CHAPTER 7

GPS Receiver and Equipment Selection

7-1. General. Selection of the right GPS receiver for a particular project is critical to its success. Receiver selection must be based on a sound analysis of the following criteria: applications for which the receiver is to be used (e.g., static or dynamic, code or carrier), accuracy requirements, power consumption requirements, operational environment, signal processing requirements, and cost. GPS receivers range from high-end, high-cost, high-accuracy "geodetic quality" to low-end, low-cost, low-accuracy "resource grade" or "recreational" models. Moderate cost, meter-level accuracy "mapping grade" receivers are also available. Dozens of vendors produce GPS receivers and there are hundreds of models and options available. This chapter presents only a brief overview on GPS survey equipment and selection criteria. References to specific brands, models, prices, and features in this chapter will be rapidly out of date. Current comparative information on GPS receivers and options is readily available in various trade magazines, such as *GPS World*, *POB*, and *Professional Surveyor*. Prior to initiating procurement, USACE commands are also advised to consult the Army Geospatial Center or other commands for technical guidance on GPS instrumentation options.

7-2. Types of GPS Receivers. There are two general types of GPS receivers: Code Phase and Carrier Phase. Geodetic quality receivers process both code and carrier phases. Geodetic quality receivers (and auxiliary equipment) can cost between $10,000 and $25,000. Resource grade (recreational navigation) receivers typically process only the L1 C/A-code and perform absolute positioning. These receivers cost between $100 and $1,000. Some moderate cost ($1,000 to $5,000) hand-held mapping grade receivers can process either differential code or carrier observations. Within these types there are C/A and P-code receivers, one- or two-channel sequential receivers, multi-channel receivers, codeless receivers, single- and dual-frequency receivers, all-in-view receivers, continuous tracking, code-correlation, cross-correlation, squaring, and a variety of other signal processing techniques. Reference *NAVSTAR GPS User Equipment Introduction* (DoD 1996) or (Kaplan 1996) for further details on receiver signal processing methods.

a. Code Phase receivers. A code receiver is also called a "code correlating" receiver because it requires access to the satellite navigation message of the P- or C/A-code signal to function. This type of receiver relies on the satellite navigation message to provide an almanac for operation and signal processing. Because it uses the satellite navigation message, this type of receiver can produce real-time navigation data. Code receivers have "anywhere fix" capability and consequently, a quicker start-up time at survey commencement. Once locked onto the GPS satellites, an anywhere-fix receiver has the unique capability to begin calculations without being given an approximate location and time.

b. Carrier Phase receivers. A carrier phase receiver utilizes the actual GPS signal itself to calculate a position. In the past, there have been only two general types of carrier phase receivers: (1) single frequency and (2) dual frequency. With the advent of GPS signal modernization and a growing number of alternative satellite positioning and navigation systems, a new generation of GNSS receivers is arriving on the market capable of fully utilizing this new and more robust signal environment.

(1) Single-Frequency receivers. A single-frequency receiver tracks the L1 frequency signal. A single-frequency receiver can be used effectively to develop relative positions that are accurate over baselines of less than 20 km or where the differences in the ionospheric effects between the base and rover receivers can generally be ignored.

(2) Dual-Frequency receivers. The dual-frequency receiver tracks both the L1 and L2 frequency signal. A dual-frequency receiver will more effectively resolve baselines longer than 20 km where ionospheric effects have a larger impact on calculations. Dual-frequency receivers eliminate almost all ionospheric effects by combining L1 and L2 observations. All geodetic quality receivers are multi-channel, in which a separate channel is tracking each satellite in view. Most manufacturers of dual-frequency receivers utilize codeless techniques, which allow the use of the L2 during anti-spoofing. Other signal processing techniques include squaring, code-aided squaring, cross-correlation, and z-tracking. Receivers that utilize a squaring technique are only able to obtain 1/2 of the signal wavelength on the L2 during anti-spoofing and have a high 30 dB loss. Receivers that use a cross-correlation technique have a high 27 dB loss but are able to obtain the full wavelength on the L2 during A/S.

(3) Beyond single and dual-frequency GPS receivers is a new generation of GNSS receiver capable of utilizing and integrating a wider range of available satellite positioning and navigation broadcast signals, including GPS L2C and L5, GLONASS L1/L2, and Galileo-compatible products (even in advance of actual Galileo system availability) and can simultaneously track many more satellites than either basic single or dual frequency GPS receivers. One example of such a system is the Trimble R8 GNSS that is capable of simultaneously tracking up to 44 satellites.

7-3. GPS Receiver Selection Considerations. There are numerous factors that need to be considered when purchasing a GPS receiver (or system) for project control or mapping purposes. The following factors and features should be reviewed during the selection process.

a. Project applications. Current USACE applications include land-based, water-based, and airborne positioning, with a wide range of accuracy requirements. Land applications include real-time topographic surveying, geodetic control, resource mapping, navigation, survey control, boundary determination, deformation monitoring, and transportation. Most of these applications require carrier phase, geodetic-quality receivers. Water or marine applications include navigation and positioning of hydrographic surveys, dredges, and drill rigs--typically using meter-level differential code phase positioning techniques. GIS development applications are commonly performed with low cost, resource-grade, hand-held, GPS receivers--using either absolute positioning or code differential techniques. Airborne applications include navigation and positioning of photogrammetric/LiDAR-based mapping and require high-end geodetic GPS receivers along with inertial measurement units (IMU). Some receivers can be used for all types of applications and accuracies--e.g., a GPS receiver may contain capabilities for performing code, carrier, RTK, GLONASS, FAA WAAS, or USCG positioning. Generally, the more applications a receiver must fulfill, the more it will cost. It is important for the receiver's potential project applications be defined in order to select the proper receiver and the necessary options, and to avoid purchase of a $50,000 GPS system when a $10,000 system would have sufficed.

b. Accuracy requirements. A firm definition of the point positioning accuracy requirements is essential when deciding on the type of GPS receiver that will be required. Receiver cost typically increases as accuracy is increased. For example, a "geodetic-quality" receiver is usually specified for high-quality Corps project control work, particularly when precise vertical control is being established. Accuracy requirements will further define procedural requirements (static or kinematic), signal reception requirements (whether use of either C/A- or L1/L2 P-codes is appropriate), and the type of measurement required (pseudorange or carrier phase measurements). If only meter-level GIS feature mapping is involved, inexpensive, single-frequency GPS receivers are adequate, if combined with differential corrections.

c. Power requirements. The receiver power requirements are an important factor in the determination of receiver type. Receivers currently run on a variety of internal and external power sources from 110 VAC to 9 to 36 VDC systems. Most systems operate on small rechargeable internal batteries and draw some 1 to 5 watts. A high-end GPS receiver can operate only a few hours on its internal batteries, whereas a low-end, resource grade receiver that draws less power may operate 1 to 2 days on a set of flashlight (AA) batteries. Use of external gel-cell batteries should be also considered as a power source. If continuous structural monitoring or navigation is performed, then the receiver must have an external power option.

d. Operational environment. The operational environment of the survey is also an important factor in the selection of antenna type, antenna and receiver mounting device, receiver dimension and weight, and durability of design. For example, the harsher the environment (high temperature and humidity variability, dirty or muddy work area, etc.), the sturdier the receiver and mount must be. Most receivers are designed to operate over wide temperature ranges and in 100% humidity conditions. Many Corps applications require receivers to be mounted in small workboats exposed to harsh sea conditions and salt water spray. The operational environment will also affect the type of power source to be used.

e. Baseline length. For static control surveys, the typical baseline lengths encountered will determine the type of receiver that is required. Single-frequency receivers are usually adequate for baseline lengths of less than 20 km. Beyond 20 km lengths, dual-frequency receivers are recommended. Real-time kinematic operations require geodetic quality, dual-frequency receivers over all baseline lengths. Precision vertical work may also require dual-frequency receivers.

f. Data logging. Most geodetic quality receivers log data to an external logging device--e.g., a Survey Controller or directly to a laptop computer. Some geodetic quality receivers can also log data internally for later downloading through a communications port. Resource grade hand-held type receivers can collect, process, and display data internally. The amount of storage required is a function of the typical project, data logging rate--1-sec, 5-sec, etc. Most high-end units use memory cards for additional storage requirements. Quality receivers will have several RS-232 and one 432 port, with high data transfer rates along with Ethernet connections

g. Operator display. Most modern receivers and data controllers contain simple icon-based displays for selecting GPS survey modes and data logging options. Costs and options will vary with the size of a LCD display on the receiver or controller. Quality receivers provide audible and visual warnings when data quality is poor. New receivers also use an HTML interface through an Ethernet connection.

h. Satellites and channels tracked. Most quality receivers are designed to track 12 or more channels in parallel mode. Many receivers can track 12 or more satellites--some can track "all-in-view." Most of the survey quality receivers on the market today also track GLONASS and are configured to accept Galileo when it becomes available

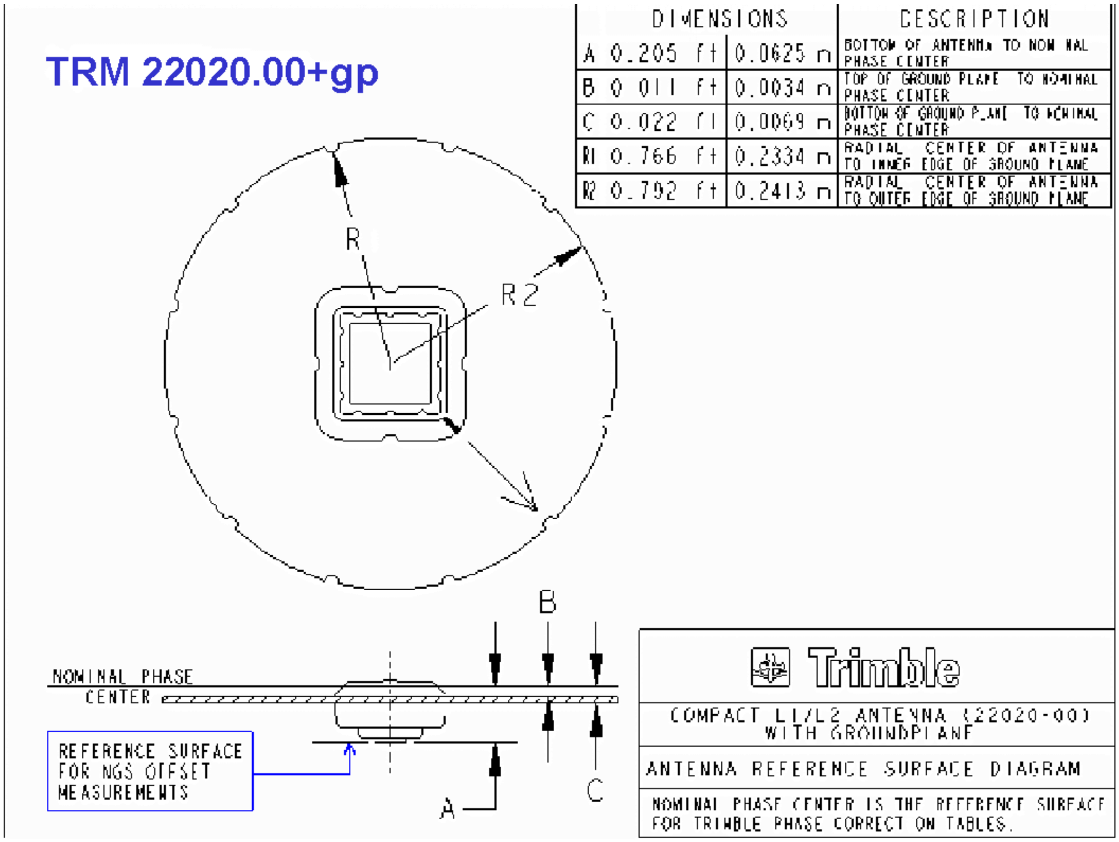
i. Time to start and reacquire satellites. GPS receivers vary in the time required to cold start (1 to 3 minutes) and warm start (< 1 minute). OTF initialization (and reinitialization) time is also varied. These criteria may be significant for some Corps topographic RTK surveying applications where loss of lock is common due to structures or canopy cover.

j. Size and weight. Size and weight are important if receivers are used for RTK topographic surveys or mapping type work. Most geodetic quality and hand-held receivers weigh from 1 to 5 pounds including integrated RF radio receivers or cellular connections for RTK .

k. FAA WAAS, USCG, and commercial provider DGPS capability. Receivers with varied code DGPS capabilities are needed in some remote or mountainous areas--especially when one of the DGPS provider signals is poor or unreceivable. Some receivers are designed to acquire commercial, FAA WAAS, and USCG DGPS pseudorange corrections.

l. GLONASS capability. The ability to acquire and process Russian GLONASS satellites (and other future GNSS systems) would be advantageous in mountainous or urban areas where GPS satellites are partially blocked. The acquisition of additional satellites also provides higher geometric accuracy. This also allows continued operations in urban canyons or mountain valleys.

m. Antenna type. A wide variety of antennas are available from GPS receiver manufacturers. In addition, optional antenna types can be ordered with the same receiver. Some antennas are built into the receiver and others are external. Multipath minimization will require more expensive antennas for static control survey applications. These include antennas configured with ground planes and choke rings. For high accuracy work, the selection of an antenna that has been modeled by NGS is strongly suggested as illustrated in Figure 7-1. Additional information on antenna modeling is available at http://www.ngs.noaa.gov/ANTCAL/.



DIMENSIONS			DESCRIPTION
A	0.205 ft	0.0625 m	BOTTOM OF ANTENNA TO NOMINAL PHASE CENTER
B	0.011 ft	0.0034 m	TOP OF GROUND PLANE TO NOMINAL PHASE CENTER
C	0.022 ft	0.0069 m	BOTTOM OF GROUND PLANE TO NOMINAL PHASE CENTER
R1	0.766 ft	0.2334 m	RADIAL CENTER OF ANTENNA TO INNER EDGE OF GROUND PLANE
R2	0.792 ft	0.2413 m	RADIAL CENTER OF ANTENNA TO OUTER EDGE OF GROUND PLANE

Figure 7-1. Typical antenna reference and offset diagram

n. Processing requirements. Operational procedures required before, during, and after an observation session are manufacturer dependent and should be thoughtfully considered (and tested) before purchase of a receiver. Often, a receiver may be easy to operate in the field, requiring very little user interface, but a tremendous amount of time and effort may be required after the survey to download the data from the receiver and process it (i.e. post-processing software may be complicated, crude, if underdeveloped). Also, whether a post-processed or real-time solution is desired represents a variable that is critical in determining the type of receiver to use.

o. Cost. Cost is a major factor in determining the type of receiver the user can purchase. Receiver hardware and software costs are a function of development costs, competition among manufacturers, and product demand. Historically, costs for the acquisition of GPS equipment have steadily fallen to the current range of prices seen today. Cost estimates must include full GPS systems along with auxiliary equipment, software, training, etc. A sample schedule for many of these cost items is shown at the end of this chapter.

p. Data exchange formats. In order to transfer data, a common exchange format is required. GPS vendors usually have their own proprietary data formats. However, most GPS receiver data can be put into a common text format, such as the Receiver Independent Exchange (RINEX) format, which is used for post-processed data. RINEX is more fully described in a later section. Real-time data exchange, such as that used on RTK surveys, is typically handled using the RTCM SC-104 format standard. Vendors often allow for optional outputs, such as ASCII, DXF, ArcInfo, DGN, NMEA 0183, etc.

7-4. Military Grade GPS Receivers. Military Grade GPS receiver systems provide high accuracy positioning for real-time and post-processed military survey applications. These applications include precise positioning and orientation of artillery, ground-based surveys, and surface navigation. Military receivers use the Precise Positioning Service (PPS) providing advanced P(Y) Code positioning technologies accurate to approximately 4 –16 meters (SEP). Using the secure (Y-code) differential GPS (SDGPS) can increase the accuracies to the sub-meter level. PPS receivers require a crypto key to decode the encrypted P-Code and typically have to be re-keyed each year.

7-5. GPS Receiver Manufacturers. Up-to-date listings of manufacturers are contained in various surveying trade publications. http://www.agc.army.mil/ndsp Contact should be made directly with representatives of each vendor to obtain current specifications, price, availability, material, or other related data on their products. Prior to purchase, it is recommended that receivers be tested to ensure they meet performance requirements and will efficiently transfer positional and feature data to post-processing devices and/or CADD/GIS platforms. Most GPS equipment required for USACE applications is listed on the GSA Supply Schedule and can be obtained directly off that schedule without competition--see FAR 8.4, Section 8.404.

Figure 7-2. Miscellaneous auxiliary equipment needed for a GPS survey

7-6. Other Auxiliary Equipment. A significant amount of auxiliary equipment may need to be acquired when making a GPS receiver selection. Some of this equipment is discussed below.

a. Data link equipment for real-time positioning. The type of data link needed for real-time positioning (i.e. code or carrier RTK) should be capable of transmitting digital data. The specific type of data link will depend on the user's work area and environment. Most manufacturers of GPS equipment can supply or suggest a data link that can be used for real-time positioning. Depending on the type and wattage of the data link, a frequency authorization may be needed in order to transmit digital data over radio frequencies (RF). Frequency authorization requires coordination with the frequency coordinator in the District and HQUSACE, and is a difficult and involved process. Some radio and GPS manufacturers produce low-wattage spread spectrum transmitters that do not require frequency authorization. These low-wattage broadcasts are normally only useful for topographic RTK surveys not exceeding 1 km from the reference station. The data link may be built into the receiver or in an external unit. Some Corps districts have obtained approval to broadcast RTK correctors on approved frequencies in the VHF range--162-174 MHz. Local VHF broadcasts have been used to transmit RTK corrections out to 10-15 miles offshore--for controlling hydrographic surveys on dredging projects. Use of wireless technology (e.g., local and satellite cell phones) may prove to be more effective and efficient data links than VHF links, especially if frequency authorizations cannot be obtained. Many commercial vendors are now using wireless satellite links to transmit DGPS correctors to users.

b. Data link equipment for Real Time Network (RTN) positioning. TCP/IP data communication, especially in regard to RTN solutions, may be done via wireless data modem, card or phone with a dynamic or static IP address, although static IP addresses provide a reliable connection and are the recommended communication link configuration. Code Division Multiple Access (CDMA) data modems and flash media modems require the user to subscribe to a wireless phone service, but this allows for use of the wireless service providers' cell towers for internet connectivity to send and receive data over much longer distances than with VHF/UHF broadcasts and could replace the previously discussed VHF/UHF radio configuration for the base and rover. Data services are available by monthly subscriptions through several carriers, varying by geographical region. The user must contact the carrier to set up a data service. Typically, rates vary by data usage rather than by time. Data are sent by the base via a TCP/IP address to the rover, that then performs the correction and difference calculations and displays the results with no loss of usable latency – typically fewer than 2 or 3 seconds total to position display. These systems enable virtually unlimited range from the base station. However, in a typical RTK scenario where only one base station is used, the ability to resolve ambiguities at a common epoch and the part per million errors limit accuracy range in most cases. The fact that atmospheric conditions can vary from base position to rover position, particularly at extended ranges, and the fact that the rover uses the conditions broadcast from the base, cause the range and phase corrections to be improperly applied, contributing to positional error. CDMA modems can be used effectively at extended ranges in RTNs where the atmospheric and orbital errors are interpolated to the site of the rover. Cell phones and stand alone Subscriber Identity Module (SIM) cards in Global System for Mobile Communication (GSM) networks use similar methods as CDMA data modems to send data. Many current GNSS receivers have integrated communication modules. Rather than communicating with a *dynamic* address as is the case in many internet scenarios, static IP addresses provide a reliable connection and are the recommended communication link configuration. Static addresses are linked with the same address every time the data modems connect and are not in use when there is no connection. However, there is a cost premium for this service. Contact the wireless service provider for the actual rates. Additional information on RTNs is available from NGS at: http://www.ngs.noaa.gov/PUBS_LIB/NGSRealTimeUserGuidelines.v1.1.pdf

Figure 7-3. Common data links for code and RTK GPS receivers

c. USCG radiobeacon receivers. The USCG provides a real-time pseudorange corrections broadcast over medium frequency (270-320 kHz marine band) from a radiobeacon transmitter tower. These towers exist in most coastal areas, the Mississippi River Basin, and the Great Lakes regions. The range from each tower is approximately 120 to 300 km. These corrections can be received by using a radiobeacon receiver and antenna tuned to the nearest tower site. USCG beacon receivers are usually contained in one unit that contains the antennas and GPS processing/display features--see Figure 7-3. Similar configurations are made for wide area, commercial-provider, differential GPS services.

d. Computer equipment. Most manufacturers of GPS receivers include computer specifications needed to run their downloading and post-processing software. Most high-end desktop and notebook/laptop computers are capable of processing GPS data. Portable laptop computers are essential for performing near real-time data post-processing--especially in remote locations. An internal CD/DVD-RW drive is also recommended for archiving the large amounts of data that will be collected.

e. Antenna types. There are three basic types of GPS antennas. These are (1) antenna with a ground plane, (2) antenna without a ground plane, and (3) antenna with a choke ring. Both the ground plane and the choke rings are designed to reduce the effect of multipath on the antenna.

f. Associated survey equipment. There are several accessories needed to support the GPS receiver and antenna. These include backpacks, tripods, tribrachs, and tribrach adapters, to name a few. Calibrated fixed height (usually 2 meter) range poles can be used to eliminate the need to measure antenna heights. Most of the other equipment needed is similar to what is used on a conventional survey.

7-7. Resource Grade GIS Mapping Receivers. Dozens of hand-held resource grade GPS receivers are produced that can display and log geospatial positional data in real-time. USACE applications for these inexpensive receivers are varied. They will provide sufficient accuracy for vessel, vehicle, and personal real-time navigation. They may also be used for building GIS databases where 5 to 10 meter horizontal accuracy is adequate for a feature, e.g., land use, point features, flood inundation limits, emergency operations, dredge disposal monitoring, etc.

7-8. Common Data Exchange Formats.

a. RINEX. The Receiver INdependent EXchange (RINEX) format is an ASCII type format that allows a user to combine data from different manufacturer's GPS receivers. Most GPS receiver manufactures supply programs to convert raw GPS data into a RINEX format. However, one must be careful since there are different types of RINEX conversions. Currently, the NGS distributes software that converts several receiver's raw GPS data to RINEX. NGS will distribute this software free of charge to any government agency. Portions of typical RINEX data files are shown below. For each satellite tracked, the code distance and L1/L2 phases and Doppler count values are listed. Many software vendors now provide routines that directly read and interconvert the various proprietary formats used by equipment manufacturers as well as RINEX.

SAMPLE RINEX DATA FILE (San Juan, PR Jacksonville District, Ashtech Z-12 Receiver)

```
2IU             OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE
ASHTORIN                                28 - JUN - 02 10:04 PGM / RUN BY / DATE
                                                            COMMENT
0003                                                        MARKER NAME
                                                            MARKER NUMBER
                                                            OBSERVER / AGENCY
                    ASHTECH Z-XII P3    5J00      1C63      REC # / TYPE / VERS
                                                            ANT # / TYPE
  2453884.6500 -5532961.0300  2004535.4500                  APPROX POSITION XYZ
       2.03800        0.0000        0.0000                  ANTENNA: DELTA H/E/N
     1     1                                                WAVELENGTH FACT L1/2
     7    L1    L2    C1    P1    P2    D1    D2            # / TYPES OF OBSERV
    15.0000                                                 INTERVAL
                                                            LEAP SECONDS
  2002     6    25    14    53   30.000000      GPS         TIME OF FIRST OBS
  2002     6    25    16    24   30.000000      GPS         TIME OF LAST OBS
                                                            END OF HEADER
 02  6 25 14 53 30.0000000  0  9G30G29G26G04G05G24G23G07G10          0.000824454
   -53922.08817    -40565.76855  24455490.816  24455491.4555   24455501.0845   244.850   190.792
  -661208.301 9   -483872.18747  22216675.275  22216675.4604   22216683.1604  3159.150  2461.675
  -820204.442 9   -618074.31947  22985123.892  22985124.3594   22985133.6494  3935.982  3066.999
   128043.142 9     93257.10846  23165282.101  23165282.0234   23165290.6074  -623.838  -486.108
   153403.432 9    116423.82546  23937298.328  23937298.3884   23937308.7384  -768.304  -598.678
  -166500.297 9   -125905.16547  22117555.722  22117555.8774   22117562.4454   793.354   618.198
  -264887.037 9   -197951.30346  22994119.533  22994119.7104   22994129.0024  1453.557  1132.642
```

```
   631877.719 9    456127.79446  23737042.567  23737042.5564   23737055.5554 -3149.638 -2454.263
    60447.345 9     43299.05948  21136470.357  21136469.9054   21136476.3494  -330.782  -257.752

02  6 25 16 24 15.0000000  0  8G29G26G04G24G23G08G10G06            0.000647879
 -9746894.726 9  -7563623.36248  20487724.730  20487724.5844   20487730.9614    53.897    41.998
-15098913.388 9 -11744332.87548  20267971.265  20267971.3024   20267977.8754   975.770   760.340
  7481368.270 9    5823092.22845  24564595.467  24564595.5644   24564609.5154 -2091.033 -1629.376
 -1518814.840 9  -1179665.38447  21860226.133  21860225.8804   21860234.9044  -476.719  -371.469
 -2944679.055 9  -2286098.15047  22484172.149  22484171.6184   22484179.9644   -68.190   -53.135
 -4418906.717 7  -3437358.05045  24462270.403  24462269.6634   24462286.6644  -294.665  -229.609
  5736700.177 9    4466347.01547  22216631.531  22216630.7024   22216638.0044 -1310.212 -1020.944
-10589645.118 9  -8230960.83247  22710603.800  22710603.6414   22710611.8954  1959.993  1527.267
```

SAMPLE RINEX DATA FILE (New Orleans District, Trimble 4000SSE receiver)

```
     2.10           OBSERVATION DATA    G (GPS)             RINEX VERSION / TYPE
DAT2RINW 3.10 001   Huber               25MAR02  6:52:52    PGM / RUN BY / DATE
Huber               USACE                                   OBSERVER / AGENCY
4936                TRIMBLE 4000SSE     Nav 7.29 Sig 3.07   REC # / TYPE / VERS
00000000            TR GEOD L1/L2 GP                        ANT # / TYPE
------------------------------------------------------------ COMMENT
Offset from BOTTOM OF ANTENNA to PHASE CENTER is  62.5 mm   COMMENT
------------------------------------------------------------ COMMENT
4936                                                        MARKER NAME
4936                                                        MARKER NUMBER
   -13020.5085 -5531624.9704  3164468.2517                  APPROX POSITION XYZ
        1.5468        0.0000        0.0000                  ANTENNA: DELTA H/E/N
*** Above antenna height is from mark to BOTTOM OF ANTENNA. COMMENT
------------------------------------------------------------ COMMENT
Note: The above offsets are CORRECTED.                      COMMENT
Raw Offsets: H=      1.6093 E=      0.0000 N=      0.0000   COMMENT
------------------------------------------------------------ COMMENT
     1     1     0                                          WAVELENGTH FACT L1/2
     4    L1    C1    L2    P2                              # / TYPES OF OBSERV
     1.000                                                  INTERVAL
  2002     3    21    14    27    2.0000000                 TIME OF FIRST OBS
  2002     3    21    16    31   49.0000000                 TIME OF LAST OBS
     0                                                      RCV CLOCK OFFS APPL
     5                                                      # OF SATELLITES
     4  4578  4579  4521  4521                              PRN / # OF OBS
     7  7488  7488  7488  7488                              PRN / # OF OBS
     8  7488  7488  7488  7488                              PRN / # OF OBS
    11  7248  7248  7185  7185                              PRN / # OF OBS
    27  5719  5719  5719  5719                              PRN / # OF OBS
                                                            END OF HEADER
 02  3 21 14 27  2.0000000  0  4   7  8 11 27
   -116189.39216  22284950.00806    -87567.87956  22284956.61746
    -24189.13717  20059524.33607     -6825.36657  20059529.75047
       388.50517  21728548.97707       302.52057  21728554.56647
     96650.22817  20791241.16407     72757.93557  20791247.08247
 02  3 21 14 27  3.0000000  0  4   7  8 11 27
```

b. Real-time data transmission formats. There are two common types of data formats used most often during real-time surveying. They are (1) RTCM SC-104 and (2) NMEA.

(1) Transmission of data between GPS receivers. The Radio Technical Commission for Maritime Services (RTCM) is the governing body for transmissions used for maritime services. The RTCM Special Committee 104 (SC-104) has defined the format for transmission of GPS corrections. The RTCM SC-104 standard was specifically developed to address meter-level positioning requirements. The current transmission standard for meter-level DGPS is the RTCM SC-104. This standard enables communications between equipment from various manufacturers.

It should be noted that not all manufacturers fully support the RTCM SC-104 format and careful consideration should be made to choose one that does. RTCM SC-104 can also be used as the transfer format for centimeter-level DGPS, and will support transmission of raw carrier phase data, raw pseudorange data, and corrections for both. Some GPS receiver manufacturers also have their own proprietary transfer formats--e.g., Trimble's Compact Measurement Record (CMR).

(2) Transmission of data between a GPS receiver and a device. The National Maritime Electronics Association (NMEA) *Standard for Interfacing Marine Electronic Devices* covers the format for GPS output records. The standard for corrected GPS output records at the remote receiver is found under NMEA 0183, Version 2.xx. NMEA 0183 output records can be used as input to whatever system the GPS remote receiver is interfaced. For example, GPS receivers with an NMEA 0183 output can be used to provide the positional input for a hydrographic survey system or an Electronic Chart Display and Information System (ECDIS). These are evolving standards and newer versions are being developed for different data types. The NMEA 0183 Version 2.00 (1992) "GGA" standard for GPS "fix data" is outlined below. This version has been subsequently updated--users need to ensure NEMA version compatibility between devices. Other NEMA 0183 standards include: GST (Position error statistics), GSV (Number of satellites in view, PRN, etc.), PTNL (Local coordinate position output), and ZDA (UTC day-month-year).

GGA--Global Positioning System Fix Data (Time, Position, and Fix Related Data for a GPS Receiver)
[Version 2.00]

Differential reference station ID (0000-1023)
Age of differential GPS data
Units of geoidal separation
Geoidal separation
Units of antenna altitude (m)
Antenna altitude
Horizontal dilution of precision

$--GGA, hhmmss.ss, llll.ll, a, yyyyy.yy, a, x, xx, x.x, x.x, M, x.x, M, x.x, xxxx*<CR.<LF>

Number of satellites in use (00-12)
GPS quality indicator (0, 1, 2)
Longitude (E/W)
Latitude (N/S)
UTC of position

7-9. GPS Training and Operation Manuals. Training should be included in the purchase of any GPS receiver system, especially if the equipment is new to a District. In addition to receiver operation, training should include baseline reduction, and network adjustment. The Corps PROSPECT program provides a one-week training course, Survey IV, on GPS surveying. This course covers all chapters contained in this engineer manual. Major GPS vendors offer training in all facets of GPS surveying unique to their equipment or software. In addition, continued technical support should be included to cover all software and firmware upgrades.