GEM STATE SURVEYOR

SUMMER | 2022

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CALENDAR OF EVENTS

2022

August	ISPLS BOG Meeting North Idaho
August 23-26	NSPS Annual Meeting
September 15-16	IBPEPLS Board Meeting
October 12-15	NSPS Annual Meeting, Tulsa OK
November 17-18	IBPEPLS Board Meeting
December 3	ISPLS BOG Meeting, Boise
December 31	Annual ISPLS membership fees are due
March 13-15	2023 ISPLS Annual Conference

EDITOR: Hagen Beckstead

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EDITOR'S MESSAGE

Summer is here and demand on your time is high, but I am glad you have found a moment to read the great articles in this summer installment of the Gem State Surveyor. We do our best to keep you informed on what the ISPLS is up to, what legislative changes are coming, and to provide you with useful information of interest to surveyors in Idaho. To this end, we thank our sponsors for their continued support, and we thank those who take time from their busy schedules to contribute content. Special thanks to Jeannie Liimakka and the faculty at ISU for their contributions this summer.

I would like to encourage the various sections in the ISPLS to get/remain active and see how you can become involved with the ISPLS. With the major disruptions Covid-19 brought behind us, now is a good time to get your Section active again. We have numerous young surveyors joining the workforce. These meetings provide young surveyors invaluable opportunities to benefit from the experience and learning of others.

In other news, we are gearing up for an election this year which always entails a certain amount of disruption and change. Fortunately, we have folks keeping an eye on what this means for the ISPLS. You will not want to miss the update from Thomas Judge. Have a good summer everyone and thank you for your continued support!

Hagen Beckstead, Editor GSS

PRESIDENT'S MESSAGE

HELLO FRIENDS,

A group of us had the opportunity to go through the ISPLS storage unit, which is full of filing cabinets, desks, chairs, and boxes upon boxes of stuff. It's amazing how many things we've collected over the years and the furniture trends that were on display.

Among piles and piles of paperwork we did, however, find some treasures. We found a history paper of the first ten years of the ISPLS by Dave Couch. A few stacks of old pictures that Loyce Smith had taken, and a couple of old aerials of the BSU campus. I sometimes forget the process we used to have to run through to see the picture of that perfect moment caught in time. Taking all the pictures, once the roll was complete, down to the local Walmart or RiteAid to be processed, and in about a week or two you find that perfect moment that you've been waiting to see covered by a thumb. Now-a-days its instant gratification. Take a picture, post it on the internet forever, and you may forget about it.

As I reflect on the age of technology, I find that it's as important as ever to remember the past and what our forefathers went through. Whether this applies to our own family history, our profession, our country, or the world, the reflections should be the same. I plan to go through these pictures so that we can upload them onto our Facebook page and website under a historical tab or something to that effect. It's rather cool to look at these old photos.

Our future is there for us to mold and to set a path for our profession to not only survive but to thrive. I believe the ISPLS has been taking the necessary steps to be proactive in our future, but it cannot end after one success. That is why we have redone our five-year plan and set achievable goals. Everything from this time on that the Board of Directors decides is predicated by "Does this help us advance our goals"? But the Board of Directors cannot do it alone. Get involved! Get off the fence! Get those mud boots on and get to work! We need you and the Profession needs you.

On another note, the economic uncertainties have been weighing on my mind. These uncertainties are becoming more and more prevalent as this year goes on. Gas prices and the cost of goods is creating a financial pinch on many of our families and clients, and this will eventually trickle down to us. Are we prepared? Have we learned from the past downturns? 2008 wasn't too far ago. It should be still fresh in our minds, but are we doing enough to put ourselves in a better position this time? Is our business financially fit to endure what may come?

How about life beyond surveying when it's time to lay down the data collector? Are we preparing ourselves for that day? I wish I had started planning twenty-five years ago when I was new into the profession, but let's be honest, when we're young we think that retirement is a long way off. But here we are at the end of June and yesterday was New Year's Day.

These are all things that I have been thinking about these past six months to better prepare myself, my family, and my business for the future. We all need to plan for the unexpected in our own lives, in our families, and in our businesses.

Thank you

Jeremy Fielding, PLS

President ISPLS

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LEGISLATIVE UPDATE

by Tom Judge

The primaries are now behind us, and it is obvious the legislative landscape will be different next session. Senator Patrick has been the Chair of the Commerce and Human Resources Committee for several years. He gave every bill we brought to him a print hearing, and for four years every bill eventually became law. Senator Woodward served as our floor sponsor for those years with 100% success. Both lost in the primary and will be sorely missed. The House leadership will also be changing. Regardless of whether this is good news for you politically it will make it tough for regulated professions.

On July 1, 2022 we will see several new provisions become law. I hate to recycle old news but this is a reminder for everyone:

LICENSING LAW - SIGNATURE UPDATES:

The definition of "signature" was originally written when paper and ink were the most common form of published plans and maps. It has been changed over the years to accommodate modern (electronic) documents. The current definition is extremely difficult to work with in practice, especially for engineers providing large plan sets. This amendment allows the use of seal images and facsimile signatures. Professional Surveyors must remember to wet seal and sign documents that may be recorded. Facsimile signatures are not recordable.

BASIS OF BEARING AND DEFINITION:

The definition of "Basis of Bearing" currently restricts surveyors to one way of expressing how they determine directions on their maps. A new option is being added to align with modern practice. This change is being made in platting, surveying, and corner record law.

The new provision will allow the surveyor to describe the bearing system rather than picking one line. Keep in mind this requires a complete citation of datum, adjustment, epoch, and projection. You must provide enough information for the following surveyor to recreate your system. "Basis of Bearing GPS" is not and will not be acceptable.

The new language will also eliminate ties to PLSS monuments and the Point of Beginning call when resubdividing. This is to encourage the use of the proper underlying Lot and Block description. There are numerous Counties that still require a metes and bounds description with PLSS ties for all subdivisions.

New corner monument options added to PLSS monuments for ties: The requirement to find or set the center of section was added in the 2020 session. The surveyor was also required to verify unchanged conditions on an existing corner record or file a new record. Given these requirements, the Board agreed the Center of Section would be acceptable to serve as one of the two reference Public Land Survey monuments required in 55-1906 and 50-1304 Idaho Code. The Board further agreed that 16th corners with a pedigree (corner record) and monument meeting all current requirements could be used as a Public Land Survey reference monument.

The style of the statute has been changed to a 'list' format, making the requirements and options clearer to the licensee.

DOPL TRANSITION:

There are numerous rumors of difficulty getting information to or from the Board, especially agency guidance. While we should rely on each other to work out professional problems or questions there are times we need to know how the Board will treat a particular question. ISPLS continues to communicate concerns to DOPL. We need your input and supporting information if we are to effect change.

As a final word on the transition, Edith Williams will be retiring from Board service on June 30th. She was the last former IPELS employee with Board related duties. A huge thank you to Keith Simila, Jim Szatkowski, Jennifer Rowe, and Edith for your years of service.


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BREAK NEW GROUND

ISU SURVEYING STUDENTS EARN NATIONAL RECOGNITION BY PLACING SECOND IN ANNUAL NSPS COMPETITION

by John W. Liimakka, M.S., P.E., LSIT

A team of student surveyors from the Surveying Geomatics/Civil Engineering Technology programs along with two team advisors traveled to Washington D.C./Arlington, VA this past year March 30 – April 1, 2022 to participate in the NSPS 21st Annual Student Competition.

Overall, 13 teams were entered into the competition in two divisions: one for programs that offer Associates degrees and the other for programs that offer Baccalaureate degrees. The ISU team was one of seven teams entered into the competition division for the Baccalaureate degrees programs.

This year's competition was composed only of field exercises, no report.

The first day of the competition was set up as a scavenger hunt event where the student teams were sent out to locate and identify as many historic monuments–worth varying competition points–as possible in a given time period throughout the District of Columbia. Though students were provided with metro passes, other modes of transportation in DC were allowed. Other competing teams used taxis, buses, scooters and bicycles besides the Metro. The team from ISU chose, for the most part, to hoof it because the monuments that they were most interested in finding were the most historically significant ones. Some, set in the year 1792, happened to be the most difficult ones to get to. As a group the ISU students decided to perambulate the monuments. Our distance tracing apps computed that we walked at least 17 miles that day.

The second day of the competition was comprised of three separate activities: leveling, running a traverse and performing a triangulation. To bring this into perspective, the monuments in the triangulation included the Washington Monument and the Jefferson Pier (pronounced pie-er, like radials of a pie). In addition, teams were encouraged to wear vintage period surveying attire. The team from ISU did not disappoint. For the leveling component, teams were asked to perform a three-wire level loop using vintage surveying equipment with the performances being graded for closure, balance of setups and field note organization. For the traverse, teams were asked to perform a 4-sided traverse using a Gunter's chain and staff compass with the performances being graded for closure, accuracy of chained distances and accuracy of measured angles. For the triangulation, teams were asked to triangulate the position of an unknown position from two other known positions using a Wild T-2 theodolite with the performance being graded solely on the accuracy of the resulting coordinates. Given the coordinates of two monument points on which the student set up and turned angle on with reference to the Washington Monument, the objective of the triangulation procedure was to determine the coordinate position of the Jefferson Pier. This part of the competition required that the students perform hand computations for

NSPS COMPETITION

distance, direction and coordinate positions. According to the judges, the ISU team's results were both accurate and precise.

On day three of the competition the points were tallied by representatives of the NSPS Young Surveyors Network with the results then being announced at the evening award ceremony by NSPS President Timothy Burch. Giving congratulations to the team from Ferris State University for taking first place in the competition, the team from ISU was elated to be awarded the second-place trophy. In retrospect, the ISU team surmised that they may have placed even higher had they rented bicycles or scooters for the monument search phase of the competition. Regardless, the significance of retracing the footsteps of surveyors such as Andrew Ellicott and the first African American surveyor Benjamin Banneker was of more importance to the students than the competition itself.

Besides the competition, the students enjoyed being able to network with members of the surveying profession at a national level, being able to learn more about the surveying history of Washington D.C. and being able to meet and network with students studying in surveying programs from around the country. An additional and unexpected highlight of the experience was that the National Park Service, at the request of the NSPS, opened the cover for us to view the little known and seldom seen Washington Mini Monument which is located in a subterranean area adjacent to the Washington monument itself. The mini monument was used as a model to the construction of the Washington Monument itself and was left intact and undisturbed. Overall, the competition was seen as a great experience and a proud moment for the team from ISU and we are already looking forward to next year's NSPS conference. The ISU students and faculty would like to thank ISPLS for their continued support, it is greatly appreciated.

Pictures: 1. L-R; Advisor John Liimakka, James Hamby-Hall, Kris James, Justin Farrish, Kyle Staley, Craig Mackay, advisor Darren Leavitt. 2. Performing a traverse using vintage equipment. 3. Team ISU on the National Mall. 4. Awards ceremony all-participant photo featuring actors representing Benjamin Banneker and Andrew Ellicott. 5. Washington D.C. boundary monument set in 1792. 6. The Jefferson Pier monument (photo from Wikipedia). 7. The Washington Mini Monument.

Introduction to Least Squares Adjustment for Surveyors – Part 1

By

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Section 1: Concept

Let us start from the end of the Least Squares Adjustment (LSA) process. Least squares adjustment means, after adjustment, we square and add the residuals and the sum will be minimum. So, the slogan of Least Squares is that the least squares adjustment produces sum of the squares of residuals minimum. *Residual* is a value which is a difference between the average value and the measured value. LSA is applied when there are more equations than unknowns. This gives rise to the terminology, *Degrees of freedom*, which is defined as the number of additional measurements made more than what is required. For example, we need to measure one distance and it is measured 5 times. Here the number of observations is 5, and number of unknowns is 1; hence degrees of freedom = 5-1 =4. Redundancy makes observations reliable.

Suppose there are 3 equations with 2 unknowns *X* and *Y*:

$X+Y=2$ Eq.1

$X-Y=0.1$ Eq.2

$2X-Y=1$ Eq.3

Here, the first equation is stated as sum of the measurements, X and Y equal to 2; the second equation is stated as the difference of measurements equal to 0.1 and so on. Whenever we take a measurement, there will be an error or residual. Hence, the 3 equations can be written as:

$X+Y-2=V_1$ Eq.4

$X-Y-0.1=V$ Eq.5

$2X-Y-1=V_3$ Eq.6

Where, V_1, V_2, and V_3 are the residuals.

After the least squares' solution, the sum of the square of residuals should be minimum; i.e.,

$V_1^2+V_2^2+V_3^2=$ Minimum …. Eq. 7

$(V_1^2+V_2^2+V_3^2)$ is also written as ΣV^2

Σ (symbol capital sigma) means sum.

The minimum functional value is demonstrated in the following section.

Section 2: Tabular method on reducing to 2 unknowns Equations

In order to find 2 unknowns, these three equations must be reduced to 2 equations. Reduction from 3 equations to 2 equations with 2 unknowns is called the formation of *normal equations*. In General, Formation of normal equations means reducing the number of equations from more than what is required to the number of equations with same number of unknowns. Normal equations can be formed by Tabular method as follows:

In the table 1 below, the column "a" picks up the coefficients of X from 3 equations: i.e.,1, 1, 2; The column "b" picks up the coefficients of Y i.e., 1, -1, and -1; in column "l" picks up the constants 2, 0.1, and 1.

Then, we set the columns a^2, ab, b^2, al, and bl as follows:

Step 1:

For equation 1, $a^2=1$ times 1 = 1; a.b = 1 times 1 =1; $b^2=1$ times 1 = 1; a.l = 1 times 2 = 2; b.l = 1 times 2 = 2. Similar to above, the cells are filled up for equations 2 and 3.

Step 2:

Add the values in column a^2, i.e., 1+1+4 =6; this sum is designated by $\Sigma a^2=6$; Σa^2 means sum of numbers in column a^2,

In the same way for other columns; i.e., $\Sigma a.b=-2$; $\Sigma b^2=3$; $\Sigma a.l=4.1$; $\Sigma b.l=0.9$.

Table 1: Tabular Method to generate Normal Equations

cc	a	b	l	a^2	ab	b^2	al	bl
1	1	1	2	1	1	1	2	2
2	1	1	0.1	1	1	1	0.1	0.1
3	2	-1	1	4	-2	1	2	-1
			SUM	6	-2	3	4.1	0.9
				Σa^2	Σab	Σb^2	Σal	Σbl

Using the sums, the two normal equation are designated as follows (Ghilani 2018):

$(\Sigma a^2)X+(\Sigma ab)Y=\Sigma al$ Eq.8

$(\Sigma ab)X+(\Sigma b^2)Y=\Sigma bl$ Eq.9

Step 3

Plug in the values 6, (-2), 3 for (Σa^2), (Σab), (Σb^2) respectively, then equations become:

$6X+(-2)Y=4.1$ Eq.10

$(-2)X+3Y=0.9$ Eq.11

Solving these equations give $X=1.01$; $Y=0.97$.

Step 4

Now, we can also solve *X* and *Y* from the following cases:

Using Eq. 1 and Eq.2, X = *1.05 Y = 0.95*

Using Eq. 1 and Eq.3, X = *1* Y = *1*

Using Eq. 2 and Eq.3, X = *0.90* and *Y = 0.80*

Step 5

Compute the sum $5V^2 = V_1^2 + V_2^2 + V_3^2$ from the Step 3 as well as from Step 4.

Table 2: for Sum of Square of Residuals

Item	*X, Y*	V_1 (Eq.4) V_2 (Eq.5) V_3 (Eq.6)	$5V^2 = V_1^2 + V_2^2 + V_3^2$
LSA	1.01, 0.97	+0.021 -0.064 +0.043	0.0064
Eq.1 & 2	1.05, 0.95	0 0 0.15	0.0225
Eq.1 & 3	1, 1	0 -0.1 0	0.01
Eq. 2&3	0.90, 0.80	-1.1 0 0	1.21

From the table above, the sum of the squares of residuals ($5V^2$) from least squares 0.0064 is less than the values from other solutions, 0.0225, 0.01, 1.21. Hence, the Least Squares Solution provides the sum of square of residual minimum.

Section 2: Weights

In order to apply LSA procedure, the use of standard deviations of measurements to assign by computing weights to the measurements is a must, otherwise, the LSA is not valid (Buckner,2004). Giving weights in the measurements means providing importance according to the reliability of measurements. The measurements might have taken using different categories of instruments, different weather conditions, and different repeatability of the same measurement items. For example, an angle is measured on a sunny day, next day the same angle is measured but the weather is wet and windy. Now we cannot throw away the second day angle because it costs money to pay survey crew to take that angle. But we can combine these observations by giving weights to calculate weighted mean. Weight for an observation is calculated by formula, weight *(W)* $= 1/\sigma^2$; which means weight is inversely proportional to square of standard deviation after taking constant of proportionality as 1; where σ (symbol sigma) is standard deviation or error. The weighted mean can be computed as follows:

Table 3: Weighted Mean Computation

Day	Measured Angle	σ	*(W)* $= 1/\sigma^2$
Sunny	$M_1 = 50^0 21' 05''$	5"	$W_1 = 1/5^2$
Wet/Windy	$M_2 = 50^0 21' 56''$	25"	$W_2 = 1/25^2$

Considering only seconds, the weighted mean (W_{mean}) can be calculated by using seconds only (Bajracharya 2006):

$(M_1W_1+M_2W_2)/(W_1+W_2)$

$$50^0 + 21' + \left((5)\left(\frac{1}{5}\right)^2 + (56)\left(\frac{1}{25}\right)^2\right)/\left(\frac{1}{5^2} + \frac{1}{25^2}\right)$$

$= 50^0\ 21'\ 07''$

Section 3: Use of Weights in Least Squares Adjustment

Suppose Eq.1, Eq.2, Eq.3 have weights chosen arbitrarily: $W_1 = 0.1$, $W_2 = 0.2$, and $W_3 = 0.5$. Then the Least Squares Adjustment slogan becomes: weighted sum of the square of residuals is minimum

$W_1V_1^2 + W_2V_2^2 + W_3V_3^2 = 5WV^2$ is minimum.

. We multiply weight by their respective residual square and add all the products to obtain the weighted sum of the squares od residuals ($5WV^2$). Since the weights are chosen arbitrarily, the following tabular method of computation is for demonstration of the method only.

The following table shows the formation of normal equation using weights. The weights for eq.1, Eq.2, and Eq.3 are respectively 0.1, 0.2, 0.5. Here, assume that weights are already computed using standard deviation formula *(W)* $= 1/\sigma^2$. The normal equations using weight are formed setting the table as follows:

Table 4: Tabular method to form Normal equations using weights

eq	a	b	l	w	wa²	wab	wb²	wal	wbl
1	1	1	1	0.1	0.1	0.1	0.1	0.1	0.1
2	1	-1	0.1	0.2	0.2	-0.2	0.2	0.02	-0.02
3	1	-1	1	0.5	0.5	-0.5	0.5	0.5	-0.5
			0.94	0.8	0.8	-0.6	0.8	0.62	-0.42
					Σwa²	Σwab	Σwb²	Σwal	Σwbl

Then the normal equations become (Ghilani, 2018):

$(\Sigma wa^2)\ X + (\Sigma wab)\ Y = \Sigma wal$ Eq.11

$(\Sigma wab)\ X + (\Sigma wb^2)\ Y = \Sigma whl$ Eq.12

Plugging in the values for $\Sigma wa^2 = 2.3$; $(\Sigma wab) = -1.1$; $\Sigma wb^2 = 0.8$; $\Sigma wal = 1.22$; $\Sigma whl = -0.32$; then, Normal Equations are:

$2.3\,X + (-1.1)\,Y = 1.22$

$(-1.1)\,X + 0.8\,Y = -0.32$

The solution of the normal equations is:

$X = 1.13$; $Y = 1.13$.

Table 5: Weighted Sum of Square of residuals

Item	X, Y	W_1 W_2 W_3	V_1 V_2 V_3	WV^2
LSA	1.13 1.13	0.1 0.2 0.5	+0.25 -0.01 +0.125	0.00625 0.002 0.0078
$\Sigma WV^2 = W_1V_1^2 + W_2V_2^2 + W_3V_3^2$				$= 0.0161$

This value of the sum of squares cannot be compared to the previous values because we choose weights for demonstration purpose only.

Now, if we choose the weights all equal to 1, i.e., $W_1 = 1$; $W_2 = 1$; $W_3 = 1$; then,

$\Sigma WV^2 = 1.\,V_1^2 + 1.\,V_2^2 + 1.\,V_3^2$

$= V_1^2 + V_2^2 + V_3^2 =$ which is same as Eq.7.

Hence, the unweighted least squares adjustment is assumed to have equal weights in the measurements.

Section 4: Applications of the Sum of the Square of Residual/Weighted Residual

The application is in computing the so-called *variance of the unit weight* $s\hat{e}^2$ (with symbol sigma hat squared), as follows:

The formula without weight is:

$$s\hat{e}^2 = \frac{\text{Sum of squars of Residuals}}{\text{Degrees of Freedom}} = \frac{\Sigma V^2}{d.f.}$$

From Table 1: $\Sigma V^2 = 0.0064$; Degrees of freedom ($d.f.$) = #of equation (=3) minus number of unknowns (=2; i.e., X and Y) = 3-2 =1

$$= \frac{0.0064}{(3-2)} = 0.0064$$

The formula with weight is:

$= \frac{\Sigma WV^2}{d.f.}$; From Table 5, $\Sigma WV^2 = 0.0161$

$s\hat{e}^2 = \frac{0.0161}{3-2} = 0.0161$

The value for $s\hat{e}^2$ should be equal to 1, if observations is properly weighted based on the calculated standard deviation from observations. Value larger than 2.5 means blunders exist (Hintz, 1998). Value less than 0.7 means lack of redundancy. However, in our case, the weights are arbitrarily chosen.

Summary and Conclusions

Concept of Least Square Adjustment has been presented. In fact, in order to form the normal equations, the use of calculus to take the derivatives was used in the literature and then only the tabular method had been developed from the calculus. In this paper, the simple concept of Least Squares Adjustment was explained without presenting the calculus material.

Without assigning weights to the measurements, the LSA will not be valid. An example of weighted LSA has been presented in this paper.

This paper presents the Part I. In future, Part II will follow with other examples.

References

Bajracharya, R.R. 2006. Random Errors in measurements for Surveyors. GEM State Surveyor, Volume XIX, Issue 1.

Buckner, R.B. 2004. Fundamentals of Measurement Theory and Analysis. Land Surveyors Publication.

Ghilani, C.G. 2018. Adjustment Computations: Spatial Data Analysis. Wiley.

Hintz, R. 1998. Understanding Least Squares Adjustment. Bureau of Lan Management. CMM Chapter 3 – Ray's Least Squares Paper.

THE TWENTY-FIRST CENTURY GEOID, AND APPLICABLE SURVEY METHODS

by Jeannie P. Liimakka

The geoid is a model of global mean sea level that is used to measure precise surface elevations. The geoid is irregular in shape and defines zero elevation. Using complex math and gravity readings on land, surveyors use this imaginary line through continents to measure surface elevations with a high degree of accuracy.

Imagine if the tide and currents were removed from the ocean, the geoid would settle onto a smooth undulating shape (rising where gravity is high, and sinking where gravity is low). The acceleration of gravity, or the "strength" of gravity's pull that is stronger near mountains, and weaker in valleys creates a very irregular surface. The geoid is a fundamental physical reference surface to which all observations refer if they depend on gravity. The NGS is working towards a very accurate geoid which will make it possible to obtain elevations to within an inch for more locations around the United States.

The image to the right depicts the geoid. Red areas have a stronger pull of gravity, where-as transitioning to blue areas the pull of gravity is much less. Gravity varies across the topography of the surface of the Earth. At every point it has a magnitude and a direction. An equipotential surface would be level and would coincide with the top of the idealized ocean. The geoidal surface is not just an imaginary product. For example, the vertical axis of a properly leveled surveying instrument and the string of any stable plumb bob are perpendicular to the geoid.

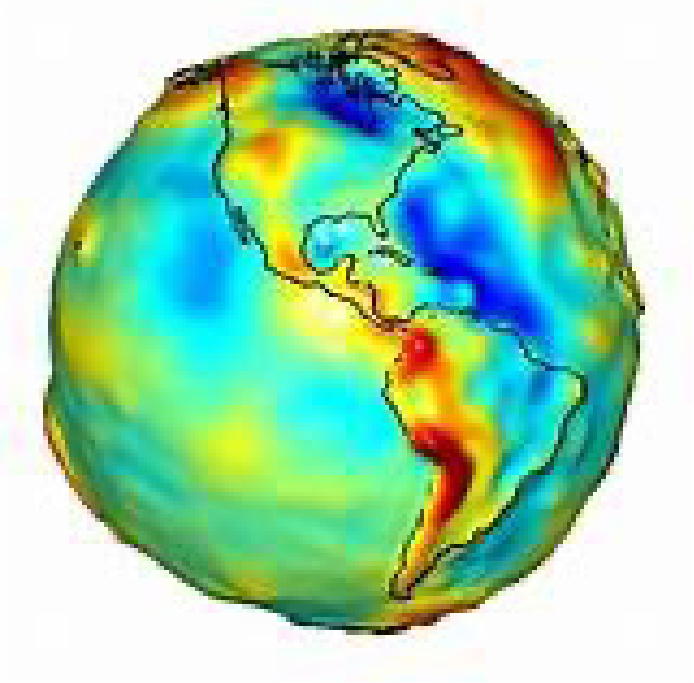
The geoid is an important aspect of today's surveying, as it is relied upon more and more for vertical control. Understanding the history of the geoid and defining it is just the start of really delving into the minutia of the geoid and its uses by surveyors. What is the difference between a hybrid geoid and a gravimetric geoid and which is more reliable? With a properly defined geoid, will there still be a need for precise leveling and precise benchmarks? Let us consider these questions further below.

THE GEOID, VERTICAL DATUMS, AND TIME?

A vertical datum is a surface representing zero elevation. The determination of heights above this zero-elevation surface is defined by the parameters and its realization. The realization is defined by the physical method of accessibility. The first physical method of determining a vertical datum began with a geodetic leveling project in the United States by the Coast Survey from 1856 to 1857. Transcontinental leveling began from Hagerstown Maryland in 1877 and general adjustments of leveling yielded datum in 1900, 1903, 1907 and 1912. These later datum are sometimes referred to as the Sandy Hook Datum.

The history of subsequent vertical datum is very well known. First came the National Geodetic Vertical Datum of 1929 (NGVD 29) also known as Sea Level Datum of 1929, followed by the North American Vertical Datum of 1988 (NAVD 88) the current datum used today. This later datum had a "zero height surface" which was very close to the geoid, and also was very close to being parallel to the geoid.

There are two historic types of geoid height models: the gravimetric (or gravity-based) and the Composite (or hybrid). The gravimetric geoid was defined by gravity data crossing the geoid and refined by terrain models (DEM's). The composite geoid used the gravimetric geoid and then was warped to fit available Global Positioning System (GPS) control data on NAVD 88 bench marks. Throughout the



country there was a campaign to observe GPS on NAVD 88 benchmarks. GPS on benchmarks (GPSBM's) were used as control to make Geoid99, Geoid 03 and Geoid 06a, Geoid 09, Geoid 2012B, Geoid 2018.

Historically, surveyors and others working with the geoid would have utilized NAD 83 (1996) and CORS 96 geoid models Geoid03, Geoid96 and Geoid99. Jumping into the twenty-first century they would have the NAD 83(2007) realization that utilized geoid models Geoid06 (Alaska only) and Geoid09. Our current realization is NAD 83(2011) utilizing Geoid12A or Geoid12B and Geoid18.

A recent PowerPoint presentation by the Northeast Regional Geodetic Advisor for the NGS, Dan Martin, in cooperation with the New York State Association of Professional Land Surveyors stresses the need to add the fourth element be-

ing time within the purview of the mission statement for the National Spatial Reference System (NSRS). There is a definite need for a consistent national coordinate system, incorporating latitude, longitude, height, scale, gravity, orientation and how each of these values change with time.

As surveyors, we know how to cite our horizontal datum (NAD 27 or NAD 83) and vertical datum (NGVD 29 or NAVD 88). This 3D datum consists of latitude, longitude and ellipsoid height, with fixed and stable coordinates such as all the realizations of NAD 83 (e.g. NAD 83 (1996), NAD 83 (2007), NAD 83 (CORS96), NAD 83 (2011). However, surveyors and the NGS, with the advances in technology have become determined on establishing a geometric datum which includes the element of time. This geodetic datum, which surveyors and the like will have to embrace, is a 4D geometric realization dealing with not only the latitude, longitude and ellipsoid height, but also velocities or how coordinates change with time (e.g. ITRF00, ITRF08). These improvements have reduced accuracies to decimeters. The bottom line is the NGS and NOAA must meet the needs of users for highly accurate and consistent coordinates and velocities using the Best Available Methods.

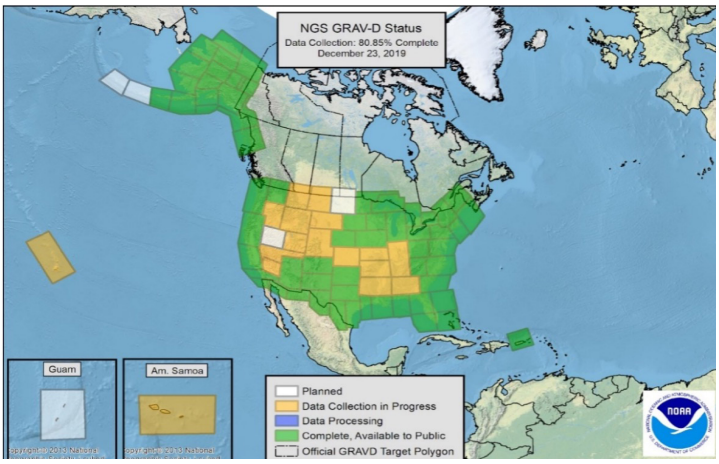
WHY A NEW DATUM?

But, why replace NAVD88 and NAD83? There are three main reasons: access, accuracy and global standards. The sky is much easier, cheaper and quicker to access with GNSS equipment. The accuracy of the GNSS is much better compared to a 60-year-old benchmark that is either destroyed by construction, or instable due to crustal movement. Today, with the ability to survey with GNSS, many systematic errors of many meters across the United States can be reduced. This future system referred aligns much better with GPS and international efforts.

There are problems with both NAD 83 and NAVD 88. NAD 83 is not quite geocentric, being approximately 2 meters from the center of the earth. It also does not define positional velocities very well. NAVD 88 is a realization of thousands of so-called passive control (bench marks), most which have not been releveled in the past forty years. NAVD 88 does not account for local vertical velocities such as subsidence and uplift: post glacial isostatic adjustment, creating uplift and subsurface fluid withdrawal, and sediment loading, creating subsidence. It also does not take into account the sea level rising approximately 1.34 feet per 100 years.

In the San Joaquin Valley in California a passive mark has subsided over six feet! This is just one example of subsidence and the need for a current up-to-date geoid. Thus, the need for the Gravity for the Redefinition of the American Vertical Datum (GRAV-D). The goal of this undertaking is to have accurate orthometric heights to within 2 centimeters, have a gravimetric geoid (Ng) accurate to 1 centimeter where possible using airborne gravity data. This will do away with the current hybrid geoid that is dependent on passive marks that have subsided or are destroyed due to construction and farming activities.

Two major campaigns which make up the GRAV-D project are; a high-resolution snapshot of gravity using primarily airborne observations, all relative gravity, covering the United States and Territories at an estimated cost of $39 million dollars, and a low-resolution "movie" of gravity changes, using primarily terrestrial, episodic observations of absolute gravity sites to monitor long-term change. Pictured below is the status as of December 23, 2019 of the GRAV-D campaign.



The Geopotential Field Model takes advantage of the latest technology in satellites, airborne observations and terrestrial/surface observations. The satellite technology uses altimetry from GRACE and GOCE satellite constellations with long wavelengths, over 250 kilometers. Intermediate wavelengths from 20 kilometers to 300 kilometers are observed via airborne gravimeters. Terrestrial surface observations and predicted gravity observations from topography are observed with short wavelengths of less than 100 kilometers.

This so-called gravity survey plan consists of predominantly airborne gravity measurements with absolute gravity measurements for ties and checks. Relative gravity measurements will be acquired for local regions where the airborne shows a significant mismatch with the existing terrestrial gravity measurements.

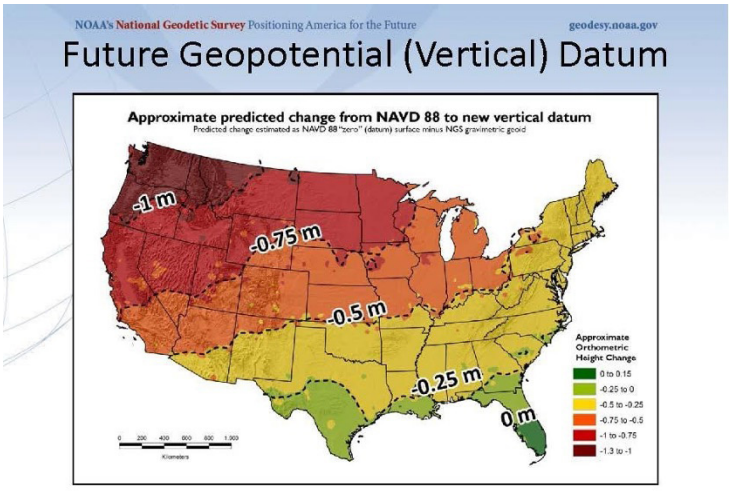
WORKING WITH THE NEW GEOID

The future geoid is currently being created with the latest technology by the NGS and is called GRACE for Gravity Recovery and Climate Experiment. The predicted difference between NAVD 88 and the new vertical datum begins around Florida with zero orthometric height

change and up to a meter orthometric height change in the Pacific Northwest of the United States. As can be seen by the following picture, NAVD 88 is tilted and biased as compared to the NGS gravimetric geoid.

The blueprint for the 2022 geopotential surface will be a global 3-D geopotential model (GGM) and will contain all GRAV-D data and be able to yield any physical value on or above the surface. This special high-resolution geoid will be consistent with the GGM and incorporate time-dependencies such as a geoid monitoring service. This monitoring will realize the impacts of deglaciation, sea level rise and earthquakes. This one vertical datum will be realized from pole-to-equator and named the North American Pacific Geopotential Datum of 2022 (GEOID2022).

The new horizontal datum, North American Terrestrial Reference Frame of 2022 (NATRF2022), will replace NAD83. The new vertical datum, North American-Pacific Geopotential Datum of 2022 (NAPGD2022), will replace NAVD88.



The latter will be primarily accessed via GNSS and the geoid. There will be an accurate continental gravimetric geoid which aligns with the Terrestrial Reference Frame of 2022 (TRF2022) and global mean sea level (GMSL). The varying nature of gravity over time will be monitored via the Geoid Monitoring Service (GeMS).

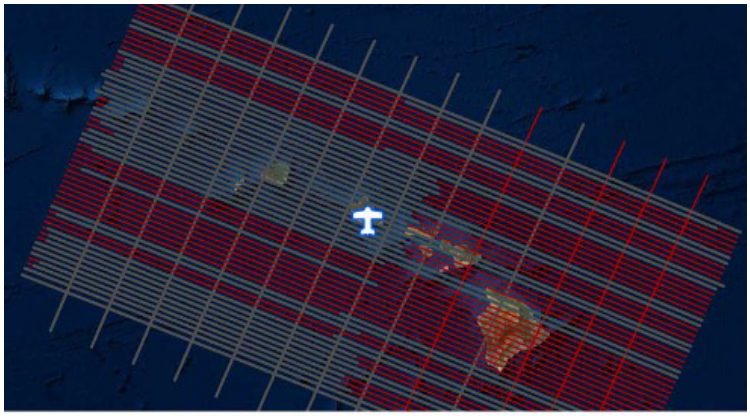
The image at the right depicts how a gravity map is made. NOAA's Aircraft flies a grid-like pattern over Hawaii in February 2019. A NGS scientist aboard uses scientific equipment to survey the geopotential for the state and surrounding coastal ocean. The lower image at the right shows the resulting partially-completed gravity survey map for Hawaii.

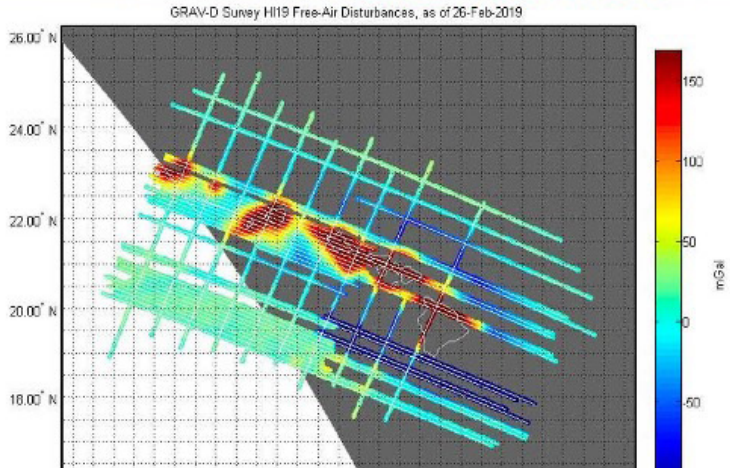
There are five individual components of NAPGD2022. The global model of the geopotential field referred to as GM2022 is the first of these components. The second is Geoid2022, also known as 'zero elevation', which will model the undulation by region. The third component models deflection of the vertical (DoV) by region as well, and will be called DEFLEC2022. The fourth and fifth components will be surface gravity models by region and will be called SGRAV2022 and DGRAV2022, being a static model and a dynamic model respectively. The picture to the left shows the estimated change in orthometric heights from NAVD88 to NAPGD2022.

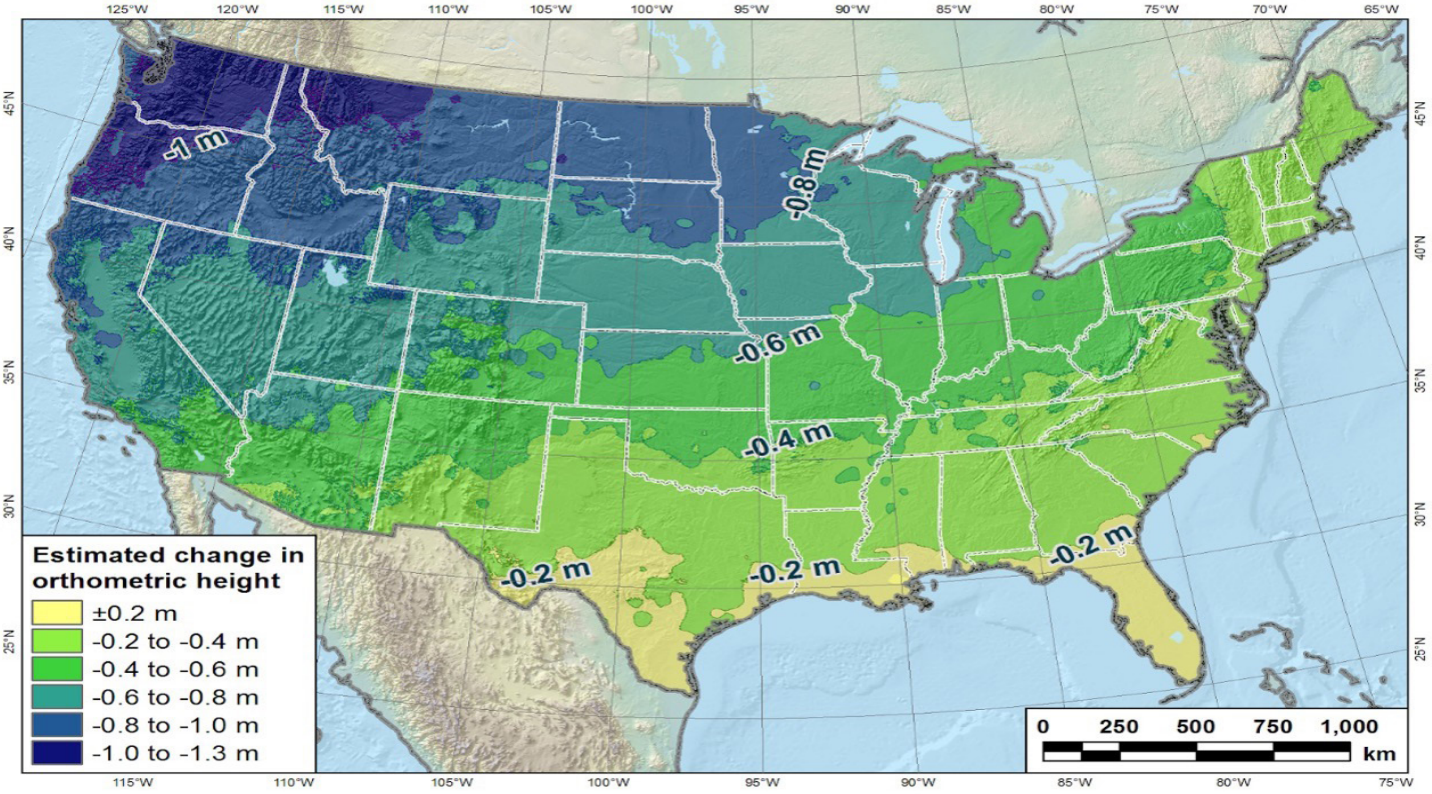
What does the blueprint for 2022 (which is upon us) look like? There will be new terminology to learn, new types of coordinates, new way of operating NOAA CORS Network (NCN), new way for Users to process GNSS projects, new way of processing leveling projects, and two new ways for NGS to process and store GNSS data, (Final Discrete and Reference Epoch). These last two will be referred to as Final Discrete Coordinates or (FDCs), and Reference Epoch Coordinates or (RECs).

GEODETIC LEVELING WITH THE NEW GEOID

Geodetic leveling is a complex process of measuring the geopotential of height times the change in gravity at any given point. Gravity must be accounted for when taking elevation measurements, because the Earth's gravity field







varies from point to point, and these variations affect how water flows.

Geodetic leveling using a level and invar rods has been performed by the NGS for many years. This leveling effort is no longer performed by the NGS, as, with the advent of GPS, they have focused their efforts toward creating an accurate geoid to be incorporated with GPS for obtaining elevations.

This begs the question, will there be ongoing NGS leveling projects? The answer to that should be a resounding yes! Leveling projects will require a time span that must not exceed 12 sequential months. Projects longer than 12 months must be broken into sub-projects each spanning less than 12 months. There will be a compromise between treating 1 GPS month as simultaneous in a GNSS area and acknowledging that leveling surveys often take weeks to months to conduct. The reality is that one cannot solve time-dependent orthometric heights in most leveling projects. GNSS projects have no time limit and are processed by GPS Month(s).

Leveling projects of the future will have to be planned and follow a six-step procedure. The first step is to identify the project marks that need to be leveled. Step two is to identify the primary control marks, each being within 30 kilometers of another primary control mark. In Step three all primary control marks will require two occupations with GNSS within plus or minus two weeks of the start of the leveling project, recommended in the same GPS month. Step four is when the actual leveling takes place, keeping the project within 12 months. If greater than 6 months, there will be a need for mid-project GNSS occupations on all primary control marks (step five, if needed). Finally step six, once all the leveling is complete, perform two final GNSS occupations on all primary control marks within the same GPS month.

Once the leveling project is complete, all the GNSS data is processed into GPS months, and adjusted to a mean epoch of the entire leveling survey to yield a representative orthometric height that will serve as control over the entire leveling project. The processing will result in absolute heights that will have standard deviations that are at GNSS accuracy levels, and differential heights that will have standard deviations that are at leveling accuracy levels.

This is offered to the Gem State Surveyor as a condensed version of my report on the geoid to my professor Dr. Ray Hintz for Spring Semester 2022, with University of Maine fully online Master's Degree in Surveying.

CALL FOR COMMITTEE MEMBERS

ISPLS is looking for members to assist on its various committees for 2022. Below is a list of our committees with descriptions on purpose. If you would like to learn more about a committee or would be interested in joining one, contact the ISPLS office at info@idahospls.org.

ADMINISTRATIVE COMMITTEE

- Duties include maintaining the Bylaws and Articles of Incorporation, financial administration, and ethical practice.

EXTERNAL MARKETING COMMITTEE

- Duties include lobbying and legislation on behalf of members, interaction with national professional surveying organizations, other professional organizations, and the community.

INTERNAL MARKETING COMMITTEE

- Duties include membership benefits and recognition, professional development, election of board members, Gem State Surveyor publication, and section support.

EDUCATION COMMITTEE

- Duties include promoting education in schools and universities and creating scholarships to promote surveying education.

INNOVATION COMMITTEE

- Duties include researching developing technologies and next generation surveying technologies.

CONFERENCE PLANNING COMMITTEE

- Assist with planning future ISPLS state conferences, including the selection of topics, speakers, locations adn sponsors.

ISPLS CALL FOR PICTURES

We are looking for great pictures depicting surveyors and surveying situations around the state for use on both our website and the Gem State Surveyor. The pictures have to be high quality, in a tif or jpeg file, and should not be long shots of anything (close-ups are preferred). We also need permission to use them now or in the future! Please submit to the ISPLS office at info@idahospls.org.

ISPLS CALL FOR ARTICLES

And we are in need of surveying related articles for the Gem State Surveyor! Please submit any suggestions or articles in electronic form to the ISPLS office at info@idahospls.org.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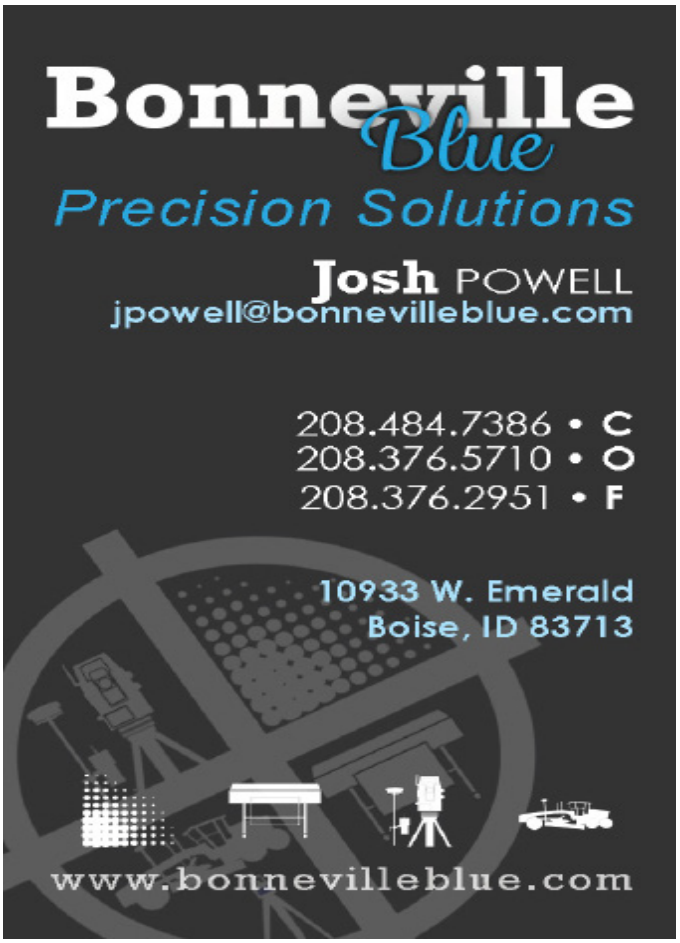
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