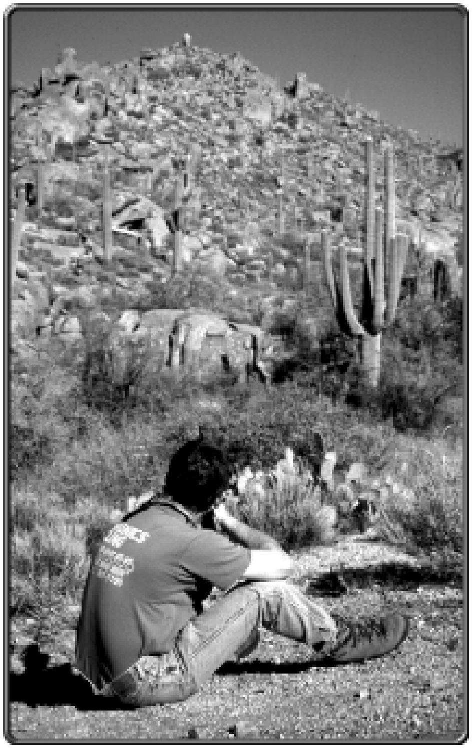
PRECISION BALLISTIC CHARTS — A CRITICAL AID TO LONG-RANGE SHOOTING

By John Antanies

There is an old saying, “Beware of the man with one gun.” Go ahead, take a big yawn and stretch — like a lot of the material published in hunting and shooting magazines, we all have heard that one. We also know the logic behind this — a shooter who owns but one gun learns its trajectory, trigger pull, etc., as intimately as he knows his wife. At least that’s the way the story goes. My observation has been that those who own one gun don’t shoot much — you could almost say “one gun, one box of ammo,” for it seems most of my hunting buddies who own one gun take tremendous pride in stretching that box of ammo over the decades. But the theory sounds good. After all, trying to learn the trajectories and wind drifts of several different rifles is bound to lead to mistakes.

My cure for the ballistic chart blues is to simply tape one on each rifle that I own. The only centerfire rifles I own that don’t have this data affixed to the stocks are my .308 Winchester, which I use for close cover deer and bear hunting in the upper Midwest, and my .416 Remington Magnum, with which I have shot two Cape buffalo at 20 and 45 yards — obviously not trajectory stretching shooting.



Shooting at uphill angles adds almost unlimited possibilities to the problems of connecting at long range. Comprehensive ballistics tables are the only solution to this problem.

I recently drew a coveted mule deer permit for the northern Kaibab plateau. Lately I have shot a ton of animals with my .338 Winchester Magnum — it may not be the flattest-shooting cartridge, and it doesn’t drip sex appeal like a .300 Remington Ultra Mag, but it really hammers animals. The rifle, a synthetic stocked Remington 700 SS, is deadly accurate. Given good conditions and lots of time shooting sitting with a tight sling (no bipod or sticks), I almost always can keep my shots inside 4 inches at 300 yards. On my last 300-yard practice session before leaving for Tanzania, I plunked in three shots in a group $1\frac{1}{2}$-inches — two of which hit the 3-inch aiming circle (proving that luck isn’t always bad). As you might guess, it is the rifle I am using for my upcoming mule deer hunt. Obviously, I don’t think you need a .338 to shoot mule deer — this simply is a rifle I feel very confident shooting.

The trajectory of my .338 Winchester certainly is not banjo-string tight, but flat enough. More important, I know it like the back of my hand. I know from lots of shooting that when zeroed at 200 yards I can hit something at 300 by cranking the scope up to 10x and holding the bottom post of the Duplex reticle right where I want to hit. In August I whacked a Nyssiland wildebeest at 308 yards shooting standing off of shooting sticks doing exactly that. Past that, I crank on the knobs. And, of course, the wind seems to have so many infinite possibilities that no one could remember them all.

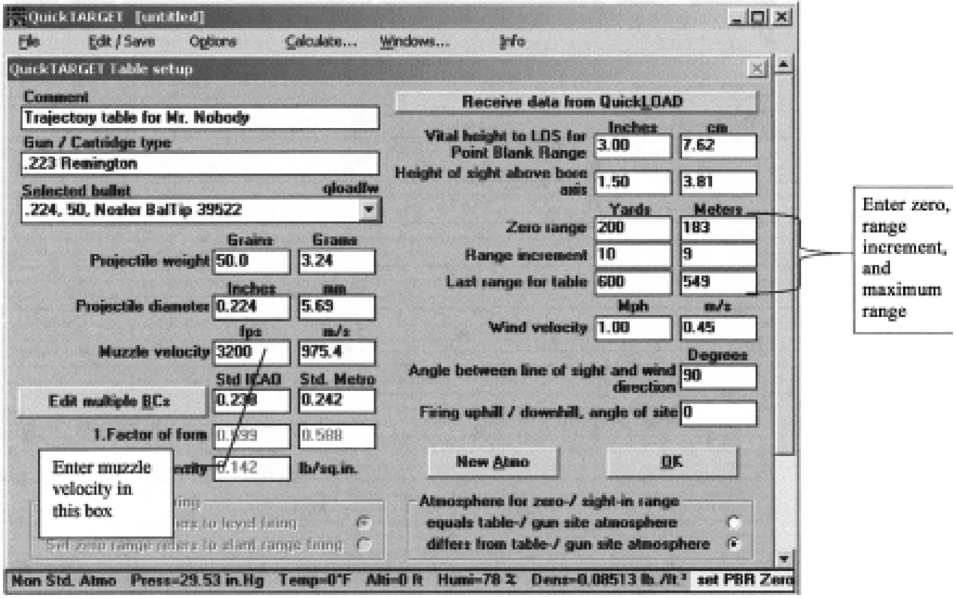
Varmint cartridges are no different. In fact, they are even worse, for two very good reasons: we tend to shoot at long range (certainly longer than big game ranges) and the tiny bullets we use are especially susceptible to wind drift (deflection). The other day I headed out to the Arizona desert for some practice. I took out my .223 and the venerable .338. The wind was blowing left to right for a combined effect that varied depending on exactly when I pulled the trigger. At 400 yards, shooting sitting with a shooting sling, I guessed 15 inches of drift for the .223 (using the ballistics chart on my rifle) and 12 inches for the .338. I was dead on for the .338, but the .223 bullets hit 8 inches to the right — I underestimated the wind, which is always tricky with such a light bullet. The wind was not blowing quite so hard when I shot at 500 yards; I held 9 inches for the .338 and hit within 4 inches of my point of aim. The .223 chart said to hold 12 inches to the left, but I had one good hit and a miss (about a foot) to the right. My shooting wasn't the greatest, but it would have been pitiful if I didn't have my ballistic charts, for even with constant shooting, who can remember the possibilities?

Just yesterday I went out into the desert and set up a target at 383 yards. The wind was howling; I didn't have my Kestrel anemometer, but it seemed to be blowing at 20 mph, which is a really strong wind. But, while it was strong, it was blowing almost totally in my face, making the drift math a lot easier. I scooped up some dust and released it. I watched how the dust blew, and then judged the wind direction using an indicator on my muzzle. I bet the wind was only 20 percent of full value, which was good, since a full value wind would have blown my bullets 28 inches instead of the 5 inches it really did. Judging all of this is tough enough with comprehensive ballistics charts; I cannot imagine even coming close without one.

When I shoot at very long range, I even compensate for changes in temperatures using ballistic tables taped to the stock. I also find an inclination/declination chart helpful (for shooting in mountainous country) as well as a trig chart (sine of a 90 degree angle in 10 degree increments) to calculate the net effect of winds at other than 90 degree angles.

John Anderson and I were discussing my use of ballistics charts the other day and he thought readers might be interested in how I create mine. You see, I don't use the tables supplied by ballistics programs such as *RCBS.LOAD* or *QuickTARGET*. They are good applications, but they don't have the detail I am looking for, so I use Microsoft *Excel* as a tool to compile the data these applications provide.

Figure 1 - Setting Up *Quick.LOAD*



Comment: Trajectory table for Mr. Nobody

Gun / Cartridge type: .223 Remington

Selected bullet (qloadfw): .224, 50, Nosler BalTip 39522

	Grains	Grams
Projectile weight	50.0	3.24
	Inches	mm
Projectile diameter	0.224	5.69
	fps	m/s
Muzzle velocity	3200	975.4
	Std ICAO	Std. Metro
Edit multiple BCs	0.230	0.242
1.Factor of form	0.599	0.588
Sectional density	0.142	lb/sq.in.

	Inches	cm
Vital height to LOS for Point Blank Range	3.00	7.62
Height of sight above bore axis	1.50	3.81
	Yards	Meters
Zero range	200	183
Range increment	10	9
Last range for table	600	549
	Mph	m/s
Wind velocity	1.00	0.45
		Degrees
Angle between line of sight and wind direction		90
Firing uphill / downhill, angle of site		0

Set zero range refers to level firing ●
Set zero range refers to slant range firing ○

Atmosphere for zero-/ sight-in range
equals table-/ gun site atmosphere ○
differs from table-/ gun site atmosphere ●

Non Std. Atmo Press=29.53 in.Hg Temp=0°F Alti=0 ft Humi=78 % Dens=0.08513 lb./ft.³ set PBR Zero

Enter muzzle velocity in this box

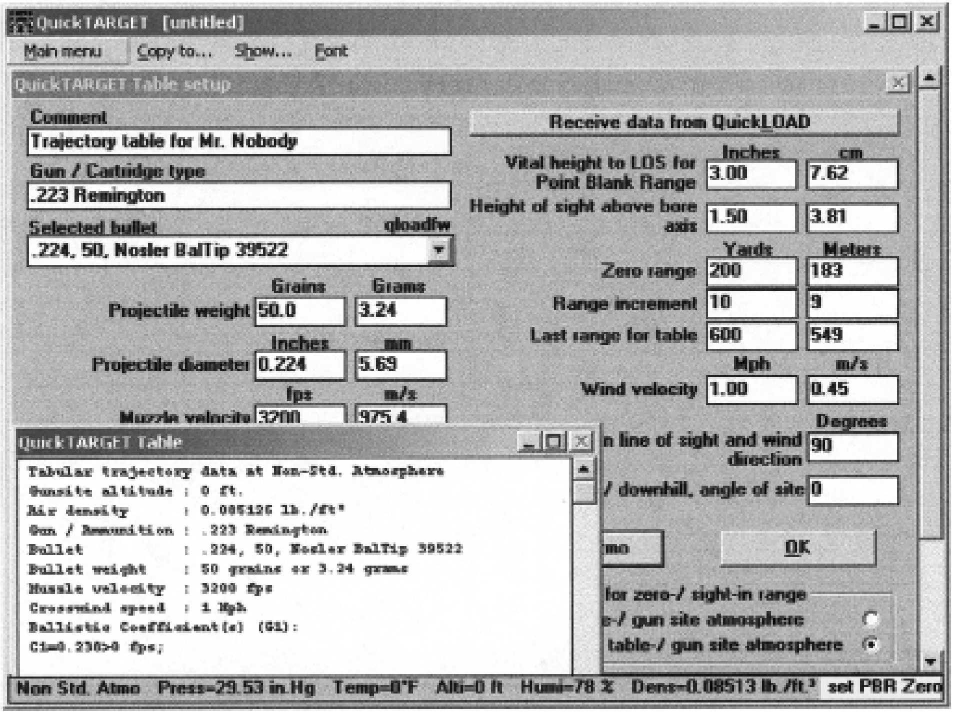
Enter zero, range increment, and maximum range

The first step in creating a good ballistic chart is to determine what you want. If you merely want a drop table in standard conditions, then lots of ballistics programs will work. One of the best I have found for those who would rather press a trigger than a keyboard is *QuickTARGET*.

QuickTARGET allows you to specify the range increments in the drop table, as well as the zero and the maximum range. For example, suppose we want to create a table for a .223 firing a 50-grain Nosler Ballistic Tip at 3,200 fps. Suppose further that we zero for 200 yards in 80 degree temperatures and want a table out to 600 yards in 10-yard increments. We launch *QuickTARGET*, then specify the bullet and muzzle velocity using the boxes provided. Next, on the right side of the user form, we enter the zero range (200 yards), the range increment (10 yards), and the maximum range, called "Last range for Table" (see Figure 1). Next, we must press the "New Atmo" button; this allows us to input our zero range environmental conditions. However, before we do this, we must select an option for under "Atmosphere for zero/sight in range." Select the "equals table" option, then click the "New Atmo" button. This will show a form that allows us to input the environmental conditions experienced when we zeroed. After that, we click the "OK" button on that form, which generates our ballistic table.

We can print this out, but there is a better option. Instead, selecting the "Copy to..." option on the menu bar allows us to export the whole works to *Excel*. Selecting this option launches *Excel* and pastes the data from *QuickTARGET* directly into *Excel*, which is my preferred tool for creating charts because I have total control of the font size, color,

Figure 2



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Zero range	200	183
Range increment	10	9
Last range for table	600	549
	Mph	m/s
Wind velocity	1.00	0.45
		Degrees
n line of sight and wind direction		90
/ downhill, angle of site		0

for zero-/ sight-in range
○ e-/ gun site atmosphere
● table-/ gun site atmosphere

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Tabular trajectory data at Non-Std. Atmosphere
Gunsite altitude : 0 ft.
Air density       : 0.085126 lb./ft³
Gun / Ammunition : .223 Remington
Bullet            : .224, 50, Nosler BalTip 39522
Bullet weight     : 50 grains or 3.24 grams
Muzzle velocity   : 3200 fps
Crosswind speed   : 1 Mph
Ballistic Coefficient(s) (G1):
C1=0.230>0 fps;
```

Non Std. Atmo   Press=29.53 in.Hg   Temp=0°F   Alti=0 ft   Humi=78 %   Dens=0.08513 lb./ft.³

lines, etc. For those readers who don't know Microsoft *Excel*, a tutorial is outside the scope of this magazine, but let's cover some basics quickly. Readers familiar with this application can skip over the next section.

Microsoft *Excel* is a spreadsheet program. If you have a home PC, you probably own a copy. In a nutshell, it lets us manipulate numbers using rows and columns. I cannot possibly teach you how to use *Excel* in a few paragraphs; whole books have been written on the subject. But, if you are reasonably intelligent (which you probably are, since you are reading **The VARMINT HUNTER Magazine**®), then you can take the tutorial. First, get on line. Next, launch *Excel* and go to the menu bar (those commands at the top of *Excel*). Select "Help," then select "Microsoft on the Web," then select "Tutorial." This is a relatively easy way to learn *Excel* basics.

Once you start using the "copy to *Excel*" feature in *QuickTARGET*, you soon will generate extremely comprehensive ballistics tables in a matter of minutes.

Getting data from other ballistics programs into *Excel* is not as easy as *QuickTARGET*. *RCBS.LOAD*, my "what if" favorite, suffers from a lack of standard MS Windows functionality. I am beta testing the next version of *RCBS.LOAD* and discussing possible improvements with Greg Mushial, the author of this application.

Let's look at a very simple table — the above .223 Remington from 100 to 400 yards. Let's assume that we have generated the drop table in 20-yard increments starting at the muzzle using *QuickTARGET*. The resulting table, after we choose the "Copy to..." option, is shown in Figure 3. Incidentally, if you get a bunch of hash marks (####), that means your column is not wide enough to display the width of the number. Just place your cursor on the right side of the column header and when you see the cursor go from a cross to a double-headed arrow with a line through it, double click your mouse. This will reformat the column width to fit the numbers.

If you used *QuickLOAD*, you will note that Column A contains the range, formatted to three decimal places. To save printing real estate, we want to reformat this to zero decimal places. With the mouse, click on the "A" in the column header. The whole column will be shaded darker, meaning you have selected it. Now go to the menu bar (the list of options starting with "File") and select "Format." A list of options will drop down; select "Cells..." and then select the number tab at the top of the form that appears (it already may be the tab selected). Under the "Category" list, select "Number." To the right you now will see a box labeled "Decimal places." Change this to zero by either clicking on the number "2" and changing it to "0," or clicking the down arrow (called a spinner bar) next to it twice. Finally, press the "OK" button. The numbers will be reformatted with zero decimal places. Notice that the first column, which indicates range, is now narrower.

If you don't have *QuickLOAD*, you can generate a trajectory table in the application that you have, and then try to copy and paste it to *Excel*. To do this, move your mouse pointer over the data you wish to copy, then left-mouse click. Holding down the left mouse button, drag the mouse over the data you want to copy. Next, right-mouse click and select

"Copy." Then select *Excel*, click the cell you want the data to start in, right-mouse click, and select "Paste." Not all applications will allow you to copy and paste data; if not, you will have to manually type data into *Excel*.

The basic data necessary in a good trajectory table is range, bullet drop, and wind drift. I used to enter wind drift data for a 10 mph crosswind, but I now use 1 mph drift data, for the simple reason that I find it much easier to "do the math." For example, I know my .220 Swift, firing 75-grain Hornady A-Max bullets at 3,185 fps, will drift 1.8 inches at 500 yards in a 1 mph wind; the drift in a 5 mph crosswind is 9 inches (1.8 multiplied by 5). I find it easy to just memorize the 1 mile per hour drift at 100 yard increments.

Once you have the basic drop and drift data for each increment in range, the next step is to calculate the number of clicks required to hit where you aim. The first step is to identify how far one click moves the bullet impact at 100 yards. Generally, one click will move the impact $^1/_4$-inch at 100 yards. Ensure that your scope does not use minutes of angle (moa) instead of inches; if it does, then one click moves the impact 0.262". Now, you might think that the difference, 0.012", is not much to get fussed about, and if you never shoot at long ranges, you are right. But at long ranges it does matter. With a .223 50-grain Nosler BT at 3,300 fps, it will result in an inch of error at 400 yards and 6.9 inches at 600, clearly something to be reckoned with.

Let's clean up our ballistics table, and then add the clicks required for drop and drift compensation. Remember the ballistics chart we created (Table 1)? Well, it has a lot more detail than we need. For example, we don't need to know the trajectory at ranges less than 100 yards, so let's get rid of those rows. To do this, simply left-mouse click on the first row number label, and while holding the mouse button, press the down arrow until all rows that you want to delete are highlighted (shaded). In the example I am using, I would delete rows 2 through 6. Once the rows are highlighted, right-mouse click and select "delete." The rows disappear. Incidentally, I find it very useful to include the trajectory at 100 yards, for it comes in handy to check the zero after traveling to a hunting area.

We probably are not particularly interested in velocity, time of flight, or energy, so let's delete these as well. Now we are deleting columns, so just click on the column label, which will be a letter, then right-mouse click and select "delete." When finished, we have drop and drift.

We want to add two columns to translate our drop and drift from inches to clicks. To do this, we go to the first empty cell in row 1 (it should be D1, if you follow my narration) and label it "Drop-Clicks." (Just type in "Drop-Clicks" and press enter.)

If you look at the drop from the line of sight, you will see the numbers are positive out to your zero; obviously, that is because the bullet is above the line of sight. Since we generally will never correct for drop at ranges less than our zero range, there is no need to calculate the number of correction clicks required. Instead, move the cursor to the row below the range at which you zeroed and click on the first empty cell to the right (D8 in my example). In this cell we will enter what is called a formula; this formula will calculate the number of clicks required to correct for the drop indicated at the far left in our table. Let's say that the range increments appear in Column A, the drop is in Column B, and currently we are in Column D. The correct formula to calculate the number of clicks required to correct for drop is: "=B8/((A8/100)*0.25)" where 8 is the row number (enter everything in between the quotes). (Note: this formula is for scopes that move impact $^1/_4$-inch per click; for scopes that move impact $^1/_8$-inch, substitute 0.125 for 0.25.) Next, we need to copy this formula. There are easier ways to copy than the one I will explain, but this is simple: just right mouse click on the cell with the just-entered formula, select copy, left-mouse click on the cell just below it, hold the mouse button, and slide the cursor down to the last row. Now right-mouse click and select paste. You know the formula is correct if the number of clicks at 400 yards exactly equals the drop in inches.

Next, we do the same thing for the wind deflection, except we use Column E and the formula is "=C8/((A8/100)*.25)". Again, if your scope has $^1/_8$-inch click adjustments (meaning one click moves the bullet impact $^1/_8$-inch at 100 yards), substitute 0.125 for 0.25 in the above formula.

Now we have a basic ballistics table. But wind rarely blows as a straight crosswind; more often than not, it is blowing at some angle less then 90 degrees. Calculating the effect of wind at less than 90 degree angles is relatively easy, but not as easy as some gun writers may have led you to believe, for occasionally I have read that a wind that quarters into the shooter has only a one-half value. Such writers prove I am not the first to write something that's incorrect; the actual effect is 71 percent. To correctly figure the net effect of wind angles less than 90 degrees, we must resort to a little trigonometry.

For those who are interested in calculating the net effect of wind angles less than 90 degrees, *Excel* works fine. First, you must express the angle in radians. To do this, use the radians formula. For example, if I were interested in calculating the net effect of a 30-degree wind, I would enter 30 in cell A1. In cell A2, I type in the formula "=radians(a1)". The result displayed in cell

Table 1 — Results After Copying Data From *QuickLOAD* to Microsoft *Excel*

Range (yd)	V (fps)	t (s)	Energy (ft-lbs)	Path to LOS (in)	WindDefl (in)	Drop (in)
0.0000	3200.1313	0.0000	1136.8799	-1.5000	0.0000	0.0000
20.0000	3106.9214	0.0190	1071.6168	-0.6095	0.0053	-0.0693
40.0000	3015.9021	0.0387	1009.7491	0.1362	0.0214	-0.2835
60.0000	2926.9250	0.0589	951.0474	0.7288	0.0476	-0.6507
80.0000	2839.8589	0.0797	895.3080	1.1613	0.0832	-1.1780
100.0000	2754.6548	0.1011	842.3903	1.4228	0.1300	-1.8763
120.0000	2671.2100	0.1232	792.1274	1.4976	0.1904	-2.7613
140.0000	2589.4465	0.1461	744.3769	1.3731	0.2646	-3.8456
160.0000	2509.2666	0.1698	698.9926	1.0395	0.3518	-5.1391
180.0000	2430.5818	0.1941	655.8423	0.4883	0.4512	-6.6502
200.0000	2353.4121	0.2191	614.8582	-0.2873	0.5620	-8.3856
220.0000	2277.3904	0.2448	575.7765	-1.2993	0.6849	-10.3574
240.0000	2202.9221	0.2715	538.7375	-2.5973	0.8275	-12.6152
260.0000	2129.9158	0.2994	503.6210	-4.1949	0.9887	-15.1726
280.0000	2058.2891	0.3282	470.3181	-6.1041	1.1672	-18.0417
300.0000	1987.9657	0.3579	438.7294	-8.3357	1.3623	-21.2332
320.0000	1918.8774	0.3885	408.7648	-10.8989	1.5730	-24.7561
340.0000	1851.1926	0.4198	380.4365	-13.7871	1.7966	-28.6042
360.0000	1784.5448	0.4525	353.5362	-17.1075	2.0451	-32.8844
380.0000	1720.0702	0.4870	328.4515	-20.9392	2.3236	-37.6759
400.0000	1657.5693	0.5229	305.0158	-25.2950	2.6294	-42.9916

A2 will be 0.523599. To calculate the net effect of this angle, we must calculate the sine of the angle. To do this in Excel, go to cell A3 and enter the formula “=sin(a2)”. If you want, you can format this as a percentage by selecting “Format-Cells-Number-Percentage.” In any event, the result is 0.5 or 50 percent, which means that a wind blowing in at a 30-degree angle has one-half of the drift value of a straight cross wind. I did the math for you for angles in 10 degree increments; see Table 2.

To use this table, first identify the 90-degree (full drift) wind drift for the range that you are shooting. Next, estimate the wind drift angle. Then, multiply the full drift effect by the corresponding correction factor for the angle of wind. For example, suppose that our bullet drifts 15 inches in a straight crosswind, but most of the wind is in our face. Consequently, we estimate the angle to be only 20 degrees, which means that our bullet will drift only 34 percent of the 15 inches, or about 5 inches.

But here is a tip for you that simplifies all of this trigonometry, and it is one that I have never seen in print. If you study Table 2 you will see that the net effect of angles other than 90 degrees is approximately the angle value plus 50 percent. In other words, a 10-degree angle possesses about 15 percent of the value of a full crosswind; a 20-degree wind 30 percent, etc. For angles that are greater than 66 degrees just use the full value. For all intents and purposes, this lets us forget about the trigonometry, especially considering that most of us do not measure wind angles with any degree of accuracy.

When I shoot in Minnesota, the last thing I have to worry about is the effect of firing uphill or downhill. But in Arizona, it is as important as looking out for rattlesnakes when walking out to place a target at a quarter mile. Common wisdom, again regurgitated by a legion of gun writers, has it that one need only worry about the horizontal distance a bullet flies, not the line of sight distance. Sports fans, that is bad advice. You see, the famous rule that a bullet’s trajectory, when fired at an angle, is affected by gravity only over the horizontal portion of its flight is just plain dead wrong. If gravity affected a bullet only over the horizontal distance of travel, a bullet fired straight up would go into orbit.

Anyone out there believe that's possible? To be honest, calculating trajectories by using the equivalent horizontal distance works for shots at 500 yards or less for reasonably flat-shooting cartridges; at longer distances, the errors become horrendous.

Time of flight always matters, and a bullet flying through 600 yards of air, no matter what the angle, still takes longer to travel than one flying 520 yards (the horizontal distance of a 600-yard shot at a 30-degree angle). To prove my point, let's assume that we are shooting a .223 Remington stoked with 50-grain Noslers at 3,400 fps. We click our scope up to our 600-yard zero and shoot at a target 600 yards away at a 30-degree angle. Our bullet hits 13.7 inches high, according to *RCBS.LOAD*. The impact at 520 yards is slightly over 20 inches high — so much for the theory that gravity affects a bullet only over its corresponding horizontal distance of flight.

Nevertheless, at distances of 500 yards or less, you can get pretty accurate using the corresponding horizontal distance theory. The easiest way to do this is to estimate the angle to the target and then multiply the distance to the target by the correction factor, which is simply the cosine of the angle to the target. The result is the corresponding horizontal distance, which you then use to estimate correct drop by using your ballistic chart.

Finally, while temperature corrections normally are not important until the range gets long, they are worth including. Obviously, including every temperature from -20 to 120 would result in 140 additional columns. Instead, I include one column 30 degrees less than the standard temperature (59 degrees F) and one column 30 degrees warmer. I use this to estimate the effects at all temperatures.

Since I would imagine a 50-grain Nosler BT at 3,400 fps is representative of something a lot of readers shoot, I constructed a trajectory table in 5-yard increments from 100 to 750 yards. It includes wind drift for a 1-mph wind and the effect of uphill/downhill angles at 10, 20, 30, 45, and 60 degrees. (Note: technically, a bullet fired at a downhill angle impacts slightly higher than one fired uphill, because of a slight reduction on the time of flight, but I simplified matters and ignored this effect.) The numbers in parentheses indicate the number of clicks required to correctly compensate. It took me about 30 minutes to construct. Combine it with the wind angle correction chart mentioned previously and you have a comprehensive ballistic chart.

To use this chart, you have to combine the effects of range, wind, temperature, and shooting angle. For example, suppose we have the following shooting conditions: range – 435 yards; temperature – 78 degrees; angle – 0; wind – 8 mph at a 45-degree angle. Tackle temperature first. The drop at 435 yards when the temperature is 59 degrees requires 24 clicks; at 89 degrees, it is 23 clicks. Since 78 is closer, dial in 23 clicks for elevation. The wind deflection at 435 yards is 2.3 clicks per mile per hour of wind, or 18 clicks for a full value 8 mph wind. But the angle is 45 degrees, so we use only 70 percent of 18 clicks. We dial in 12 clicks of windage and get ready to shoot. If you prefer, you can use inches and simply hold off.

If you have a mil. dot reticle scope, you can calculate drop and windage in miliradians. (Actually, after a lot of practice, you will just "know" where to hold with a mil. dot reticle.)

When John Anderson first suggested this article, I had to admit I questioned whether readers would really learn anything. If my detailed descriptions on Excel were a little tedious, my apologies. But in the end, I think this piece provides a few hints and tricks on how to quickly calculate trajectories at long range in various conditions. I am lucky to be able to shoot a lot at long range, and my hope is to share my observations with readers who share my passion but who might not be able to shoot as much. My personal goal in writing for this magazine is to impart at least one piece of knowledge with every submission that might help you hit the target at which you are aiming. I know I am not always right, but I hope this piece keeps that charter intact.

Table 2
Correction Factor for Wind at Angles Other Than 90 Degrees

Angle	Effect
10	17%
20	34%
30	50%
40	64%
50	77%
60	87%
70	94%
80	98%
90	100%

Note: A 90 degree angle is one that is blowing perpendicular to the shooter. To use this table, first identify the 90-degree (full drift) wind drift for the range that you are shooting. Next, estimate the wind drift angle. Then, multiply the full drift effect by the corresponding correction factor for the angle of wind. For example, suppose that our bullet drifts 15 inches in a straight crosswind, but since most of the wind is in our face, we estimate the angle to be only 20 degrees, which means that our bullet will drift only 34 percent of the 15 inches, or about 5 inches.