APPENDIX G – TRANSIT CITY TRACTION POWER OVERVIEW

TRANSIT CITY
Traction Power Overview

Toronto Transit Commission
Transit City
Engineering Division
Traction Power Design

March 12, 2009

EXECUTIVE SUMMARY

This study outlines the traction power substation (TPS) requirements and estimates the maximum power demand for the Toronto Transit City-Light Rail Plan (TTC-LRP).

Full implementation of the TTC-LRP will necessitate the construction of 73 TPSs and five Storage and Maintenance Facility (S&MF) TPSs. Based on the proposed program construction schedule, the first set of mainline TPSs would be commissioned in year 2013 followed by additional groups as shown below:

- 2013: 10 TPSs
- 2014: 12 TPSs; 22 grand total
- 2015: 2 TPSs; 24 grand total
- 2016: 21 TPSs; 45 grand total
- 2017: 11 TPSs; 56 grand total
- 2018: 9 TPSs; 65 grand total
- 2019: 8 TPSs; 73 grand total

The five S&MF TPSs would be commissioned between 2012 and 2016.

The cumulative electrical power demand during peak transit service levels (morning and afternoon rush hour periods) is estimated at:

- 2013: 14.7 MW
- 2014: 30.2 MW
- 2015: 56.3 MW
- 2016: 120.1 MW
- 2017: 139.4 MW
- 2018: 156.7 MW
- 2019: 178.9 MW

The S&MF TPSs electrical demand will peak during non revenue periods when the entire LRV fleet is in storage during severe winter conditions. The totalized estimated peak for all five locations is 13.0 MW which is non-coincidental with the above service peak period figures. If switchpoint heaters are installed at the yards, and powered by the traction system, the estimated S&MF TPS peak is estimated at 17.0 MW.

The TTC-LRP TPS quantity and estimated electrical demand peak is presented for discussion purposes only. Demand peak calculation excludes all non-traction power requirements such as passenger station services and fire ventilation equipment. Calculations were based on the proposed light rail routes, proposed transit service levels, preliminary vehicle performance data, 1.5 km substation spacing and a rudimentary traction loading algorithm.

Computerized train performance simulation is recommended to obtain more accurate electrical demand peak estimates, and to refine the spacing, location, and capacity of each of the TPS on the TTC-LRP routes.

TABLE OF CONTENTS

Transit City Traction Power Overview

1. INTRODUCTION

The City of Toronto Official Plan, the TTC Ridership Growth Strategy, the Building a Transit City Plan, and the Mayor's 'Transit City' Platform (2006), have been distilled and consolidated into one high-level plan for light rail for Toronto – Toronto Transit City – Light Rail Plan (TTC-LRT).

The plan is premised on developing a widely-spaced network of electric light-rail lines, each on its own right-of-way. The lines reach all across Toronto, all connecting with the city's existing and planned rapid transit routes.

In total, 120 km of service will be added over the entire city. By 2021, the new lines would carry 175 million riders per year.

The seven routes suggested for the TTC-LRP are:

- Don Mills – Steeles Avenue to Bloor-Danforth Subway
- Eglinton Crosstown – Kennedy Station to Pearson Airport
- Etobicoke-Finch West – Yonge Street to Highway 27
- Jane – Jane Station to Steeles West Station
- Scarborough Malvern – Kennedy Station to Malvern/Morningside
- Sheppard East – Don Mills Station to Morningside Avenue
- Waterfront West – Union Station/Exhibition to Long Branch

2. REPORT OBJECTIVES

This report outlines the traction power substation (TPS) requirements and estimates the maximum electrical power demand for the TTC-LRP.

In addition to the seven routes identified above, the traction power assessment will include the following:

- Scarborough Rapid Transit (SRT) Expansion and associated maintenance and storage facility
- Four Transit City maintenance and storage facilities

3. MAINLINE TRACTION POWER SUBSTATIONS

A traction power system must be capable of supplying adequate power at an acceptable voltage to the transit vehicles while minimizing stray current activity, and step and touch voltage hazards. Consideration for contingency conditions, such as a single TPS outage, and future service growth should also be accommodated in the traction power system design.

For this study, a TPS spacing of 1.5 kilometres has been selected for the initial quantity take-off for the TTC-LRP. This provides consistency with the (Sheppard East) LRT Operating Philosophy – Electrical System document prepared by Subway Operations. The 1.5 km spacing is further validated upon review of transit systems listed in Appendix A where the average TPS spacing for 750Vdc systems and less, is calculated at 1.8 km.

An exception to the 1.5 km spacing occurs along the Eglinton Crosstown below grade portion. A spacing of 2.0 km was used in the Eglinton Crosstown LRT Conceptual Design Report. Enhancements to the wayside traction distribution system may be required to maintain acceptable voltage levels to the transit vehicles at this spacing.

Appendix B contains maps identifying the approximate location of each TPS on the proposed routes. Aside from the 1.5 km spacing, placement methodology situates a TPS at each end of a transit line, and at route intersections (thereby minimizing the overall number of TPSs). A further reduction of six TPSs may be achieved by installing the TTC-LRP traction equipment at four existing subway TPSs, and two proposed Spadina Subway Extension TPSs. However more investigation is required to determine the feasibility of this option.

The mainline TPSs are tentatively sized at 1.5 MW. This again is for consistency with the above mentioned report, but also coincides with the smallest sized TPS presently operated by the Commission. At TTC-LRP route intersections, double capacity TPSs (3.0 MW) were positioned to service both routes.

Table 1 summarizes the number of mainline TPSs required for the TTC-LRP.

TABLE 1 - Transit City Mainline Traction Power Substation Summary

Transit City Route	Route Length (km)	In Service Date	TPS Quantity	Total Connected Capacity (MW)
Sheppard East	14	2013	10	19.5
Etobicoke-Finch	18	2014	12	19.5
SRT Extension		2015	2*	4.5
Waterfront West	11	2016	2**	3.0
Eglinton Crosstown	31	2016	19	33.0
Don Mills	18	2017	11	16.5
Jane	17	2018	9	13.5
Scarborough Malvern	15	2019	8	12.0
Total	124		73	121.5

* A total of three new TPSs are required for the SRT Extension; conversion of the existing SRT TPSs are not included in this table (note that only 2 are indicated; a third is included as a double capacity TPS built with the Sheppard East route).
** The majority of the Waterfront West route is presently serviced by the existing 600Vdc traction power network. Therefore only two new TPSs are shown to improve two weak areas along the proposed route. Computerized simulation may reveal a need for more TPSs.

4. STORAGE & MAINTENANCE FACILITY TRACTION POWER SUBSTATIONS

The 'Streetcar Maintenance and Repair Facility Master Plan' recommends the construction of four carhouses to service the TTC-LRP fleet.

Table 2 summarizes the S&MF TPS requirements along with the proposed SRT Extension S&MF. Worst case electrical demand of 30 kW per Light Rail Vehicle (LRV) would be experienced during non revenue service periods when all vehicles are in storage during extreme winter conditions. These TPSs would require a minimum of two rectifier branches for contingency conditions and maintenance requirements. Standardized rectifier sizes of 1000 kW and 1500 kW are used.

TABLE 2 – Storage & Maintenance Facility Traction Power Substation Summary

S&MF	LRV Capacity	Traction Power Demand (kW)	TPS Capacity (kW)
Sheppard	100	3000	2x 1500
Finch	60	1800	2x 1000
Eglinton	150	4500	3x 1500
Don Mills	60	1800	2x 1000
Bellamy (SRT)	62	1860	2x 1000

Subway and ICTS storage yards are equipped with switchpoint heaters which ensure proper track switch operation during winter storm conditions. The heaters are typically tubular type heater elements mounted on the rail. They are also typically powered from the traction system because of the close proximity to the power rail.

Photo 1

Switchpoint Heater

If it is determined that switchpoint heaters are required for the TTC-LRP storage yards, then an additional 800 kW should be added to the estimated traction power demand for each TPS shown in Table 2.

Alternatively, the switchpoint heaters could be supplied from an AC power system. The heater demand would then be added to the carhouse and yard electrical demand peak estimation rather than the traction system's electrical demand.

5. OVERALL TRACTION POWER DEMAND

The greatest power demand for the TTC-LRP will be during the morning and afternoon transit service peaks. The estimated power demand peak shown in Table 3, has been developed using the individual TTC-LRP line in service dates, and the following factors and assumptions:

- Peak load is calculated on the maximum number of LRVs operating on a TTC-LRP route (ie demand is not calculated on the total connected TPS load)
- The maximum LRV number includes a 15% contingency for service growth.
- Power demand during LRV acceleration is limited to 740 kW (includes electrical auxiliary system load of 100 kW)
- The traction demand peak algorithm assumes that 50% of the LRVs are accelerating (at 740 kW each), and 50% are coasting or stopping (at 100 kW each).
- Traction demand peak algorithm disregards regenerative braking.
- Electrical demand figures shown are for the traction system loads only (excludes all ancillary AC loads associated with the LRT route such as passenger station and fire ventilation equipment).
- S&MF traction load peaks do not coincide with the transit service peaks, and therefore are not included in the figures listed in Table 3.

TABLE 3 – Yearly Traction Power Demand Peak Summary

Year	Transit City Route In Service	Number of LRVs	Power Demand Peak (MW)	Cumulative Power Demand Peak (MW)
2013	Sheppard East	35	14.7	14.7
2014	Etobicoke-Finch	37	15.5	30.2
2015	SRT Expansion	62	26.0	56.3
2016	Waterfront West & Eglinton Crosstown	152	54.2	120.1
2017	Don Mills	46	19.3	139.4
2018	Jane	41	17.2	156.7
2019	Scarborough Malvern	53	22.3	178.9

6. TYPICAL SUBSTATION CONFIGURATION

The Transit City program proposes to use prefabricated TPSs which are also known as pre-engineered or container type TPSs. These are vendor designed and factory built structures containing all the necessary electrical equipment to control and convert the electrical utility primary voltage to the required traction power voltage. The completed assemblies are transported to site as a packaged unit facilitating rapid installation and quick placement into service.

Refer to Appendix C for a typical prefabricated TPS layout, dimensions, and building elevations. Photos have also been included to illustrate how other transit authorities have located and architecturally finished these structures. Note that the TPSs shown in the photos are of unknown electrical capacity and should not be considered typical for the size of the units required for Transit City. Drawings and photos were provided by Siemens Canada Ltd.

7. RECOMMENDATIONS

1. The TTC-LRP traction power demands identified in this report are for discussion purposes only. It is recommended that a commercially available computerized train performance simulation program be utilized to obtain more accurate power demand estimates.
2. The TPS sizing and placement identified in this report are for discussion purposes only. It is recommended that a commercially available computerized simulation program be utilized to obtain a more accurate analysis of the TPS requirements.
3. A study is recommended to evaluate the commercially available traction power energy recovery systems and their applicability on the TTC-LRP program.
4. A study is recommended to establish the characteristics of a typical TTC-LRP TPS. TPS features should be developed in conjunction with Subway Operations to address maintainability and operational issues.

8. REFERENCES

1. Toronto Transit City – Light Rail Plan: Commission Report, March 21, 2007.
2. Streetcar Maintenance and Repair Facilities Master Plan: Transit City Vehicle Maintenance Centres, Rev 9.
3. Transit City: Sheppard LRT East Operating Philosophy: May 9, 2008.
4. Eglinton Crosstown LRT Conceptual Design Report – Stage 1: TTC Engineering Dept, August 2008.
5. Eglinton Crosstown LRT Conceptual Design Report – Stage 2: TTC Engineering Dept, September 2008.
6. Siemens AG website.
7. One Break Point is Enough: Traction Power Simulation in Portland, D.L. Porter, T Heilig

APPENDIX A

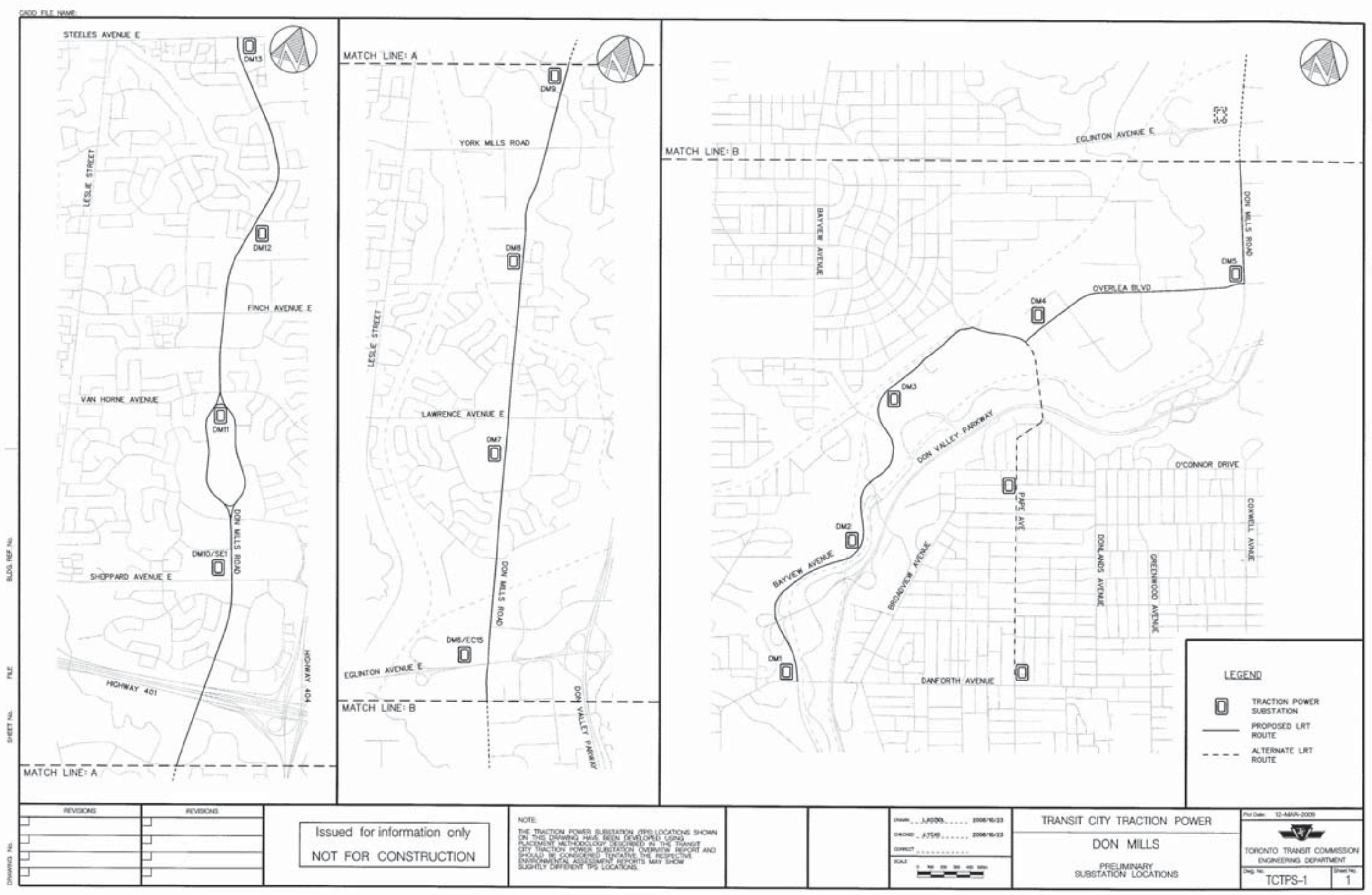
Transit System TPS Spacing Survey

Transit Line	In Service Date	Route Length (km)	Passenger Stations	Number of TPS	DC Supply Voltage	Contact System	TPS Spacing (km/TPS)
GVB Tramway, Netherlands (TPSS only)	2004	9		6	600		1.50
GVB Tramway VU-Lijn, Netherlands (TPSS only)	2003	9		8	600		1.13
LRT Mashhad, Iran (TPSS only)	2005	19.5		11	600/750	catenary	1.77
Metro System Valencia Line 1, Venezuela	2007	6.3	7	5	750	catenary	1.26
Monterrey Metro Line 2 Extension, Mexico	2008	8.5	7	3	750		2.83
MST Light Rail Transit System, Lisbon, Portugal	2006	13	19	11	750	catenary	1.18
Elevated Rapid Transit System, Bangkok, Thailand	1999	23.1	23	12	750	third rail	1.93
Athens Metro Extension, Greece	2005	12.5		10	750		1.25
Beijing City Rail, China	2003	40.5		22	750		1.84
Santiago Chile Line 2 Extension, Chile	2004	5		2	750		2.50
Calgary, Canada	2004	7		4	750	catenary	1.75
Metro Valenc, Venezuela		6.2		5	750	catenary	1.24
Pasadena	2003	22		10	750	catenary	2.20
Portland IMAX Interstate Extension	2003	9.3		6	750	catenary	1.55
Portland PDX Extension	2002	8.8		4	750	catenary	2.20

Transit Line	In Service Date	Route Length (km)	Passenger Stations	Number of TPS	DC Supply Voltage	Contact System	TPS Spacing (km/TPS)
LRT Maracaibo, Venezuala	2007	6.9	6	4	750	catenary	1.73
LRT Konya, Turkey	1996	18	20	6	750	catenary	3.00
LRT Ankara, Turkey	1996	8.7	11	4	750	third rail	2.18
Metro Bangkok, Thailand	2004	20	18	14	750	third rail	1.43
Metro Kaohsiung, Taiwan	2007	42.7	37	28	750		1.53
Metro Tren Urbano, San Juan, Puerto Rico	2004	17.2	6	11	750	third rail	1.56
TriMet Eastside		24.3		15	750	catenary	1.62
TriMet Westside		28.2		18	750	catenary	1.57
TriMet Airport		9.2		5	750	catenary	1.84
TriMet Interstate		9.3		6	1000	catenary	1.55
LRT Bursa, Turkey	2002	17.3	17	7	1500	catenary	2.47
LRT Houston, Texas	2004	12	16	10	1500	catenary	1.20
Metro Guangzhou, China	1999	18.5	16	8	1500		2.31
Metro Line 1, Shanghai, China	1995	16.1	13	16	1500	catenary	1.01
Metro Line 2, Shanghai, China	2000	16.4	12	7	1500	catenary	2.34
Metro Santo Domingo, Dominican Republic	2008	13.8	16	4	1500	catenary	3.45

APPENDIX B

Transit City
Preliminary TPS Locations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DM12
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HIGHWAY 401
HIGHWAY 404
MATCH LINE: A
YORK MILLS ROAD
DM9
DM8
LAWRENCE AVENUE E
DM7
DM6/EC15
EGLINTON AVENUE E
MATCH LINE: B
DON VALLEY PARKWAY
EGLINTON AVENUE E
BAYVIEW AVENUE
OVERLEA BLVD
DM5
DM4
DM3
DM2
DM1
PAPE AVE
DANFORTH AVENUE
BROADVIEW AVENUE
DONLANDS AVENUE
GREENWOOD AVENUE
COXWELL AVENUE
O'CONNOR DRIVE
LEGEND
TRACTION POWER SUBSTATION
PROPOSED LRT ROUTE
ALTERNATE LRT ROUTE
REVISIONS
Issued for information only
NOT FOR CONSTRUCTION
NOTE:
THE TRACTION POWER SUBSTATION (TPS) LOCATIONS SHOWN ON THIS DRAWING HAVE BEEN DEVELOPED USING PLACEMENT METHODOLOGY DESCRIBED IN THE TRANSIT CITY TRACTION POWER SUBSTATION OVERVIEW REPORT AND SHOULD BE CONSIDERED TENTATIVE. THE RESPECTIVE ENVIRONMENTAL ASSESSMENT REPORTS MAY SHOW SLIGHTLY DIFFERENT TPS LOCATIONS.
TRANSIT CITY TRACTION POWER
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12-MAR-2009
TORONTO TRANSIT COMMISSION
ENGINEERING DEPARTMENT
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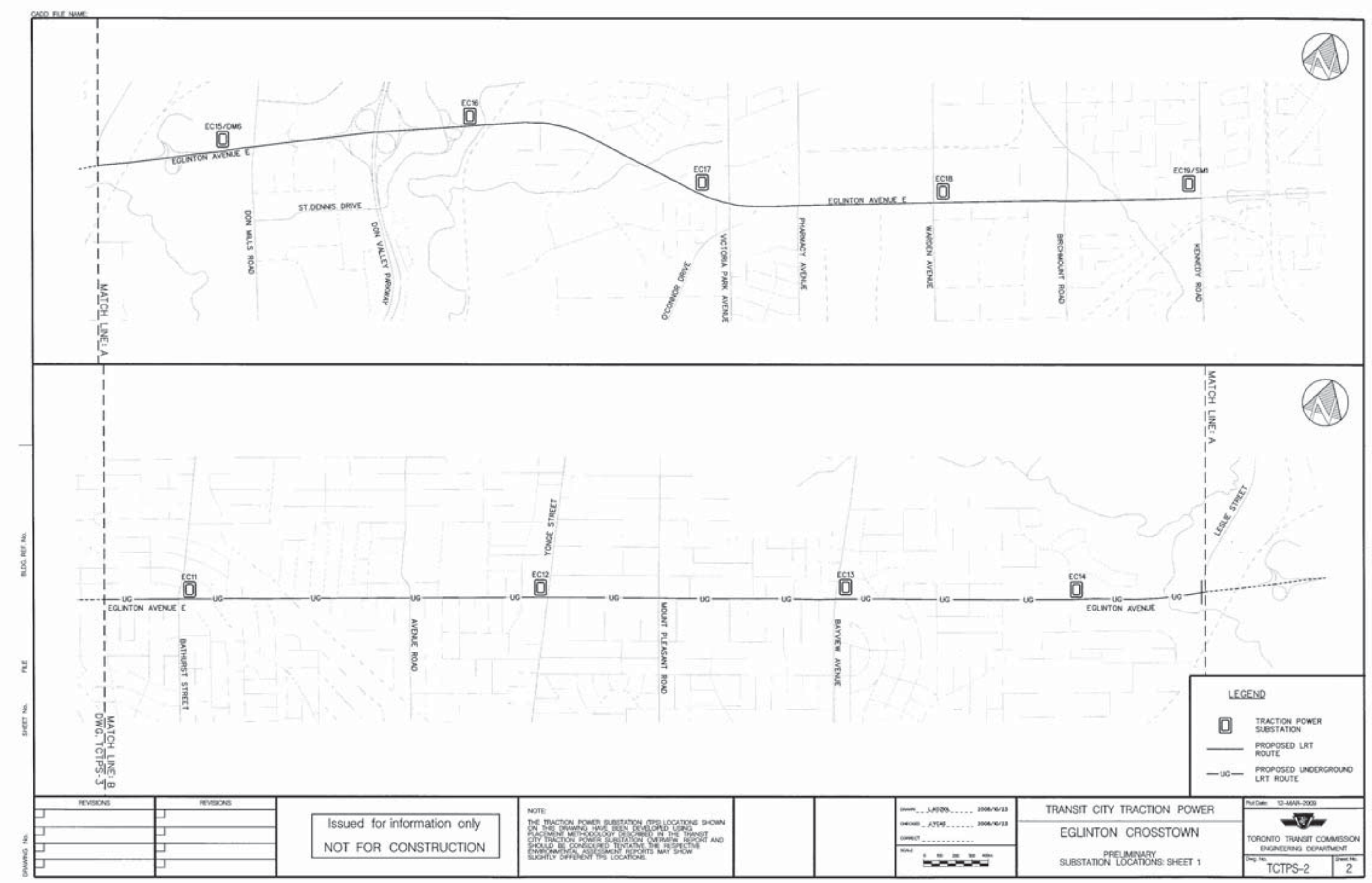
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VICTORIA PARK AVENUE
PHARMACY AVENUE
WARDEN AVENUE
BIRCHMOUNT ROAD
KENNEDY ROAD
MATCH LINE: A
EC11
EC12
EC13
EC14
EGLINTON AVENUE
BATHURST STREET
AVENUE ROAD
YONGE STREET
MOUNT PLEASANT ROAD
BAYVIEW AVENUE
LESLIE STREET
MATCH LINE: B
DWG. TCTPS-3
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TRACTION POWER SUBSTATION
PROPOSED LRT ROUTE
PROPOSED UNDERGROUND LRT ROUTE
REVISIONS
Issued for information only
NOT FOR CONSTRUCTION
NOTE:
THE TRACTION POWER SUBSTATION (TPS) LOCATIONS SHOWN ON THIS DRAWING HAVE BEEN DEVELOPED USING PLACEMENT METHODOLOGY DESCRIBED IN THE TRANSIT CITY TRACTION POWER SUBSTATION OVERVIEW REPORT AND SHOULD BE CONSIDERED TENTATIVE. THE RESPECTIVE ENVIRONMENTAL ASSESSMENT REPORTS MAY SHOW SLIGHTLY DIFFERENT TPS LOCATIONS.
TRANSIT CITY TRACTION POWER
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12-MAR-2009
TORONTO TRANSIT COMMISSION
ENGINEERING DEPARTMENT
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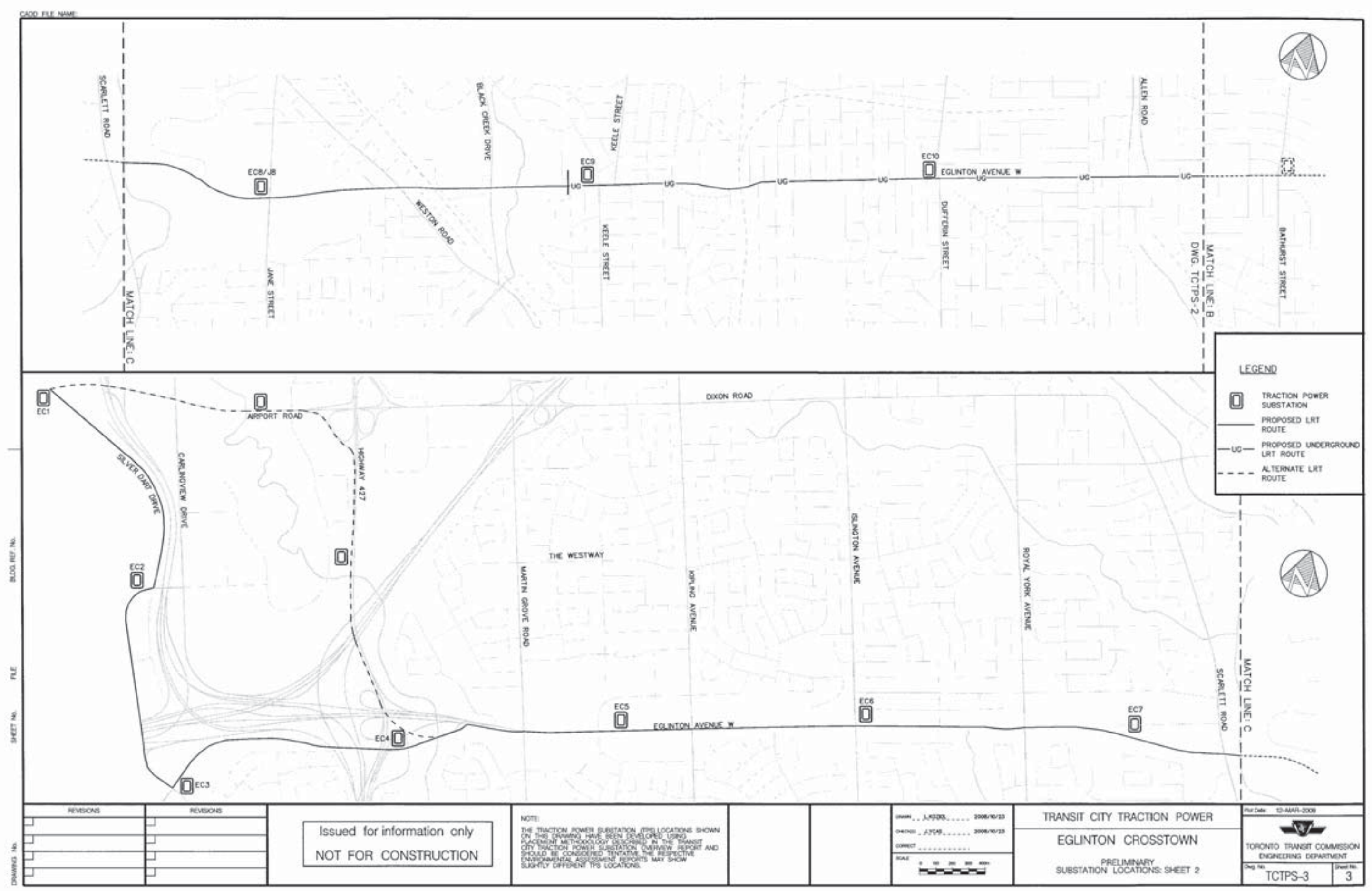

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KEELE STREET
ALLEN ROAD
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EC9
EC10
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KEELE STREET
DUFFERIN STREET
BATHURST STREET
MATCH LINE C
MATCH LINE B DWG. TCTPS-2
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AIRPORT ROAD
DIXON ROAD
SILVER DART DRIVE
CARLINGVIEW DRIVE
HIGHWAY 427
EC2
THE WESTWAY
MARTIN GROVE ROAD
KIPLING AVENUE
ISLINGTON AVENUE
ROYAL YORK AVENUE
SCARLETT ROAD
MATCH LINE C
EC3
EC4
EC5
EC6
EC7
EGLINTON AVENUE W
REVISIONS
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TRANSIT CITY TRACTION POWER
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PRELIMINARY SUBSTATION LOCATIONS: SHEET 2
Plot Date: 12-MAR-2009
TORONTO TRANSIT COMMISSION ENGINEERING DEPARTMENT
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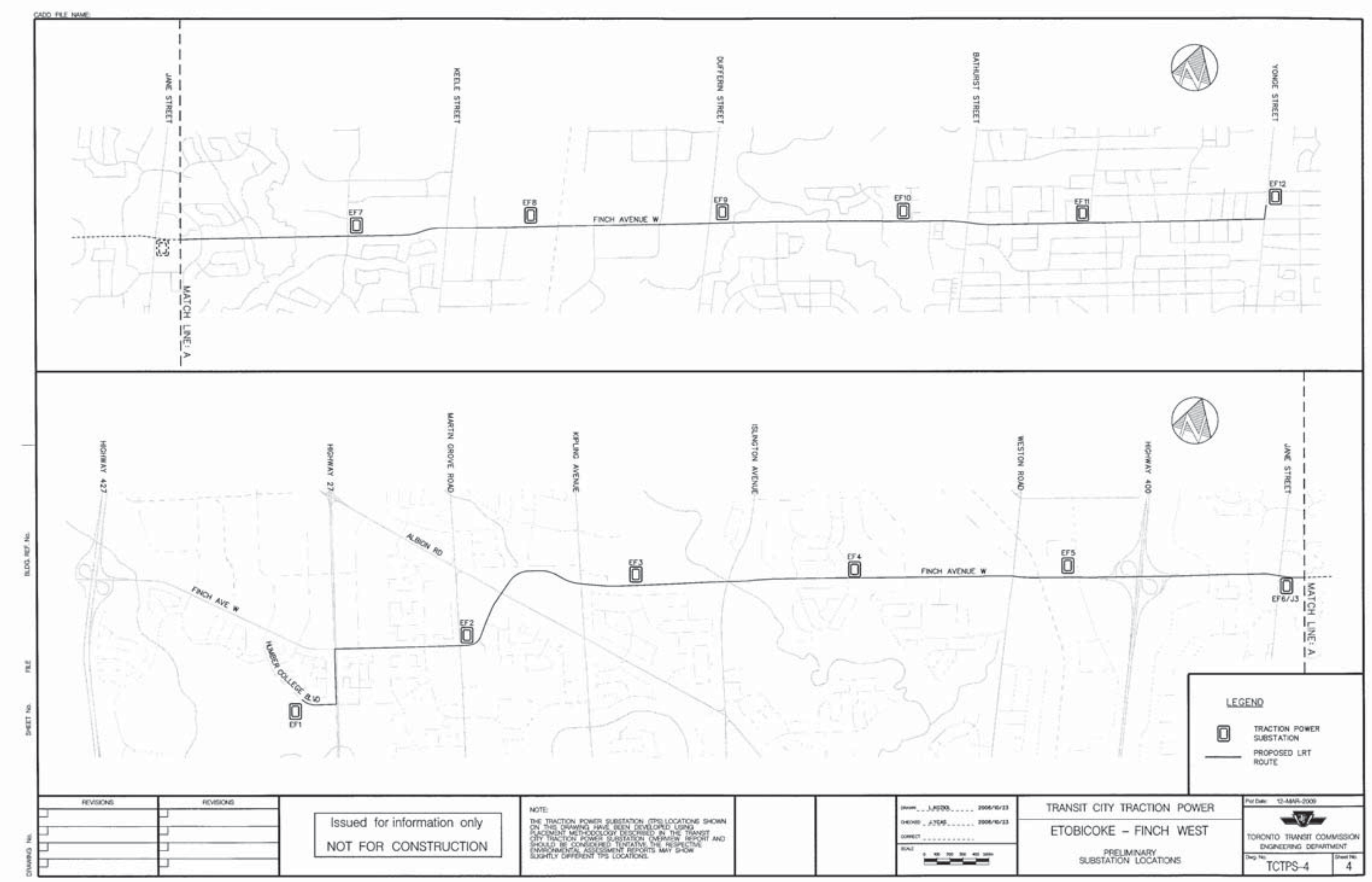

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DUFFERIN STREET
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YONGE STREET
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EF8
EF9
EF10
EF11
EF12
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MATCH LINE A
HIGHWAY 427
HIGHWAY 27
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KIPLING AVENUE
ISLINGTON AVENUE
WESTON ROAD
HIGHWAY 400
JANE STREET
ALBION RD
FINCH AVE W
HUMBER COLLEGE BLVD
EF1
EF2
EF3
EF4
EF5
EF6/J3
FINCH AVENUE W
MATCH LINE A
LEGEND
TRACTION POWER SUBSTATION
PROPOSED LRT ROUTE
REVISIONS
Issued for information only
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NOTE:
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TRANSIT CITY TRACTION POWER
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PRELIMINARY SUBSTATION LOCATIONS
Plot Date: 12-MAR-2009
TORONTO TRANSIT COMMISSION ENGINEERING DEPARTMENT
TCTPS-4
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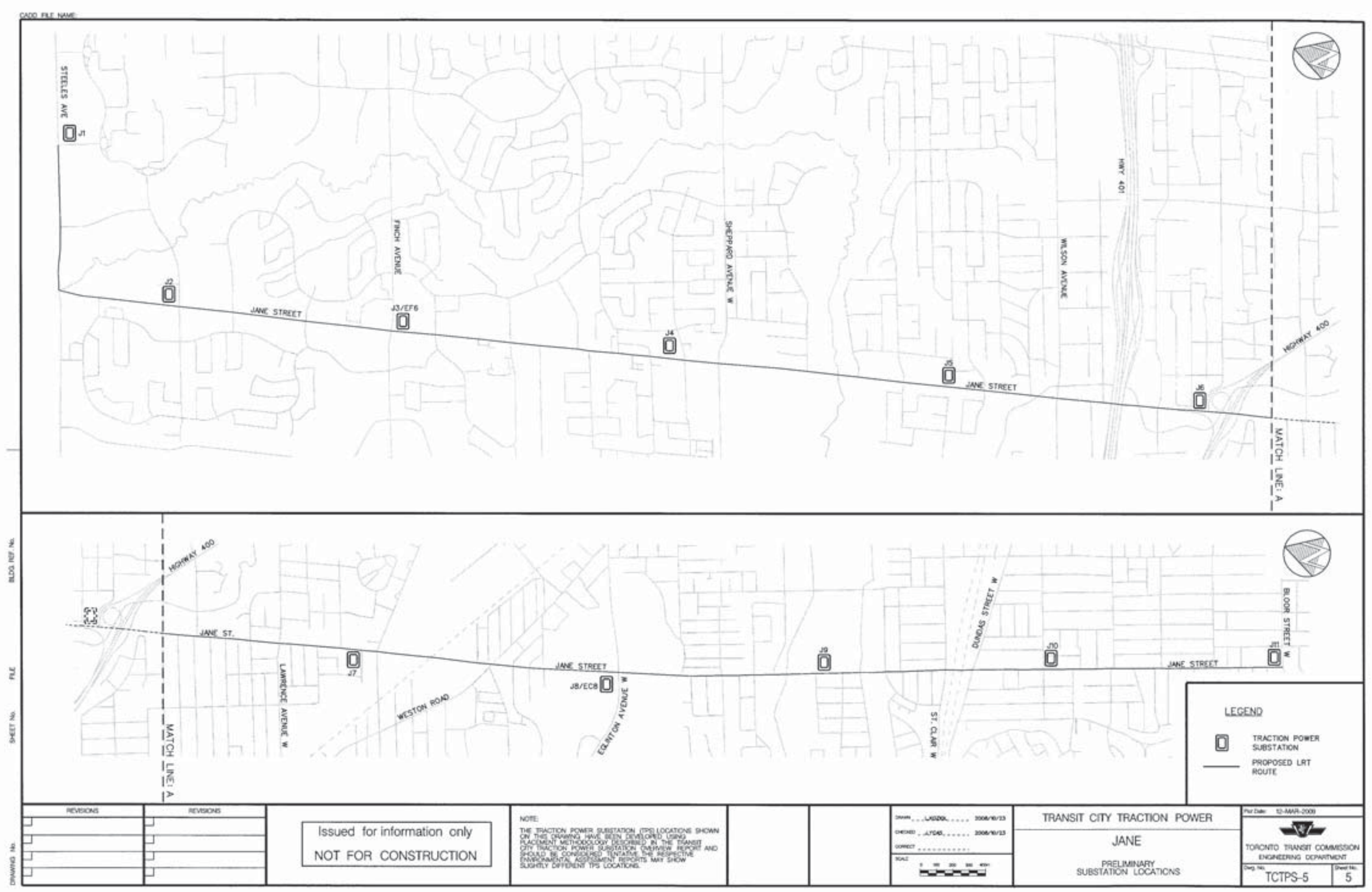
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J2
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FINCH AVENUE
SHEPPARD AVENUE W
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J5
WILSON AVENUE
HWY 401
J6
HIGHWAY 400
MATCH LINE A
JANE ST.
J7
LAWRENCE AVENUE W
WESTON ROAD
JANE STREET
J8/EC8
EGLINTON AVENUE W
J9
DUNDAS STREET W
J10
ST. CLAIR W
J11
BLOOR STREET W
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TRACTION POWER SUBSTATION
PROPOSED LRT ROUTE
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THE TRACTION POWER SUBSTATION (TPS) LOCATIONS SHOWN ON THIS DRAWING HAVE BEEN DEVELOPED USING PLACEMENT METHODOLOGY DESCRIBED IN THE TRANSIT CITY TRACTION POWER SUBSTATION OVERVIEW REPORT AND SHOULD BE CONSIDERED TENTATIVE. THE RESPECTIVE ENVIRONMENTAL ASSESSMENT REPORTS MAY SHOW SLIGHTLY DIFFERENT TPS LOCATIONS.
TRANSIT CITY TRACTION POWER
JANE
PRELIMINARY SUBSTATION LOCATIONS
Plot Date: 12-MAR-2009
TORONTO TRANSIT COMMISSION
ENGINEERING DEPARTMENT
TCTPS-5
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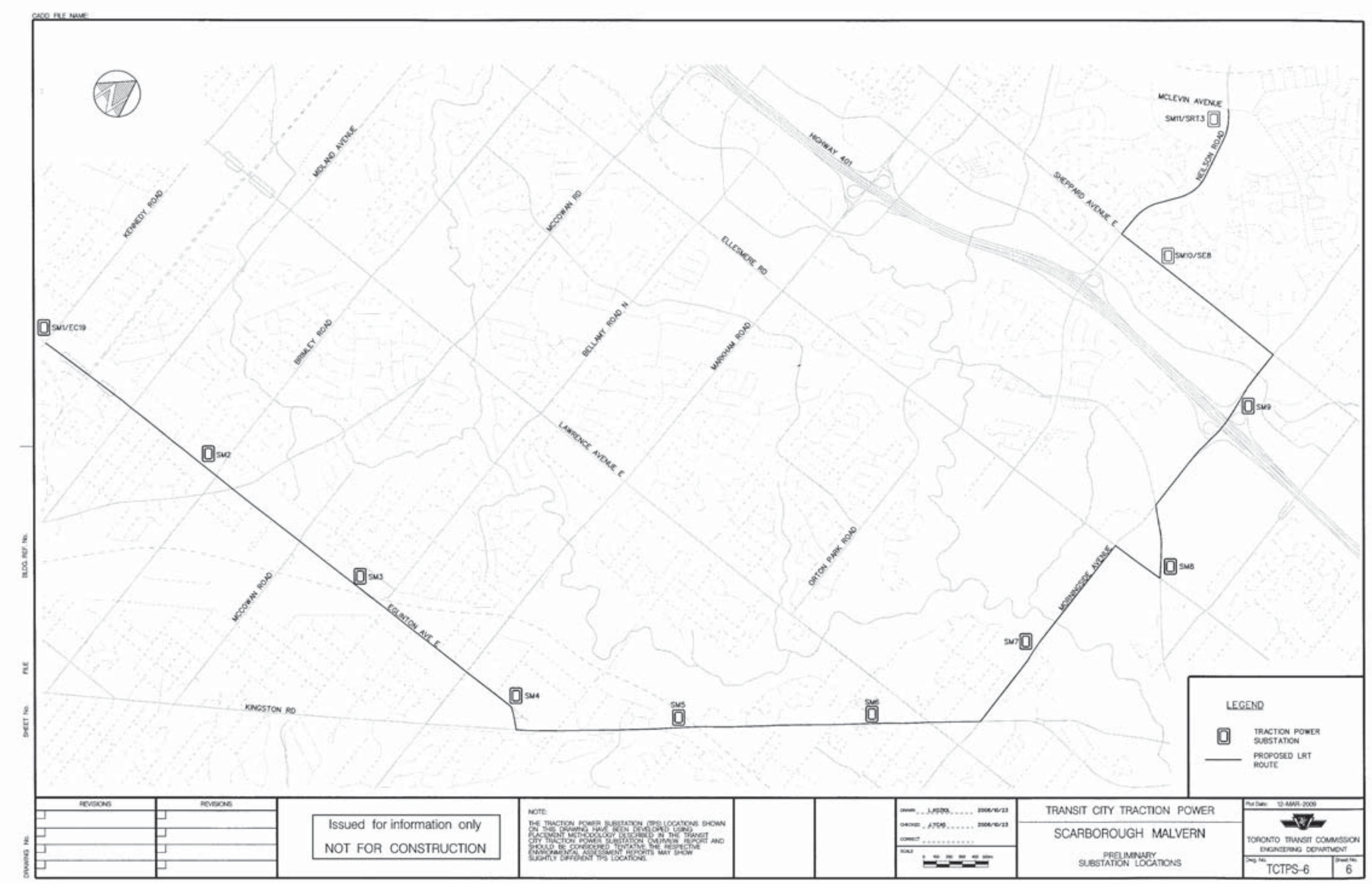
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ELLESMERE RD
SM1/EC19
BRIMLEY ROAD
BELLAMY ROAD N
MARKHAM ROAD
SM9
SM2
LAWRENCE AVENUE E
ORTON PARK ROAD
SM8
SM3
MCCOWAN ROAD
EGLINTON AVE E
MORNINGSIDE AVENUE
SM7
SM4
KINGSTON RD
SM5
SM6
LEGEND
TRACTION POWER SUBSTATION
PROPOSED LRT ROUTE
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TRANSIT CITY TRACTION POWER
SCARBOROUGH MALVERN
PRELIMINARY SUBSTATION LOCATIONS
Plot Date: 12-MAR-2009
TORONTO TRANSIT COMMISSION
ENGINEERING DEPARTMENT
TCTPS-6
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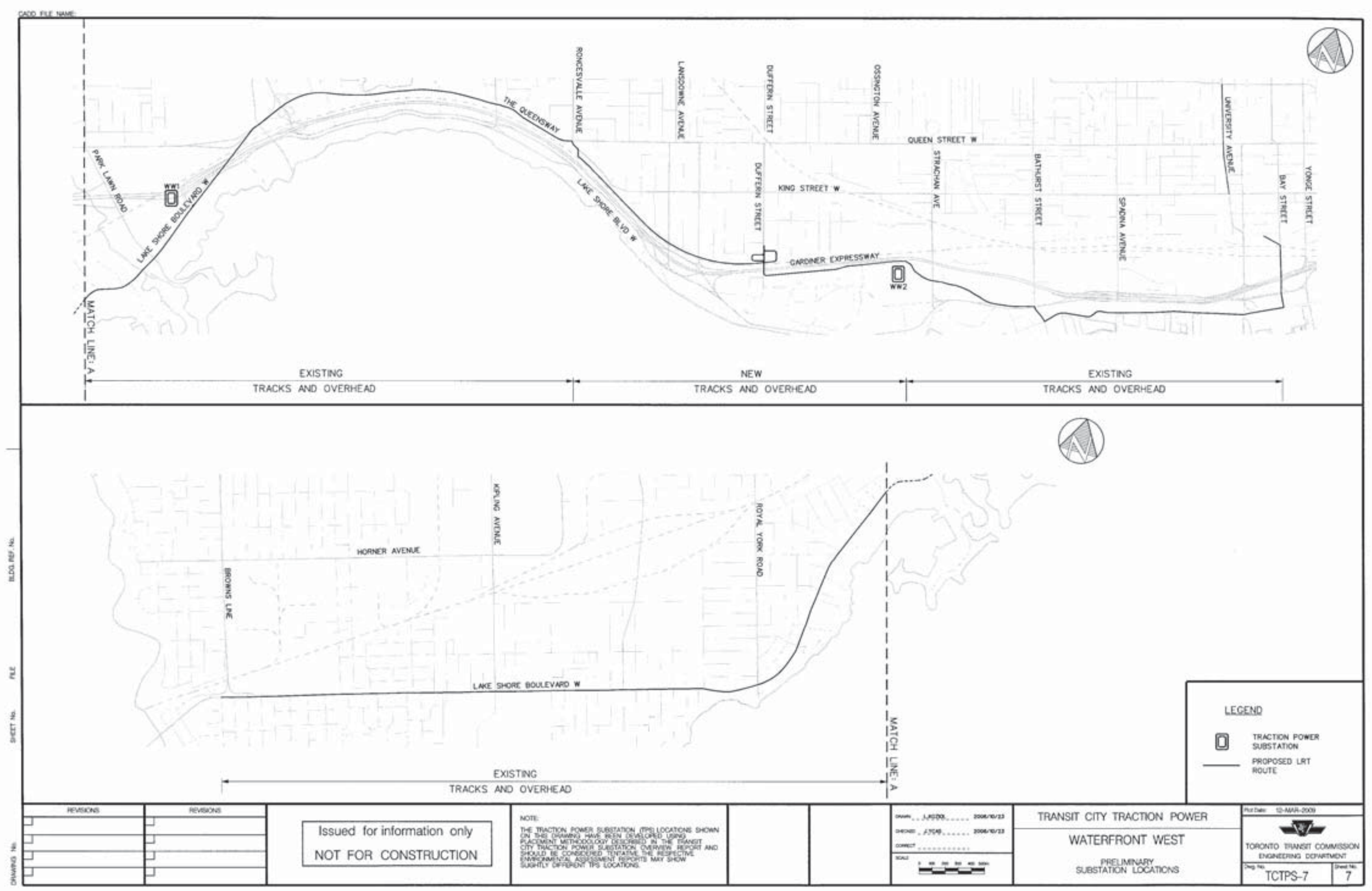
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DUFFERIN STREET
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KING STREET W
LAKE SHORE BLVD W
GARDINER EXPRESSWAY
WW2
STRACHAN AVE
BATHURST STREET
SPADINA AVENUE
UNIVERSITY AVENUE
BAY STREET
YONGE STREET
MATCH LINE: A
EXISTING
TRACKS AND OVERHEAD
NEW
TRACKS AND OVERHEAD
EXISTING
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KIPLING AVENUE
ROYAL YORK ROAD
BROWNS LINE
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MATCH LINE: A
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TRACKS AND OVERHEAD
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REVISIONS
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TRANSIT CITY TRACTION POWER
WATERFRONT WEST
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TORONTO TRANSIT COMMISSION
ENGINEERING DEPARTMENT
TCTPS-7
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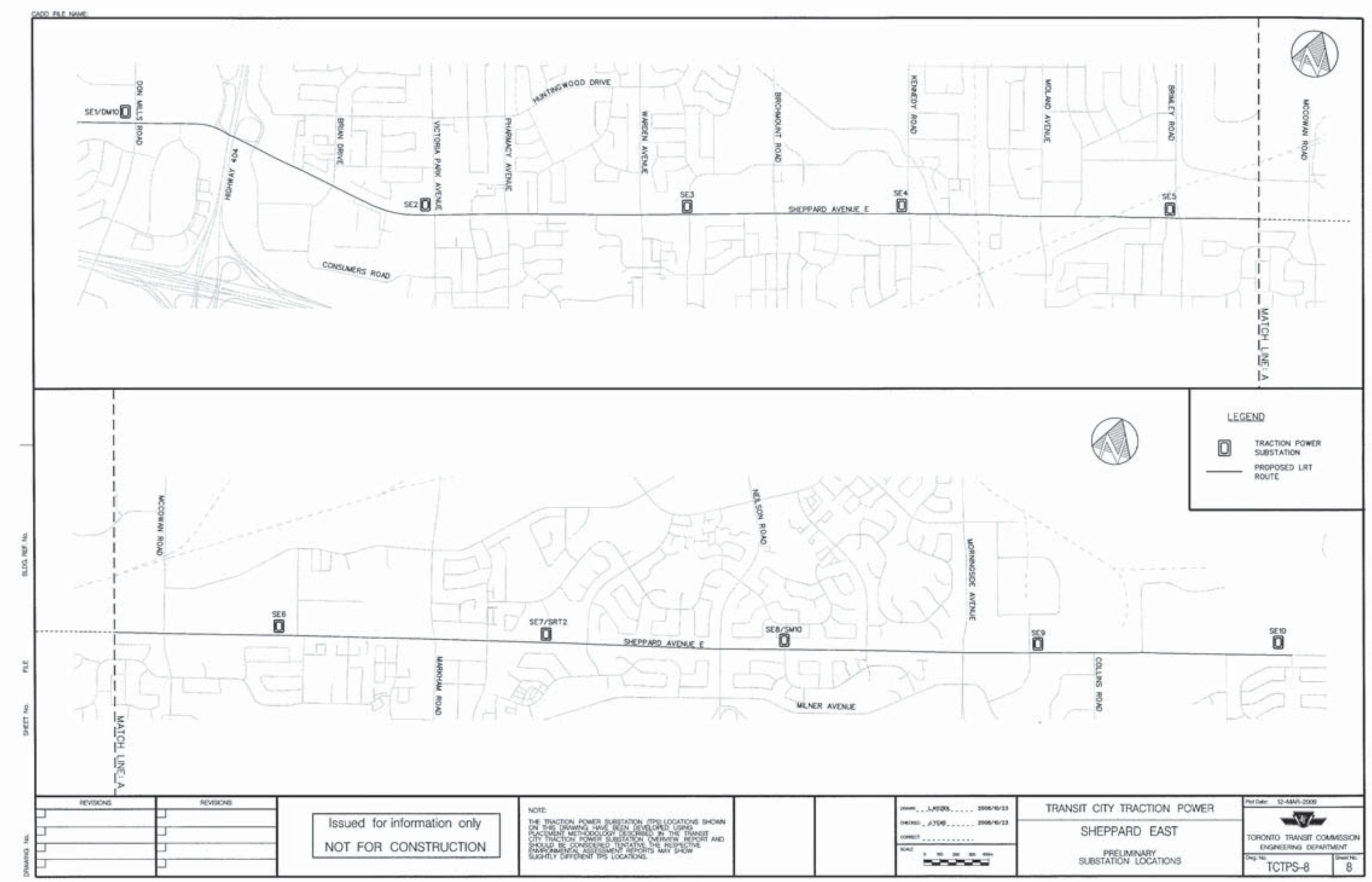
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WARDEN AVENUE
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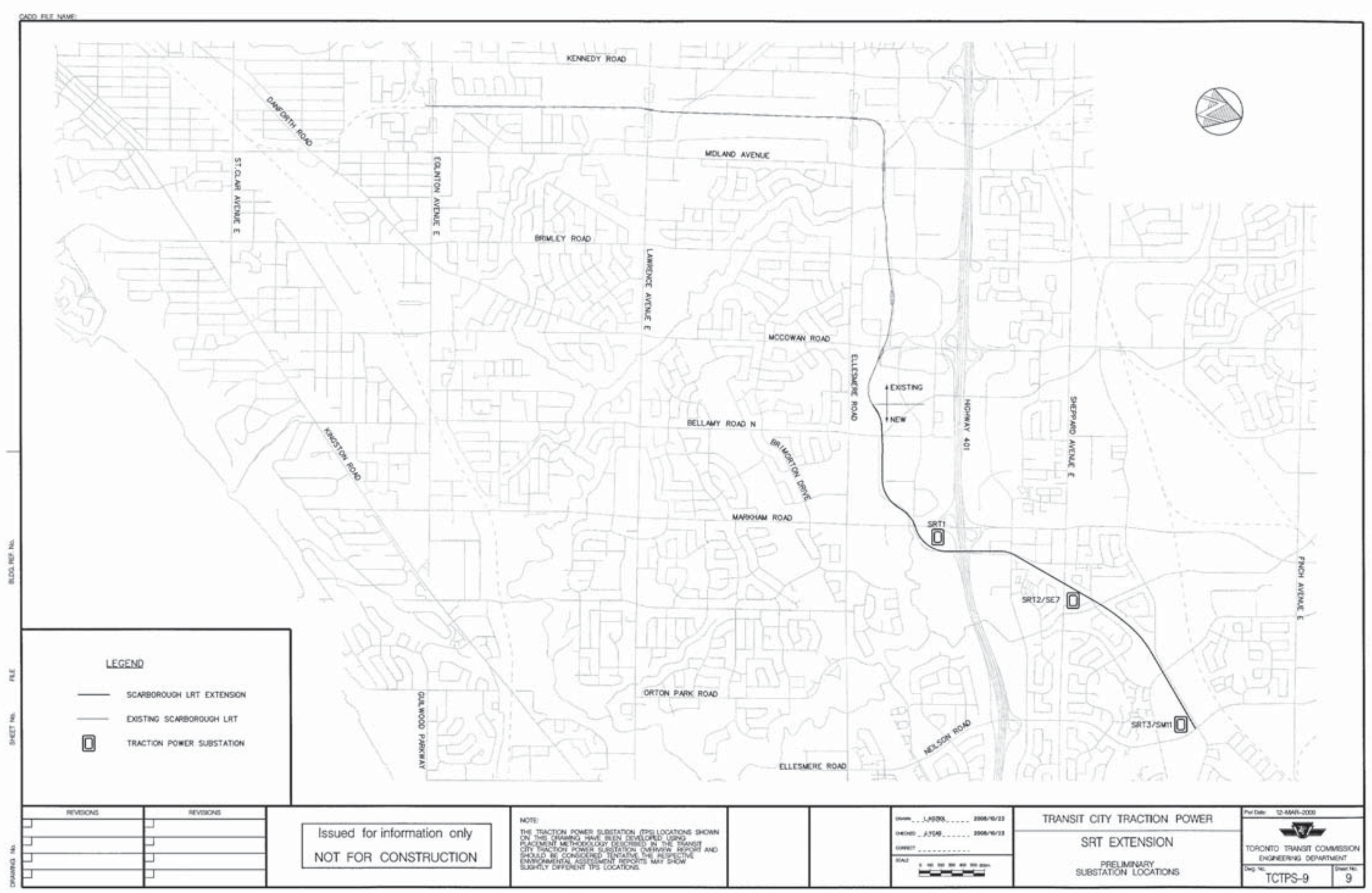
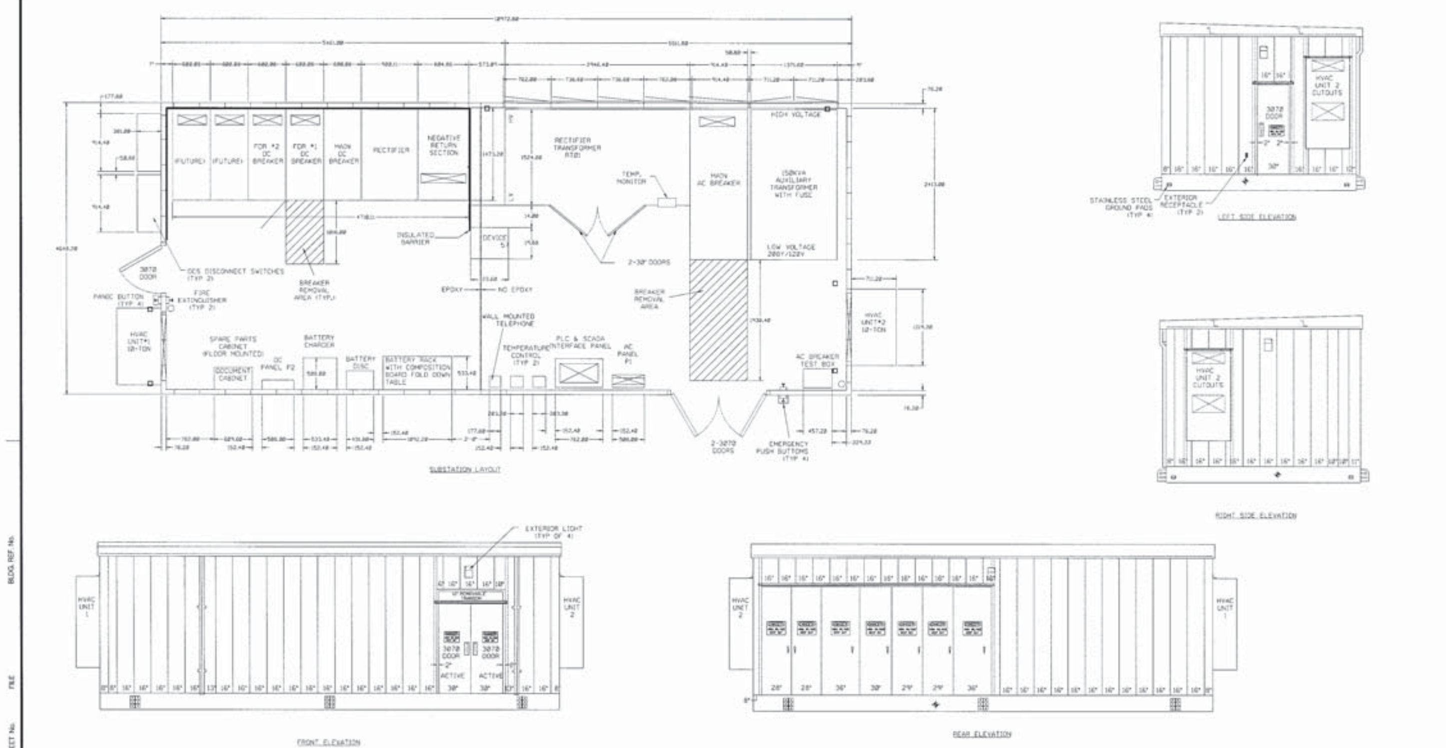
KENNEDY ROAD
MIDLAND AVENUE
BRIMLEY ROAD
MCCOWAN ROAD
SE2
SE3
SE4
SE5
SHEPPARD AVENUE E
CONSUMERS ROAD
MATCH LINE: A
LEGEND
TRACTION POWER SUBSTATION
PROPOSED LRT ROUTE
MCCOWAN ROAD
NEILSON ROAD
MORNINGSIDE AVENUE
SE6
SE7/SRT2
SE8/SW10
SE9
SE10
SHEPPARD AVENUE E
MARKHAM ROAD
MILNER AVENUE
COLLINS ROAD
MATCH LINE: A
REVISIONS
REVISIONS
Issued for information only
NOT FOR CONSTRUCTION
NOTE:
THE TRACTION POWER SUBSTATION (TPS) LOCATIONS SHOWN ON THIS DRAWING HAVE BEEN DEVELOPED USING PLACEMENT METHODOLOGY DESCRIBED IN THE TRANSIT CITY TRACTION POWER SUBSTATION OVERVIEW REPORT AND SHOULD BE CONSIDERED TENTATIVE THE RESPECTIVE ENVIRONMENTAL ASSESSMENT REPORTS MAY SHOW SLIGHTLY DIFFERENT TPS LOCATIONS.
TRANSIT CITY TRACTION POWER
SHEPPARD EAST
PRELIMINARY
SUBSTATION LOCATIONS
Plot Date: 12-MAR-2009
TORONTO TRANSIT COMMISSION
ENGINEERING DEPARTMENT
TCTPS-8
8



APPENDIX C

Typical TPS Configuration & Photos



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Drawn LKOZOL 2009/03/03
Checked J.YCAS 2009/03/03
Correct
Scale N.T.S.

TRANSIT CITY TRACTION POWER
TYPICAL SUBSTATION
LAYOUT AND ELEVATIONS

Plot Date 12-MAR-2009
TORONTO TRANSIT COMMISSION
ENGINEERING DEPARTMENT
Dwg. No. TCTPS-11
Sheet No. 11

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Drawn LKOZOL 2009/03/02
Checked J.YCAS 2009/03/02
Correct
Scale

TRANSIT CITY TRACTION POWER
TYPICAL SUBSTATIONS
PHOTOS FROM VARIOUS U.S
TRANSIT AUTHORITIES

Plot Date 13-MAR-2009
TORONTO TRANSIT COMMISSION
ENGINEERING DEPARTMENT
Dwg. No. TCTPS-12
Sheet No. 12