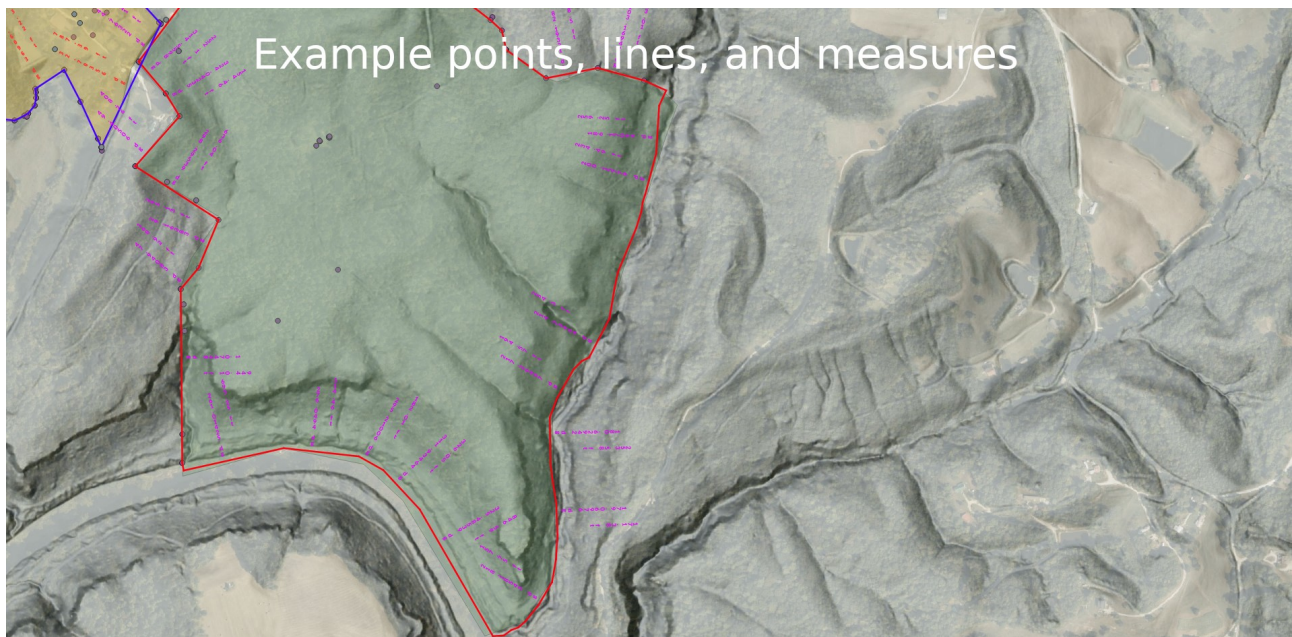


Survey Procedure for Deed Work

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Introduction

This document details a system of files and documentation for making a cadastral (Latitude/Longitude, bearing/distance) real estate survey to locate the calls in a deed. The same setup can be used for many other applications, e.g., fine resolution flora and fauna surveys, laying out dimensions on the ground, mapping water line or electric line reticulation, roads, trails and the like. Anything that needs highly accurate repeatable location surveys can use these methods. The procedure described here has many steps. For those unfamiliar with deeds, mapping and, optionally, Geographic Information System (GIS) tools, there is a steep learning curve. As discussed below, hiring a professional surveyor may be the far better option. The GIS discussed here, QGIS, is not required. What is essential is a high accuracy GPS device to geolocate deed call monuments.

Land titles are generally recorded by a local government to define the ownership and taxation of a tract. In the USA, states typically declare a ranked system detailing the authority given to a location reference (a call) declared in a deed. For example, a fixed physical object like the confluence of a stream and river or a monolith may prevail over a measure like a distance and direction. The statutory precedence is generally well established by law and regulation, and it may vary from locale to locale. A decent rule of thumb in the construction of a deed is to use immobile entities and monoliths as the monument cited in the deed when available, construct physical monuments (set stones, concrete markers, steel posts, etc) when there is not already one, and use vectors of distance and bearing when no better call can be made. Familiarity with the local statutes and deed standards are required. Not all locales permit an individual to record a survey of their own tract in their local courthouse. Licensed professional surveyors could be required in order to file plats (line drawings) vs deeds. Unlicensed individuals may be constrained to written calls (vs plat drawings) when filing a deed, and only for tracts they currently hold title to. This document is for locales that permit an individual to make such a survey of their own tract and file their deed in the courthouse.

The goal of this case study is to demonstrate how to acquire the necessary deeds, how to extract the calls within the deeds, how to then geolocate the calls and, optionally, how to provide those locations to QGIS, a free geographic information system used to make maps, and finally, how to verify those location calls in a deed to validate a prior survey or compose a new survey with them.

While many professional grade survey tools are available, only the Ublox C099-F9P (kit) with the Zed-F9P radio receiver is detailed here. At the time of this writing, it is one of the least cost

solutions for high precision (millimeter scale) accuracy. In addition to the Ublox C099-F9P Base and Rover, at a minimum, you will need a Bluetooth enabled laptop or tablet that can run the Ublox U-Center software under Windows (or Linux with Wine). No other tools are essential, as U-Center can both configure the Base and Rover, log the Base location observations, and all the calculations can be managed by hand or with web based tools. Using an Android phone, Iphone or QGIS during the surveys may be easier, but not essential.

Note, however, that unless you have an expensive survey or the need to make many surveys, the methods detailed here are not worth the effort and you should hire a professional. The surveys that drove this work had more than 120 calls and more than fifty adjacent, legacy, or antecedent deeds, some 140 years old, to contend with.

Why You Might Want To Hire A Professional

The advent of high precision and accuracy hardware makes the determination of an absolute physical Latitude/Longitude position available to the non-professional. However, professional surveyors can make a far better interpretation of a deed and it's derivation than most. They are a lower cost solution, both in dollar terms and in time spent in most cases. Evaluating how old surveys can be mapped to the current day is not trivial: changes in magnetic bearing, language and reporting requirements, the contemporary standards for rods, chains, northings, eastings and the like take training and familiarity with historical methods. Local standards and the tract's history may make that difficult or more ambiguous. Old surveys might have poorly referenced calls, calls that refer to adjacent tracts held at the time of the old survey and the like. Mapping deed calls to ground truths is a matter of opinion in nearly all cases. In the event of a boundary dispute that cannot be resolved by dialog, courts will prefer the testimony of a professional. Making your own survey may not be adequate if there is any dispute.

It is also worth noting that the dollar cost of a deed call can be expensive. Making more calls in a deed may encumber the tract with a future dollar cost when resurveyed. Lenders may expect a professional survey, so selling a tract with a surfeit of calls may add to the cost of the sale. Fewer calls and simpler lines might cost some ground now, but may make the tract more affordable and marketable in a future sale. Few and simple lines will also make future disputes far easier to sort out.



PPP, RTK and UBX: What are they?

What is described below is a means to document and authenticate location observations (Latitude and Longitude) made using modern geopositioning PPP (Precise Point Position) and RTK (Real Time Kinetic) technologies. PPP and RTK refer to standard methods and mathematical models used to ascertain a physical location. The case study detailed here uses a U-Blox TM Zed-F9P device (the C099-F9P kit) to measure and record radio broadcasts from earth orbiting satellites (viz:

<http://www.appal.org/webnewspro/162341461594024.shtml>) “How to Build an Affordable RTK GPS Base/Rover Survey Tool” for a detailed discussion of the survey technology and hardware used in this document.). Those observations are recorded in “UBX” files, then translated to a standardized format called RINEX (Receiver Independent Exchange Format) and submitted to a post-fix service that removes some errors in the observations and does the math to return a PPP Latitude/Longitude location along with a measure of the accuracy errors. The service detailed here is provided at no cost by the Canadian government (<https://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php>). They handle the RINEX observations for all the satellites and radio bands recorded by the U-Blox TM Zed-F9P and return a set of reports in various formats (CSV, PDF, Text, etc) detailing the PPP measures.

A set of standardized names, file folders, and subfolders is described here to preserve the UBX observations and PPP reports for a tract’s deed calls. This naming convention is just a suggestion. A Linux (a computer operating system) BASH script (a simple program) is provided to make the standardized files. Windows users will need to make their own file folders. NB: when used below, the tilde (“~”) character is Linux specific, it is a reference to the users home folder. Windows users need only reassign all the folders prefixed here with ~ to lie within the user’s home folder. The naming conventions will work under Windows or Linux, but most of the documentation and all of the scripted automation detailed below is Linux specific- you will have to do more work by hand under Windows.

QGIS, the geographic information system mapping program, runs under Linux, Windows, macOS, or Android, but it is not a simple tool. Skip it unless you have prior experience with a GIS or are interested in mapping. Install QGIS from <https://qgis.org/en/site/forusers/download.html> .

The RTK technology requires a Base station with a known fixed (PPP or surveyed benchmark) location, so, absent a pre-existing benchmark, the means to make a survey is usually a two step process, first to set the Base, and once that has been located by a PPP point, to then make the RTK survey. There is a coarser real time measure available in some cases using internet available base stations (NTRIP), but it is not discussed in this document. Those with a previously surveyed PPP benchmark may directly implement the RTK steps described below.

The surveyed PPP corrections become more accurate after a couple of weeks, so expect to wait a bit for the satellite corrections to mature before submitting the RINEX observations for correction. This is because the GNSS (Global Navigation Satellite System, aka GPS) satellites, on their own, are slightly unaware of their own exact position at any given moment and it takes time to repair their reports to correct those small position errors. Again, expect to wait a couple of weeks for those corrections to be applied before submitting the Zed-F9P’s UBX->RINEX files to post-fix the PPP location of the Base station and making the final RTK survey.

Where to Start

Plan the survey. Become familiar with the tract boundary and the deed. Determine how well the Base and Rover will perform in that terrain. Determine if there are neighbors disputing the boundary. Settle those disputes if you can, and if you anticipate a lawsuit, hire a professional surveyor, at least for the disputed segment. Once you have the basic notions, begin the plan. Making the Base station PPP locations includes the delay mentioned above, so it is reasonable to first make the files for PPP corrections, survey the Base station sites and then, while waiting for the PPP correction observations to mature, make the title search, settle any disputes, and make the file folders for all the deed calls. NB: the county tax and deed records may not be entirely up to date or accurate, so talk to the neighbors about their tracts.

First things first: make the Base station's fixed location observations. Pick locations within the tract to be surveyed that have both good radio coverage for the RTK rover as it traverses the survey boundary, and a good clear line of sight to the constellation of GNSS satellites. The Base to Rover coverage depends on your hardware. This case study has radio equipment connecting the Base to the Rover with good range, so relatively few fixed Base locations on this large tract were needed. After those Base station observations are collected, use the intervening time to locate and read all the deeds, discuss the property lines with the neighbors, and construct the title search as described below. Decide if you are resurveying and confirming old boundary calls or creating a new boundary survey, e.g., for a tract that has been subdivided or for one with an old ambiguous deed. Last, make the RTK survey of the deed's calls.

Deeds are opinions. The adjacent tracts may confirm or conflict with a given call. To make a new set of observations about the calls in a deed, the deed itself and the adjacent deeds' calls should be considered and resolved. Boundary disputes are expensive to resolve in a courtroom, it's good advice to try to sort out boundary line conflicts directly with your adjacent neighbor.

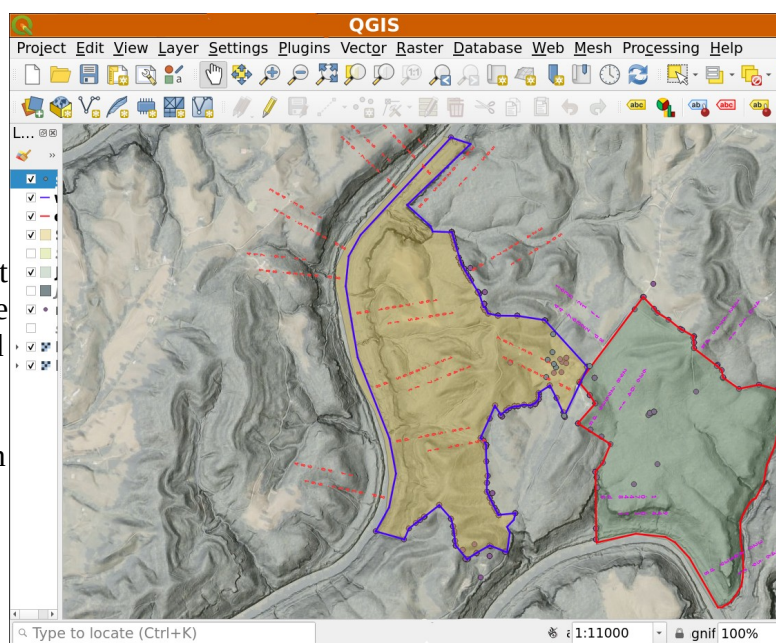
Your deed may never refer to adjacent deeds, and in that case, absent a boundary dispute, you may not need to be as diligent about the adjacent tracts. Parts of the next paragraphs detail the procedure should you need to apply calls and references from adjacent tracts. If you don't have references to or conflicts with neighboring lines, ignore the instructions about them given below.

The model offered here works for both setting the Base Stations and for a confirmation type resurvey where each call in the deed to be surveyed is extracted and listed in it's own line in a text file named **calls**. Each line in the **calls** text file must begin with "**call_#** " where # is replaced by an integer in sequence (the blank after the integer is required too). The sequence numbers for a resurvey follow the path described in the deed's boundary. The exact same convention is used to locate the Base stations in a **calls** text file. You only need the Base stations listed in **calls** if you are not resurveying and confirming old deed calls, but instead are making a new set of boundary calls. Germane, antecedent, and adjacent deeds can kept in a folder named after that deed and the deed book and page reference where the deed is filed. Using these optional file structure conventions makes a title search validating your deed and the adjacent tracts far easier to document and archive.

About QGIS

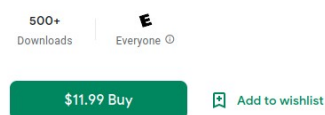
QGIS is a free geographic information system (GIS) application. You may not want to use QGIS, it has a steep learning curve. All of the distance and bearing measures needed to construct linear (straight line) deed calls can be made by other tools or made by hand with simple triangulation using the Polar and Cartesian vector calculations generally offered in high school geometry classes.

QGIS offers mapping and the means to extract the distance and bearing between deed calls. It can also determine precise areas within complex boundaries, like the meanders of a river or cliff line. QGIS also provides Qfield, a field ready Android/Iphone mapping application for cell phones and tablets (viz: <https://www.qfield.org>). Another virtue of QGIS is to document the location of other features



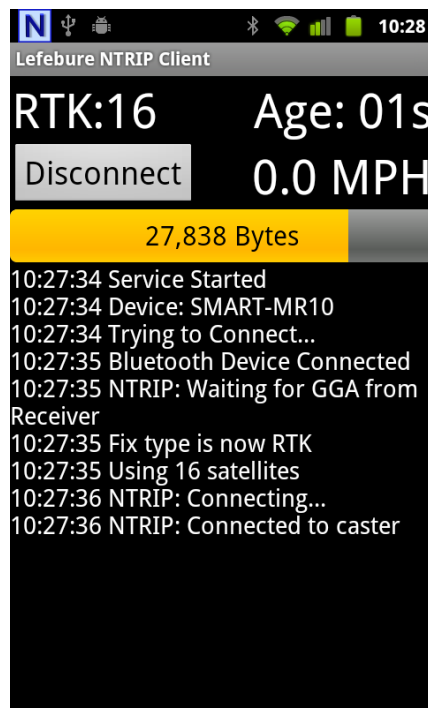
within a tract like roads, water reticulation, trails, and the like. You can skip all the QGIS discussion below to make a deed, all that is required is the math skills or a computer application to calculate the distance and direction from call to call once you have surveyed the Latitude and Longitude of each call. However, while you can skip QGIS and Qfield, this document requires the Ublox U-Center or one of the Android apps available from the Google Play store to log the UBX records for a Base station needed for the PPP calculations.

U-Droid Center for u-blox®



About this app →

This application allows you to work with navigation chips directly, without the help of navigation services Android. Connection to the navigation chip is possible via USB, Bluetooth and RS232 (Uart) port, as well as to the built-in motherboard chip u-blox®. To connect the USB navigation receiver, your smartphone must support USB Host OTG. To connect to the chip on RS232 or to the built-in chip in most cases it is necessary to have Root rights.



When logging records to make the PPP located Base needed to make an RTK survey of the calls' Latitude and Longitude, the Base's Zed-F9P is attached by a Bluetooth connection to a Windows laptop/tablet running the Ublox U-Center application, or an Android phone or tablet running either Udroid's ACenter app (buy it from Google Play store), LeFebure's Ntrip Client app (free from www.lefebure.com/software/android-ntripclient) or the Linux GPSD. They provide a "mock location" service using the Base/Rover locations to record the log files. After the PPP corrections are made, Real Time Correction Measures (RTCMs) from the Base to the Rover fix the exact position of the Rover for RTK mapping. Similar logging applications for the Iphone that use an external GPS device via Bluetooth and UBX messages exist, but are not documented here.

Once the Base station has been configured, set in place and is running, the fixed Rover position measures sent from the Rover via Bluetooth can be recorded directly to the Qfield mapping application as point layer features in the field and subsequently transferred from the phone or tablet to QGIS on the PC. NB: instead of Qfield, the locations can be hand recorded. Other apps on the phone/tablet use the mock location position sent by the Rover too, so a geopositioned photograph taken with the phone's camera (e.g., with the Android application "Solocator", <https://solocator.com>), can embed the precise Latitude and Longitude into the image.

If you don't use QGIS and QField, expect to make a Latitude/Longitude record by hand (or with Solocator) for each deed call and to do the math or use a web calculator (search the web for Latitude Longitude to bearing and distance calculators) to compute the distance and bearing from call to call.

QGIS uses "plugins" to add tools and functions, and one of those is used in this example. The Qfield plugin exports and imports a working copy of the QGIS map and selected overlays to a cell

phone or tablet for field work. Typical uses other than deed calls are mapping and naming a road, mapping the location of plants, etc. If an observable feature can be placed on a QGIS map, Qfield is a good tool for the job. Keep both QGIS and Qfield updated to their current release to avoid problems with transferring data between QGIS and QField.

The QGIS stock “Field Calculator” will compute the direction and length of a span between points. The use of the Field Calculator is documented below. Distance and bearing are the measures commonly used in a deed survey, along with asserting the projection and methodology, to describe the enclosed boundary.

Make a preliminary assignment of Base locations.

Use your own judgment or use QGIS to estimate a good location for all the fixed base sites needed to make a feasible RTK survey.

The Base location estimates should accommodate the Line of Sight radio range and obstructions that limit the RTCM (Real Time Correction Measures) sent by radio from the Base to the Rover to assure good RTK readings to fix the locations of the Calls. You will also need to return to the Base station monument again when you are ready to RTK survey with the Rover, so construct a good monument that you can locate again after some weeks at the surveyed location.

Using QGIS and QField

If you use QGIS and QField the project needs a base map, and for each tract, an editable vector layer for the field surveyed deed calls located by the RTK Rover and recorded with Qfield. Optionally, you may want a vector layer for the preliminary locations (the estimated points for the Base stations and the deed calls to be surveyed). Use QGIS’ Field Calculator to add a text feature attribute to the deed call layer so you can edit that text to describe the monument when you take the Rover location reading during the RTK survey. See the QGIS documents on how to add a text field with the Field Calculator.

Before taking any measures, you can add estimated Base location points to a preliminary vector layer in QGIS by hand. The estimated points can help guide you to the Base monument locations for the first pass that logs the UBX observations for PPP corrections and during the second pass, guide you to the boundary monument locations. Place a preliminary point for each Base station site and an estimated preliminary point for each deed call along the boundary to be surveyed, then save the project. Next use the QGIS project to configure and generate the portable Qfield project and copy the Qfield project to the phone/tablet (see the Qfield plugin documentation). The Iphone is trickier to manage the copy, but the **grcp** application in Linux, plus the **File Manager** on the Iphone will move the Qfield project files from Linux to the Qfield directory on the Iphone.

Once ready to begin the Base Station surveys, set up the C099-F9P/Zed-F9P Base configuration to self-locate and log as described below and run the Base station to log for some hours. If you use Qfield on the Android phone or tablet (or the Iphone) and made the preliminary map layer just described, Qfield, using just the cell phone’s location, can to guide you to each Base station site. Use Ublox U-Center or one of the android apps A-Center or LeFebure Ntrip to collect and log the UBX observations needed for PPP corrections. Weeks later, once the UBX records are made with RTKLib into RINEX files and have been corrected by the NRCAN’s web site and you have their reported PPP position of the Base on hand, configure the Ublox files for the PPP fixed Base, as discussed further below, and return to the Base’s monument with the Base Station C099-F9P and run it to provide the correction measures to the Rover C099-F9P while you survey the boundary.

The example below may suffice, or see www.appal.org/pix/c099f9pbaserover.pdf for more detailed instructions on how to to set up the Base for a fixed location.

Field Work

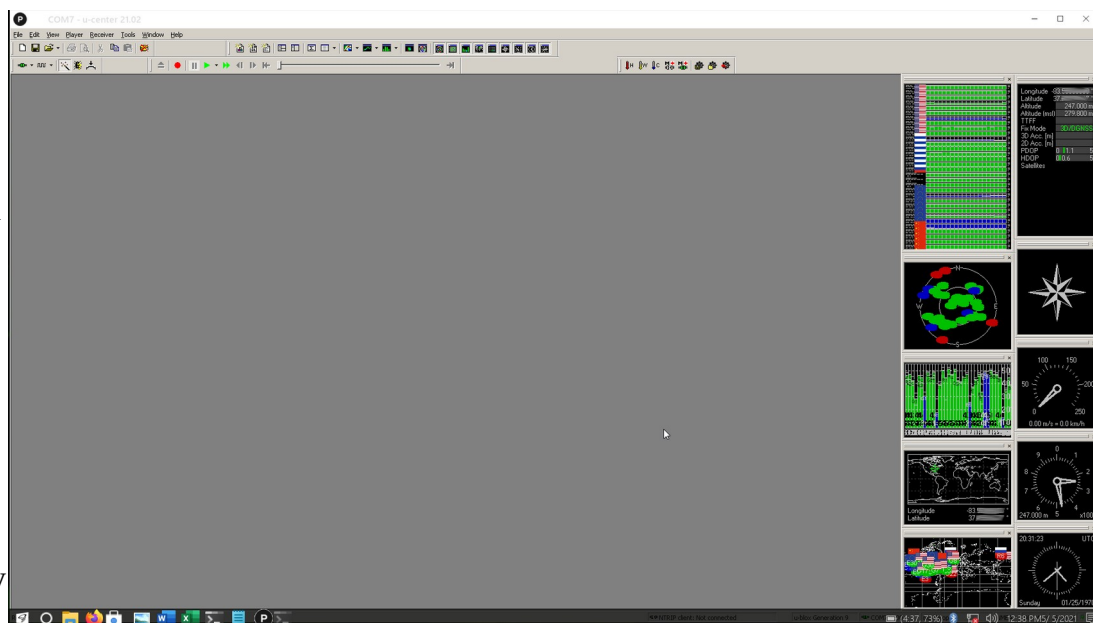
Site Base monuments, Make UBX logs, then wait up to two weeks.

For Base monuments that cannot be assigned a location from a prior known monument, set up the Base C099-F9P at the monument and log UBX RAWX and SFRBX messages for 4 to 24 hour sessions. If height/altitude is important in the RTK survey, measure and record the precise height of the C099-F9P antenna above the Base Monument ground level then restore the Base C099-F9P antenna to that exact same height when you run the RTK survey in some weeks. The duration needed is a function of the required precision and the number of satellites visible to the Base. Six, twelve, or twenty four hour sessions are likely to yield more precise PPP results, though more than four hours shows only small improvements in most conditions. Shorter observation intervals may suit your needs. Excellent conditions can yield a Base location accurate to two centimeters after two hours logging and the subsequent PPP corrections, bad conditions might take four hours and only be accurate to a meter, or worse.

In practice, a temporary benchmark can use long nails with a colored ribbon or some 6" plastic pipe sections to mark the exact location of the base benchmark. Drive the marker high flush with the ground to avoid it being disturbed. Several Base benchmarks in this example had to be resurveyed because forest animals had disturbed the monuments, some were dug up and chewed to bits!

Ublox Ucenter

Use Ublox U-Center software to load the self-locating and logging **Survey In** configuration template, as shown below, to the Base station's Zed-F9P (the GPS chip on the C099-F9P). Transport the Base station to each preliminary Base monument site. If you made the preliminary map discussed above, use the Qfield map to find the Base monument.



Once in the field, use the laptop, tablet or android phone's Bluetooth to link to the C099-F9P/Zed-F9P and use Ublox U-Center (Windows or linux), GPSD's UBX Tools (Linux), Udroid's ACenter or LeFebure's Ntrip (Android) to log the UBX messages for some hours. In the example here, this is done using the Android cell phone's Udroid application linked to the C099-F9P by Bluetooth. In practice, power up the Base station and give it five minutes or more before attaching to Udroid (etc.) to begin logging. The first minutes of observation records are too noisy and will add variance to the PPP solution.

Survey In Base Configuration Template

```
# Config changes format version 1.0
# created by u-center version 21.09 at 10:02:37 on Monday, 10 Jan 2022
[del]
[set]
  RAM CFG-UART1INPROT-NMEA 0
Flash CFG-UART1INPROT-NMEA 0
  RAM CFG-UART1INPROT-RTCM3X 0
Flash CFG-UART1INPROT-RTCM3X 0
  RAM CFG-UART1OUTPROT-UBX 0
Flash CFG-UART1OUTPROT-UBX 0
  RAM CFG-UART1OUTPROT-NMEA 0
Flash CFG-UART1OUTPROT-NMEA 0
  RAM CFG-UART1OUTPROT-RTCM3X 1
Flash CFG-UART1OUTPROT-RTCM3X 1
Flash CFG-UART1INPROT-UBX 0
  RAM CFG-UART1INPROT-UBX 0
  RAM CFG-MSGOUT-RTCM_3X_TYPE1005_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1005_UART1 0x1
  RAM CFG-MSGOUT-RTCM_3X_TYPE1074_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1074_UART1 0x1
  RAM CFG-MSGOUT-RTCM_3X_TYPE1084_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1084_UART1 0x1
  RAM CFG-MSGOUT-RTCM_3X_TYPE1124_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1124_UART1 0x1
  RAM CFG-MSGOUT-RTCM_3X_TYPE1230_UART1 0x5
Flash CFG-MSGOUT-RTCM_3X_TYPE1230_UART1 0x5
  RAM CFG-MSGOUT-RTCM_3X_TYPE1005_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1005_USB 0x1
  RAM CFG-MSGOUT-RTCM_3X_TYPE1074_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1074_USB 0x1
  RAM CFG-MSGOUT-RTCM_3X_TYPE1084_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1084_USB 0x1
  RAM CFG-MSGOUT-RTCM_3X_TYPE1124_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1124_USB 0x1
  RAM CFG-MSGOUT-RTCM_3X_TYPE1230_USB 0x5
Flash CFG-MSGOUT-RTCM_3X_TYPE1230_USB 0x5
  RAM CFG-MSGOUT-RTCM_3X_TYPE1094_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1094_UART1 0x1
  RAM CFG-MSGOUT-RTCM_3X_TYPE1094_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1094_USB 0x1
  RAM CFG-MSGOUT-UBX_NAV_PVT_USB 0x1
Flash CFG-MSGOUT-UBX_NAV_PVT_USB 0x1
  RAM CFG-MSGOUT-UBX_NAV_SVIN_USB 0x1
Flash CFG-MSGOUT-UBX_NAV_SVIN_USB 0x1
  RAM CFG-UART1-BAUDRATE 0x1c200
Flash CFG-UART1-BAUDRATE 0x1c200
Flash CFG-MSGOUT-UBX_RXM_RAWX_I2C 0x1
  RAM CFG-MSGOUT-UBX_RXM_RAWX_I2C 0x1
Flash CFG-MSGOUT-UBX_RXM_RTCM_I2C 0x1
  RAM CFG-MSGOUT-UBX_RXM_RTCM_I2C 0xa
Flash CFG-MSGOUT-UBX_RXM_SFRBX_I2C 0x1
  RAM CFG-MSGOUT-UBX_RXM_SFRBX_I2C 0x1
Flash CFG-MSGOUT-NMEA_ID_DTM_I2C 0xa
  RAM CFG-MSGOUT-NMEA_ID_DTM_I2C 0xa
Flash CFG-TMODE-MODE 1
  RAM CFG-TMODE-MODE 1
```

Flash CFG-TMODE-SVIN_ACC_LIMIT 0x9c40
RAM CFG-TMODE-SVIN_ACC_LIMIT 0x9c40
Flash CFG-TMODE-SVIN_MIN_DUR 0x3840
RAM CFG-TMODE-SVIN_MIN_DUR 0x3840

Repeat the above for each Base and collect UBX log files for all the Base station sites.

They all need a couple of weeks before the PPP services can fully correct the observations. You can run them through RTKLib's RTKConv (see below) to make the RINEX files from the UBX logs at anytime however.

Given the two week delay, now is a good time to collect all the deeds, make the title search and sort out any boundary issues with adjacent neighbors.

Office Work

A Note About Title Searches

Even if you intend to hire a professional surveyor, you can save money by making the title search yourself. It is often not hard, but it may take some time. Providing the professional surveyor with courthouse sourced copies of your deed, the currently adjacent deeds (these may reveal past subdivisions excised from your tract's original survey), plus the full chain of antecedent deeds that determine when the original surveys were made will save you the cost of having that search made by others. Surveyors need the first deed holding a germane survey so they can correct for changes in Magnetic North and convert any arcane methods to their modern equivalent. The legacy of adjacent deeds can determine prior subdivisions and establish boundaries based on those facts. If the facts are indeterminable, a dialog and agreement, amicable or adjudicated, between adjacent landowners is the only solution. By examining the deeds personally, you may make a better informed agreement with your neighbor.

This part starts with a trip to your local courthouse's Tax Office. There you can ask for the public records showing the Deed Book and Page for your deed and all the adjacent deeds surrounding yours. Note, however, that the tax records may not be up to date. Ask the adjacent neighbors to locate unrecorded subdivisions, unfiled or untaxed deeds. Next, go to the Courthouse Deed Room and copy each current deed. A camera works well with a bit of practice, but be sure to photograph the Deed Book and Page for each deed you copy and that the images you make are complete and clearly legible. If you are providing the deeds to others, you may want to make better copies. Any litigation might demand certified copies.

Where Was Magnetic North In The Original Survey

Now comes a time consuming part. In order to validate a survey that references Magnetic North, you **must know when** it was first made, and in order to determine if parcels have been previously subdivided from your deed, you must examine the history of the adjacent deeds, so don't leave the Deed Room yet. Read your deed and consider your dialog with the neighbors to decide if you need other deeds to determine the location of the boundary line (some deeds may say something like "And with the John Smith line to..."). For each of the germane deeds (ones that bear on your boundary descriptions), read each of them closely, starting with the most recent deeds and find the Deed Book and Page citation for each antecedent deed that a recent deed was derived from. If your deed claims a line defined by another landowner's property line, you'll need to track the legacy of the deeds for that adjacent line to find their original survey too. Some property's original survey might precede the construction of the county, and in that case, the original deeds will lie in another courthouse-the one from which your county was subdivided. Make copies as needed.

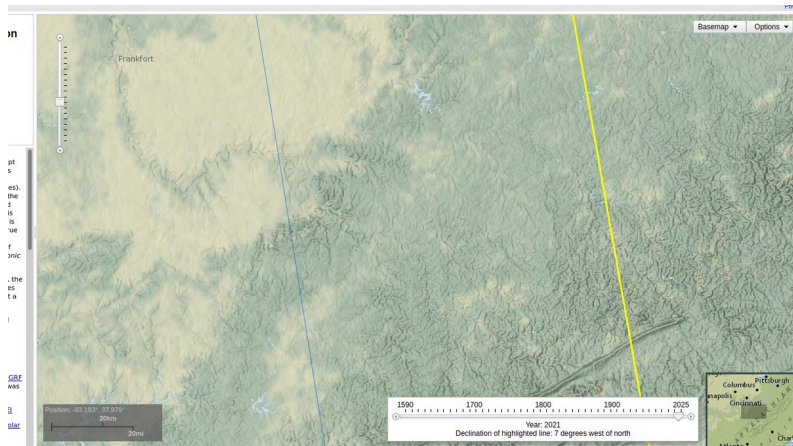
To find the original survey, pull an antecedent deed, and if it has the same set of survey calls and is not declaring that it is the original survey, find it's antecedent citation and pull the next (older) deed in the chain. Repeat this procedure and track each deed back until you find the original survey and it's date, however many deeds prior it might be.

If there's no explicit declaration that a new survey was made for a deed, the oldest deed that uses that list of deed calls is the original survey. For example, in this case study, surveys made in 1887 and 1904 were the basis for some of the current deeds, and there were several intervening deeds citing those survey calls.

Note the date of the original deed & survey. If your line is defined by some other adjacent landowner, do the same for their deed. Those dates will be the basis for determining the correct Magnetic North and the standards of measure used at the time of the original surveys.

Examine the adjacent deeds, track them back to when their or your deed's survey was made looking to see if they are subdivisions made from your tract.

It is a good idea to copy all the original deeds and their Deed Book and Page too, and, as well, all the intervening deeds to have a complete record of title and survey. File those deed copies in the ~/**Survey** folders as suggested above. You or your hired surveyor will need those records to accurately define the tract boundaries for the new survey.



Once you find the original surveys, use this NOAA web service to sort out the Magnetic North extant at the time of your surveys and the current

Magnetic North: https://maps.ngdc.noaa.gov/viewers/historical_declination/

Use the Magnetic North values from the website to reconcile and translate the descriptions in the original surveys with the current day orientation of Magnetic or True North.

Some details about deeds

Deeds of Correction and deeds from oneself may not require statements of valuation. Your locale may have different standards. You can, however, include them anyway to ease the filing clerk's mind.

States offer regulatory guidelines to surveyors, judges, and lawyers that rank the validity of deed calls. Typically geographically fixed objects like monoliths, rivers, or blue line streams supersede. Fixed objects like steel posts, USGS type benchmarks, or set stones are second best. Latitude/longitude references without a monolith or marker using only reported datums, projections and precision, or bearing and distance measures are next best. Combining a monolith/river etc with a bearing and distance or latitude/longitude measure is both common and effective. Writing a deed survey that offers century scale validity is best done with an eye to these rankings as many things won't last 100 years. Adding accurate Latitude and Longitude measures to a physical benchmark can hold up over time well. Deeds that only refer to a line as being defined by an adjacent landowner's deed or, for example, a fence, may prove ambiguous over time. Deed that cite calls to short lived objects like wooden stakes or most trees will also fail the test of time.

Rural deed surveys that declare the call described by a distance and bearing to be “near the Monument” don’t need centimeter-level accuracy, the GPS’d point need only reliably lead the next surveyor to the called durable locatable physical monument. The monument, not the GPS point, is the Call.

Projections and Geographic Reference Systems

Deed calls only described as a short (less than a mile) distance and bearing generally don’t require a full description of the map projection or the geographic coordinate system, but they do require a declaration of the North baseline: either “True North, or Magnetic North, and how the bearings are reported (Degrees, Minutes, Seconds vs Decimal Degrees, degree measures from 0-360, +- 180, etc). Calls that subtend longer runs may accumulate deviations leading to measurable errors and will require projection assignments. Positioning the set of distance and bearing vectors on a map with other features will require a coordinate system. For deeds that include a Latitude and Longitude as a call reference, you should declare the datum and the prime meridian and angular units that comprise your “geographic coordinate system” (GCS). The GCS reference establishes the 3D ellipsoidal approximation to the earth’s shape, something that begins to matter on larger scale measures.

Surveys that subtend large (more than a few miles/kilometers) distances will need the GCS projection details. Along with a GCS description, declare the “Projected Coordinate System” (PCS), often called the “State Plane”, that maps the GCS’ Latitude and Longitude as it is flattened down onto a 2D surface (e.g., paper, computer screen, etc.) The state plane (PCS) is generally declared in state statutes and regulations. These two systems are also commonly described with the Co-ordinate Reference System (CRS) value and the EPSG (European Petroleum Survey Group) table reference, both methods resolve the same issues of projecting a 3D location onto a 2D map.

The EPSG reference is commonly used in GIS. Each layer in a GIS map may have it’s own EPSG projection value. The GIS will resolve and fix the array of projections in the layers to make a corrected map. QGIS, for example, will use aerial photographs projected in WGS84(2020)/EPSG:4326 along with state proffered lines for rivers and districts using the state’s projections. QGIS can manage the projections to translate and present the rivers and districts (for example) correctly located on the aerial photograph.

Typical small scale boundary surveys may need those values to file a deed in your locale, but they don’t meaningfully change the reported bearing and distance call measures. Given that most property surveys are not large scale regions running over miles, the GCS and PCS/ CRS and EPSG state plane projections don’t impact the reported measures beyond fractions of inches and so reporting the deed calls as a text sequence of distances and bearings makes an excellent repeatable survey. Here anyway, only a licensed professional can file the graphic depiction, the “plat”, and they are well schooled in managing projections and state planes.

It may matter when resolving GNSS measures to a state plane, should those measures require accuracy on the scale of fractions of inches. There one can use the US or Canadian ITRF14(2022) lat/long/hgt “horizontal time dependent position” transformation tools. Viz: <https://www.ngs.noaa.gov/TOOLS/Htdp/Htdp.shtml> and the windows tool <https://www.ngs.noaa.gov/TOOLS/Htdp/HTDP-download.zip> However, “[Wolfgang R. Dick](#) at the German Federal Agency for Cartography and Geodesy says: ” There is [usually] no need to transform the ITRF2014 coordinates. ‘ITRF2014, ITRF2008 and WGS84 (G1674) are likely to agree at the centimeter level’, see

<https://confluence.qps.nl/qinsy/latest/en/international-terrestrial-reference-frame-2014-itrf2014-182618383.html> “.

Create a master file folder for the Base Station Calls, and subfolders for the log files.

This section makes files and directories for the recording, processing and archiving of the base monuments log files that need to be corrected. You can skip this and simply use your own file setups, it's just a suggested method. If you use this example, have a full list of the base stations you'll require and some way of naming them, those will compose the **calls** file described next.

If you are resurveying a boundary to verify it, you may also want to make **calls** file entries for that resurveyed deed just as you do for the Base stations. This file system also offers a uniform location for all the deeds you've copied.

Once you've read your deed, your adjacent neighbor's deeds, and all the other germane deeds including those documenting the history of the surveys, you can begin to construct the file folders and calls on the PC. Make a top level folder with a meaningful name, for example: **~/Survey**. Under that folder make new folders for your deed and the adjacent deeds. Name those folders with the landowner's name, the date of the deed, and the deed book and page of the deed, ie: **JohnSmith.2020.DB100P100** for a deed titled to John Smith filed in 2020 in Deed Book 100, Page 100. If needed, include the county name. The **MKcalls.sh** script (below) will make folders for the Base stations and deed calls listed in the **calls** file. The folders will hold the UBX logs, RINEX files, PPP reports and summaries for each Base station (and resurvey call if needed, and copies of deeds you collected from the Courthouse deed room).

If you have JPG or PDF copies of deeds, store those in their named folders. If you are resurveying and verifying a deed, you may want to create call text file entries for that deed (see above) to annotate a RTK surveyed monument with a reference to the original deed call.

Using this file structure make future reference to the archives straightforward.

The next paragraphs describe how to make a set of files and directories that break out each base station location call.

If not yet done, make the top level directory folder e.g., **~/Survey**. All the base stations call folders and subfolders will be placed under that directory. Within **~/Survey**, create a text file named **“calls”**. The **“calls”** file must contain a line for each base station (and maybe also call lines for a resurvey) you have surveyed. Each call line must start with **“call_# ”**. Replace the # with an integer (starting with 1) to enumerate the call. Note the blank after the **call#**, it is required. The remainder of the line is a description of the call, e.g., **“call_1 this is a description of the first Base Station call”** or **“call_10 this is the starting point for the resurvey, the steel post at the county road adjacent to John Doe's field”**.

Once a base station's observations are logged to UBX files, then, as detailed below, those files are converted to RINEX format, and the RINEX files are processed and corrected by CNRSPPP (Canadian Natural Resources) services to refine the Latitude and Longitude. Deed resurvey calls generally won't have any of the UBX, RINEX or PPP files, they just use this structure to help indicated calls that need to be resurveyed with the RTK Rover.

Once you've made the ~/Survey directory and the **calls** text file, run the **MKcalls.sh** script (shown below). Pass **MKcalls.sh** the full pathname of the ~/Survey folder where you want to construct the deed's base station call folders, and the number of base station call folders to create.

This script will parse the **calls** file then create and traverse the call subfolders, adding a text file, **description** to each that contains the text from the **calls** file describing that base station location call, and finally, making the RINEX and CNRSPPP directories that will contain the survey's UBX log file sourced RINEX files and the results from the PPP correction services for the Base station monuments, e.g.:

./MKcalls.sh ~/Survey 4

to make 4 subfolders under ~/Survey named call_1 through call_4.

An example "calls" file:

call_1 First Base: at a point on the County road comprising the corner between the J. Doe and J. Smith properties near a set stone,

call_2 Second Base: Approximately 150 yards from the small E/W draw marked with a set stone,

call_3 Third Base: A set stone marker situated about 50 yards beyond the power line,

call_4 Resurvey starting point, the set stone at the J. Doe and A. Smith corner

Count the calls contained in the file "call" (in the above example, 4), and from the ~/Survey directory, execute the script "MKcall.sh", listed below, as **MKcall ~/Survey 4**

Mkcall.sh, the BASH script to make the file folders

```
#####
# Usage: ./MKcalls Subfolder count
# e.g. ./MKcalls.sh ~/surveys/survey.DeedName.Date.DbxxPyy 10
#####
#!/bin/bash

declare -a call_folders          # bash arrays for text manipulation
OutFile="description.txt"
folder_name="call_"
Infile="$1/calls"
cd $1
echo `pwd`
tLen=$((2+1))
for((i=1; i<tLen; i=i+1));
do
    mkdir call_$i
done
# read calls file in <dir> and extract a description,
# copy description to call_x subfolder file "description"

printf "$Infile\n"
tree -f -i | grep $folder_name > ~/t1.txt
tr -d './' < ~/t1.txt > ~/t.txt          # cull ./
rm ~/t1.txt
cat ~/t.txt
readarray -t call_folders < ~/t.txt     #load tmp file records to array
rm ~/t.txt                               # clean up & delete tmp.
tLen="${#call_folders[@]}"               # get total # records loaded.
```

```

echo "$tLen"
for((i=0; i<tLen; i=i+1));
do
    echo "${call_folders[i]}"
    cd "${call_folders[i]}"
    echo `pwd`
    grep "${call_folders[i]}\s" "$Infile" > "$OutFile"
    cat $OutFile
    mkdir RINEX
    mkdir CNRSPPP
    cd ..
done
#####
#####

```

Once satisfied that the **calls** file and deed folder pathname are good run the “**MKcall.sh**” script with the fully qualified pathname of the directory with the calls file to process (as shown above) once.
e.g., **./MKcalls.sh ~/Surveys 4**

The example shown above will make 4 subfolders in the **~/Survey** directory titled **call_1** through **call_4**.

```

~/Survey
├── call_1
│   ├── CNRSPPP
│   ├── description.txt
│   └── RINEX
├── call_2
│   ├── CNRSPPP
│   ├── description.txt
│   └── RINEX
├── call_3
│   ├── CNRSPPP
│   ├── description.txt
│   └── RINEX
└── call_4
    ├── CNRSPPP
    ├── description.txt
    └── RINEX

```

Each subfolder holds a text file, **description.txt**, that has a single call derived from the text in the **calls** file in it. For example: the **call_1** directory’s **description.txt** file holds: “First Base: at a point on the County road comprising the corner between the J. Doe and J. Smith properties near a set stone”

As you proceed through the next sections, once you have made all the Base survey’s files and subdirectories, copy into each the UBX log file for the base, and once you’ve run that UBX file through **RTKLib**’s **RTKconv** to make the RINEX file, copy the RINEX file to the subdirectory’s RINEX folder. Once you submit the RINEX file to the PPP corrections website and gotten the PPP reports back, copy them to the CNRSPPP folder.

Once you have run the Base corrected RTCM values to the Rover and made the fixed RTK observations on the calls, if you are making a resurvey to validate a deed, copy any Solocated photographs to the call’s folder. If you are making a new boundary description, either make a

subfolder (e.g., NewSurvey) under ~/Survey, and copy the photos there, or place them in the ~/Survey folder.

The purpose of all the file structure detailed above is to make a systematic file name set for a survey's base stations. It is optional.

Process the log files.

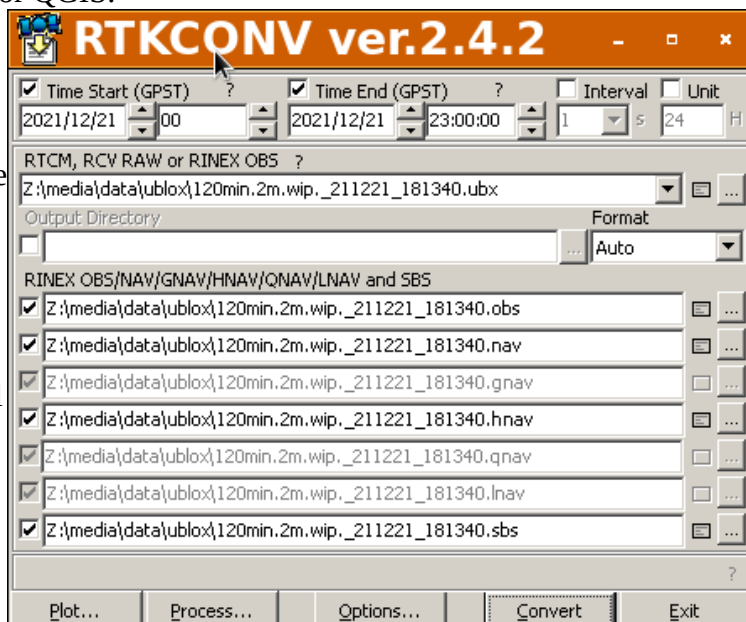
After making the log files of Base monument observations from the field, if you used a phone, laptop or tablet to log the UBX observations, retrieve the UBX file. For example, if you used an Android phone and Udroid ACenter, plug the phone in by USB cable and copy the **Android/data/com.droid.acenter/files/UBX_Log *.ubx** files to the PC you will use to run **RTKLib** (see below). For whatever device used to log the files, copy each session's files to their subfolder, e.g. ~/Survey/call_1. Copy any photos (e.g. **solocator** pictures of site & height) associated with the session to the subfolder as well. If recorded by hand, make a text file reporting the antenna height above ground as well. Together, these files constitute the entire record of observations for a PPP session: the RINEX formatted data are derived from the UBX file using RTKLib's **RTKConv** routine and the PPP corrected files will be stored in the CNRSPPP directory when they are corrected and reported, some weeks hence. Later all the subfolders with a PPP summary file will be added to a point layer for QGIS.

RTKLib: UBX log files → RINEX

RTKLib is a free toolset for GNSS observation files. The “**Demo_b43e**” release (<https://github.com/rtklibexplorer/RTKLIB/releases/tag/b34e>) currently supports the C099-F9P/Zed-F9P well. The only tool needed to convert UBX logged data to the RINEX format is **RTKConv**. **RTKLib** is a windows application that generally runs well under Linux with **wine**.

Copy the UBX log file from the Android/Windows/Linux tablet/phone to the machine running RTKLib. In this example,

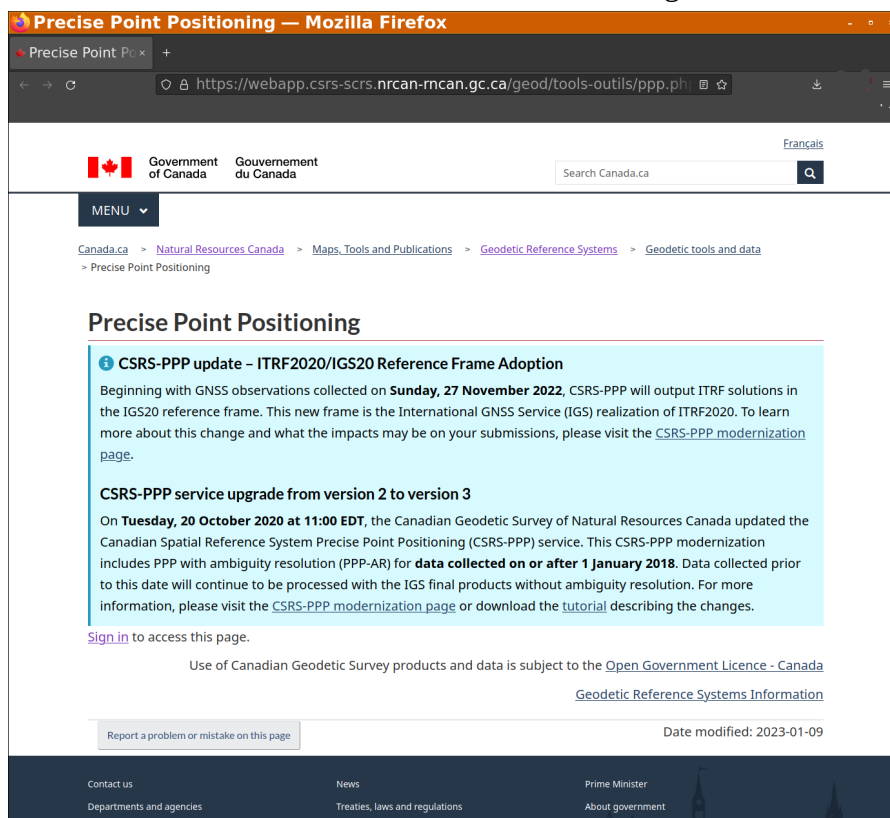
that would be the Android phone running Udroid/Acenter that was linked to the C099-F9P during the base survey (see above). Launch **RTKLib** and run the **RTKConv** conversion tool. Select the UBX log file to convert. **RTKConv** will make the RINEX files from the logged UBX RAWX & SFRBX messages. The conversion tool will make the RINEX OBS, NAV and SBS files with the same name as your source UBX log file in the same directory as the log file. Copy the **.obs**, **.nav** & **.sbs** files made by **RTKConv** to the base station's RINEX subfolder (see the suggested file structures above). Make a bundled archive of those three files with zip (windows) or gzip (linux) tool in the RINEX subfolder. The zip file is what you'll send to the Canadian Natural Resources website for PPP corrections.



Submit the RINEX file for PPP Corrections

Days or weeks after logging the observations to a UBX file, converting the UBX observations to RINEX and zipping them as described above, submit the RINEX folder's zip/tgz file to <https://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php>, the Canadian PPP correction service site. On your first visit, you'll need to create an account, but it is free and asks nothing more than a name, a return email address, and a password. If after signing in, you are not on the URL listed

above, simple re-enter it to see the PPP page. From the PPP page, select the **Static ITRF processing mode**, then click on the **Browse** button below the “RINEX Observation Files and select your zip file to send. Then click on **Submit to PPP**. If you have more zip files to process, repeat the above and submit all the files. When done quit the web site. Some minutes/hours after you submit the RINEX files for PPP corrections, you will get an email with a link to the “**full_output.zip**” file attached. Use your browser to download the zip file. This file contains the post-fixed observations for the base station. It includes a detailed description and summary of the results, and a PDF file reporting the precise point (PPP) location and estimates of the accuracy and precision. The summary file (*.sum), once copied to the survey folders, is used by the automation scripts to provide the CSV file for QGIS to make a shape file layer and to provide the ECEF X,Y, Z values for U-Center to make the Base station’s fixed location configuration file.



Expand the “**full_output.zip**” file returned from the CNRS PPP website to the subfolder you’ve set up (see above) for the base station. Save each SUM (summary) file from the zip files to their respective call’s subfolder e.g. ~/Desktop/survey1/call_1

For more information on post-processing, viz:

<https://rtklibexplorer.wordpress.com/2019/08/24/dual-frequency-ppk-solutions-with-rtklib-and-the-u-blox-f9p/> , <https://trimblertx.com/Home.aspx> , <https://docs.emlid.com/reachrs/tutorials/post-processing-workflow/ppp-introduction/#ppp-services-overview> , <https://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php>

Ready the PPP Corrected files and run the BASH script PPP2CSV.sh

This step is Linux only, other OS’ must extract the summary data by hand. This step both transfers the precise location of the base station’s monuments to QGIS, and prepares the records needed to make the C099-F9P/Zed-F9P Base Station configuration files. The configuration files are used to set up the Base so it can issue the Real Time Correction Measures to the RTK Rover while it makes the boundary survey. As well, the script makes the Comma Separated Value (CSV) text file of the Base Station positions to import to QGIS as a map layer of points. That map of Base station PPP

locations can then export to Qfield and guide you to the Base station monuments for the RTK survey with the Rover.

When ready to setup the PPP corrected Base station location needed for the RTK Rover survey, open a command line console and change to the top directory in the deed folder (i.e.: ~/Survey) then invoke the Bash shell script below, **PPP2CSV.sh**

The three files made by **PPP2CSV.sh** offer the values extracted from the PPP summary reports returned from the Canadian web site. The first file, **PPP.csv**, can be directly added to a QGIS layer as described below. The second file, **FixedBaseLLH.txt** offers the Decimal degree values for Latitude and Longitude and the Height Above Ellipsoid returned from each PPP Base station file. The last file, **FixedBaseECEF.txt**, provides the X, Y, & Z ECEF values in meters.

Do not store the **PPP2CSV.sh** script file in the survey folder (~/Survey) or it's subfolders, it will confuse the results. A good location is ~/Documents.

All **.sum** files within the folder (e.g., ~/Survey) and it's subfolders will have their corrected Latitude and Longitude values extracted and added to the file **PPP.csv**. This file is made in the same directory used to launch **PPP2CSV.sh**. QGIS will add a delimited map layer directly from the **PPP.csv** file showing a PPP location point for each Base monument.

The **PPP2CSV.sh** routine also makes the **BaseFixList.txt** file that contains a line for each PPP Base Station surveyed. A line will show the CNRS PPP summary (**.sum**) source file and the PPP corrected decimal Latitude and decimal Longitude.

PPP2CSV.sh also makes the file **FixedBaseECEF.txt** needed to construct the PPP fixed Base Station configuration files in U-Center for running the Base Station as a Fixed Base for the RTK rover sessions. This file is the source for all the fields needed to set the Base to it's PPP located monument so it will offer the RTK correction fixes to the Rover for your final boundary survey.

PPP2CSV.sh, the BASH script to prepare the PPP Base station configuration

```
#!/bin/bash
#####
#
# Extract CSV Lat/Long strings to ~/PPP.csv from Corrected PPP positions
# from summarized UBX->RINEX Zed-F9P observation messages (UBX-RAWX, UBZ-SFRBS)
# processed by Canadian Dept of Natural Resources (CNRS) RINEX L1/L2
# website: https://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php
#
# This routine also computes the decimal degree Lat/Long value for each .sum file
# and reports them in ~/BaseFixList.txt, and makes a list of the ECEF X,Y,& Z
# values for U-Center to configure Fixed Base locations, reporting them in
# the file FixedBaseECEF.txt
#
# The summarized PPP LAT LON records are returned in *.sum files contained in
# the "full_output.zip" file returned by CNRS.
#
# From a directory, this routine will traverse all subdirs and find
# all .sum files and from them extract the Station name and
# the refined LAT/LON then saving them as a CSV for QGIS or spreadsheet.
#
# Once the CSV file is written, you can quit or continue and
# choose to archive the .sum files. You are offered the
# file suffix .bak or to rename the summary files to remove them
# from subsequent runs (ie: to make different QGIS layers
#
# NB: /tmp is presumed RW accessible scratch directory. Revise as needed.
#
# Usage: ./PPP2CSV.sh
#
# WSH 20220121
```

```

#
#####

#####
function MakeSumBax
#####
{
# offer to suffix a string to the filename, e.g. ".bak" | ".Base"
# to remove the PPP locus from the CSV by renaming the file type
declare -a vex4
echo -n " To use default .bak, press ENTER, or enter new file suffix for .sum files ==> "
read suffix
if [ "$suffix" != "" ]; then
    NewSuffix=$suffix
fi
echo "#####"
echo "# Renaming all .sum files in subfolders to .sum$NewSuffix"
echo "#####"

tree -f -i | grep sum >/tmp/t.txt
readarray -t vex4 < /tmp/t.txt                #load tmp file records to array
rm /tmp/t.txt                                  # clean up & delete tmp.
tLen=${#vex4[@]}                               # get total # records loaded.
echo "#!/bin/bash" >/tmp/sum2bak.sh
for((i=0; i<tLen-1; i=i+1));
do
    printf 'mv %s %s' "$NewSuffix\n" ${vex4[i]} ${vex4[i]} >>/tmp/sum2bak.sh
done
echo "--==-- sh routine to make bak files ==--=="
cat /tmp/sum2bak.sh

echo -n "Continue? Enter Y/N"
read -s -n1 MakeBax
echo $MakeBax
if [ "$MakeBax" == "Y" ]; then
    /bin/bash /tmp/sum2bak.sh
    rm /tmp/sum2bak.sh
    exit 0
fi
rm /tmp/sum2bak.sh
unset vex4
}

#####
function MakeFixFile
# Compute decimal degree Lat/Long from values extracted from CNRS PPP summary files
#####
{
InFile=/tmp/t3.txt                                # /tmp/t3.txt from main routine, $OutFile
OutFixFile="FixedBaseLLH.txt"
SumPos=".sum:POS,"
PastSumPos=0;NextPos=0;CutLen=0;StrLength=0;Tmp0Str="";
Tmp1Str="";Tmp2Str="";Tmp3Str="";Tmp4Str="";Tmp5Str="";Tmp6Str="";LatDG=0;LatMin=0;LatSec=0;LongDG=0
;LongMin=0;LongSec=0;
declare -a CSV_Line

echo -n "" > $OutFixFile
if [ "$#" -gt 0 ]; then
    InFile=$1                                     # assign a new input file name
fi
# Read the CSV file made from PPP2CSV.sh
readarray -t CSV_Line < $InFile                    # load CSV file records to array
tLen=${#CSV_Line[@]}                               # get total # records loaded.
for((i=0; i<tLen; i=i+1 )); do                     # For each line:
    Tmp4Str=${CSV_Line[i]%%,*}                     #delete from right up to first
    SumPos=${#Tmp4Str}                               # length up to first ","
    Tmp6Str=${Tmp4Str/:POS/ }                       # print the dir name + 2 spaces
    printf "$Tmp6Str " >> $OutFixFile
    Tmp5Str=${CSV_Line[i]:SumPos}
    printf "${Tmp5Str:1:1}" >> $OutFixFile            # print 1 char LatSign
    LatDG=${Tmp5Str:2:2}                             # snag 2 chars to LatDG &
    Tmp1Str=${Tmp5Str:6:2}                             # snag 2 chars to LatMin
    LatMin=`bc <<< "scale=12;$Tmp1Str/60"`           # compute decimal LatMin
    Tmp2Str=${Tmp5Str:9:9}
    LatSec=`bc <<< "scale=12;$Tmp2Str/3600"`         # compute decimal LatSec
    Tmp0Str=`bc <<< "scale=12; $LatDG+$LatMin+$LatSec"`
    printf "$Tmp0Str " >> $OutFixFile                # print decimal DG lat
}

```

```

    Tmp3Str="${Tmp5Str:29}" # substring with just LongDD MM SS
, stderr & a 0
    printf "${Tmp3Str:1:1}" >> $OutFixFile # print 1 char LongSign
    LongDG="${Tmp3Str:2:2}" # snag the DG
    Tmp2Str="${Tmp3Str:6:4}" # snag Min
    LongMin=`bc <<< "scale=12;$Tmp2Str/60"` # compute decimal LatMin
    Tmp2Str="${Tmp3Str:10:8}" # snag last 7 chars to LongSec
    Tmp7=( $Tmp3Str ) # Make an array- the () from the
string
    Tmp3Str=${Tmp2Str// } # cull the ,
    LongSec=`bc <<< "scale=12;$Tmp3Str/3600"` # compute decimal LatMin
    Tmp0Str=`bc <<< "scale=12; $LongDG+$LongMin+$LongSec"`
    printf " $Tmp0Str" >> $OutFixFile # print decimal DG lat
    printf " ${Tmp7[4]// } \n" >> $OutFixFile # print the 4rth word with the
commas culled
done
echo
echo "==== Decimal Lat/Long/Hgt (m above Ellipsoid), written to:" $OutFixFile "===="
cat $OutFixFile
unset CSV_Line
rm /tmp/t3.txt
}

```

```

#####
# Routine to extract ECEF from .sum files
#####
function XtractECEF
{
declare -a ECEFvex1
declare -a ECEFvex2
declare -a ECEFvex3
declare -a ECEFvex4
ECEFOutFile="FixedBaseECEF.txt"

grep -r -e "POS X" -e "POS Y" -e "POS Z" ./* >/tmp/t.txt # For all subfolder files
containing "POS X | POS Y | POS Z",
readarray -t ECEFvex1 < /tmp/t.txt # load tmp file records to array
rm /tmp/t.txt # clean up & delete tmp
tLen="${#ECEFvex1[@]}" # get total # records loaded
for((i=0; i<tLen-1; i=i+3 )); do # by 3s make new tmp file
    printf "\n" >/tmp/t.txt # start with newline
    printf "${ECEFvex1[i]} ${ECEFvex1[i+1]} ${ECEFvex1[i+2]}" >/tmp/t.txt # concatenate line
& next line & next line
done
printf "\n" >/tmp/t.txt # suffix final double quote to tmp
IFS=' ' # delimit by spaces to make fields within records
readarray ECEFvex2 < /tmp/t.txt # gather the joined ECEF E Y Z
rm /tmp/t.txt # clean up & delete tmp
printf "' '%s' ${ECEFvex2[@]} >/tmp/t2.txt # prefix " " to t2 tmp's X Y Z line
cut -b 4- /tmp/t2.txt > /tmp/t.txt # ~/PPP.csv
readarray ECEFvex3 < /tmp/t.txt # load tmp file records to array vex3
tLen="${#ECEFvex3[@]}" # get total # records loaded to array
rm /tmp/t.txt # clean up & delete tmp
rm $ECEFOutFile # delete prior PPP.csv, begin new file
rm /tmp/t2.txt # clean up and delete t2 tmp
IFS=' ' # delimit by spaces to make fields within records
for((i=1; i<tLen; i=i+1 )); do # skip line 0, make new tmp file
    Tmp1Str=${ECEFvex3[i]}
    Tmp2Str=${ECEFvex3[i]%'/*'}
    SumPos=${#Tmp2Str} # get length of string up to first ","
    Tmp5Str=${ECEFvex3[i]:SumPos}
    printf "$Tmp2Str $Tmp5Str" > /tmp/t2.txt
done
IFS=' ' # delimit by spaces to make fields within records
# awk '{print $1, $6, $15, $25}' /tmp/t2.txt >/tmp/t1.txt # snag the dir & the correct X Y
Z ECEF values
awk '{print $1, $7, $16, $26}' /tmp/t2.txt >/tmp/t1.txt # snag the dir & the correct X Y
Z ECEF values
tr -d '"' < /tmp/t1.txt | sort > "$ECEFOutFile" # cull double quotes
rm /tmp/t2.txt # clean up and delete t2 tmp
rm /tmp/t1.txt
echo
echo "==== ECEF X Y Z values (meters) were written to $ECEFOutFile "===="
cat "$ECEFOutFile" # show the product
echo ""
unset ECEFvex1
unset ECEFvex2
unset ECEFvex3
unset ECEFvex4

```



```
}
```

```
#####  
# Main Routine to make CSV strings from .sum files  
#####
```

```
declare -a vex                                # bash arrays for text manipulation  
declare -a vex2  
declare -a vex3  
declare -a vex4  
declare -a vex5  
declare -a vex6  
  
MakeBax="F"  
NewSuffix=".bak"  
OutFile="PPP.csv"  
  
clear  
if [ "$#" -gt 0 ]; then  
    OutFile=$1                                ## assign a new output file name  
fi  
grep -r -e "POS LAT" -e "POS LON" -e "POS HGT" ./ * >/tmp/t.txt    # For all subfolder files  
containing "POS LAT | POS LON",  
  
    readarray -t vex < /tmp/t.txt              # cut all of file but for LAT & LON to tmp file  
    rm /tmp/t.txt                             # load tmp file records to array  
    tLen="${#vex[@]}"                         # clean up & delete tmp  
    for((i=0; i<tLen-1; i=i+3 )); do           # get total # records loaded  
        printf "\n\n" >>/tmp/t.txt             # by 2s make new tmp file  
        printf "${vex[i]} ${vex[i+1]} ${vex[i+2]} " >>/tmp/t.txt    # start with newline  
        printf "${vex[i]} ${vex[i+1]} ${vex[i+2]} " >>/tmp/t.txt    # concatenate line & next line  
    done  
    printf "\n\n" >>/tmp/t.txt                 # suffix final double quote to tmp  
    IFS=' '                                    # delimit by spaces to make fields within records  
    readarray vex2 < /tmp/t.txt                # gather the joined LAT LON  
    rm /tmp/t.txt                             # clean up & delete tmp  
    printf '"', "${vex2[@]}" >>/tmp/t2.txt      # prefix ", " to t2 tmp's LAT LON line  
    cut -b 4- /tmp/t2.txt > /tmp/t2.txt        # ~/PPP.csv  
    readarray vex3 < /tmp/t2.txt              # load tmp file records to array vex3  
    tLen="${#vex3[@]}"                       # get total # records loaded to array  
    rm /tmp/t2.txt                           # clean up & delete tmp  
    rm $OutFile                              # delete prior PPP.csv, begin new file  
    rm /tmp/t2.txt                           # clean up and delete t2 tmp  
    for((i=1; i<tLen; i=i+1 )); do            # skip line 0, make new tmp file  
        printf "${vex3[i]}" >> /tmp/t2.txt  
    done  
  
    awk -F, < /tmp/t2.txt > /tmp/t.txt ' { A[NR]=$1; B[NR]=$8; C[NR]=$9; D[NR]=$10; I[NR]=$12;  
F[NR]=$21; G[NR]=$22; H[NR]=$23; K[NR]=$25;  
    printf "%s,%s %s %s, %s, %s %s %s, %s,%s, 0 \\  
n",A[NR],B[NR],C[NR],D[NR],I[NR],F[NR],G[NR],H[NR],K[NR],$33}'  
    rm /tmp/t2.txt                           # clean up and delete t2 tmp  
    tr -d '"' < /tmp/t.txt > /tmp/t3.txt      # ~/PPP.csv  
    awk -F/' ' '{print $2 " ",}' /tmp/t3.txt >/tmp/t1.txt          # cull double quotes  
    # snag the dir & the correct X Y Z ECEF values  
    # snag the dir & the correct X Y Z ECEF values  
    awk -F,' ' '{print $2 " ", $3 " ", $4 " ", $5 " ", $6 " ", $7}' /tmp/t3.txt >/tmp/t2.txt    #  
    readarray -t vex5 < /tmp/t1.txt           # load tmp file records to array  
    readarray -t vex6 < /tmp/t2.txt           # load tmp file records to array  
    rm /tmp/t1.txt                           # clean up & delete tmp  
    rm /tmp/t2.txt                           # clean up & delete tmp  
    tLen="${#vex5[@]}"                       # get total # records loaded  
    echo -n "" >$OutFile  
    for((i=0; i<tLen; i=i+1 )); do            # by 2s make new tmp file  
        printf "${vex5[i]} ${vex6[i]}\n" >>$OutFile    # concatenate line & next line  
    done  
    echo  
    echo "==== CSV LAT/LONG/HGT (m above Ellipsoid) values were written to $OutFile ====="  
    cat "$OutFile"                          # show the product  
    rm /tmp/t1.txt  
    unset vex                                #clean up, delete old arrays  
    unset vex2  
    unset vex3  
    unset vex4  
    unset vex5  
    unset vex6  
  
echo  
MakeFixFile                                # make the file decimal lat long for u-center
```

```

echo
XtractECEF

echo -n "Rename *.sum files to .sum.bak, removing them from future CSVs made by this routine Y/N ==>
"

read -s -n1 MakeBax
echo $MakeBax

if [ "$MakeBax" == "Y" ]; then
    MakeSumBax
    exit 0
fi

exit 0
#

#####

```

Notes about **PPP2CSV.sh**:

- * To remove the current PPP results from subsequent runs, accept the option to rename the CNRS PPP Summary (.sum) files. You probably don't need to do that.
- * To preserve an isolated set of PPP stations in QGIS, rename and save the shapefile layer that you make from the PPP.csv file, and as above, remove the CNRS PPP Summary files from the main folder & subfolders by running **PPP2CSV.sh** and saying Y when prompted (see example below).
- * Adding more PPP summary files to ~/Survey folders after a prior run will yield new PPP points added to the PPP.csv shapefile layer. Import that CSV file to QGIS to see all the old and new points.

Results From An Example **PPP2CSV.sh** Run

```

===== CSV LAT/LONG values were written to PPP.csv =====
base1.corn.crib, 31 36 31.45431, 0.0078, -81 33 44.09996, 0.0101, 0
base2.hillcrest.above.cliff, 31 36 46.67245, 0.0324, -81 33 57.76764, 0.1142, 0
base3.field, 31 36 50.01585, 3.1530, -81 34 0.14130, 4.3205, 0
base5.Black.Oak.1878, 31 36 29.95913, 0.0229, -81 33 44.80795, 0.0441, 0
base6.below.hill.crest, 31 36 29.60136, 0.0450, -81 33 55.36449, 0.0609, 0
base7.sawmill, 31 36 19.20606, 0.0071, -81 33 57.24993, 0.0073, 0
base8.above.Smith, 31 36 12.26743, 0.0609, -81 34 0.63410, 0.1889, 0

===== Decimal Lat/Long, written to: FixedPosList.txt =====
./base1.corn.crib/CNRS.PPP/2022-01-10_10-16-18.sum 31.643131324999 -81.562249988888 255.2841
./base2.hillcrest.above.cliff/CNRS.PPP/2022-01-11_11-36-35.sum 31.646297902777 -81.566046566666
269.7046
./base3.field/CNRS.PPP/2022-01-25_13-13-55.sum 31.647226624999 -81.566705916666 257.8526
./base5.Black.Oak/CNRS.PPP/2022-01-12_11-44-03.sum 31.641655313888 -81.562446652777 244.6521
./base6.below.hill.crest/CNRS.PPP/2022-01-13_08-59-07.sum 31.641555933333 -81.565319025000
253.7715
./base7.sawmill/CNRS.PPP/2022-01-13_13-00-06.sum 31.638668549999 -81.565902758533 231.9357
./base8.above.Smith/CNRSPPP/2022-01-23_10-36-36.sum 31.636740952777 -81.566842805554 254.8169

===== ECEF X Y Z values were written to FixedBaseECEF.txt =====
base1.corn.crib 561994.8433 -5024995.3031 3674361.4847
base.2.hillcrest.above.cliff 561646.7054 -5024874.3080 3674607.7932
base.3.field 561578.4459 -5024804.7328 3674670.6117
base5.Black.Oak.1878 561989.0578 -5025127.4121 3674175.3168
base6.below.hill.crest, 561736.7556 -5025169.2899 3674174.8151
base7.sawmill, 561712.6362 -5025352.4310 3673908.0063
base8.above.Smith, 561650.9882 -5025509.6340 3673153.6310

```

Rename *.sum files to .sum.bak, removing them from future CSVs made by this routine Y/N ==>

The PPP summary has the data to configure the Fixed Base

The Fixed Base text files made by **PPP2CSV.sh** are used to set values in the Ublox **U-Center Advanced Configuration View** to configure the Base station. See the examples below. The text file values can be pasted into the U-Blox U-Center configuration dialogs to set up a Fixed Base. Choose whether to assert the Fixed Base as an ECEF or an LLH setup. They are essentially

identical in practice, though the ECEF is less confusing in terms of height measures. The ECEF values in **FixedBaseECEF.txt** are expressed in meters.

U-Center expects centimeters for the ECEF values, not meters, so shift the decimal right two columns.

When referring to the examples below, note that you will copy all but the last two digits from each ECEF measure and paste those digits into the X, Y, & Z fields, then copy the last two digits from each ECEF measure and enter them as the High Precision (mm) ECEF values. **If present, include the minus sign in both the X,Y and Z centimeter values and their High Precision (millimeter) fields.** See the **Construct F9P Fixed Base files for each of the Base Monuments** sections (ECEF and LLH) below for examples.

Invoke QGIS and Add New Layer with the PPP.csv file made above.

Skip this section if you are not using QGIS, and instead proceed directly to the next discussion of how to make the ECEF Fixed Base station configuration files.

To begin, QGIS will import the CSV file made by **PPP2CSV.sh** for the PPP fixed Base location's Lat/Long & feature name. Use the **Add Layer/ Delimited Text** dialog from the main menu in QGIS to add the points from the CSV file made by the script above to a new QGIS shapefile layer.

Open the project you want to add the new layer to (likely your Qfield project) and add a layer from the PPP corrected points in the CSV file made above:

- * Choose Delimited text, and assign the input file **PPP.csv** (see **PPP2CSV.sh** above)
- * Checkmark the DMS field.
- * Assign the Longitude to the X Field, Latitude to the Y Field, and altitude to the Z Field.
- * In order to not overwrite an old map layer (if you've already added some Base station PPP locations to a map layer) with the new PPP Layer, rename the old PPP QGIS layer.
- * Accept the above and create the new layer "PPP", save the project, and exit.

In general, you can make repeated **PPP2CSV.sh** runs. Each time, all CNRS PPP Summary pages under the starting folder & subfolders will be read and assigned to the PPP.csv file. You can remove the summary files when prompted by the script to rename them if you want distinct map layers for different groups, but usually you don't. Re-import the CSV layer to include the new features. If you have retained all the **.SUM** files in **~/Survey** (as in the examples) each re-run will include them, so you may want to overwrite the PPP map layer rather than rename and save it.

Once you have created all the PPP locations for the Base Stations as a QGIS map layer, construct the Qfield project and make the export files then copy them to the field tools: typically the Android phone or tablet (see the Qfield documentation for the details). Once you complete the next step to make the Base station configuration files and load them to the Base C099-F9P, you are ready to finally RTK survey the boundary survey.

To be clear, you don't need Qfield or QGIS to make the Base Station configuration files, those only require the **FixedBaseECEF.txt** file (or LLH file) made by the script shown above and detailed below or extracted by hand from the Canadian processed summary text files. If you do not use Qfield, you will have to both find your own way back to the Base station monuments and hand capture the locations of each call monument in your final survey.

Construct F9P ECEF Fixed Base files for each of the Base Monuments.

Use the PPP summary results extracted by the **PPP2CSV.sh** generated **FixedBaseECEF.txt** file to construct an ECEF fixed base configuration for each Base monument you've received PPP summary files for. The configuration file is passed to the C099-F9P using the Ublox U-Center program, see below, and it sets up the Base Station so that when you return to the Base Monument's location and run the C099-F9P from there, it will send real time correction messages (RTCM) to the Rover. When the Rover gets its location "fixed" by the RTCMs sent from the PPP located Base, the Rover gains the same accuracy as the PPP Base, within a couple of centimeters (or less). Make a separate configuration file for each Base Station monument.

The template listed below has a large error value for the accuracy (low accuracy) setting. It is a bit arbitrary, it is used only in some reporting and has no real impact on the accuracy or precision of the C099-F9P Base PPP and Rover RTK location measures. If you should want a different value (i.e.: the error measure returned by the CNRS PPP report), load the template file in U-Center's Advanced Configuration and assign the new measure and revise your template to that value, then save the template file. Next you must hand edit the saved text file and move the **CFG-TMODE-FIXED_POS_ACC** RAM and Flash settings to the same location as shown in the template text below. **The templates below have a strict order, don't rearrange the configuration order without expecting some trouble.** The configurations will fail without showing any error messages, they just won't send RTCM values from Base to Rover. Again, Do Not Change The Order Of The Settings In The Configuration File!

There is a second alternative configuration template for Fixed LLH setups offered below.

Copy each fixed base configuration file to the subfolder assigned to that monument and name the text file with that same name. Load each fixed base file in U-Center and then transfer it to the Base station's C099-F9P/Zed-F9P to use that fixed location in the field for the RTK.

Copy and paste the template example below to a plain text file. Use the Ublox U-Center to import the text file and then suffix the Latitude and Longitude measures from the **FixedPosList.txt** to the template file, then save the configuration file and also upload it to the C099-F9P/Zed-F9P. Make a separate configuration file for each line (each Base Station PPP monument) in the **FixedPosList.txt** file.

Example Base Station PPP configurations.

First, launch **U-Center.exe**, invoke **View/Generation 9 Advanced Configuration View/Advanced Configuration** from the main menu and click **Load From File**, then select and load the file basic template shown below.

As previously stated, the order of the settings below must be preserved. Failing that will cause the Base to not send RTCM fixes to the Rover.

NB: Make sure to always set the Fixed Mode CFG values before setting the ECEF/LLH values. If you get those settings out of order, the configuration will fail and the Base will not offer RTCM values to the Rover. Again, the MODE, POS TYPE and FIXED POS ACC values must be set before the location values.

A Fixed Base ECEF Configuration Template

```
[del]
[set]
```


RAM CFG-TMODE-MODE 2
Flash CFG-TMODE-MODE 2
RAM CFG-TMODE-POS_TYPE 0
Flash CFG-TMODE-POS_TYPE 0
RAM CFG-TMODE-FIXED_POS_ACC 0x1f4
Flash CFG-TMODE-FIXED_POS_ACC 0x1f4
RAM CFG-UART1INPROT-NMEA 0
Flash CFG-UART1INPROT-NMEA 0
RAM CFG-UART1INPROT-RTCM3X 0
Flash CFG-UART1INPROT-RTCM3X 0
RAM CFG-UART1OUTPROT-UBX 0
Flash CFG-UART1OUTPROT-UBX 0
RAM CFG-UART1OUTPROT-NMEA 0
Flash CFG-UART1OUTPROT-NMEA 0
RAM CFG-UART1OUTPROT-RTCM3X 1
Flash CFG-UART1OUTPROT-RTCM3X 1
Flash CFG-UART1INPROT-UBX 0
RAM CFG-UART1INPROT-UBX 0
RAM CFG-MSGOUT-RTCM_3X_TYPE1005_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1005_UART1 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1074_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1074_UART1 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1084_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1084_UART1 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1124_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1124_UART1 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1230_UART1 0x5
Flash CFG-MSGOUT-RTCM_3X_TYPE1230_UART1 0x5
RAM CFG-MSGOUT-RTCM_3X_TYPE1005_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1005_USB 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1074_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1074_USB 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1084_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1084_USB 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1124_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1124_USB 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1230_USB 0x5
Flash CFG-MSGOUT-RTCM_3X_TYPE1230_USB 0x5
RAM CFG-MSGOUT-RTCM_3X_TYPE1094_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1094_UART1 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1094_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1094_USB 0x1
RAM CFG-MSGOUT-UBX_NAV_PVT_USB 0x1
Flash CFG-MSGOUT-UBX_NAV_PVT_USB 0x1
RAM CFG-MSGOUT-UBX_NAV_SVIN_USB 0x1
Flash CFG-MSGOUT-UBX_NAV_SVIN_USB 0x1
RAM CFG-UART1-BAUDRATE 0x1c200
Flash CFG-UART1-BAUDRATE 0x1c200
Flash CFG-MSGOUT-UBX_RXM_RAWX_I2C 0x1
Flash CFG-MSGOUT-UBX_RXM_RTCM_I2C 0x1
Flash CFG-MSGOUT-UBX_RXM_SFRBX_I2C 0x1
RAM CFG-MSGOUT-UBX_RXM_RAWX_I2C 0x1
RAM CFG-MSGOUT-UBX_RXM_RTCM_I2C 0xa

RAM CFG-MSGOUT-UBX_RXM_SFRBX_I2C 0x1
Flash CFG-MSGOUT-UBX_NAV_HPPOSLLH_I2C 0x1
RAM CFG-MSGOUT-UBX_NAV_HPPOSLLH_I2C 0x1
Flash CFG-MSGOUT-NMEA_ID_DTM_I2C 0xa
RAM CFG-MSGOUT-NMEA_ID_DTM_I2C 0xa

Next, while still in the U-Center Advanced Configuration, find the + **CFG-TMODE** line in the list shown in the middle panel and click on the + to expand and show the **TMODE** options.

Click on the **CFG-TMODE-ECEF_X** option, and in the **Selected Configuration Item** dialog (top right panel) paste the X value (in meters) copied from the **FixedBaseECEF.txt** file for the base you are setting up. Shift the decimal two digits to the right to make centimeters and leave off the last 2 digits, those go next as high precision (HP) X values. Click the **Set in RAM** button and the **SET in Flash** button.

NB: When entering the HP values, be sure to apply the same sign as the X,Y, or Z setting. So if the Y is a negative value, set the pair of HP digits to be negative as well.

Click on the **CFG-TMODE-ECEF_X_HP** option, and in the **Selected Configuration Item** dialog (top right panel) paste the last two digits of the X value from the **FixedBaseECEF.txt** file for the base you are setting up. Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **CFG-TMODE-ECEF_Y** option, and in the **Selected Configuration Item** dialog (top right panel) paste the Y value from the **FixedBaseECEF.txt** file for the base you are setting up. As before, shift the decimal two digits to the right to make centimeters and leave off the last 2 digits, those go next as high precision Y values. Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **CFG-TMODE-ECEF_Y_HP** option, and in the **Selected Configuration Item** dialog (top right panel) paste the the last 2 digits of the Y value from the **FixedBaseECEF.txt** file for the base you are setting up. If the Y value is negative, include the sign with the two digits. Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **CFG-TMODE-ECEF_Z** option, and in the **Selected Configuration Item** dialog (top right panel) paste the Z value from the **FixedBaseECEF.txt** file for the base you are setting up. Again, shift the decimal two digits to the right to make centimeters and leave off the last 2 digits, those go next as high precision Z values. Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **CFG-TMODE-ECEF_Z_HP** option, and in the **Selected Configuration Item** dialog (top right panel) paste the the last 2 digits of the Z value from the **FixedBaseECEF.txt** file for the base you are setting up. Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **Save To File** button (third panel down on right, next to the **Load From File** button). Paste the filename copied from the **FixedBaseECEF.txt** line you've used for the X, Y, & Z ECEF values and suffix ".base.txt" to the filename. Save the configuration file to the directory of that same name, e.g., ~/Survey/call_1/call_1.base_cfg.txt .

Make a Base station configuration file for each base listed in **FixedBaseECEF.txt**. While still in the Ublox U-Center Advanced Configuration dialog, click the **Clear List** button, reload the basic template file (above) and repeat the Base Station setup for the next line in **FixedBaseEXEF.txt**

until all the Base Station configuration files are done. Quit U-Center once you've finished making the configuration files.

NB: You can replace the discussion above about using ECEF measures returned by the CNRS PPP report with instead using Latitude, Longitude, and Height measures should you prefer them. They are effectively the same thing, describing an exact location. To use the LLH (Latitude, Longitude, Height) values for the Fixed Base, use the template and instructions below. Skip this section if you want to use the ECEF method detailed above.

A Fixed Base LLH Configuration Template

[del]

[set]

```
RAM CFG-TMODE-MODE      2
Flash CFG-TMODE-MODE     2
RAM CFG-TMODE-POS_TYPE  1
Flash CFG-TMODE-POS_TYPE 1
RAM CFG-TMODE-FIXED_POS_ACC 0x64
Flash CFG-TMODE-FIXED_POS_ACC 0x64
RAM CFG-UART1INPROT-NMEA 0
Flash CFG-UART1INPROT-NMEA 0
RAM CFG-UART1INPROT-RTCM3X 0
Flash CFG-UART1INPROT-RTCM3X 0
RAM CFG-UART1OUTPROT-UBX 0
Flash CFG-UART1OUTPROT-UBX 0
RAM CFG-UART1OUTPROT-NMEA 0
Flash CFG-UART1OUTPROT-NMEA 0
RAM CFG-UART1OUTPROT-RTCM3X 1
Flash CFG-UART1OUTPROT-RTCM3X 1
Flash CFG-UART1INPROT-UBX 0
RAM CFG-UART1INPROT-UBX 0
RAM CFG-MSGOUT-RTCM_3X_TYPE1005_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1005_UART1 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1074_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1074_UART1 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1084_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1084_UART1 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1124_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1124_UART1 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1230_UART1 0x5
Flash CFG-MSGOUT-RTCM_3X_TYPE1230_UART1 0x5
RAM CFG-MSGOUT-RTCM_3X_TYPE1005_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1005_USB 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1074_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1074_USB 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1084_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1084_USB 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1124_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1124_USB 0x1
RAM CFG-MSGOUT-RTCM_3X_TYPE1230_USB 0x5
Flash CFG-MSGOUT-RTCM_3X_TYPE1230_USB 0x5
RAM CFG-MSGOUT-RTCM_3X_TYPE1094_UART1 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1094_UART1 0x1
```

RAM CFG-MSGOUT-RTCM_3X_TYPE1094_USB 0x1
Flash CFG-MSGOUT-RTCM_3X_TYPE1094_USB 0x1
RAM CFG-MSGOUT-UBX_NAV_PVT_USB 0x1
Flash CFG-MSGOUT-UBX_NAV_PVT_USB 0x1
RAM CFG-MSGOUT-UBX_NAV_SVIN_USB 0x1
Flash CFG-MSGOUT-UBX_NAV_SVIN_USB 0x1
RAM CFG-UART1-BAUDRATE 0x1c200
Flash CFG-UART1-BAUDRATE 0x1c200
Flash CFG-MSGOUT-UBX_RXM_RAWX_I2C 0x1
Flash CFG-MSGOUT-UBX_RXM_RTCM_I2C 0x1
Flash CFG-MSGOUT-UBX_RXM_SFRBX_I2C 0x1
RAM CFG-MSGOUT-UBX_RXM_RAWX_I2C 0x1
RAM CFG-MSGOUT-UBX_RXM_RTCM_I2C 0xa
RAM CFG-MSGOUT-UBX_RXM_SFRBX_I2C 0x1
Flash CFG-MSGOUT-UBX_NAV_HPPOSLLH_I2C 0x1
RAM CFG-MSGOUT-UBX_NAV_HPPOSLLH_I2C 0x1
Flash CFG-MSGOUT-NMEA_ID_DTM_I2C 0xa
RAM CFG-MSGOUT-NMEA_ID_DTM_I2C 0xa

Next, while still in the U-Center Advanced Configuration, find the + **CFG-TMODE** line in the list shown in the middle panel and click on the + to show the **TMODE** options.

Click on the **CFG-TMODE-LAT** option, and in the **Selected Configuration Item** dialog (top right panel) paste the X value from the **FixedBaseLLH.txt** file for the base you are setting up (shift the decimal two digits to the right to make centimeters and leave off the last 2 digits, those go next as high precision X values). Click the **Set in RAM** button and the **SET in Flash** button.

NB: When entering the HP values, be sure to apply the same sign as the LAT, LON, HGT setting. So if the LON is a negative value, set the HP digits to be negative as well.

Click on the **CFG-TMODE-LAT_HP** option, and in the **Selected Configuration Item** dialog (top right panel) paste the last two digits of the X value from the **FixedBaseLLH.txt** file for the base you are setting up. Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **CFG-TMODE-LON** option, and in the **Selected Configuration Item** dialog (top right panel) paste the Y value from the **FixedBaseLLH.txt** file for the base you are setting up (shift the decimal two digits to the right to make centimeters and leave off the last 2 digits, those go next as high precision Y values). Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **CFG-TMODE-LON_HP** option, and in the **Selected Configuration Item** dialog (top right panel) paste the last 2 digits of the Y value from the **FixedBaseLLH.txt** file for the base you are setting up. Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **CFG-TMODE-HEIGHT** option, and in the **Selected Configuration Item** dialog (top right panel) paste the Z value from the **FixedBaseLLH.txt** file for the base you are setting up (shift the decimal two digits to the right to make centimeters and leave off the last 2 digits, those go next as high precision Z values). Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **CFG-TMODE-HEIGHT_HP** option, and in the **Selected Configuration Item** dialog (top right panel) paste the last 2 digits of the Z value from the **FixedBaseLLH.txt** file for the base you are setting up. Click the **Set in RAM** button and the **SET in Flash** button.

Click on the **Save To File** button (third panel down on right, next to the **Load From File** button). Paste the filename copied from the **FixedBaseECEF.txt** line you've used for the X, Y, & Z ECEF values and suffix ".txt" to the filename. Save the configuration file to the directory of that same name.

Quit **U-Center.exe** once you've made all the configuration files for the Base stations used in your upcoming survey.

You will need to later run U-Center again for each Base Station monument to load the PPP located Base Station configuration file to the Base C099F9P/Zed-F9P before heading to the Base Station monument and running the station to send the correction messages to the Rover to make the RTK survey.

Field Work, 2nd Pass: the RTK Rover Survey

If you plan to use Qfield, run QGIS to make the Qfield project with the PPP located Base station layer and shapefile layer with the editable description field for the RTK located Boundary Calls. The text field will permit you use Qfield to add a description of the boundary monument in the field as you take the location measures. You may also want to add a layer you make by hand in QGIS that sets the estimated points you want to survey as a guide to finding the boundary calls in the field. Solocator is very handy too, allowing you to include a geolocated photograph of the boundary monument timestamped with the Latitude and Longitude overlayed on the photograph. If you use QGIS, you can add those photographs to the boundary.

To begin the final RTK survey, use **U-Center** to load the correct fixed base configuration file (made above) for a Base monument (e.g., ~/Survey/call_1/call_1.base_cfg.txt) to the C099-F9P/Zed-F9P Base Station.

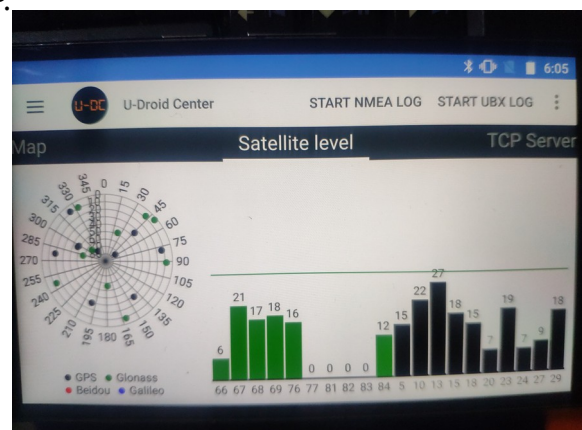
If you are re-surveying, you will need to find the location of the calls as described by the deed, if a new survey description, use locations that effectively detail the boundary.

Place the Base Station at the PPP monument location, start the Rover

Set the Base Station C099-F9P/Zed-F9P tripod directly over the PPP located monument. If height is important, set the C099-F9P antenna to the same exact height as used to make the UBX logged survey. Power up the Base station and in a few (5-10) minutes it will begin to offer RTCM values. Power up the Rover and after about 5 minutes the yellow RTCM LED on the C099-F9P should flash and then soon after, remain lit indicating that the Rover is receiving RTCM fixes and can now report RTK locations with nearly the same accuracy as the PPP located Base, and you are now ready to finally survey the boundary. Udroid ACenter will also report the reading as Fixed (vs float).

Make a bluetooth connection to the Rover's C099-F9P. If you are using QGIS, launch Qfield, otherwise plan to hand copy the Rover's Latitude and Longitude position: either use U-Center on the laptop, or Udroid Acenter, or LeFebure NTrip on the android phone attached to the rover at each monument call.

With the android phone and Udroid Acenter/LeFebure Ntrip set to the "mock location", begin the boundary survey. The photo application (the standard camera app set to record location or Solocator) will use the



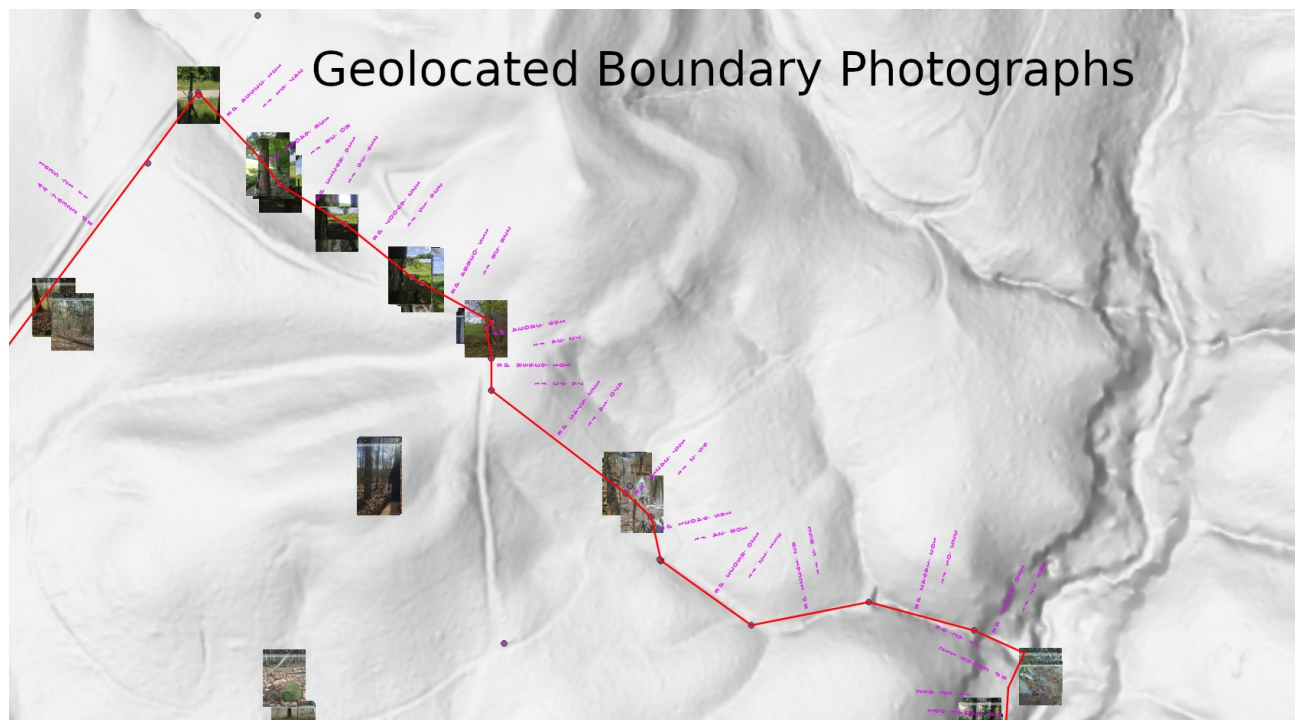
location of the Rover to geoposition pictures of the monuments. Solocator will embed the location into the image itself.

Udroid Acenter will report the fix/float condition, or you can inspect the Rover's yellow LED and see if it is flashing (float) or a solid yellow (fixed). The fixed state is the accurate one, float measures are only good to about four feet. You will lose the fix when the Base is out of radio range from the Rover- a brief wait may bring the fix, or you may need more Base PPP locations.

In Qfield, the Rover's fixed (or float) RTK location will appear and show your position on the map. From Qfield, first invoke the Settings menu and select the shape file layer you created for the boundary calls, the one with the Description field you can edit. Set that layer as shown on the map and set it to edit. Now, as you use Qfield to add a new point to the layer, you can compose a text description for that boundary call. If you are not using Qfield, record the descriptions by hand. As you survey the deed calls feature at each point called for in the deed photograph the monument with Solocate, and if using Qfield, add a point and description. Be sure you are still seeing a solid yellow LED lamp indicating the RTCM messages are being received. You may need to pause at a location for minutes until the LED stays lit. If the LED is not a solid Yellow, you are getting "float" precision which is far less accurate-note that float condition in the text description in Qfield or your handwritten notes. Take the Rover to each deed call and while the RTK (solid yellow) LED is lit, add that new point to the boundary. If you cannot maintain the solid yellow fix, consider adding more Base Stations (adding the PPP logging and delays described above).

If you made a map layer showing the preliminary calls, use Qfield to show the preliminary layer to guide you to the deed's called location, then add your new boundary point.

Proceed to boundary call point and do it again, until all calls are surveyed. Move the Base station and take as many sessions as needed to complete the full survey.



A Note About RTK Precision vs PPP

Using the Ublox C099-F9P gear for the Base and Rover, the RTCM fixed Rover location reading is accurate to within a couple of centimeters plus whatever error range the Base station has. A PPP located Base with good line of sight to the GNSS constellation of satellites can achieve accuracy on the scale of one or two centimeters. This accuracy degrades with conditions-obstructions blocking the view, few satellites in view, short UBX logging sessions, radio frequency reflections that confound the receiver (Multipath errors), etc.

If you need better accuracy (millimeter scale) in your location measures, you can log the Rover's UBX messages for an RTK surveyed point, like you did for the Base stations, for later PPP correction and authentication by the Canadian government. However, Kinetic accuracy is not quite as good as a fixed Base Stationary PPP measure. A corrected RTK measure may not suffice, and you'll need to treat the point as a PPP Base station, and log the UBX records then process them as described above like a Base station to get the most accurate location.

Skip the step discussed next and just go to the second pass/office work discussion below if the RTCM fixed RTK measures have all the accuracy that you need. What follows describes how to correct the Rover's RTK UBX logs like the Base, something you not likely to do.

Broadly: leave Qfield and launch Ucenter (or use a PC laptop/tablet with Ublox U-Center). NB: as noted above, the Rover's "kinetic" positioning model is not stationary and may be trouble. Use bluetooth to connect to the Rover's C099-F9P and use the Ucenter Log UBX button to capture UBX observations for the location and leave the Rover stationary at that point for minutes to hours. If height is important, measure and record the height of the antenna above ground. Note the starting time for logging to later associate the surveyed points with the boundary call. Log the NMEA and UBX files for some minutes/hours. Once done, return to Qfield. Take Solocator photographs to validate the location and recording session. Treat the UBX logs like a Base Station Monument as described earlier. First locate the UBX records in a text editor for the time interval you logged, and copy just those records and, like a Base Station, submit them to the CNRS PPP website- **use the "Kinetic" model, not the "Static" for the PPP survey**. You will get the same summary report as with a Base Station that offers a measure of the accuracy. Likely, you will never need or want to do this. NB: If you want the most precise location measure, just treat the position as if it was a Base Station and use the methods detailed above for setting a Base Station PPP monument, they yield better accuracy than the RTK model.

Office Work, 2nd Pass, calculate by hand or use QGIS

Using Handwritten Records

If you recorded the Rover's call monument locations by hand, organize the boundary calls in the order you'll cite them in the deed. Find a Distance and Bearing calculator that accepts Latitude and Longitude measures on the web, or compute the measures by hand, and construct the list of starting, intermediate and end points and the bearings and distances between them from the start to the finish. Use those locations and measures to describe the tract in your deed. If you are not using QGIS, skip down to the Writing The Deed section below.

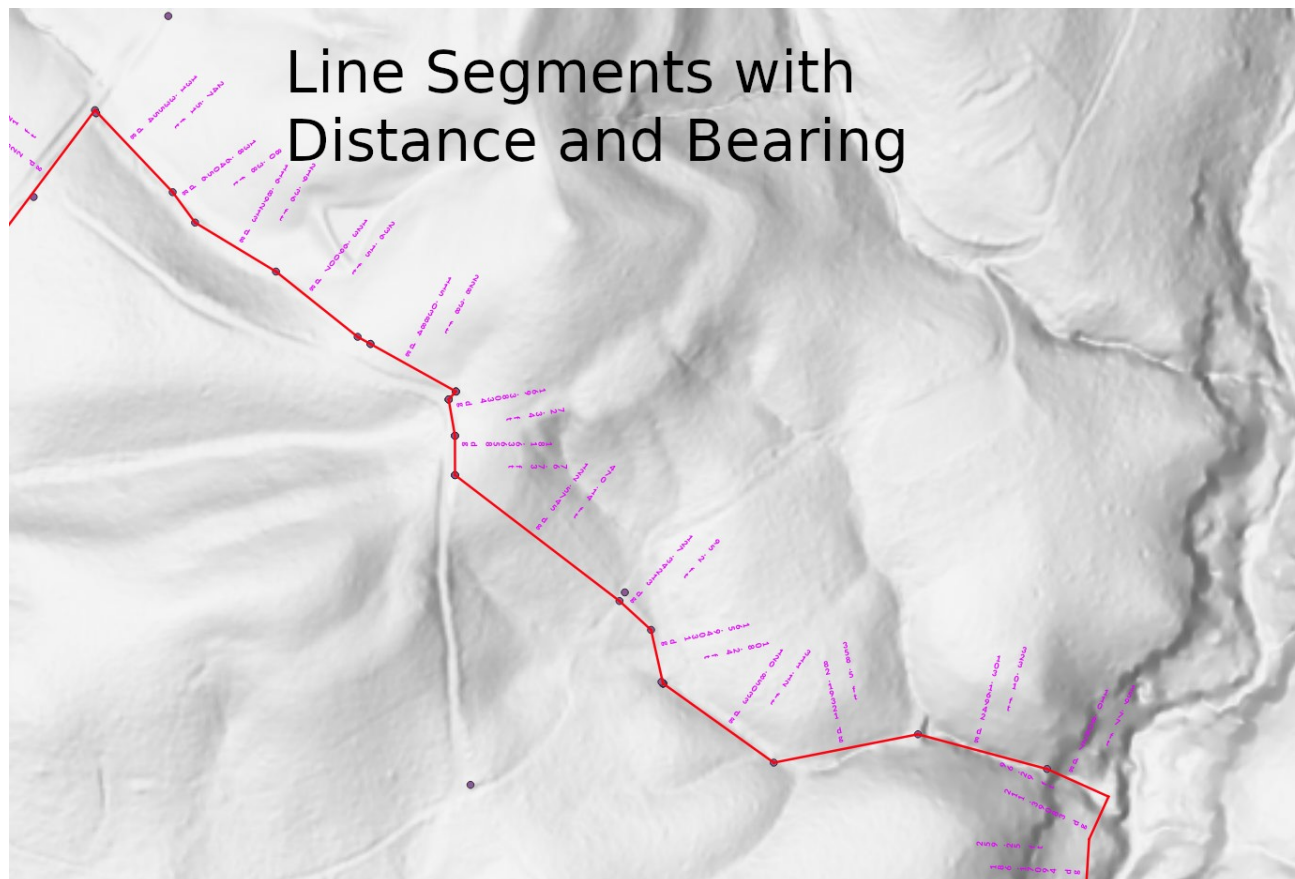
Describing the Boundary With QGIS

What is detailed here is how to use Qfield and QGIS to make the map, boundary line, and calculate the bearing and distance from call to call.

Import the Qfield survey layers back to the QGIS project on the PC. That requires copying the Qfield project files from the phone/tablet to the PC running QGIS then using the Qfield plugin in QGIS to bring in the new data. You also just open the Qfield project in QGIS, sometimes that works better than merging the QGIS project with the Qfield project. Make several backups of the survey files, they are a permanent record of the survey that needs to endure.

The next step follows each line segment in the deed calls, one by one, to capture the bearing and distance from call to call.

The first discussion below speaks to managing records from more than one shapefile source- if you have all your measures in one QField map layer, skip to Making the Boundary Shapefile below.



You can merge GPS point layers if you have more than one shapefile holding boundary points. To do that, from the QGIS Main Menu, select Vector/Data Management Tools/Merge Vector Layers. Click the three dots [...] button to the right of the “Input Layers” field and select the layers to merge. Assign a meaningful name to the merged layers in the “Merged” field- you can use the [...] button to the right of that field to select a directory and file name for the merged shapefile. Click the Run button to make the merged layer.

If you need to consolidate values from fields within the merged individual point features, (for example, if different Qfield sessions had assigned text descriptions to different fields), use the Field Calculator and create a new field called, for example “Combined”. As an example, to merge the Latitude, Longitude, fields 1 through 3 and a label field into a single string useful for assigning the monuments to a call, assign the expression ‘Lat: ‘ + to_string(\$y) + ‘Long: ‘ + to_string(\$x) + ‘ + “field_1” + ‘ + “field_2” + ‘ + “field_3” + ‘ + “label”

To use QGIS to report the vectors as length and bearing, open layers for all the surveyed calls made either from Qfield or the PPP CSV file, e.g. the merged layer described above.

Making the Boundary Shapefile in QGIS

Now that all the surveyed boundary locations are shown as points in a QGIS map layer, save the project and decide on the exact path and call sequence for the deed description. The order that you next create the lines in QGIS from point to point will determine the order and direction from call to call.

Enable Snapping on All Layers. Set the Snapping Tolerance to 12 pixels (adjust to suit). Snapping to All Layers also allows you to describe a line that follows both the GPS points and natural features like rivers (if you have included a rivers line layer or the like).

It is useful to have two instances of QGIS running for this step, but not essential. If you can, open the saved project in a second copy of QGIS. The second instance will let you view the attributes of a GPS point and also view images associated with a point (if you add them as described below)- this aids in selecting the exact GPS point during the line construction described next.

Use Ctrl-S often to save the project while doing this procedure, QGIS can block after a while so it's best to write the file to storage often. If QGIS seems to hang, just save and close the project and QGIS then restart.

From the Layer Menu pulldown, select **Create Layer/New Shapefile Layer** and name it with something like **deed.boundary.line** (pick any meaningful name). Set the **Geometry Type** to **LineString** and click **OK**. Select the new layer as the Active Layer and toggle Editing on by clicking the **Pencil** icon in the menu bar. Click on the **Add Line Feature** icon (or press **Ctrl+.**) in the menu bar. Choose your starting point for your deed description and move the cursor to where it snaps to that GPS point. Left click once to start the boundary line. Carefully move the mouse from boundary point to boundary point by snapping to each point in the exact sequence you will make in the deed description and left click on the point to add to the boundary line.

You can use the mouse wheel to zoom in and out and you can pan left/right up/down with the keyboard arrow keys. If you have a second instance of QGIS running, you can query a point for a photograph or description without interrupting the boundary construction.

Repeat this procedure for all calls to close the boundary and once snapped to the original starting point, right click to end the line.

Toggle editing off and save the layer. Save the project with the **Main Menu Project/Save** or with **Ctrl-S**.

With the deed boundary line layer you just created still selected, click on the **Processing** icon in the menu bar and select the **Processing Toolbox**. Click on the toolbox search field and key in **explode**, then click on the **Vector Geometry/Explode Lines** option. The deed boundary line layer should be listed in the **Input Layer** dialog, choose it from the pulldown list [...] if it is not. Click on the [...] to the left of the **Exploded** field. Choose **Save to File** and select the destination directory and key in **deed.boundary.line.annotated.shp** (or any meaningful name you prefer that ends with **.shp**). NB: the layer will be named with the string left of the first dot, e.g., from above, "deed". Use underscores or CamelCase to apply the full name to the new layer. Click on the **Run** button to make a new boundary layer with a single line segment from each GPS point to the next- these lines now have the length and bearing needed to make the standard survey text description of distance and bearing. Close the **Processing Toolbox**.

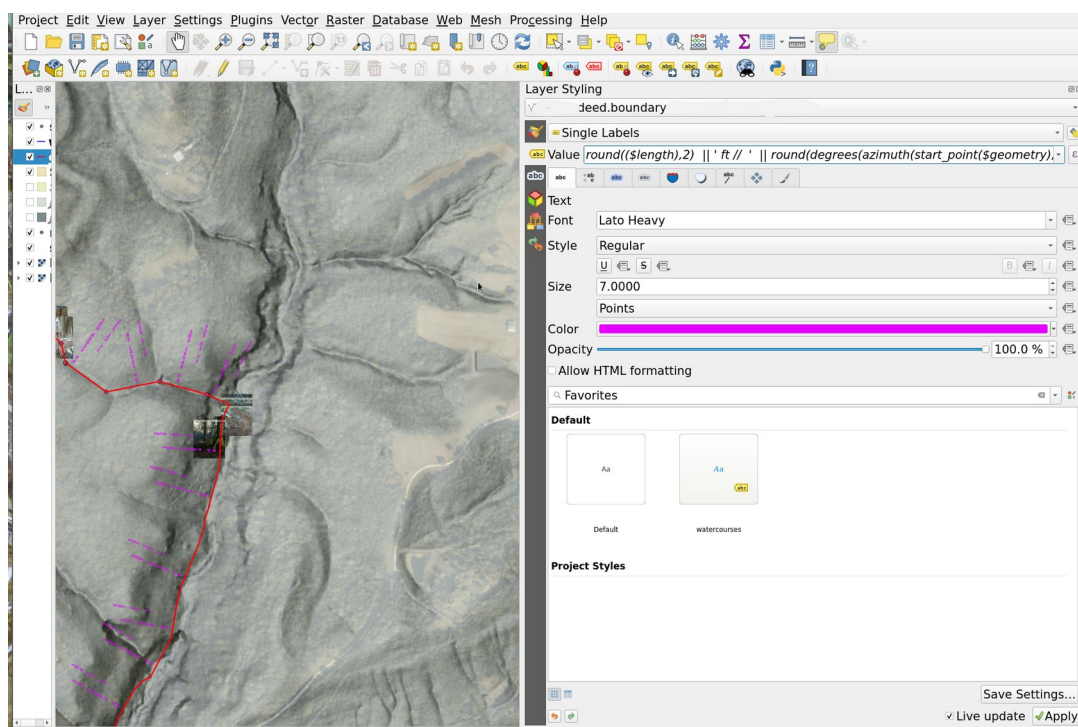
To label each line segment with its length and bearing, with the new exploded line layer still selected, click on the **Layer Labeling Options** icon in the menu bar. The **Layer Styling** dialog will come up with the exploded and annotated deed boundary line listed as the current layer. Click on the second field in the dialog and choose **Single Labels**. Click in the **Value** field.

This next relation assumes the map's **length** units is set to meters and you want to present the distances in feet. Adjust the formulas to suit if this is not the case.

In the value field key in **round(((((\$length*100)/2.54)/12),2) || ' ft // ' || round(degrees(azimuth(start_point(\$geometry),end_point(\$geometry))),5) || ' dg '**

Click on the **abc** tab and set the font and size. A monotype font at 14 points will work. Choose a color if the default black is unsuitable. Click on the **+ab<c** tab and set the **Text Orientation** to **Vertical** and **Wrap on Character** to **"/**". Click on the **Live Update** check box at the bottom of the dialog and click the **Apply** button. Close the **Layer Styling** panel. Save the project.

Zoom in on the boundary line to see the labels assigned to each exploded line segment. The labels won't display until you zoom in enough.



You can export the bearing, distance and starting point of each exploded line segment to a text file. For the first two fields, while it's easiest to re-open the **Layer Labeling Options** dialog and copy the value field you'd already entered above and paste parts of that string, you can instead simply key in the strings as shown below.

To create the text file, add new fields to the layer to hold the bearing, distance, and starting point's Latitude and Longitude. To add the fields to the **deed.boundary.line.annotated.shp** line layer, select the layer (as above) and click on the **Field Calculator** button (the abacus icon) in the Main Menu. From the calculator dialog, choose **Create New Field**, and assign the field a name in the **Output Field Name**.

Create each of the four fields separately. The bearing, distance, and starting point's Latitude and Longitude fields are all of field type **Decimal Number (real)**. Choose a length of 13 for the Latitude/Longitude with a precision of 8. A length of 12, precision 4 should suffice for the distance and bearing values.

Assign the Output Field Name **Bearing** for the bearing field. Assign the type, length, and precision as described above. Click into the **Expression** box and key in (or paste)

round(degrees(azimuth(start_point(\$geometry),end_point(\$geometry))),2)

Now the **Preview** in the bottom right should show the computed bearing. The blue arrow right of the **Feature** field above the **Preview** will step through the lines and show you the computed bearing for a line segment. When satisfied that the calculations are correct, click **OK** to make the new field and assign the computed bearings.

Next, again click the **Field Calculator** button and assign the Output Field Name **Distance** for the distance field. Assign the type, length, and precision as described above. Click into the **Expression** box and key in **round((((length*100)/2.54)/12),2)** then click **OK**.

Again click the **Field Calculator** button and assign the Output Field Name **LongiStPt** for the longitude of the starting point field. Assign the type, length, and precision as described above. Click into the **Expression** box and key in **round(x(start_point(\$geometry)),8)** then click **OK**.

And finally, again click the **Field Calculator** button and assign the Output Field Name **LatiStPt** for the latitude of the starting point field. Assign the type, length, and precision as described above. Click into the **Expression** box and key in **round(y(start_point(\$geometry)),8)** then click **OK**.

Toggle off editing for the layer and save the layer and the project.

When done, you'll have the complete list and map of the deed boundary calls reported as a starting point and the sequence of line segments labeled with their distances and bearings displayed from the **deed.boundary.line.annotated.shp** layer. The attribute table for that layer also contains the **Bearing, Distance, LongiStPt** and **LatiStPt** of the starting point for each line segment. Finally, export that layer as a Comma Separated Value (CSV) formatted file.

Click on the Main Menu's **Layer** button and select **Save As**, select the **CSV** format and choose a file name and location for the Comma Separated Value text file. The CSV file has text strings of each of the fields you created above: bearing, distance, LongiStPt and LatStPt. Once you save the CSV file you can open it in any text editor or spreadsheet to cut and paste or report those values for the written deed.

If you are re-surveying a tract to validate the deed's description, you now have the precise locations measured and can compare your survey to the extant deed. In that case, you are done with the survey work. If you are revising the boundary, adding or removing subdivisions etc, you will write a new deed.

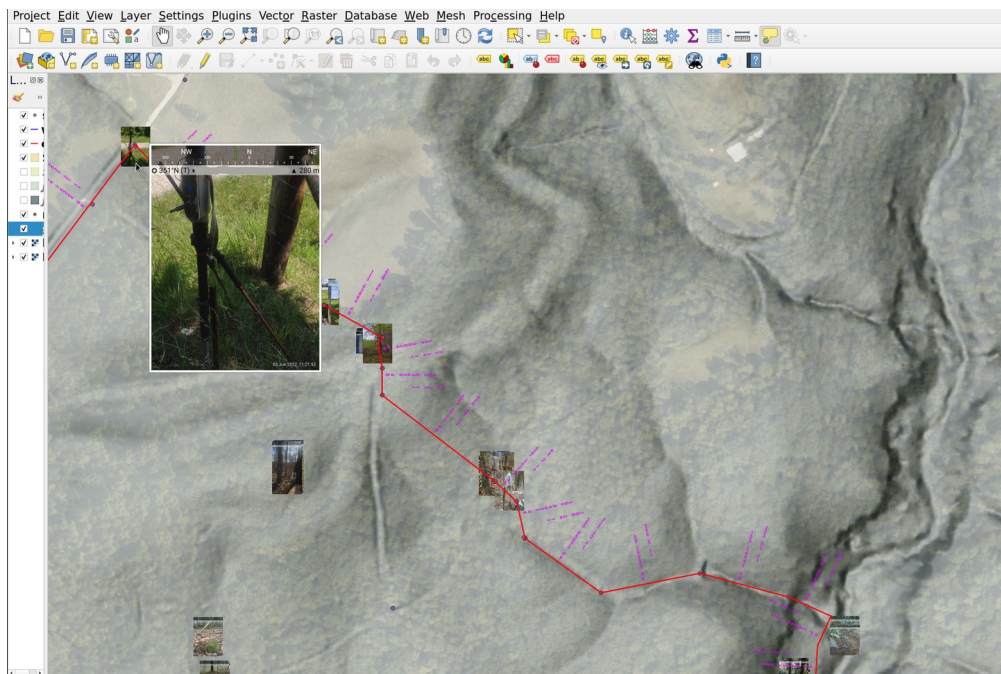
For a new deed you will need to add a description of the called monument/point to each call. Either using the CSV file as is, or in a new text file, cut and paste the distance, bearing, latitude, longitude, and description of each call as detailed below.

To use the text descriptions recorded in the Qfield survey, open the CSV file you just created in an editor or spreadsheet. From QGIS, select the GPS point layer (e.g. **Merged**) that holds the descriptions you entered when you used Qfield and the Rover to survey the boundary points. Click on the **Identify Features** icon (or **Ctrl-Shift-I**) and find the first GPS point in your survey. Click on that point and the data source(s) for the point will be listed. You may need to click on **Show Attribute Table** (or Show Merged). Find the **Description** field, then left click in the field to focus on it, then right click and choose **Copy Cell Content** (or **Copy Attribute Value**, whichever is shown). The **Combo** field example above holds the Latitude, Longitude and Description label values, if you made that field. Otherwise use the uncombined fields. Compare the Latitude and Longitude between the GPS point (e.g., the Qfield shapefile **Merged** layer calls) and the CSV file values to assure the Qfield based text field matches the boundary point and that your deed description is accurate.

You may have geolocated photographs, as described below, to confirm and better describe the monument being surveyed. Click on the photograph layer and hover the mouse over the point of interest to see the image and validate and refine the text description, then click back on the GPS layer (Merged) to continue.

Repeat for each boundary call listed in the CSV file to make a text file with all the calls' distance, bearing, latitude, longitude and description in the boundary path order for the deed.

You now have a text file of all the sequential calls needed to file the deed. Reporting the monument description, the Latitude, Longitude, and it's bearing and distance from the preceding monument call provides the statutory methods accepted for a deed call and makes finding the monument and the boundary envelope easy for a re-survey. Edit the list of calls to conform to the local format for a deed and save the file. Copy that file into the text of the deed to describe the boundary.



Displaying Geolocated photographs on the map with QGIS

Consolidate all the photographs you want to display into a single directory. Launch QGIS and open the project with your map and survey layers. From the main menu, select the **Processing/Toolbox/Vector Creation/Import Geotagged Photos**. From the dialog, select the

directory containing your photographs. Click into the field titled **Photos [optional]** and select **Save to File** and select the file format **SHP files**. Click **Run** to create the point layer with your geolocated photographs. Close any remaining windows to return to the QGIS main menu and display.

To view the photos by hovering over the points in the new layer you just created open the Properties of the point layer. Select the Display option and key in

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NB: set the width and height values to fit your photographs scale, although there seems to be an upper limit to the scale, so, smaller scales may work better. Click on **Apply** and **OK**. From the main menu select **View/Show Map Tips** and from the **Layers** panel, select the photographs layer you just created. Now when you hover the mouse over a point in that layer, the photograph will pop up. Selecting other layers will leave the thumbnails on the map (see below), but the hover and popup won't work until you again select the photographs layer.

To display thumbnails of the photos on the map select the photograph layer's **Properties** and click on **Symbology/Simple Marker** and click in the **Symbol Layer Type** field and choose **Raster image marker**, then click on the **Data Define Override** button, and choose **Field Type/Photo**. Set the **Size** value to **30** (adjust to fit, larger numbers make bigger thumbnails). Click **Apply** and **OK**. You can change the size of the thumbnails at any time.

Create a JPG Plat of the Boundary With QGIS

QGIS can make a JPG or PDF of your boundary.

To print a PDF of the boundary, choose the layers to print (uncheck any not to be printed in the QGIS Layers panel). Zoom out to show the entire deeded area. Open the Project menu pulldown **Export/Export Map to PDF**. Click on **Calculate From** and choose **Layer**, then select the exploded deed boundary layer with the assigned labels made above. The scale will be set automatically. Change it to 1:800 or better to get small (<30') line distance and angle labels. Click **Save** and choose a destination directory and filename, then click the **Save** button in that dialog to make the PDF. PDFs with background imagery, like satellite photos, can be very large and fail due to lack of RAM. PDFs of the boundary line layer tend to be small. You can also choose to **Calculate From** the **canvas**, if the JPG fails to include all the boundary or isn't scaled to show the labels.

Writing the Deed With the New Boundary Description

Model the deed language on recently filed deeds filed in your local courthouse. Compose the paragraphs needed to establish the methods and procedures used to acquire the bearings i.e., True vs Magnetic North, Decimal Degrees vs Degrees, Minutes, and Seconds, +- 180 degrees vs 0-360, etc. Declare the Datum CRS, the ECEF, Latitude, and Longitude measures. Declare the Base and Rover technology, i.e., C099-F9P/Zed-F9P. Declare the date range of the observations and possibly the range of estimated precisions. State explicitly that the call is to the monument and that the bearing, distance, Latitude and Longitude measures are estimates, that the called monument is near that bearing, distance, Latitude and Longitude.

Report the deed's starting point, and each line segment in the subsequent calls as a Latitude, Longitude, bearing and distance from the line segments' starting point. Describe each called monument as **near** a Latitude, Longitude, and near the distance and bearing. Be clear that the monument is the call, and the position measures are the hints to help you find the monument.

File the New Deed, Archive Your Work

Take your draft deed to a lawyer and have it repaired to meet local standards. Once it passes muster, take it to the county courthouse and file the deed.

Some surveys persist in deeds for more than a century, keep that in mind as you archive your work.

Make archival backups of all log files, CNRS PPP reports, Qfield and QGIS projects, deeds and photographs. Archive those backups into a well named zip file, and back that up too. Store the backups where you and others can find them. Print paper copies of the final deed, the CSV file used to source the bearing, distance, latitude and longitude in the calls. You may well need to produce these records to defend the boundary description in the future. You are done.