Version 2.02 - 4/6/04

# The Spatial Reference Center of Washington
# SRCW

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# Implementation Plan for the SRCW

*Version 2.02*

## March 16, 2004

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*note: Large portions of this Implementation Plan were obtained with permission from the CSRC Master Plan Document (see Reference 1).*

## Overview

Modern society is becoming increasingly dependent on geographic data that is accurately and reliably spatially referenced. In response to this increasing demand for dependable spatially referenced data and the decreasing availability of "up-to-date" control (reference) data from the federal government, the Spatial Reference Center of Washington (SRCW) has developed a "implementation plan" for a modern statewide geodetic control network for Washington State. The plan specifies that each network station shall have at least the following geodetic values – latitude (northing, Y), longitude (easting, X), height (elevation, orthometric, ellipsoidal), velocity (magnitude/direction), and a stated accuracy for each value.

This planned network also will achieve the goals of the federal National Height Modernization initiative as determined by the SRCW Council in consultation with NGS. SRCW's ultimate goal is to establish a geodetic control network consisting primarily of Continuously Operating Reference Stations (CORS). However, the proposed initial implementation includes a number of passive (in-ground) stations, as well as CORS, because of funding limitations. The hope is for a CORS-only network in the greater Seattle-Tacoma area.

The Implementation Plan includes systematic network maintenance procedures to maintain control values up to date; i.e., procedures that monitor temporal changes in geodetic coordinates due to tectonic motion, seismic activity, volcanic deformation, and land subsidence. The described statewide network utilizes existing CORS and related data-processing infrastructure that have been established by close to a decade of investment in GPS-based tectonic and earthquake-related science. Thus, the planned network not only provides an accurate, consistent foundation for Washington's spatial referencing needs, but also facilitates the continuation of this vital scientific research.

The initial implementation of the statewide geodetic network, as detailed in the Implementation Plan, consists of approximately 80 CORS of which 23 exist from the previously noted geophysical research or were recently installed by other GPS users. Outside of the Seattle-Tacoma and Spokane areas, the CORS are to be located throughout the state in a grid-like pattern with a nominal spacing of 70 kilometers. About 850 passive stations (in-ground monuments) also are included in the network to supplement these CORS. The passive stations are to be established along selected transportation corridors and other critical infrastructures at an average spacing of seven kilometers.

The initial implementation, as outlined, can be completed over a five-year period, if sufficient funds are available. The total estimated implementation cost is $8 million. This includes constructing 53 new CORS, installing 150 new passive station monuments, and performing observations, data processing, and adjustments for the entire network.

Nearly 50 percent of the resources are allocated for improving the accuracies of GPS-derived elevations (orthometric heights). The vast majority of the initial implementation is to be accomplished through contracts with private industry. The "on-going" support and network maintenance efforts for the initial implementation are estimated to cost $400,000 annually. These annual (on-going) funds are critical to the long-term success of the network because of the significant crustal motion issues throughout western Washington. The on-going support and maintenance efforts will be accomplished by SRCW staff and through contracts with private firms. The planned, modern statewide geodetic control network, including access to the basic geodetic data, is to be available at no charge to all users. Participating members of the SRCW may be charged a nominal annual membership fee to help defray the center operating costs.

## Introduction

Traditionally and historically, Washington users have depended on the National Geodetic Survey (NGS), and its predecessor agencies, for geodetic control – many horizontal stations and benchmarks have been established by the USGS and later, the NGS in the state of Washington. But, in the last 10 to 15 years, the direction of NGS has changed (largely due to budget constraints) from maintaining relatively dense control networks to maintaining a basic "framework" system consisting primarily of CORS GPS sites. NGS's published strategic goals state that NGS will observe, monitor, and maintain a network of high-accuracy stations at a spacing of one degree by one degree (75 km to 125 km) – *and even this commitment is becoming questionable*. Any additional geodetic control is to be established and maintained either through cooperative agreements, with NGS or by independent, local efforts. Unfortunately, the decline in NGS's geodetic control efforts has occurred just as the need for an accurate, seamless statewide control network has greatly increased. This expanded need is being driven by GPS – its positioning capabilities and its many diverse applications (including numerous non-surveying applications) have only furthered society's dependence on accurate reference systems. We are becoming increasingly dependent upon spatial information for making critical decisions regarding such varied activities as environmental monitoring, civil infrastructure management, earthquake research, and emergency response operations. The increased spatial positioning capabilities, uses, and dependencies are demanding the use of an accurate geodetic control network that is seamless throughout the State of Washington for all spatial referencing activities.

National Height Modernization Study

In 1998, NGS prepared and submitted a *"National Height Modernization Study"* to Congress. This study recommended a state-by-state implementation of a "National Height Modernization Program" that would establish three-dimensional control monuments at a 10-kilometer spacing, each with an NAVD88 elevation. The study proposed an initial five-year implementation schedule for a few demonstration states; however, it is now clear that full implementation will take longer. Washington, like demonstration states California and North Carolina are "…states subject to extreme seismic activity, subsidence, floodplain management, coastal erosion, and heavy urbanization." The study estimated the cost for California's height modernization to be $4.6 million using GPS technologies (1998 cost figures). If conventional surveying technologies were to be used, the cost estimate for California is $41.2 million. This figure provides some insight into the magnitude of the effort that will be required. Our goal in the initial phase is to achieve a statewide CORS density of approximately 70 km spacing.

The geodetic network and associated activities described in this Implementation Plan achieves the National Height Modernization goals for Washington as determined by the SRCW Council in consultation with NGS.

Implementation Plan Objective

The objective of the Implementation Plan is to specify (detail) a modern statewide geodetic control network as envisioned by the Spatial Reference Center of Washington (SRCW). However, readers should be aware that a statewide control network is but one component of a "complete" spatial reference system. Other components of an overall spatial reference system include the following:

- Guidelines and specifications.
- Observation data archives.
- Metadata records.
- Data processing capability.
- Geodetic models and formulas.
- Data portal (database and user interface).
- Support services (user assistance).
- Outreach and education programs.
- Real-time positioning infrastructure.

These other components will not be discussed in this document. As appropriate, these components will be addressed in SRCW's annual work plans as funding becomes available to develop and improve these capabilities.

Implementation Plan Review and Modifications

The intent of this Implementation Plan is to establish a strategy for the development of a modern, statewide geodetic control network – its basic policies and scope (funding needs and the type and number of stations). Details of the network, such as the actual station locations, are flexible and will be determined based on user needs during the actual network implementation. In general, SRCW will not consider modifications to the basic network policies and scope unless the requesting user provides cost-sharing funds. SRCW will consider alternative geodetic control schemes (e.g., exchanging passive stations for CORS), if the overall funding needs are not significantly increased or additional funds are provided. Additionally, this effort will continue to utilize regional GPS resources provided by the scientific community and will attempt to integrate these activities in the planning of the SRCW.

The Implementation Plan provides various tasks for improving orthometric heights (elevations) – conventional geodetic leveling, gravity measurements, etc. However, the extent and costs of these tasks are rough estimates as no definitive study has been made to estimate these needs accurately. Thus, it is likely that these Implementation Plan tasks will require modification when such needs are known. The plan itself will be updated to meet future technology improvements as the users adopt these improvements. (See next section.)

Updates and revisions to the Implementation Plan will be made through a review process determined by the SRCW Council. Prior to the beginning of each fiscal year, the SRCW shall prepare an annual work plan for the next fiscal year that describes the various tasks to be performed, the planned expenditures for each task, and the anticipated funding source for each task. A SRCW Work Plan Committee will prepare the annual work plans with assistance from SRCW staff. The Work Plan Committee shall be appointed by the SRCW Council Chairperson and approved by the entire Council. The annual work plans will be highly dependent upon funding received and the priorities established for each task. Each annual Work Plan Committee, shall a) review the status of on-going tasks, b) examine the availability of current and future funds, c) solicit work suggestions from the NGS and other “Funding Agencies” (defined as agencies recognized by the SRCW as current or potential future funding sources), SRCW partners, and interested users (both GPS and non-GPS users), and d) prepare and recommend next year’s plan to the funding agencies and other associated agencies as deemed appropriate. The Funding Agencies shall review and approve (or modify) the portion of the annual work plan that is funded by the anticipated allocations, before any monies from such allocations are expended. If the Funding Agencies suggest modifications to the prepared annual work plan, SRCW and the Funding Agencies shall work in good faith to develop a compromise work plan that is acceptable to both.

## Technological Advances

The design of the statewide geodetic control network described in this Implementation Plan is based upon current positioning capabilities and the anticipated utilization of the network by today's users. It is fully recognized that future advances will likely affect the requirements and demands for this control network. Examples include the GPS modernization program, which will offer increased accuracy and reliability by increasing the number and signal strength of civilian frequencies (planned improvements starting in 2005 and new generation GPS III improvements in 2009). This program, when fully implemented, will most certainly attract additional and more diverse GPS users. Real-time GPS positioning, which is being implemented by SRCW partner Puget Reference Station Network (PRSN, see: http://www.surveycontrol.state.wa.us/prsn.htm), has the potential to decrease dramatically the need for passive stations. These advanced technologies, and others, will increase in use incrementally over time. Their ultimate implementation will be based upon sound and proven geodetic surveying practices. While future versions of this Implementation Plan and the corresponding statewide geodetic control networks may have a different appearance, the planned network outlined in this document provides the necessary geodetic infrastructure to support both current and future applications and users.

## Network Issues

Specific critical Washington State geodetic control issues are:

- Secular crustal motions (differential movement of the tectonic plates throughout much of Washington) – in excess of one centimeter per year along the coast (driven by Pacific and Juan de Fuca ocean plate motion) relative to the stable North American plate.
- Compressional north-south shortening of up to 5 mm per year across the Olympic mountains and Puget Sound region (comparable to that seen in the Los Angeles Basin).
- Episodic crustal motions (earthquakes) – deformations resulting from specific events, with horizontal and vertical displacements of meters (e.g., paleoseismic evidence of a single event 7 meter vertical offset along the east-west trending Seattle thrust fault).
- Aseismic deformations (fault creep and deep "silent" earthquakes) – these events were discovered only by the implementation of CORS style GPS stations in the region. (e.g. 14.5 month interval events occurring along subduction plate interface below Puget Sound)
- Areas of subsidence, landslide, liquefaction (e.g. Renton, WA – 18 inch subsidence observed at Boeing Renton facility and NGS benchmarks near this area with unknown elevations).
- Sparse releveling in much of Washington.

- Two vertical datums in use in Washington: NGVD29 and NAVD88.
- Incomplete implementation of NAVD88
- Extensive coastal infrastructure facilities (harbors, international boundaries, major shipping lanes, etc.) – these facilities generally are referenced to tidal datums, which are not necessarily referenced to a national geodetic vertical datum.
- Use of numerous local vertical datums – information from different sources cannot be related.
- Incorrect (obsolete) published values for many geodetic control stations – due to crustal motions, subsidence, etc.
- Limited station maintenance during the last 20 to 30 years (monitoring, updating values, station replacement, etc.).
- Reduced NGS assistance – today, NGS does not have any dedicated resources for the acquisition of field data; e.g., field personnel to perform vertical control surveys.

*The result of these issues is that many of today's geodetic control (reference) values are incorrect or questionable. This represents a critical concern for the State of Washington and those agencies and businesses that are dependent on spatial information and its applications.*

## Network Solutions

Long-Term Goal

As a long-term goal, SRCW envisions a statewide geodetic control network that ultimately will consist entirely of CORS; i.e., a "CORS-only" statewide network. A network of only CORS would ensure that the geodetic values for all stations are valid and current (up to date) at all times and eliminate the need for any resurveys of the statewide control network; i.e., surveys required after earthquakes and to monitor secular crustal motion and subsidence. It would also help meet the Federal Emergency Management Agency's (FEMA) goal of transitioning from the old NAVD29 to the more up-to-date NAVD88 vertical datum.

The envisioned CORS-only network would include the following components:

1. Framework CORS spaced, statewide, on a nominal 70-kilometer grid.
2. Regional CORS spaced on an approximately 15-kilometer grid in densely populated regions. Candidate regions are the Seattle and Tacoma areas, with future emphasis moving out to the cities of Spokane and Everett, the Tri-cities region, and portions of Kitsap, Thurston, Clark, Island and San Juan counties.
3. Corridor CORS spaced 15 to 20 kilometers along major infrastructure corridors. (The selected corridors would be similar to those identified for passive stations in this document. See section entitled "Station Spacing," below.)

4. Real-time infrastructure systems that provide “real-time” GPS capabilities for a regional or corridor area. Such systems would be similar to the demonstration project now being developed for Puget Sound region (PRSN project). Implementation of extensive real-time capabilities is dependent, however, on the availability of emerging wireless technologies and the cooperative and financial support of others; e.g., a state agency, county and/or city.

It is estimated that a CORS-only statewide geodetic control network, as described above, would require up to an additional 200 to 250 CORS to what is provided in this plan (including the existing CORS installed by the scientific community). However, there exists a potential future cost savings and the realization of a CORS-only network may be achieved by utilizing sites established in new upcoming scientific programs (e.g. the Plate Boundary Observatory). The $8 million implementation cost (including the $2.9 million for conventional leveling and other efforts to improve GPS-derived elevations) would of course need to be scaled accordingly to achieve this full CORS capability. The support/maintenance costs alone for the envisioned CORS-only statewide network are estimated to be $750,000 to $1.5 million each year. These costs would be expected to decrease in the future with reductions in equipment and installation costs – the latter primarily the result of less extensive monumentation requirements.

With the development of better models, the need for high density CORS may become less important for surveying and mapping, which will decrease maintenance costs. Since the initial costs of CORS-only networks and real-time capabilities are still comparatively high, implementation of these capabilities within each region or corridor area will be dependent on the willingness of others (local entities, state agencies, etc.) to collaborate (partner) with SRCW and share the cost of such installations. The CORS-only network is a SRCW goal – the ultimate network to work towards and achieve. It provides a guide for improving the existing network and identifying opportunities to complete portions of the ultimate network.

Initial Implementation

Today, the establishment of a “CORS-only” geodetic control network throughout the state, the goal, is not feasible for various reasons – comparatively high costs, absence of sufficient conventional leveling and gravity data, an inadequate geoid model in some areas, lack of developed SRCW partnerships, increased difficulty and time to establish a CORS-only network, uncertainties of future GPS capabilities and their effect on control needs, unfamiliarity of users with CORS usage, etc. Thus, to address Washington’s immediate spatial referencing needs as quickly as feasible, SRCW has formulated an initial Implementation Plan that

expands and improves the existing statewide geodetic control network. SRCW will outline, explain, and provide means to obtain project control for classical surveys for non-GPS users. Nearly 40 percent of the initial implementation is for conventional leveling and other work that is necessary to improve the accuracy of elevations derived by GPS survey techniques – a crucial need for this evolving and expanding GPS usage. The initial implementation is described in detail throughout the remainder of this Implementation Plan. In brief, the network consists of approximately 80 CORS, of which approximately 22 are existing scientific CORS and another 7 contributed from other regional sources.

A CORS-only network is planned for the Seattle - Tacoma region. In this area, the scientific community has established a few CORS but not nearly enough to implement a CORS-only network. The PRSN program, when fully implemented will approximate a CORS-only network. However, as many as 15 new CORS would be required to enable a CORS-only network and avoid the need for conventional surveys in this highly congested area. The additional costs are offset partially by the reduction in passive stations.

SRCW will continue to seek partners and financial support to establish a CORS-only network in other urban and corridor areas as opportunities permit. Outside of the Seattle and Tacoma areas, the CORS are to be located throughout the state in a grid-like pattern with a nominal spacing of 70 kilometers. This fulfills another portion of the CORS-only network goal. In addition, about 850 passive stations (in-ground monuments) are included in the network, initially, to supplement the CORS outside the CORS-only areas. The passive stations are to be established along selected transportation corridors and other critical infrastructures at an average spacing of seven kilometers. This spacing is dictated by the NGS *"Guidelines for Establishing GPS-Derived Ellipsoid Heights"* for the two-centimeter accuracy standard.

See Attachment A for a map of the planned network. The statewide geodetic control network described in this document provides both horizontal and vertical control at each station. However, the primary considerations that were adhered to in the network design are the NGS guidelines for performing vertical GPS surveys. It is well known that GPS vertical surveys require more stringent specifications than horizontal surveys to achieve the same degree of accuracy. Thus, the needs of the vertical component have determined the overall design of the network.

## Network Policies

The planned statewide geodetic control network shall observe the following policies:

a. The network shall be part of the "National Spatial Reference System" and comply with the national spatial data infrastructure standards.
b. The network shall conform to the datum, accuracy classifications, guidelines, and methodologies accepted by NGS.
c. The network shall meet the goals and objectives of the federal National Height Modernization initiative as determined by the SRCW Council in consultation with NGS.
d. The basis of the network shall be CORS that have NGS-sanctioned geodetic values.
e. The network design shall facilitate establishment, maintenance, and monitoring through GPS survey procedures.
f. The network design also shall facilitate the utilization of other modern surveying and remote sensing technologies.
g. The accuracies of the network stations shall be the "best" that are technically and fiscally feasible.
h. Stations shall have, at a minimum, values for horizontal position, ellipsoidal and orthometric heights (vertical values), horizontal velocity (also vertical velocity on certain CORS), and a stated accuracy standard for each value.
i. The stations in the network shall be maintained (repaired or replaced if destroyed, disturbed, or, in the case of CORS, failed).
j. The network stations shall be monitored and their geodetic values kept current or supplemental information shall be provided to enable the user to determine the current geodetic values. *In certain subsidence or unstable areas, this might be impossible for passive stations. In such cases, an appropriate note will be included with the published geodetic values. These areas will be subject to additional monitoring.*
k. The network shall provide stations suitable for GPS positioning techniques; and the related database and Internet data portal shall provide appropriate geodetic data in a user-friendly, convenient manner.
l. The statewide geodetic control network, including access to the basic geodetic data, is to be available "free of charge" to all users.
m. The network shall provide a statewide geodetic control network; it is not intended to provide specific project-related control monuments. *SRCW will outline, explain, and provide means to obtain project control for classical surveys for non-GPS users.*

## Network Specifications

Station Accuracies

The minimum accuracies of the network stations, at their published epoch date, shall conform to those shown in the table below. The accuracies listed are at the 95 percent confidence level and shall be defined and documented in accordance with the specifications given in the Federal Geographic Data Committee's "Geospatial Positioning Accuracy Standards, Part 2: Standards for Geodetic Networks," "http://www.fgdc.gov/standards/standards.html," (FGDC-STD- 007.2-1998), or an officially-sanctioned successor document that replaces the referenced publication.

| Value | Minimum Station Accuracy | | Comment |
|---|---|---|---|
| | CORS | Passive | |
| Horizontal Position[1] | 3 mm – 4 mm | 10 mm | CORS are assumed to be the network's absolute basis. |
| Ellipsoidal Height | 10 mm | 20 mm | CORS are assumed to be the network's absolute basis. |
| Orthometric Height | 20 mm | 20 mm | Or as feasible with the latest, sanctioned geoid model. |
| Horizontal Velocity | 1 mm/yr | 3 mm/yr | |

*Note: 1) Based on station accuracy determined by Panga GPS studies.*

Station Specifications

The physical architecture of the stations included in the statewide geodetic control network shall comply with the requirements noted below.

*CORS*: The CORS specifications (site conditions, equipment, communications, and installation procedures) will be modeled after the following:

i. Established GPS site designs (e.g. Unavco Permanent GPS station guidelines – see: http://unavco.ucar.edu/project_support/permanent/permanent.html) and those that have been used in Panga and PRSN site installations (see: http://www.panga.cwu.edu/).
ii. The "Cooperative CORS" as published by NGS. For additional details, refer to "www.ngs.noaa.gov/CORS/Coop/Coop_details.html."

To avoid any confusion, the geodetic values of all CORS will be referenced to an official "Geodetic Reference Point" that is published in SRCW's database along with the appropriate offsets to the GPS antenna. In some cases, the Geodetic Reference Point may be a physical point on the antenna due to constraints upon the site construction.

*Passive Stations*: Passive stations shall conform to the specifications and installation procedures specified by NGS for bedrock marks or Class B rod marks (aluminum rods may be substituted for stainless steel rods). See NOAA Manual NOS NGS 1, "Geodetic Bench Marks," 1978.

Station Spacing

The spacing of the network stations shall be as stated below. Existing stations will be utilized to achieve the specified station spacing. See the subsection below entitled "Stations Established by Others."

| Station Type | Spacing | Location | Comment |
|---|---|---|---|
| Framework CORS | 70 km (nominal) grid. | Established where security, power, and communications are conveniently available, if feasible. | Higher densities will be achieved in some areas by collaboration with regional and scientific programs. |
| Regional CORS | 15 km (nominal) grid. | See above. | |
| Corridor CORS | 15 to 20 km, generally linear. | See above for CORS locations.<br><br>Established along selected transportation corridors and other critical infrastructures, as supported by population, economic, terrain, and crustal motion needs. | |
| Passive Stations | 7 km (average) generally linear. | | The linear configuration is similar to the original NGS vertical control surveys. |

Attachment B shows a county-by-county tally of existing and new CORS that are included in the initial implementation. See Attachment C for a tally of planned passive stations in the initial implementation.

Survey Method

GPS survey methods, using the specifications and procedures that achieve the station accuracies specified above, shall be utilized to establish the entire statewide geodetic control network. Conventional geodetic vertical survey methods are simply too costly to employ. *(The NGS "National Height Modernization Study" reported that, for a statewide effort, conventional surveys were nine times more costly than GPS surveys. See previous section entitled "National Height Modernization Study.")* GPS survey methods also facilitate the subsequent monitoring of stations in an efficient and timely manner.

Orthometric Height Improvements

To improve the vertical values (heights) of the network stations and the geoid model in Washington, conventional geodetic vertical surveys and other efforts shall be performed to supplement the GPS surveys. It is estimated that these efforts will require a significant portion (nearly 40 percent) of the total initial implementation effort. The planned efforts include:

a. Perform conventional geodetic vertical surveys to establish NAVD88 elevations on selected CORS.

b. Perform additional conventional vertical surveys and GPS observations at selected locations to improve Washington's geoid model.

c. Develop models with real and simulated data, which then can be used to test the sensitivity of orthometric heights to data coverage, network configurations, and single-point errors. The results will be used to determine additional observational needs.

d. Measure gravity at selected CORS sites and in sparsely sampled areas, as guided by the effort described in item "c," above. For additional information, refer to the table included in the section below entitled "Estimated Initial Implementation Costs."

Stations Established by Others

Stations that are established by others and meet the adopted specifications may be included in the statewide geodetic control network to reduce initial implementation costs and to subsequently densify the network. However, the number of stations incorporated into the network (beyond the minimum spacing requirements) adversely affects the annual maintenance costs (e.g., station, data portal, and database maintenance costs). Thus, policies are required that "balance" the need/value of such stations with the additional annual maintenance costs. The SRCW policies regarding stations established by others are outlined in the table below.

| Responsibility | Approved Stations Established By Others [1] | |
|---|---|---|
| | **CORS** [2] | **Passive Stations** |
| **Station Included** as part of statewide geodetic control network. | Yes, provided the spacing is not less than 10 km from another "network" CORS. | Yes, provided the average spacing is not less than 7 km. |
| **Station Maintained**; i.e.; physical facilities replaced if destroyed, disturbed, or, in the case of CORS, failed. | Generally yes, if cost effective and provided the spacing is not less than 10 km from another "network" CORS. | No. |
| **Station Values Monitored**; i.e., geodetic values are monitored and updated as appropriate. | Yes, provided the spacing is not less than 10 km from another "network" CORS. | No. |
| **Station Data Distributed** as part of the statewide geodetic control network. | Yes, provided the spacing is not less than 10 km from another "network" CORS. | Yes, provided the average spacing is not less than 7 km. All such data will be noted as being for a station that is not maintained or monitored by SRCW. |

Notes:
1) Stations that meet the specifications and requirements specified for the statewide geodetic control network.

2) Agreements may be executed with others to make additional CORS (CORS less than 10 kilometers from an existing "network" CORS) part of the statewide geodetic control network. Generally, such agreements will specify that the other party will be responsible for the additional costs associated with the added CORS.

SRCW will encourage surveyors to file "records of survey" for control surveys that establish stations at a denser spacing than shown in the table; i.e., a spacing less than that acceptable for inclusion in the statewide geodetic control network. It is anticipated that the location and monumentation of many existing passive stations will be satisfactory for inclusion into the initial implementation of the planned network (e.g., High Accuracy Reference Network, HARN, stations, NAVD88 benchmarks, etc.). However, new geodetic values will be established for all stations included. For cost estimating purposes, it was estimated that approximately two thirds of the passive stations already exist. See subsection below entitled "Estimated Initial Implementation Costs."

Existing Geodetic Control

NGS has published values for a large number of horizontal control monuments and vertical control benchmarks in Washington State. However, much of this original, published control is unreliable for the reasons outlined above in the "Network Issues" section. There are three notable exceptions: 1) horizontal control included in the " Washington High Accuracy Reference Network"; 2) NAVD88 benchmarks in stable areas; 3) GPS measured airport surveys.

Existing stations (monuments and benchmarks) will be incorporated into the initial implementation of the planned statewide geodetic control network as outlined in the previous section, "Stations Established by Others." Selected existing stations that are not included in the initial implementation shall be updated (geodetic values and epoch) to be consistent with the Implementation Plan network adjustment, providing they meet all of the following criteria:

a. The station is included in the "Washington High Accuracy Reference Network" or is a NGS NAVD88 benchmark.
b. The station (monument or benchmark) is stable.
c. The station is essential to users.

The update (adjustment) of these selected stations will occur after the adjustment of the initially implemented network is completed and the horizontal velocity model has been updated. The stations will be selected, in cooperation with NGS and local users, based on the above criteria. These selected updated stations will not be maintained or monitored (see policies outlined in the previous section, "Stations Established by Others"). Existing "National Spatial Reference System" stations (i.e., NGS database stations) that are not included in the initial implementation and are not selected for updating will remain in NGS database. Data and other information for such stations will remain available through NGS. Caution: These stations might not be acceptable for use as control for a survey using the Washington Coordinate System of 1983 because they will not be maintained and their positions will not included in any new adjustment.

## Initial Implementation

Estimated Initial Implementation Costs

The estimated cost for initially implementing the statewide geodetic control network, as outlined in this Implementation Plan, is $8 million. Details, including how the various tasks are anticipated to be accomplished, are shown in the following table.

**TOTAL IMPLEMENTATION COSTS (5 Years)**

| Operation | Methodology | Stations | | Unit Cost | Total Cost |
|---|---|---|---|---|---|
| | | New | Existing | | |
| **Continuously Operation Reference Stations (CORS)** | | 53 | 29 | | |
| Reference Station Installation | Contract | 53 | | $35,000.00 | $1,855,000.00 |
| Data Processing & Adjustment (0.5 PYE) [2] | SRCW & contract | 82 | | $1,000.00 | $82,000.00 |
| Oversight (1.0 PYE) [2] | SRCW | | | | $141,000.00 |
| *Subtotal* | | | | | *$2,078,000.00* |
| **Passive Monumentation** | | 150 | 700 | | |
| Installation | Contract | 150 | | $1,000.00 | $150,000.00 |
| GPS Observation | Contract | 850 | | $1,000.00 | $850,000.00 |
| Data Processing & Adjustment (0.5 PYE) [2] | SRCW & contract | 850 | | $250.00 | $212,500.00 |
| Oversight (1.0 PYE) [2] | SRCW | | | | $141,000.00 |
| *Subtotal* | | | | | *$1,353,500.00* |
| **Height Modernization** | | Number | Units | | |
| CORS Site Leveling | Contract | 650 | km [1] | $430.00 | $559,000.00 |
| Geodetic Leveling | Contract | 5350 | km [1] | $430.00 | $2,300,500.00 |
| Gravity Surveys | Contract | 125 | points | $300.00 | $37,500.00 |
| Data Processing & Adjustment (1.0 PYE) [2] | SRCW & contract | | | | $230,050.00 |
| User Support (1 PYE) [2] | SRCW | | | | $100,000.00 |
| Oversight (3.0 PYE) [2] | SRCW | | | | $423,000.00 |
| *Subtotal* | | | | | *$3,650,050.00* |
| **Annual Maintenance Operations** | | **Annual %** | **%Complete** | | |
| *1st Year* | | 5.00% | 5.00% | | $0.00 |
| *2nd Year* | | 20.00% | 25.00% | | $15,352.50 |
| *3rd Year* | | 30.00% | 55.00% | | $76,762.50 |
| *4th Year* | | 25.00% | 80.00% | | $168,877.50 |
| *5th Year* | | 20.00% | 100.00% | | $245,640.00 |
| *Subtotal* | | 100.00% | | | $506,632.50 |
| **Spatial Reference Center of Washington [5]** | | Number | Units | | |
| Oversite | $705,000.00 | 5 | PYE [2] | $141,000.00 | |
| [4] Data Processing | $240,000.00 | 2 | PYE [2] | $120,000.00 | |
| User Support Staff | $100,000.00 | 1 | PYE [2] | $100,000.00 | |
| Maintenance | $160,000.00 | 2 | PYE [2] | $80,000.00 | |
| *Subtotal* | $1,205,000.00 | | | | |
| Equipment [6] | | | | | $200,000.00 |
| Center Indirect Costs [3] | | | | | $169,650.00 |
| *Subtotal* | | | | | $369,650.00 |
| ***SubTotal*** | | | | | **$7,957,832.50** |
| NGS Indirect Costs [7] | | | | | *$1,989,458.13* |
| **Total** | | | | | ***$9,947,290.63*** |

Notes:

1) Double run distance & cost per Km based on an average 3.5 Km per 3 person crew per day @ $1500 per

2) SRCW Staff - Inclusive of all expenses (labor, benefits & overhead) PYE: Person Year Equivalent

3) 13% of direct, minus capital expeditures over 25K, to Host agency.

4) 44% of Data Processing & Adjustment expeditures

5)Center costs below 20% of Total less NGS 20%

6) Vehicles, computers, phones & other capital assets $50K/yr only $25K/yr to Indirect costs

7) 20% NGS appropriation

Although the table above indicates how the various tasks will be accomplished (SRCW staff, SRCW Consultant, Contract, etc.), this does not preclude, by any means, a state or local agency from collaborating with SRCW to implement a portion of the planned network. For example, a county agency might assume the responsibility for installing the passive stations within the county or a state agency might implement selected CORS throughout the state. Such partnership proposals are welcomed (encouraged) by SRCW.

Implementation Contracts

Contracts shall be issued to private firms to perform the CORS installations (excluding certain equipment), establish the passive stations (i.e., install monuments as required, perform observations, and process data), and perform surveys to improve the geodetic heights. SRCW will perform the final adjustment for the entire network (approximately 80 CORS and 850 passive stations). It is anticipated that there will be the following contracts: CORS installation contract, contracts to establish the passive stations, and contracts for surveys to improve the geodetic heights.

The number of contracts awarded each year will depend on available funding. SRCW, with the assistance of others, is seeking sufficient funds to complete the initial implementation within five years. All contracts will be issued and administered by the SRCW with possible assistance from the hosting agency, currently the Washington State Department of Natural Resources (DNR). The contracting procedures, rules, and regulations of the state will be observed. All professional surveying contracts shall be awarded in compliance with Chapter 39.80 RCW, which requires that a “qualification based selection” (QBS) process be employed. In addition, all contracts shall conform to the terms of funding organizations; e.g., contracts involving NGS funds will conform to the federal “Brooks Act” if specified by NGS. It is anticipated that selection committees will consist of selected SRCW Executive Committee members and others.

## Support and Maintenance

Policies

All stations in the described statewide geodetic control network shall be maintained and their geodetic values kept current (up to date) through systematic monitoring. See policies “i” and “j” under the section entitled “Network Policies” in this document. The policy to monitor and update station values is important in the State of Washington due to the significant tectonic motions seen in the western portion of the state.

Procedures

Planned maintenance procedures are listed below.

a. Volunteers through an "Adopt-A-CORS and Adopt-A-Station" program shall perform minor maintenance and annual station checks. *This has been used in California in their program.*
b. CORS will be maintained by SRCW.
c. Passive stations that are disturbed or destroyed shall be repaired or replaced through an "on-call" contract. The on-call contract will be for a multi-year period and shall be awarded through a process following Chapter 39.80 RCW, requiring qualification based selection similar to those outlined for the initial implementation (see above).
d. Approximately 10 to 15 percent of the passive stations shall be resurveyed each year. The resurveys shall be performed through contracts similar to the initial implementation contracts (see above).
e. The resurvey results shall be used to update the station's geodetic values (i.e., a new epoch) and/or used to update the horizontal velocity model. If feasible, results from the resurveys will be used also to develop a vertical velocity model.
f. A **statewide** network adjustment with a new statewide epoch shall be made each decade.
g. SRCW shall seek FEMA funding to perform resurveys after earthquakes or major floods.

Estimated Annual Support and Maintenance Costs

The estimated cost for supporting and maintaining the statewide geodetic control network, based on the initial implementation as outlined in this Implementation Plan, is approximately $400,000 **annually**. Details are shown on the next page.

## ANNUAL MAINTENANCE & OPERATIONS

| Operation | Methodology | Stations (Estimated) | Unit Cost (Estimated) | Total Cost (Estimated) |
|---|---|---|---|---|
| **CORS** | | 82 | | |
| Maintenance *(Minor)* [1] | user | 82 | $0 | $0 |
| Maintenance *(Major)* | SRCW & contract | 82 | $1,500 | $123,000 |
| Utilities [2] | various | 82 | $500 | $41,000 |
| *Subtotal* | | | | *$164,000* |
| **Passive Monuments** | | 850 | | |
| Station Check [1] | contract | 850 | $0 | $0 |
| Maintenance *(Physical)* [3] | contract | 43 | $350 | $15,050 |
| Maintenance *(Survey)* [6] | contract | 128 | $1,000 | $128,000 |
| *Subtotal* | | | | *$143,050* |
| ***Total*** | | | | **$307,050** |
| **SRCW Operations & Management (Part of Operations Above)** | | | | |
| Equipment [3] | | | | $10,000 |
| *Staff (0.5 FTE)* [4] | | | | $70,000 |
| Center Indirect Costs [5] | | | | $10,400 |
| ***SRCW Subtotal*** [6] | | | | **$90,400** |
| **TOTAL Annual** | | | | **$397,450** |

Notes:

1) Performed by the user community and participating agencies
2) WAG
3) Vehicles and other equipment not provided by the host agency
4) Inclusive of all expenses (labor, benefits & overhead) FTE: Full Time Equivalent
5) 13% of SRCW Salaries to Host agency.
6) SRCW Costs at less than 20% of total annual

## User Information

Epochs

An epoch date is the **effective** date of a geodetic value (northing/easting coordinate value, latitude, longitude, ellipsoid height, orthometric height/elevation, etc.) for a given datum and adjustment; i.e., ***the date the geodetic values are valid***. Epoch dates are necessary because points (control stations) move over time as a result of tectonic plate motions, subsidence, and other factors. Currently, the use of epoch dates is essentially limited to horizontal values. Although the vertical values of some control stations do vary, the changes are a function of a number of underlying issues such as soil characteristics, water withdrawal, tectonic uplift or subsidence, etc. Generally, there is insufficient information to develop a useful model of the vertical changes; thus, epochs are not noted – at least currently. In Washington, the use of epoch dates is critical for horizontal values because of extensive crustal motions (secular and episodic tectonic plate motions) within the state. In some cases, SRCW may identify sites where the vertical component will also be epoch dependent.

Epoch dates are established (determined) as follows:

- For surveys that establish the positions of "primary" geodetic control (reference) stations, such as those included in the " Washington High Accuracy Reference Network" - HARN, etc., the epoch date is the mean date of the survey observation period.

- For local surveys, including most project control surveys, the epoch date is the same as the epoch date of the controlling (reference) stations. (See below for additional information.)

The year and the decimal portion of the year identify epoch dates. For example, take the epoch date of 1991.35. The decimal portion of the epoch date refers, in this case, to May 8, 1991, the mean date of a four-month HARN survey.

Secular crustal motions are generally uniform over time and thus can be accurately predicted by historical data (models). However, episodic crustal motions (earthquakes) cannot be predicted; thus, a new geodetic survey is required of the affected primary geodetic control after each major earthquake (magnitude generally greater than about 6.0) to measure the movements. The frequency of such events within Washington State is low (unlike California). However, large earthquakes do occur in our region, so the SRCW will be prepared to deal with this scenario.

NGS has incorporated the available crustal motion data (secular crustal motion data and data from surveys performed after major earthquakes) into a computer-

modeling program called "Horizontal Time Dependent Positioning" (HTDP). The model is updated after each major earthquake upon completion of the post-earthquake survey. The specific accuracy of HTDP is unknown, but is currently estimated by the NGS to be ± 0.5 centimeter per year.[1] HTDP can be used to convert (adjust) data from one epoch date to another epoch date. *Note that the program accounts for both the uniform secular motion, as well as episodic motion caused by earthquakes.* For example, if the primary geodetic control stations have different epochs (this is not unusual), HTDP can be used to adjust the control stations to a consistent epoch date; i.e., the same date. HTDP also can be used to relate a survey to a required date such as might be mandated by a local agency. HTDP is available from NGS at "www.ngs.noaa.gov."

A sample epoch calculation is illustrated below:

- Epochs for the Controlling Stations
  of a Survey to Establish Project Control: CORS A …..…… 2000.35
  Passive Station B … 1992.88
  Passive Station C … 1995.00

- Desired Epoch of the Project Control Being Established: 2000.35
  *(And the desired epoch of the project's detailed surveys.)*

  The surveyor uses the NGS HTDP modeling program to adjust the positions of controlling stations B and C from their various epochs to epoch 2000.35, prior to computing the positions of the project control stations. By performing this epoch adjustment initially, the project control *(and all subsequent detail project surveys based on the project control)* will be on a 2000.35 epoch.

It is anticipated, that eventually GPS vendors will incorporate HTDP (or some equivalent) into their software. When this occurs, the user will simply input the epoch of the controlling station and the desired epoch of the survey, and the software will automatically compute the necessary corrections. Of course, the "responsible charge" surveyor will remain responsible for the validity of such corrections and the overall survey results. The use of epoch dates and a seamless, statewide geodetic control reference network permit various surveys, conducted at various times, to be related to each other. This is a huge benefit to the surveyors and other spatial referencing professionals – and, in general, to the public.

Geodetic Heights

The vertical value (or height) of a point is commonly expressed in terms of "orthometric" height, or elevation, and is the primary "height" value used for

[1]A subcontract has been issued by the NGS to Smithsonian Astrophysical Observatory to generate a more accurate model of the Pacific Northwest for inclusion in HTDP.

mapping, surveying, GIS, and engineering applications. An orthometric height is referenced to the "geoid' – in simple terms, the surface obtained if the entire Earth was covered by water. This surface is not a smooth, mathematical spheroid; instead, it is an irregular surface that varies with the changes in the direction and magnitude of the gravity force. Such changes are caused by differences in the Earth's mass at different locations; e.g., mountains as opposed to flat surfaces. Conversely, GPS height values are referenced to an ellipsoid – a mathematical figure that is selected to represent the earth. The difference, or displacement, between the orthometric height (H) and the ellipsoidal height (*h*) is termed the "geoid height" (N).

$$\mathbf{N = \mathit{h} - H}$$

In most of Washington, the magnitude of geoid heights vary from about –18 to –30 meters. In a few locations around the state geoid heights can vary from this range slightly.

NGS and others have developed geoid height models that can be used to derive orthometric heights from a GPS survey; i.e., H = *h* - N, where N is obtained from the model. The current NGS geoid model is GEOID99. It has an accuracy, at the national scale, of about five centimeters (root mean square error); however, the relative accuracy over 10 kilometers is generally about one centimeter according to NGS officials. Although desirable, an accuracy map of the modeled geoid heights in Washington is not a simple product to develop. Geoid heights are sensitive to gravity and other data coverage and, currently, there is a lack of data in various areas of Washington.

Network Usage

All data for the described statewide geodetic control network will be available from a SRCW's data portal via a web interface. The basic data will be sanctioned by NGS and available to all users free of charge. The primary objective of the planned statewide geodetic control network (and SRCW) is to provide a seamless, statewide geodetic control reference network. Refer to Item "m" under "Network Policies."

For some surveys, the network data obtainable through SRCW might be used for other purposes beyond providing basic control data; e.g., positioning data for detailed survey points. See below for additional explanation.

Users have various options to utilize the statewide geodetic control network data from SRCW, depending on the type and accuracy of the data required and the availability of such data. The two basic methods are described below.

1. *CORS control data for positioning detailed project data.*

Usage: To provide control data for post processing the positions of detailed points for a project survey.

- This approach is only feasible where CORS are close enough to the survey to yield valid results with reasonable observation times.
- Specific guidelines for this type of work are still under development. Until such guidelines are developed, contact SRCW staff or an NGS Geodetic Advisor for advice. Example: NGS guidelines for GPS-derived ellipsoid heights (two-centimeter standard) currently state that two 30- minute observation periods are required for baselines less than 10 kilometers. *Note: This observation procedure continues to be investigated by NGS and others and might be revised to two 45-minute periods in the future.*
- If the published CORS epoch and the desired survey epoch are different, the surveyor must apply the adjustment for the epoch difference to the CORS and the detailed survey points. See discussion on epochs above.

2. *CORS and/or passive station control (reference) data for establishing project control.*

Usage: To establish detailed project control for a specific project or projects.

- Initially, SRCW anticipates that this will be the primary use of the statewide geodetic control network.
- SRCW will develop detailed instructions for such usage, as this will be (is) a common use of CORS data. In addition, SRCW staff will be available to conduct “CORS usage” training for groups.
- If the desired project control epoch is different from the published epochs of the controlling stations (CORS and/or passive stations), or if the controlling stations themselves have different published epochs, the surveyor must adjust the controlling stations and project control data to a consistent, valid epoch. For additional information, refer to the discussion on epochs above. See also the sample epoch calculation in the “Epochs” section, above.
- Once the project control is established for a project, that project control can be used to control all subsequent surveys throughout the duration of the project; i.e., from preliminary survey work, through the final land, design, and construction surveys. Additional reference to the statewide geodetic control network is not necessary for other project-related surveys, except for replacing destroyed project control or for checking the project control – in which case, corrections for the differences in epochs must be made (the controlling statewide network station epochs versus the project control epoch).
- For long, linear work involving several projects, it might be advantageous to establish a common project control, on a single epoch, for all projects.

(Future-option): *Real-time positioning data*.

Usage: To determine the position of detailed survey points in **real time**.

- This option will only be available where a Real Time Kinematic (RTK) GPS infrastructure system has been established; e.g. PRSN *(Puget Reference Station Network - a joint project between King County, City of Renton, the City of Seattle, and the Washington Dept. of Transportation.)*
- If the real-time CORS epoch is different from the desired survey epoch, the surveyor must apply an epoch adjustment to the real-time positioning data. See discussion on epochs above.

***Contacting SRCW*:** For general information or comments regarding the SRCW, this Implementation Plan, or other SRCW matters, contact the SRCW Council Chair, Gary Gervelis at *Gary.Gervelis@Seattle.Gov*, or Spencer Reeder, SRCW Interim Director, at wsreeder@yahoo.com. Additional information regarding the SRCW also can be found at SRCW's website, "http://www.surveycontrol.state.wa.us/srcwmain.html."

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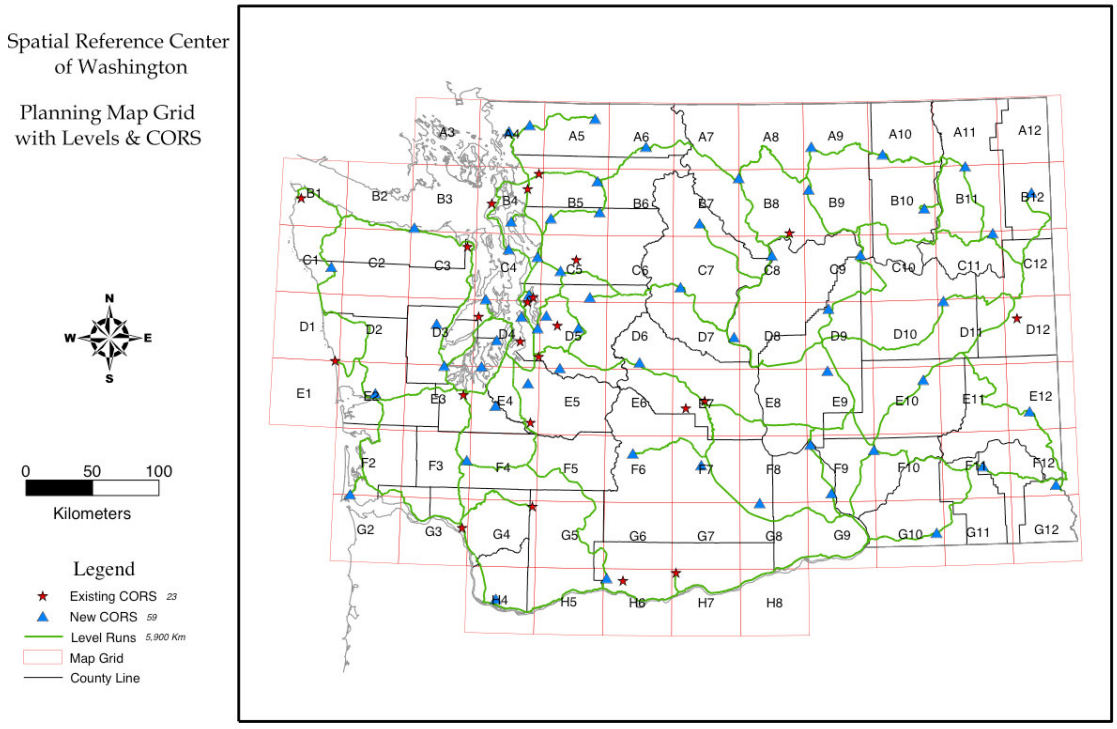
References:

*California Spatial Reference Center, A Master Plan for a Modern California Geodetic Control Network*, CSRC self-published document, Don D'Onofrio, et al, October 18, 2002, http://csrc.ucsd.edu/.

SRCW By-Laws, Revision 1, October 2003.

**Attachment A**

## Statewide Geodetic Control Network (Initial Implementation)




*

**Note: This map is available in color from SRCW in hard copy and electronic file formats.**

# Attachment B: Continuously Operating Reference Stations in the Statewide Geodetic Control Network (Initial Implementation)

| County | Exist | New | | Total |
|---|---|---|---|---|
| | | No. | Location | |
| Adams | 0 | 1 | Ritzville | 1 |
| Asotin | 0 | 1 | Clarkston | 1 |
| Benton | 0 | 2 | Richland<br>Hanford | 2 |
| Chelan | 0 | 2 | Lucerne<br>Nason Cr. | 2 |
| Clallam | 1 | 1 | Port Angeles | 2 |
| Clark | 0 | 1 | Vancouver | 1 |
| Columbia | 0 | 0 | | 0 |
| Cowlitz | 1 | 0 | | 1 |
| Douglas | 0 | 2 | Wells Dam<br>East Wenatchee | 2 |
| Ferry | 0 | 2 | Republic<br>Moon Mtn | 2 |
| Franklin | 0 | 1 | Connell | 1 |
| Garfield | 0 | 1 | Dodge | 1 |
| Grant | 0 | 2 | Coulee City<br>Moses Lake | 2 |
| Grays Harbor | 1 | 1 | Aberdeen | 2 |
| Island | 1 | 2 | Camano<br>Freeland | 3 |
| Jefferson | 1 | 1 | Hell Roaring | 2 |
| King | 5 | 7 | Hale<br>West Seattle<br>Renton<br>Eastgate<br>North Bend | 12 |
| Kittitas | 1 | 1 | Silverdale | 2 |
| Kitsap | 2 | 1 | Easton | 3 |
| Klickitat | 2 | 1 | Husum | 3 |
| Lewis | 0 | 1 | Napavine | 1 |
| Lincoln | 0 | 1 | Davenport | 1 |
| Mason | 0 | 2 | Shelton<br>Lake Cushman | 2 |
| Okanogan | 1 | 4 | Coulee Dam<br>Winthrop<br>Omak<br>Tonasket | 5 |
| Pacific | 0 | 1 | Ilwaco | 1 |
| Pend Oreille | 0 | 1 | Usk | 1 |
| Pierce | 1 | 3 | Purdy<br>Longbranch<br>Thun Field | 4 |
| San Juan | 0 | 0 | | 0 |
| Skagit | 2 | 1 | Rockport | 3 |
| Skamania | 1 | 0 | | 1 |
| Snohomish | 1 | 4 | Darrington<br>Arlington<br>Everett<br>Monroe | 5 |
| Spokane | 1 | 0 | | 1 |
| Stevens | 0 | 2 | Deer Lake<br>Colville | 2 |
| Thurston | 1 | 1 | Yelm | 2 |
| Wahkiakum | 0 | 0 | | 0 |
| Walla Walla | 0 | 1 | Walla Walla | 1 |
| Whatcom | 0 | 3 | Bellingham<br>Lawrence<br>Nooksack | 3 |
| Whitman | 0 | 1 | Colfax | 1 |
| Yakima | 0 | 3 | Sunnyside<br>Yakima<br>Rimrock Lake | 3 |
| **Total** | **23** | **59** | | **82** |

# Attachment C:

## Passive Stations in the Statewide Geodetic Control Network (Initial Implementation)

| County | Location | No. Sta. |
|---|---|---|
| | | |
| Adams | SR 395 | 20 |
| Asotin | SR 12 | 4 |
| Benton | I 82, SR97, Hanford | 35 |
| Chelan | SR 97, SR 2, SR 28, Lake Chelan | 30 |
| Clallam | SR 101, SR 112 | 31 |
| Clark | I 5, SR 14 | 9 |
| Columbia | SR 12, SR 260, SR 261 | 10 |
| Cowlitz | I 5, SR 4, St. Helens RR | 24 |
| Douglas | SR 2, SR 97, SR 28 | 11 |
| Ferry | SR 20, Colville Reservation | 22 |
| Franklin | SR 395, SR 17, SR 260 | 16 |
| Garfield | SR 12 | 8 |
| Grant | SR 17, SR 26, SR 28, SR 155 | 42 |
| Grays Harbor | SR 101, SR 109, SR 12, SR 8 | 39 |
| Island | SR 20, SR 525 | 13 |
| Jefferson | SR 101 | 17 |
| King | I 5, SR 2, I 90, SR 202, SR 520 | 53 |
| Kitsap | SR 3, SR 16 | 7 |
| Kittitas | I 90, I 82 | 24 |
| Klickitat | SR 14, SR 97, S. Cascades | 30 |
| Lewis | I 5, SR 12, SR 7, S. Cascades | 27 |
| Lincoln | SR 2, SR 28, SR 395 | 21 |
| Mason | SR 3, SR 101 | 16 |
| Okanogan | SR 20, SR 153, SR 97, Conconully Rd., Colville Res. | 60 |
| Pacific | SR 4, SR 101 | 14 |
| Pend Oreille | SR 2 | 8 |
| Pierce | I 5, SR 7 | 19 |
| San Juan | | 0 |
| Skagit | I 5, SR 20, SR 530 | 27 |
| Skamania | SR 14, S. Cascades | 19 |
| Snohomish | I 5, SR 2, SR 530, SR 202 | 32 |
| Spokane | SR 2, SR 395, SR 292 | 23 |
| Stevens | SR 20, SR 25, SR 292, SR 395 | 33 |
| Thurston | I 5, SR 8, SR 12, SR 101 | 10 |
| Wahkiakum | SR 4 | 8 |
| Walla Walla | SR 12 | 16 |
| Whatcom | I 5, SR 542 | 24 |
| Whitman | SR 23, SR 195 | 25 |
| Yakima | I 82, SR 12 | 18 |
| | | |
| **Total** | | **848** |

## Attachment D
## SRCW CURRENT & TARGETED MEMBERSHIP

**Professional Surveying and Mapping Organizations 4**
Land Surveyors' Association of Washington 1
Washington State Section - American Congress on Surveying and Mapping 1
Washington Council of County Surveyors 1
American Society for Photogrammetry & Remote Sensing 1

**GIS Organizations and Professionals 1**
Urban and Regional Information Systems Association

**Geophysical Research Professionals 2**
PANGA, others - 2

**Federal Agencies 8**
USGS -1
Director of NGS 1
NGS State Geodetic Advisor 1
FEMA 1
US Army Corps of Engineers 1
BLM 1
U.S. Forest Service 1
U.S. Bureau of Reclamation 1

**Washington State Agencies 12**
Dept. of Natural Resources - 2
WSDOT -2
- Aviation
- Transportation

Department of Agriculture 1
Office of the Attorney General 1
Department of Ecology -1
Washington Military Dept. -4
- Emergency Management
- Air National Guard
- Army National Guard
- Homeland Security

Other State Agencies - (at large) 1

**Cities 4**
Seattle
Tacoma
Spokane
One at large

**Counties 4**
King
Snohomish
Pierce
One at large

**Utility Districts 2**
Northshore Utility district
Shoreline Utility district

**Utility Firms 4**
Puget Sound Energy
Snohomish Public Utility
Seattle Public Utilities
One at large

**Flood/Irrigation Districts (at large) 1**

**Energy & Energy Transmission Firms 1**

**Educational Professionals 7**
Surveying 2
Geophysical 2
GIS 2
At large 1

**Non-Designated Professionals 6**
Various Professionals (at large)

**Total 56**