Section VIII

Survey Standards

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VIII. Survey Standards

A. Introduction

This section defines collection requirements for all preliminary surveys associated with the PS15 Feature Code list. The survey standards defined in this section apply only to preliminary collection surveys. For information on construction surveys or land surveys, consult the Construction Manual or the Right-of-Way Program.

Control, topographic, utility, and hydraulic (or drainage) surveys are all examples of preliminary surveys. Geology surveys are also considered preliminary surveys and have their own specialized feature codes. Control surveys establish the horizontal and vertical coordinates for each project control monument. Surveying standards are especially rigid for control surveys because they provide the basis for subsequent preliminary, cadastral, and construction surveys.

The data collected during a preliminary survey is made up of measurements that define locations and elevations of natural and man-made features. Once collected, the survey data is plotted in a MicroStation design file using Geopak software to develop planimetric maps and three dimensional (3-D) terrain models. The design of roadway elements is based on the mapping files created by the Photogrammetry & Surveys Section (P&S).

The survey standards defined in this section represent the minimum accuracy required for horizontal and vertical measurements. The primary reason for specific standards is to ensure that the desired positional accuracy for each survey code is attained throughout the survey. All surveys performed by WYDOT personnel or consulting firms contracted by WYDOT shall meet or exceed these accuracies.

Each surveyor must be aware of the accuracy requirements associated with each feature prior to collecting the survey. They must also understand how to meet those requirements through methodology and instrumentation. To a great degree, the acceptability and cost effectiveness of mapping, design, land acquisition, and construction depend upon properly collected surveys.

Instrument	Horizontal Accuracy	Vertical Accuracy
GPS/RTK	0.034 ft (0.010 m)	0.066 ft (0.020 m)
Optical Total Station	0.011 ft (0.003 m)	0.007 ft (0.002 m)
Digital Level	N/A	0.001 ft

Table VIII-1. Instrumentation accuracy.

The horizontal and vertical accuracies defined in Table VIII-1 are based on Trimble and Leica surveying equipment under optimal conditions. The accuracies are based on published datasheets for instrument measurements over a 750 ft. (230 m) distance. Refer to Part C in this section for accuracy calculations pertaining to a Trimble R8 GPS system, Trimble S6 optical total station, and Leica DNA10 digital level.

As shown in Table VIII-1, the vertical component of GPS measurements do not meet collection standards established for features with critical elevations. The use of an optical total station by itself or in conjunction with GPS equipment may be more effective in some surveying applications. Differential leveling with a digital level is the most accurate method for determining elevations. Refer to Section V, Control Surveys, in this manual and Chapters 6 and 9 in the Data Collection Manual for operating procedures that maximize the accuracy of each instrument.

The two main components of the WYDOT PS15 feature code list are DTM and Map codes. The main purpose of a DTM code is to define the ground surface for the development of digital terrain models (DTM's). Most, but not all DTM codes are also used to represent planimetric features in the project mapping. Map codes are used exclusively to map planimetric features, but do not contribute to the ground surface.

Vertical accuracies have been established for some of the Map codes (e.g. BRG and BCUL). Although the elevations are not used by P&S, they are used by other WYDOT Programs or Sections. As with the DTM codes, the vertical accuracies associated with the Map codes determine the collection methodology.

B. PS15 Feature Code Accuracy Tables

1. Project and Photo Control Codes

Code	Description	Horizontal Accuracy (ft)	Vertical Accuracy (ft)
AUXC	Auxiliary supplemental control point	0.05	0.02
EMKR	Engineering marker	0.05	0.02
PCPT	Project control point	0.05	0.02
TCP	Temporary control point	0.05	0.02
PAUX	Photo control, pick point	0.10	0.10
PFLT	Photo control, 4 leg target	0.10	0.10
PWPT	Photo control, 3 leg target	0.10	0.10

2. DTM Codes

Code	Description	Horizontal Accuracy (ft)	Vertical Accuracy (ft)
Bridge/Approach Slab/Retaining Walls			
BAS	Bridge approach slab	0.05	0.02
BRDG	Bridge end	0.05	0.02
RWB	Retaining, head and wing walls, bottom front	0.05	0.02

RWT	Retaining, head and wing walls, top back	0.05	0.02
Buildings/Sidewalks/Curb & Gutter/Concrete Items			
BLD	Building	0.05	0.02
CON	Selected concrete point	0.05	0.02
CSP	Concrete slope protection	0.05	0.02
FLC	Flow line of curb & gutter or valley pan	0.05	0.02
SLAB	Concrete slab	0.05	0.02
SWC	Sidewalk edge, concrete	0.05	0.02
SWE	Sidewalk edge, not concrete	0.10	0.10
TBC	Top, back of curb	0.05	0.02
Roadway/Railroads/Parking Areas			
CRS	Center of roadway, surfaced	0.05	0.02
CRUS	Center of roadway, unsurfaced	0.10	0.10
EP	Edge of pavement	0.05	0.02
EPS	Edge of paved shoulder	0.05	0.02
ESD	Edge of surfaced driveway	0.05	0.02
ESPL	Edge of surfaced parking lot	0.05	0.02
ETW	Edge of traveled way	0.05	0.02
EUR	Edge of unsurfaced road	0.10	0.10
EUSD	Edge of unsurfaced driveway	0.10	0.10
EUSPL	Edge of unsurfaced parking lot	0.10	0.10
PAV	Selected pavement point	0.05	0.02
RRBS	Railroad bed shoulder	0.10	0.10
TRL	Pack Trail or two-track vehicle trail	0.10	0.10
Terrain			
BKLS	Breakline, generic ground break	0.10	0.10
GRD	Selected original ground point	0.10	0.10
SPILE	Base of stock piles	0.10	0.10

Water/Drainage Structures			
CLBD	Concrete lined ditch, bottom	0.05	0.02
CLDT	Concrete lined ditch, top	0.05	0.02
DBI	Drainage bottom, irrigation	0.10	0.10
DTI	Drainage top, irrigation	0.10	0.10
DFL	Drainage flow line, natural ground	0.10	0.10
WAT	Existing water edge as breakline	0.10	0.10
WATVOI	Existing water edge as void	0.10	0.10

3. Map Codes

Code	Description	Horizontal Accuracy (ft)	Vertical Accuracy (ft)
Bridges/Barriers/Guardrails/Railroads			
BREJ	Bridge expansion joint	0.05	0.02
BRG	Bridge	0.05	0.02
BRP	Bridge pier	0.05	0.02
COB	Concrete barrier	0.05	0.02
COPB	Concrete post barrier	0.05	0.02
GR	Bridge and roadway guardrails	0.05	0.02
RCS	Railroad crossing signal	0.10	0.10
RR	Railroad; center of tracks	0.10	0.10
SRCP	Structure roadway clearance point	0.05	0.02
Campgrounds/Rest Areas			
BBQ	Campground barbecue pit or fire pit	0.10	N/A
FBX	Fee box depository	0.10	N/A
PICT	Campground picnic table	0.10	N/A
RVDP	RV water and sanitation dump site	0.10	N/A
Culverts/Pipes/Tanks			
BCUL	Box culvert	0.10	0.02
CULL	Pipe culvert, 60" and larger	0.10	0.10

CULS	Pipe culvert, smaller than 60"	0.10	0.10
DP	Above ground drain pipe	0.10	0.10
FLP	Flow line, bottom of pipe	0.10	0.10
FLRD	Flared end	0.10	0.10
IRP	Pipe used for crop irrigation	0.10	0.10
LFLD	Leach field	0.10	0.10
SPTC	Septic tank	0.10	0.10
STK	Stock tank	0.10	0.10
TANK	Storage tank	0.10	0.10
TPC	Top of pipe culvert	0.10	0.10
UDT	Underground drain pipe	0.10	N/A
UDTO	Above ground and underground drain pipe outlet	0.10	0.10
Fences & Accessories			
CTGD	Cattle guard	0.10	N/A
FBP	Fence, buck and pole	0.10	N/A
FBR	Fence; block, brick, or rock	0.10	N/A
FBW	Fence, barbed wire	0.10	N/A
FBWW	Fence, barbed w/ woven wire	0.10	N/A
FEO	Fence, other	0.10	N/A
FIND	Fence, industrial wire	0.10	N/A
FSN	Fence, snow	0.10	N/A
FWD	Fence, wooden	0.10	N/A
FWW	Fence, woven wire	0.10	N/A
GATE	Gate for fence	0.10	N/A
POST	Single fence post	0.10	N/A
Fields/Foundations/Rocks			
CULB	Cultivated field boundary	0.10	0.10
FOND	Foundation	0.10	0.10

ROCS	Rock outcropping or boulder field	0.10	0.10
Miscellaneous			
MISCB	Miscellaneous boundary features	0.10	N/A
MISCL	Miscellaneous line features	0.10	N/A
MISCP	Miscellaneous point features	0.10	N/A
PROF	Profile of a specific features	0.10	N/A
Note: When using the PROF feature code for top of rail shots, the horizontal and vertical accuracies are 0.05 ft and 0.02 ft, respectively.			
Signs/Man-Made Items			
CEMT	Cemetery	0.10	N/A
FP	Flag pole	0.10	N/A
GRAV	Grave	0.10	N/A
HRMP	Highway reference marker post	0.10	N/A
ITSS	Intelligent transportation system sign (weather stations/web cams)	0.10	N/A
MB	Mailbox	0.10	N/A
MEM	Memorial marker	0.10	N/A
PB	Parking block	0.10	N/A
SBB	Billboard	0.10	N/A
SHP	Heavy duty single pole sign	0.10	N/A
SMP	Multi-post major highway sign/VMS sign	0.10	N/A
SOLP	Solar panel	0.10	N/A
SP	Single post small highway sign	0.10	N/A
SST	Overhead structural sign	0.10	N/A
Trees/Bushes			
BRL	Brush line	0.10	N/A
BU	Bush, single	0.10	N/A
TR	Tree, single	0.10	N/A
TRLN	Tree line	0.10	N/A
Utilities (Fiber Optics)			

FOBX	Fiber optic junction box or pull box	0.10	N/A
FOMH	Manhole, fiber optic	0.10	0.02
OFOW	Overhead fiber optic wire	0.10	N/A
UFO	Underground fiber optic line	0.10	N/A
UMFO	Underground fiber optic marker post	0.10	N/A
Utilities (Gas)			
AGG	Above ground gas or methane line	0.10	N/A
GASM	Gas meter	0.10	N/A
PROT	Propane tank	0.10	N/A
UGAS	Underground gas or methane line	0.10	N/A
UMGS	Underground gas or methane marker post	0.10	N/A
VG	Valve, gas	0.10	N/A
WELG	Well, gas or methane	0.10	N/A
Utilities (Inverts and Pothole Locations)			
INVRT	Manhole/drop inlet invert elevation point	0.10	0.02
PINVRT	Pipe, invert elevation point	0.10	0.02
POTH	Utility pothole location	0.10	0.10
Utilities (Oil)			
AGO	Above ground oil line	0.10	N/A
GASP	Gasoline pump	0.10	N/A
UMOL	Underground oil line marker post	0.10	N/A
UOIL	Underground oil	0.10	N/A
WELO	Well, oil	0.10	N/A
Utilities (Power)			
DGA	Down guy anchor, all utility poles	0.10	N/A
ELMT	Electrical meter	0.10	N/A
OPOW	Overhead power wire	0.10	N/A
PP	Power pole	0.10	N/A

PPC	Combination power pole	0.10	N/A
PWBX	Power junction box or pull box	0.10	N/A
PWWT	Power wind turbine	0.10	N/A
TRAT	Transmission tower	0.10	N/A
UMPO	Underground power marker post	0.10	N/A
UPOW	Underground power line	0.10	N/A
Utilities (Sanitary Sewer and Storm Drains)			
DI	Median and curb & gutter drop inlets	0.10	0.02
GD	Gutter slotted drain	0.10	0.02
LSSA	Lift station, sanitary sewer	0.10	N/A
MHSA	Manhole, sanitary sewer	0.10	0.02
MHST	Manhole, storm drain	0.10	0.02
USAS	Underground sanitary sewer	0.10	N/A
USTS	Underground storm drain	0.10	N/A
Utilities (Telephone)			
CT	Communication tower	0.10	N/A
MHT	Manhole, telephone	0.10	0.10
OTEL	Overhead telephone wire	0.10	N/A
TBX	Telephone junction box or pull box	0.10	N/A
TP	Telephone pole	0.10	N/A
UMTL	Underground telephone marker post	0.10	N/A
UTEL	Underground telephone line	0.10	N/A
Utilities (Television)			
TVBX	Television junction box or pull box	0.10	N/A
UMTV	Underground television marker post	0.10	N/A
UTVC	Underground television cable	0.10	N/A
Utilities (Traffic)			
LP	Luminaire pole	0.10	N/A

TS	Traffic or pedestrian signal pole	0.10	N/A
TSB	Traffic signal box	0.10	N/A
Utilities (Undefined Items)			
MH	Manhole, undefined	0.10	0.02
OUTL	Overhead utility, undefined wire	0.10	N/A
POLE	Single pole	0.10	N/A
UMUN	Undefined underground marker post	0.10	N/A
UNBX	Undefined junction box or pull box	0.10	N/A
UUTIL	Underground utility, undefined	0.10	N/A
UVAL	Undefined valve	0.10	N/A
VALT	Utility vault	0.10	N/A
VENT	Underground utility vent	0.10	N/A
Utilities (Water)			
AGW	Above ground water line	0.10	0.10
FHY	Fire hydrant	0.10	N/A
MHW	Manhole, water	0.10	0.02
UMWA	Underground water line marker post	0.10	N/A
UWAT	Underground water line	0.10	N/A
VW	Valve, water	0.10	N/A
WM	Water meter	0.10	N/A
WSP	Water spigot	0.10	N/A
Water/Drainage Structures			
DAM	Dam or dike	0.10	0.10
HWL	High water line	0.10	0.10
IRBX	Irrigation box	0.10	0.10
IRHG	Irrigation headgate	0.10	0.10
IRSH	Irrigation sprinkler head	0.10	0.10
IRWR	Weir	0.10	0.10

MARB	Marsh boundary	0.10	0.10
RIPL	Riprap line	0.10	0.10
RIPS	Riprap shape	0.10	0.10
WELW	Well, water	0.10	0.10
WML	Windmill	0.10	0.10

4. Geology Survey Codes

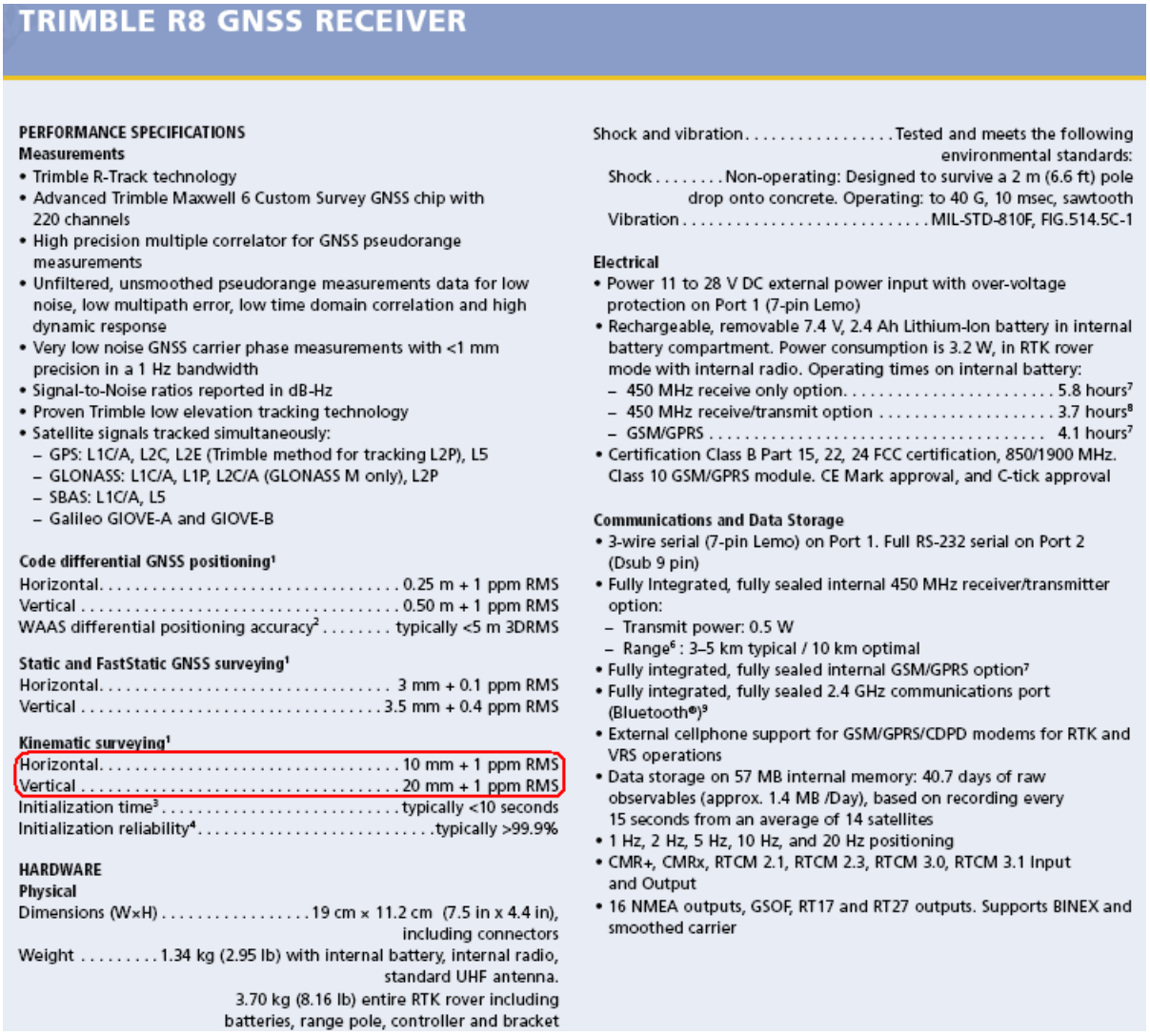
Code	Description	Horizontal Accuracy (ft)	Vertical Accuracy (ft)
DTM Codes			
GENG	Natural ground to paleosurface	0.10	0.10
Map Codes			
GEBH	Backhoe hole	0.10	N/A
GEBHP	Old backhoe hole	0.10	N/A
GEDL	Depleted pit limit	0.10	N/A
GEFC	Formation contact	0.10	N/A
GEGM	Monitoring tube	0.10	N/A
GEIN	Inclinometer tube	0.10	N/A
GEIP	General geology information point	0.10	N/A
GEIS	Instrument station	0.10	N/A
GELS	Deformation limits	0.10	N/A
GEPB	Permit area boundary	0.10	N/A
GEPL	Pit limit	0.10	N/A
GEQL	Quarry top or bottom limits	0.10	N/A
GERP	Reject piles	0.10	N/A
GESC	Scarp	0.10	N/A
GESL	Seismic lines	0.10	N/A
GESP	Settlement platform	0.10	N/A
GESRP	Soil retention piling	0.10	N/A
GESS	Surface sample location	0.10	N/A

GEST	Slide toe	0.10	N/A
GETC	Tension cracks	0.10	N/A
GETE	Terrace edge	0.10	N/A
GETH	Test hole	0.10	N/A
GETHP	Old test hole	0.10	N/A
GETP	Topsoil pile	0.10	N/A
GEUS	Unknown survey point	0.10	N/A
GEWC	Weathered or unweathered contact	0.10	N/A

C. Accuracy Calculations

The following accuracy calculations are based on measurements taken over a distance of 750 ft (230 m). Refer to Appendix G for Metric and US Survey foot conversions.

1. GPS/RTK



TRIMBLE R8 GNSS RECEIVER

PERFORMANCE SPECIFICATIONS

Measurements

- Trimble R-Track technology
- Advanced Trimble Maxwell 6 Custom Survey GNSS chip with 220 channels
- High precision multiple correlator for GNSS pseudorange measurements
- Unfiltered, unsmoothed pseudorange measurements data for low noise, low multipath error, low time domain correlation and high dynamic response
- Very low noise GNSS carrier phase measurements with <1 mm precision in a 1 Hz bandwidth
- Signal-to-Noise ratios reported in dB-Hz
- Proven Trimble low elevation tracking technology
- Satellite signals tracked simultaneously:
  - GPS: L1C/A, L2C, L2E (Trimble method for tracking L2P), L5
  - GLONASS: L1C/A, L1P, L2C/A (GLONASS M only), L2P
  - SBAS: L1C/A, L5
  - Galileo GIOVE-A and GIOVE-B

Code differential GNSS positioning[1]

Horizontal . . . . . 0.25 m + 1 ppm RMS
Vertical . . . . . 0.50 m + 1 ppm RMS
WAAS differential positioning accuracy[2] . . . . . typically <5 m 3DRMS

Static and FastStatic GNSS surveying[1]

Horizontal . . . . . 3 mm + 0.1 ppm RMS
Vertical . . . . . 3.5 mm + 0.4 ppm RMS

Kinematic surveying[1]

Horizontal . . . . . 10 mm + 1 ppm RMS
Vertical . . . . . 20 mm + 1 ppm RMS
Initialization time[3] . . . . . typically <10 seconds
Initialization reliability[4] . . . . . typically >99.9%

HARDWARE

Physical

Dimensions (W×H) . . . . . 19 cm × 11.2 cm (7.5 in x 4.4 in), including connectors
Weight . . . . . 1.34 kg (2.95 lb) with internal battery, internal radio, standard UHF antenna.
3.70 kg (8.16 lb) entire RTK rover including batteries, range pole, controller and bracket

Shock and vibration . . . . . Tested and meets the following environmental standards:
Shock . . . . . Non-operating: Designed to survive a 2 m (6.6 ft) pole drop onto concrete. Operating: to 40 G, 10 msec, sawtooth
Vibration MIL-STD-810F, FIG.514.5C-1

Electrical

- Power 11 to 28 V DC external power input with over-voltage protection on Port 1 (7-pin Lemo)
- Rechargeable, removable 7.4 V, 2.4 Ah Lithium-Ion battery in internal battery compartment. Power consumption is 3.2 W, in RTK rover mode with internal radio. Operating times on internal battery:
  - 450 MHz receive only option. . . . . 5.8 hours[7]
  - 450 MHz receive/transmit option . . . . . 3.7 hours[8]
  - GSM/GPRS . . . . . 4.1 hours[7]
- Certification Class B Part 15, 22, 24 FCC certification, 850/1900 MHz. Class 10 GSM/GPRS module. CE Mark approval, and C-tick approval

Communications and Data Storage

- 3-wire serial (7-pin Lemo) on Port 1. Full RS-232 serial on Port 2 (Dsub 9 pin)
- Fully Integrated, fully sealed internal 450 MHz receiver/transmitter option:
  - Transmit power: 0.5 W
  - Range[6]: 3–5 km typical / 10 km optimal
- Fully integrated, fully sealed internal GSM/GPRS option[7]
- Fully integrated, fully sealed 2.4 GHz communications port (Bluetooth®)[9]
- External cellphone support for GSM/GPRS/CDPD modems for RTK and VRS operations
- Data storage on 57 MB internal memory: 40.7 days of raw observables (approx. 1.4 MB /Day), based on recording every 15 seconds from an average of 14 satellites
- 1 Hz, 2 Hz, 5 Hz, 10 Hz, and 20 Hz positioning
- CMR+, CMRx, RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1 Input and Output
- 16 NMEA outputs, GSOF, RT17 and RT27 outputs. Supports BINEX and smoothed carrier

Figure VIII-1. Trimble RTK accuracy standards.

Horizontal Accuracy:

$\pm(10\ mm + 1\ ppm) = \pm(0.010\ m + 1 * (230\ m/1{,}000{,}000)) = \mathbf{\pm 0.0102\ m}$

$\pm(0.0328\ ft + 1\ ppm) = \pm(0.0328\ ft + 1 * (750\ ft/1{,}000{,}000) = \mathbf{\pm 0.0336\ ft}$

Vertical Accuracy:

$\pm(20\ mm + 1\ ppm) = \pm(0.020\ m + 1 * (230\ m/1{,}000{,}000) = \mathbf{\pm 0.0202\ m}$

$\pm(0.0656\ ft + 1\ ppm) = \pm(0.0656\ ft. + 1 * (750\ ft/1{,}000{,}000) = \mathbf{\pm 0.0664\ ft}$

2. Optical Total Station

TRIMBLE S6 DR PLUS™

PERFORMANCE

Angle measurement	
Sensor type	Absolute encoder with diametrical reading
Accuracy (Standard deviation based on DIN 18723)	2" (0.6 mgon)
	3" (1.0 mgon), or 5" (1.5 mgon)
Angle reading (least count)	
Standard	1" (0.3 mgon)
Tracking	2" (0.6 mgon)
Averaged observations	0.1" (0.03 mgon)
Automatic level compensator	
Type	Centered dual-axis
Accuracy	0.5" (0.15 mgon)
Range	± 5.4' (±100 mgon)
Distance measurement	
Accuracy (RMSE)	
Prism mode	
Standard	2 mm + 2 ppm (0.0065 ft + 2 ppm)
Standard deviation according to ISO17123-4	1 mm + 2 ppm (0.003 ft + 2 ppm)
Tracking	4 mm + 2 ppm (0.013 ft + 2 ppm)
DR mode	
Standard	2 mm + 2 ppm (0.0065 ft + 2 ppm)
Tracking	4 mm + 2 ppm (0.013 ft + 2 ppm)

Figure VIII-2. Trimble optical total station accuracy standards.

Horizontal Angular Accuracy (2" instrument):
$230\ m * \tan(2" / (3600" / 1°)) = \mathbf{0.0022\ m}$
$750\ ft * \tan(2" / (3600" / 1°)) = \mathbf{0.0073\ ft}$

Distance Accuracy:
$\pm(2\ mm + 2\ ppm) = \pm(0.002\ m + 2 * (230\ m/1{,}000{,}000) = \mathbf{\pm 0.0025\ m}$
$\pm(0.0065\ ft + 2\ ppm) = \pm(0.0065\ ft + 2 * (750\ ft/1{,}000{,}000) = \mathbf{\pm 0.0080\ ft}$

Total Horizontal Accuracy:
$\pm\sqrt{(0.0022\ m)^2 + (0.0025\ m)^2} = \mathbf{\pm 0.0033\ m}$
$\pm\sqrt{(0.0073\ ft)^2 + (0.0080\ ft)^2} = \mathbf{\pm 0.0108\ ft}$

Vertical Angular Accuracy (2" instrument):
$230\ m * \tan(2" / (3600" / 1°)) = \mathbf{0.0022\ m}$
$750\ ft * \tan(2" / (3600" / 1°)) = \mathbf{0.0073\ ft}$

3. Digital Level

Technical data	LEICA DNA03	LEICA DNA10
Area of use	– Quick measurements of heights, height differences and stake outs	– Quick measurements of heights, height differences and stake outs
	– I. and II. order levelling	– Cadastral levelling
	– High precision measurements	– Precision measurements
Accuracy	Standard deviation height measurement per 1km	
	double-run (ISO 17123-2)	
Electronic measurements:		
with Invar staffs	0.3 mm	0.9 mm
with standard staffs	1.0 mm	1.5 mm
Optical measurements	2.0 mm	2.0 mm
Distance measurement (standard deviation)	(electr.) 1 cm/20 m (500 ppm)	

Figure VIII-3. Leica digital level accuracy standards.

Vertical Measurement Standard Deviation:
$\pm 1.5\ mm\ per\ 1\ km = \pm 1.5\ mm/(1{,}000\ m) * 230\ m = \pm \mathbf{0.345\ mm\ per\ 230\ m}$
$\pm 0.0049\ ft\ per\ 3{,}280.83\ ft = \pm 0.0049 ft/(3{,}280.83\ ft) * 750\ ft =$
$\pm \mathbf{0.0011\ ft\ per\ 750\ ft}$