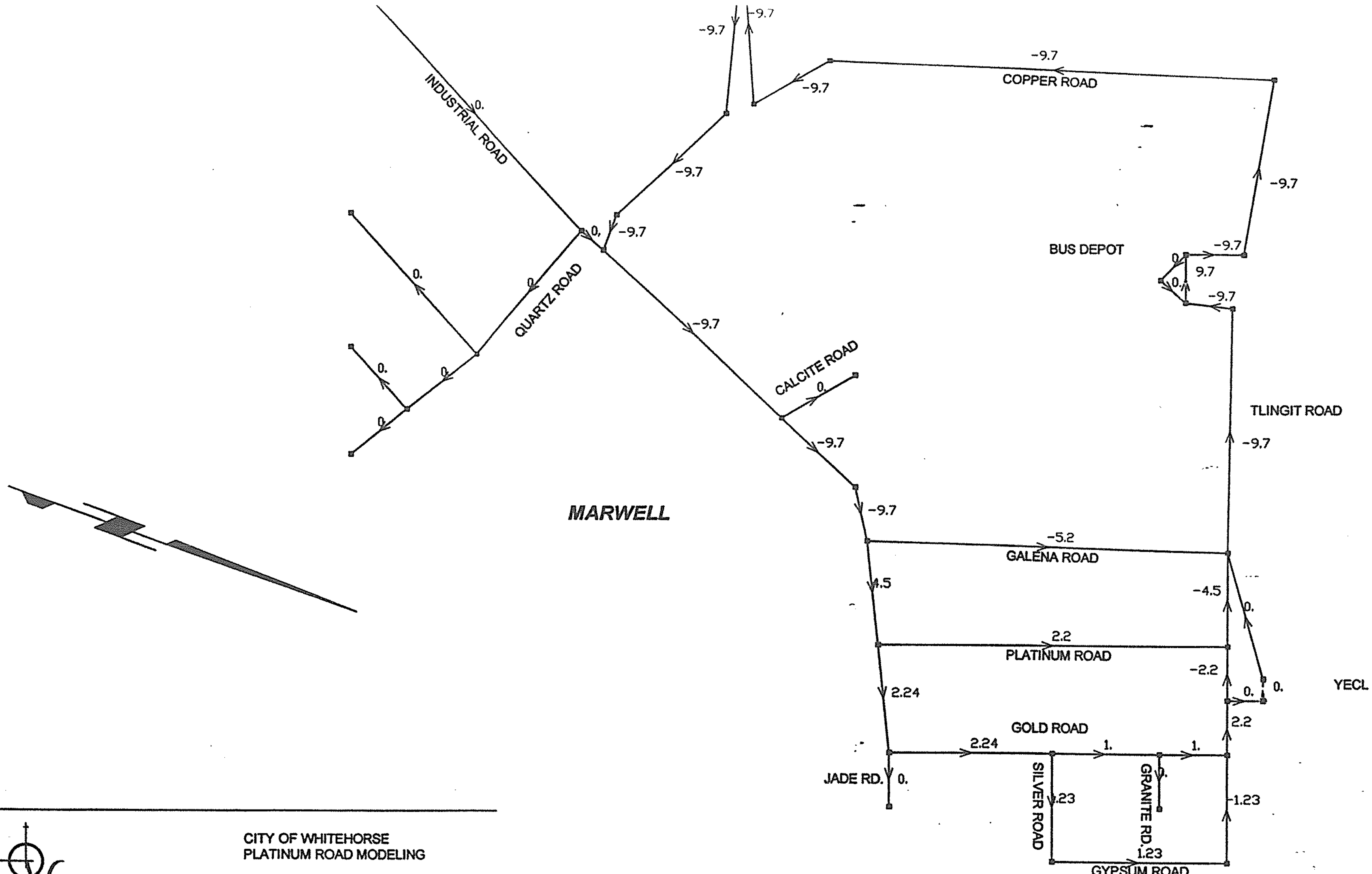
CITY OF WHITEHORSE
PLATINUM ROAD MODELING

ULTIMATE DEVELOPMENT
PIPE LENGTHS (m)



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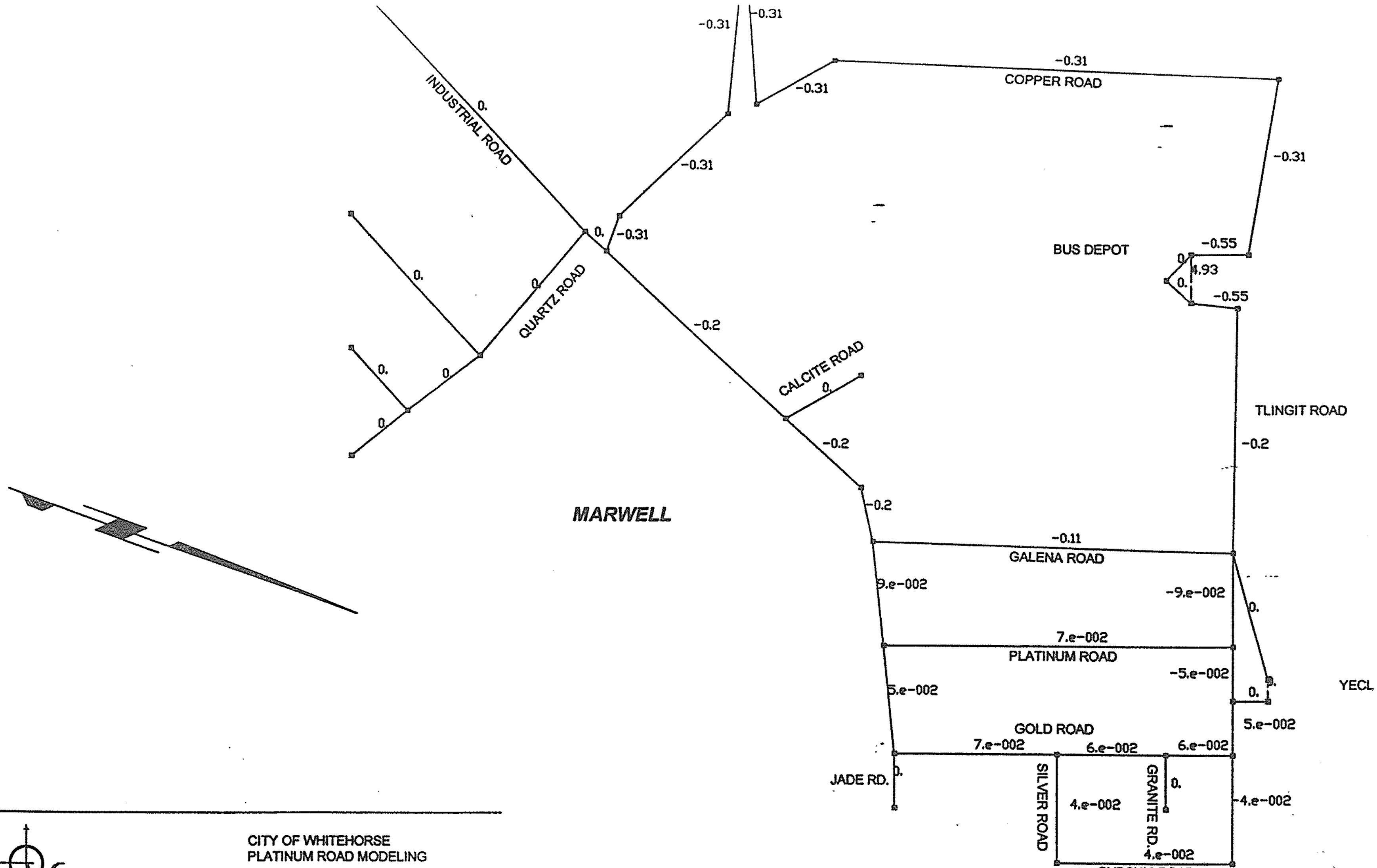
CITY OF WHITEHORSE
PLATINUM ROAD MODELING

ULTIMATE DEVELOPMENT
NFD - PIPE FLOW (l/s)



CITY OF WHITEHORSE
PLATINUM ROAD MODELING

ULTIMATE DEVELOPMENT
NFD - PIPE VELOCITY (m/s)

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Assumptions:

Soils are saturated gravels and sand bedding	$k_{g\,(soil)}$ =	3.07	W/m°C	From EBA Thermal Report
Water temperature	t_w =	**2.75**	°C	Ave. water temp. (4 - 1.5)
Ambient Temperature	t_a =	-25	°C	
50 mm UIP insulation	k_i =	0.024	W/m°C	From CCU Manual
Specific Heat Capacity of Water	C =	4190000	J/m³°C	From CCU Manual
	k_p =	50		Ductile
	k_p =	375		Copper
	k_p =	0.25		HDPE/PVC
	L =	334000000	J/m³	From CCU Manual

Determine: Time to Cool (Design Time) and Time to Reach -3°C (Safety Factor Time)

$T_{o\,(Hours)}$ = ((A R C) Ln (t_w-t_a/t_o-t_a))/3600

A = pipe area
R = total Thermal Resistance for pipe + Insulation

$T_{-3\,(Hours)}$ = ((A R C) Ln $(t_w-t_a/t_{-3}-t_a)$)/3600
$T_{f\,(hous)}$ = (ARL)/(t_o-t_a)
R_g = Arch (z/r)/2(3.17)k_g
R_p = $(r_p-r_w)/(r_p+r_w)(3.17)k_p$ (x2 = R_p+R_{al})
R_i = $\ln(r_i/r_p)/2(3.17)k_i$
q = $(T_w-T_a)/R$

For Bare Water Pipes:

Pipe Size	mm	20	25	40	50	75	100	150	200	250	300
r (radius)	m	0.01	0.0125	0.02	0.025	0.0375	0.05	0.075	0.1	0.125	0.15
A (area)	m²	0.000314159	0.000490874	0.001256637	0.001963495	0.004417865	0.007853982	0.017671459	0.031415927	0.049087385	0.070685835
R_p		8.4122E-05	6.72976E-05	4.2061E-05	3.36488E-05	0.00168244	0.00126183	0.00084122	0.000630915	0.000504732	0.00042061
R_g	2.0 depth	0.307825722	0.296361	0.272212639	0.260747375	0.239913111	0.225129232	0.204287435	0.189493001	0.178010353	0.168620985
R_g	2.5 depth	0.31929038	0.307825722	0.283677643	0.272212639	0.251379279	0.236596665	0.215758485	0.20096912	0.189493001	0.180111627
R_g	3.0 depth	0.328657656	0.317193033	0.293045108	0.281580244	0.260747375	0.245965448	0.225129232	0.210342619	0.198870041	0.189493001
T_o	2.5 depth	0.012186971	0.018357579	0.043305696	0.06492882	0.135795231	0.226910297	0.464917524	0.769282995	1.132827996	1.550003967
T_{-3}	2.5 depth	0.027115117	0.040844267	0.096351999	0.144461868	0.302134437	0.504858783	1.034407423	1.711598294	2.520459279	3.448645247
T_f	2.5 depth	0.372352325	0.560884837	1.323132449	1.983790537	4.148994106	6.932861193	14.20477037	23.5041437	34.61164768	47.35775548
q	W's	86.8885895	90.12870768	97.8077996	101.9297644	109.6570441	116.6660036	128.1165181	137.6487855	146.0543746	153.7121598
Min. Q	m³/s	7.54078E-06	7.82198E-06	8.48842E-06	8.84615E-06	9.51678E-06	1.01251E-05	1.11188E-05	1.19461E-05	1.26756E-05	1.33402E-05
Min. V	m/s	0.024003035	0.015934797	0.006754869	0.004505307	0.002154157	0.001289163	0.000629196	**0.000380256**	0.000258225	0.000188725
T_o	3.0 depth	0.012544415	0.018916088	0.044735503	0.067162928	0.140822237	0.235847852	0.485031238	0.805051209	1.188736945	1.630550064
T_{-3}	3.0 depth	0.027910405	0.04208691	0.099533216	0.149432594	0.313319157	0.524744188	1.079158963	1.791179948	2.644852594	3.627854409
T_f	3.0 depth	0.383273444	0.57794915	1.366817802	2.052049931	4.302585789	7.205933099	14.81931095	24.59698111	36.31985126	49.81870552
q	W's	84.41275765	87.46760086	94.68172948	98.53917249	105.7425586	112.2448956	122.8036664	131.5330861	139.1851117	146.1190691
Min. Q	m³/s	7.32591E-06	7.59103E-06	8.21712E-06	8.55189E-06	9.17705E-06	9.74137E-06	1.06577E-05	1.14153E-05	1.20794E-05	1.26812E-05
Min. V	m/s	0.023319085	0.015464312	0.006538974	0.004355443	0.002077259	0.001240309	0.000603104	**0.000363361**	0.00024608	0.000179402

For Insulated Water Pipes (50 mm UIP)

R_I		11.88205814	10.67298394	8.307684518	7.285432661	5.620500888	4.597836833	3.388358848	2.689454923	2.231805552	1.908171604
T_o	2.0 depth	0.465155429	0.654031872	1.309603212	1.799718767	3.14565452	4.602177378	7.713192934	10.98814806	14.371112	17.83442537
T_{-3}	2.0 depth	1.034936744	1.45517299	2.913771182	4.004242376	6.9988508	10.23950743	17.16128907	24.44782424	31.97467113	39.68028957
T_f	2.0 depth	14.21203914	19.98284013	40.01271609	54.98736975	96.11016532	140.6117632	235.6635935	335.7243205	439.0850749	544.9007701
q	W's	2.274323091	2.527120567	3.229972573	3.671762215	4.72456018	5.738574935	7.697730665	9.598572285	11.45840382	13.28575141
Min. Q	m^3/s	1.97381E-07	2.19321E-07	2.80319E-07	3.1866E-07	4.10029E-07	4.98032E-07	6.68061E-07	8.33029E-07	9.94437E-07	1.15303E-06
Min. V	m/s	0.000628283	0.000446796	0.000223071	0.000162292	9.28116E-05	6.34114E-05	3.78045E-05	2.65161E-05	2.02585E-05	1.6312E-05
T_o	3.0 depth	0.465950352	0.655273946	1.312782986	1.804687259	3.156834376	4.62205454	7.757928529	11.06770785	14.49548422	18.0136272
T_{-3}	3.0 depth	1.036705389	1.457936512	2.920845946	4.015296908	7.023725162	10.28373266	17.26082249	24.62483894	32.25139019	40.07900052
T_f	3.0 depth	14.23632668	20.02078958	40.10986872	55.13917365	96.45174697	141.2190764	237.0304141	338.1551357	442.885058	550.3759797
q	W's	2.272578389	2.524966627	3.226454673	3.667216767	4.717036696	5.727478392	7.677773024	9.56755197	11.41420886	13.22634553
Min. Q	m^3/s	1.97381E-07	2.19321E-07	2.80319E-07	3.1866E-07	4.10029E-07	4.98032E-07	6.68061E-07	8.33029E-07	9.94437E-07	1.15303E-06
Min. V	m/s	0.000628283	0.000446796	0.000223071	0.000162292	9.28116E-05	6.34114E-05	3.78045E-05	2.65161E-05	2.02585E-05	1.6312E-05

WATER TEMP AVG $\left(\frac{4.0 + 1.5}{2}\right) = 2.75$

MARWELL
THERMAL CALC'S
R. SAVAGE
FEB 11/03

HEAT LOSS IN PIPES	150 BARE	128	W/m
	150 INSULATED	8	W/m
	200 BARE	138	W/m
	200 INSULATED	10	W/m
	250 BARE	146	W/m
	250 INSULATED	12	W/m

PIPE VOLUMES	150 m = .018 m^3/m	Q @ .15 m/s =	3 L/s
	200 m = .032 m^3/m	Q @ .15 m/s =	5 L/s
	250 m = .049 m^3/m	Q @ .15 m/s =	7 L/s

START TEMP @ 5095 = 4°C (EXISTING BOILER CAPABILITY)

END TEMP @ 5090 (55 m – 150 INSULATED) 55 × 8 = 440 W = J/s

Q = 9.9 L/s V = .55 m/s

T = 55/.55 = 100 SEC.

Δ_H = 100 × 440 = 44000 J

Δ_J = (55 × 18 L/m × 4200 J/L × 4°C = 16,632,000 – 44,000 = 16,588,000

Δ_T = .9973 × 4°C = <u>3.989 °C</u>

END TEMP @ 5020 (1085 m – 200 INS) 1085 × 10 = 10,850 W = J/s

Q = 9.7 L/s V = .31 m/s

T = 1085/.31 = 3500 SEC.

Δ_H = 3500 × 10,850 = 37,975,000 J

Δ_J = 1085 × 32 × 4200 × 3.98 = 580,379,520 – 37,975,000 = 542,404,520

Δ_T = .9359 × 3.989 = <u>3.73 °C</u>

END TEMP @ 5130 (380 m @ 250 BAR) = 380 × 146 = 55,480 W = J/S

Q = 9.7 L/S V = 0.2 m/s

T = 380/.2 = 1900 S

Δ_H = 1900 × 55480 = 105,412,000

Δ_J = 380 × 49 × 4200 × 3.73 = 291,700,920 − 105,412,000 = 186,288,920

Δ_T = .638 × 3.73 = 2.382 °C

END TEMP @ 5120 (345 m @ 250 BAR) = 345 × 146 = 50370

Q = 5.2 L/s V = .11 m/s

T = 345/.11 = 3136 SEC.

Δ_H = 3136 × 50370 = 157,960,320 J

Δ_J = 345 × 49 × 4200 × 2.38 = 168,982,380 − 157,960,320 = 11,022,060

Δ_T = .065 × 2.382 = .16 °C

END TEMP @ 6005 (240 m @ 250 INS.) = 240 × 12 = 2880 W

Q = 4.5 V = .09 m/s

T = 390/.09 = 4333 SEC

Δ_H = 4333 × 2880 = 12,479,000

Δ_J = 390 × 49 × 4200 × 2.382 = 191,184,084 − 12,479,000 = 178,705,084

Δ_T = .935 × 2.382 = 2.226 °C

END TEMP @ 6010 (150 m @ 250 INS.) = 150 × 12 = 1800 W

Q = 2.24 V = .05 m/s

T = 150/.05 = 3000 S

Δ_H = 3000 × 1800 = 5,400,000 J

Δ_J = 150 × 49 × 4200 × 2.226 = 68,716,620 − 5,400,000 = 63,316,620

Δ_T = .921 × 2.226 = 2.051 °C

END TEMP @ 6020 (70 m - 200 INS) = 70 x 10 = 700 W

Q = 2.24   V = .07 m/s

1. T = 70/.07 = 1000 SEC

Δ_H = 1000 x 700 = 700,000 J

Δ_J = 70 x 32 x 4200 x 2.051 = 19,295,808 - 700,000 = 18,595,808

Δ_T = .9637 x 2.051 = 1.98 °C

END TEMP @ 6050 (170 m @ 150 INS.) = 170 x 8 = 1360 W

Q = 1.0   U = .06 m/s

T = 170/.06 = 2833 S

Δ_H = 2833 x 1360 = 3,853,333 J

Δ_J = 170 x 18 x 4200 x 1.98 = 25,446,960 - 3,853,333 = 21,593,627

Δ_T = .848 x 1.98 = 1.68 °C

END TEMP @ 6050 (470 m @ 200 INS) = 470 x 10 = 4700 W

Q = 1.23 L/s   V = .04 m/s

T = 470/.04 = 11750 SEC.

Δ_H = 11750 x 4700 = 55,225,000 J

Δ_J = 470 x 32 x 4200 x 1.98 = 125,072,640 - 55,225,000 = 69,847,640

Δ_T = .558 x 1.98 = 1.106 °C

MIXED TEMP @ 6050 = $\frac{(1.0 \times 1.68) + (1.23 \times 1.106)}{2.23}$ = 1.36 °C ←

END TEMP @ 6040 (95 m @ 250 INS) = 95 x 12 = 1140 W

Q = 2.2 L/s   U = .05 m/s

T = 95/.05 = 1900 SEC

Δ_H = 1900 x 1140 = 2,166,000 J

Δ_J = 95 x 49 x 4200 x 1.36 = 26,589,360 - 2,166,000 J = 24,423,360

Δ_T = .919 x 1.36 = 1.249 °C

END TEMP @ 6040 (310 m @ 200 INS) = 310 × 10 = 3100 W

Q = 2.2 L/s U = .07 m/s

T = 310/.07 = 4428 SEC.

Δ_H = 4428 × 3100 = 13,728,570 J

Δ_S = 310 × 32 × 4200 × 2.382 °C = 99,243,648 − 13,728,570 = 85,515,0..

Δ_T = .862 × 2.382 = 2.052 °C

→ MIXED TEMP @ 6040 = $\frac{(2.2 \times 1.249) + (2.2 \times 2.052)}{4.4}$ = 1.6505 °C ←

END TEMP @ 5120 (250 m @ 250 INS) = 250 × 12 = 3000 W

Q = 4.5 L/s U = .09 m/s

T = 250/.09 = 2778 s.

Δ_H = 2778 × 3000 = 8,333,333 J

Δ_S = 250 × 49 × 4200 × 1.6505 = 84,918,225 − 8,333,333 = 76,584,900

Δ_T = .902 × 1.6505 = 1.488 °C

MIXED TEMP @ 5120 = $\frac{(5.2 \times .16\,°C) + (4.5 \times 1.488)}{9.7}$ = .776 °C ←

END TEMP @ 5110 (280 m @ 250 INS) = 280 × 12 = 3360 W

Q = 9.7 V = .2 m/s

T = 280/.2 = 1400 S

Δ_H = 1400 × 3360 = 4,704,000

Δ_S = 280 × 49 × 4200 × .776 = 44,716,224 − 4,704,000 = 40,012,224

Δ_T = .895 × .776 = .694 °C

END TEMP @ 5105 (55 m @ 150 INS) = 55 × 8 = 440 W

Q = 9.7 U = .55 m/s

T = 100 SEC Δ_H = 44000 J

Δ_S = 55 × 18 × 4200 × .694 = 2,885,652 − 44000 = 2,841,652

Δ_T = .985 × .694 = .683 °C

Estimated Fire Flow Requirements

Estimated Fire Flow Requirements:

Estimated fire flow requirements based on Fire Underwriters Survey recommendations:

Assumptions:

- fire flow requirement shall not exceed 750 l/s or be less than 33.3 l/s
- Maximum building size not requiring sprinklers is 1500 sq.m. (by City bylaw)
- Therefore, average building size is 750 sq.m., total floor area, single storey
- Assume Non-combustible construction, unprotected steel frame, masonry and steel outer shell, C = 0.8, for most large warehouse style buildings
- Assume rapid burning surcharge for occupancy, 25% surcharge over base flow
- Complete automatic sprinkler protection, with alarms, 50% reduction allowed, With no sprinklers, 0% reduction
- Maximum exposure surcharge is 75%, average exposure surcharge is 10 m rear (15%), 3 m right and left (25%), over 45 m front (0%), total minimum surcharge of 65%.

For maximum required fire flows:

Base flow required = 220 x 0.8 x Sq.Rt.(1500)	=	6816 l/m
Round to nearest 1000	=	7000 l/m
Surcharge for occupancy, 25% of base flow	=	8750 l/m
Reduction for sprinklers, 0 % reduction	=	8750 l/m
Surcharge for exposure on 3 sides, maximum 75 %	=	15312 l/m
Round to nearest 2000	=	**16000 l/m**
Total required fire flow (maximum)	=	**267 l/s**
Fire storage required = 3.5 hours duration @ 267 l/s	=	**3365 cu.m.**
Available fire storage @ Valleyview Reservior	=	3340 cu.m.

For average required fire flows:

Base flow required = 220 x 0.8 x Sq.Rt.(750)	=	4819 l/m
Round to nearest 1000	=	5000 l/m
Surcharge for occupancy, 25% of base flow	=	6250 l/m
Reduction for sprinklers, 0 % reduction	=	6250 l/m
Surcharge for exposure on 3 sides, (25+25+15) 65 %	=	10312 l/m
Round to nearest 2000	=	**10000 l/m**
Total required fire flow (maximum)	=	**167 l/s**
Fire storage required = 2 hours duration @ 167 l/s	=	**1200 cu.m.**
Available fire storage @ Valleyview Reservior	=	3340 cu.m.

Allowable building size for available 100 l/s fire flows:

Working backwards through formula results in:

Divide available by 1.65 for surcharge		=	61 l/s
Divide remainder by 1.25 for occupancy		=	49 l/s
Solve for equation (49x60 = 220 x 0.8 x Sq.Rt.(x))	x	=	280 sq.m.

The existing available 100 l/s fire flow is adequate to protect a building of 280 sq.m., single storey, non-sprinklered, with high hazard occupancy and evarage exposures on 3 sides.

Most large warehouse facilities in Marwell are over 280 sq.m.(2800 sq.ft.), therefore the existing available fire flow is considered insufficient for probable average developments.

Water system should be designed to provide average required fire flows of 167 l/s as a minimum. Maximum anticipated fire flows would be 267 l/s, up to 1500 sq.m. building size, at which point sprinklers would be required, and would reduce fire flows by 25 to 50% of base flow or 205 to 170 l/s.