## Article



Quantitative Hydrology of Noah's Flood

# Quantitative Hydrology of Noah's Flood

Alan E. Hill



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[I will] explore the plausibility of Noah's Flood being local, i.e., localized within the Mesopotamian hydrologic basin ... The possibility that Noah's Flood could have been local rather than universal has been rejected by many people who argue that a local flood would have floated the ark into the Persian Gulf. This paper will explore the possibility that the wind could have blown the ark upstream, against the gradient, landing it some 650 to 700 miles inland from the Persian Gulf. First, the model determines the rate of water influx needed to flood the entire populated area of Mesopotamia. Then flood depths, range of flow velocities, etc. are generated based on a literal reading of Genesis 6–8. Finally, one plausible set of wind conditions (out of many possible) able to transport the ark to the mountains of Ararat is presented. Depending on the weight of the ark, wind velocities average as low as 50 mph, but peaks near 70 mph are adequate to accomplish the task. For all cases studied, the required wind velocities fall well within reason for a large stalled cyclonic storm over the Mesopotamian region.

he object of this paper is to explore the plausibility of Noah's Flood being local, i.e., localized within the Mesopotamian hydrologic basin rather than being universal over the entire planet Earth. A discussion of how this position meets with God's purposes and conforms to a rational interpretation of his Word has been addressed elsewhere, and will not be repeated here.1 Rather, this paper specifically answers the physical objections raised by Young Earth Creationists, who ask: (1) How could the flood waters, if constrained to a local region, have stayed backed up for 150 days, and (2) How could the ark have traveled against the current, landing in the mountains of Ararat, instead of floating with the current down to the Persian Gulf?

It seems inconsistent to question God's ability to perform simple miracles, such as those required to manage a local flood, yet allow for God to manage a giant-scale miracle related to a universal, worldwide flood.

Physicist Alan E. Hill is President and Chief Scientist of Plasmatronics, Inc., and Distinguished Scientist of the Quantum Physics Institute at Texas A&M University. Alan has spent some forty years inventing and developing evermore-powerful lasers of the Star Wars variety. In the early 1960s, while at the University of Michigan, Alan was the first person to discover nonlinear optics phenomenon. Alan and his geologist wife Carol are members of Heights Cumberland Presbyterian Church in Albuquerque, New Mexico, where they have taught "Science and Bible" Sunday School classes. Alan can be reached at: 17 El Arco Drive, Albuquerque, NM 87123 or at alanehill@aol.com. Consistent or not, the argument prevails, which is why I became motivated to write this paper. I wish to clarify my personal position that God can perform both "nature miracles," in which he manipulates natural forces, as well as "full blown" miracles in which he momentarily modifies his original laws of nature.

Since there is no rational evidence backed by mainstream scientific investigations for there ever having been a worldwide universal flood, I have turned my attention to providing mathematically quantifiable evidence that a local flood is plausible in terms of God's having performed a "nature miracle." More specifically, I have constructed a mathematical model into which the most critical topological features of the Mesopotamian region have been incorporated. Then, the literal biblical description of the period of rainfall and period of spring-water flow ("fountains of the deep") was entered into the calculation. The Bible does not give quantitative information on the magnitude of rainfall or spring flow rates, but it does give conditions as to the initial water depth at the point of the ark's departure ("15 cubits upward," Gen. 7:20), the total duration of rainfall and spring flow (150 days, Gen. 8:2), the presence of water at the ark's landing position (mountains of Ararat, Gen. 8:4), and the point in time when Noah disembarked

from the ark, i.e., when the mud hardened (exactly one year or 365 days after the Flood started, Gen. 8:14).

The details of rainfall and spring flow distribution functions in the model were manipulated in order to discover if any (or multiple) input scenarios could be fabricated which produced end results that matched a full ensemble of predictions stipulated by Scripture. Also, differing outcomes were explored to cover cases where biblical mandates were less clear. Finally, having developed input conditions that conform with Scripture, it is most interesting that the required rainfall and spring flow rate values are entirely consistent with the actual meteorological and hydrological conditions that can prevail in the Mesopotamian region.<sup>2</sup>

Since there is no rational evidence backed by mainstream scientific investigations for there ever having been a worldwide universal flood, I have turned my attention to providing mathematically quantifiable evidence that a local flood is plausible in terms of God's having performed a "nature miracle."

The ark was modeled to be situated upon the water in a manner wherein drag forces, due to water flow, pull the ark downstream, but intense winds blowing inland apply a driving force to that portion of the ark situated above the water line, which tends to drive the ark upstream, against the gradient. Most of the "wind work" is needed simply to hold the ark in place against the current. Then only a slight increase in wind velocity is needed to actually move the ark upstream. So, the computer model is programmed to derive the wind velocity versus time needed to move the ark from its (assumed) initial position to its final one within a period of 40 days (or less).

# Overview of the Mathematical Model

An outline of the mathematical approach used in this paper is included in the Appendix. However, since most of this mathematical detail will not be comprehensible to a general readership, some general comments need to be made with regard to its methodology, extent of applicability, and most specifically, its intended purpose. First, this model, and the nature of the assumptions it embraces, are crude at best. A full-blown hydrodynamics approach would be to prepare a "finite element" code wherein a network of cells are distributed across the entire flooded area, and each cell is mathematically tied to each of the cells adjacent to it. The physically defining equations for a full-blown approach include the Navier-Stoke's equation, or at least a composite of equations that invoke the conservation of energy, conservation of momentum, flow-stream continuity, and viscous losses.<sup>4</sup>

In contrast, my model relies fundamentally on a differential equation defining the continuity of flow and the "Manning formula," which hydrologists normally use to derive the velocity of flow versus the water depth and the hydrological gradient. This formula normally provides a method of dealing with flow losses caused by boundary drag effects. However, the Manning formula, as it is used in the formulation presented in this paper, can also include pressure head loss caused by turbulence and eddy currents.

I have assumed that the rainfall and spring flow are time variable, but that these two sources of water are distributed uniformly, but differently, over each of the three regions constituting the entire flooded space. Boundaries that control the flow pattern are also assumed, as shown in Fig. 1. The hydrological gradient is assigned one of two values that characterize the Mesopotamian alluvial plain and the ascent into the foothills of the mountains of Ararat, respectively. These gradients correspond to the currentday topology, which is believed to be relatively unchanged since Noah's time.

So, what has been lost by replacing a full-blown sophisticated model with a more simplistic one? Answer: nothing is lost, really, because we do not have the pertinent, detailed data from Scripture that is necessary to give meaning to a full-blown model. In either case, we are unable to realistically determine what actually happened to any level of detail during Noah's Flood. However, even my simplistic approach can be used to determine what *might* have happened, in terms of possible scenarios consistent with the Genesis record. And, we are enabled

The ark was specified according to the physical dimensions described in Gen. 6:15, and it was presumed to have been endowed with other sound engineering practices to minimize drag and maximize stability. Shipbuilding expertise existed in the time of Noah.<sup>3</sup> Furthermore, God gave Noah specific instructions on how to construct the ark suitable to meet his purposes (Gen. 6:14–16). Noah could have used sails (as was typical for boats of that time), but since Genesis does not mention sails, no use of sails is assumed.



It is fortuitous that the geometry of this region could be developed using cylindrical coordinates, referenced to a point of origin at the top, wherein both the flooded region and a smaller central channel serve as the major flow conduit spread at constant angles,  $2\theta_1$  and  $2\theta_2$ ,

respectively.

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to generate a plausible set of conditions, and subject to these, show that the ark could have readily been blown against the gradient to land 440 miles upstream, over an elevation change of 2100 feet within 40 days.

## Assumptions Concerning the Topology

The model overlays the Mesopotamian region considered to be flooded, shown as an area bounded A, B, C, and D in Fig. 1. This area covers the land region shown in figure 1 of the previous paper "Qualitative Hydrology of Noah's Flood" (p. 121) and it is assumed that the ark follows the route shown in that figure, i.e., from Shuruppak past present-day Baghdad, past present-day Mosul, up to Cizre in the foothills of the mountains of Ararat.

It is fortuitous that the geometry of this region could be developed using cylindrical coordinates, referenced to a point of origin at the top, wherein both the flooded region and a smaller central channel serve as the major flow conduit spread at constant angles,  $2\theta_1$ and  $2\theta_{2}$ , respectively. This choice of conditions allows for the entire region to be flooded, causing total destruction. In addition, for each of the three regions shown in Fig. 1, it provides a primary channel flow of constant depth and flow velocity at any given moment in time.

Here I am taking the liberty to define conditions that make the calculations easy, and this should be acceptable since the actual conditions are unknown and my choices have been made in conformance with the parameters specified in Genesis.



Figure 1. Geometric Model of the Topology of the Mesopotamian Hydrologic Basin.

Any scenario that can be found to work is acceptable toward meeting the purpose of this paper.

The three regions dealt with separately include: (1) the alluvial plain, which is one of the flattest places on Earth, its gradient is only 0.00072, over which the ark is being assumed to have traveled some 360 miles; (2) the foothills of Mount Ararat, where the gradient increases to 0.0017, over which the ark is being assumed to have ascended some 80 miles; and (3) a marshland delta region of some 120 miles, where the floodwaters could have escaped through marshlands to the Persian Gulf (figure 1 of the previous paper, p. 121).

The dynamics of flow (and reservoir backup) are determined by a competition between waters being supplied to the three regions and waters being lost through the marshland channel. Viewed end on (see cross-sectional views of Fig. 1), the coastline is assumed to vary gradually and slope down toward the Tigris River channel, and that within the marshland this constriction chokes the primary flow conduit channel to perhaps 40 miles wide. That is, the main radially directed channel is bounded by the angle  $2\theta_1$  of Fig. 1, and the full width of the flooded region is bounded by the angle  $2\theta_2$ . All of the land (at least inland of the marshes) is assumed to be flooded – deep enough to destroy life, but relatively shallow compared to the main channel flow so that the drainage can be assumed to flow laterally toward the drainage channel rather than radially downward. The marsh area can be adjusted by weighting the Manning friction factor to account for additional drag caused by the marshland vegetation.

The most populated areas at that time were those along the Euphrates and Tigris Rivers, or along canals connecting to these rivers. In any case, all of the ziggurat towers, onto which people could climb to escape the floodwaters, lie within the main channel regions defined by  $2\theta_1$ . For this reason, and because of scriptural definitions, the floodwaters were modeled to peak at least at a 40-ft depth over the entire region bounded by  $2\theta_1$  and the Gulf to the south, and the start of the ascent into the foothills of the mountains of Ararat. In addition, a formerly present river channel of some 600 ft wide and 20–40 ft deep is assumed to have extended the maximum water depth to some 60–80 ft. However, its inclusion into the calculation makes an imperceptible difference in the outcome.

The third region, the ascent into the foothills, was modeled to reach only a 20 to 30-ft depth in the region bounded by main channel flow, but with the possibility that there also existed an additional narrow central channel, perhaps extending the total depth to ~70 ft. Naturally, the water flow velocities in this steeper region were higher, mandating that somewhat stronger winds were needed to push the ark up the final assent to the foothills region of Cizre.

#### Noah's Ark

A literal translation of Gen. 6:15, and using the conversion factor 1 cubit = 18 inches,<sup>5</sup> places the dimensions of the ark at approximately 450 ft (300 cubits) long by 75 ft (50 cubits) wide by 45 ft (30 cubits) high. The ark is assumed to have been situated upon the water as shown in Fig. 2. Most likely the ark was configured as a barge, having an upturned prow to reduce drag, but otherwise box-like in shape. It may have had rudders and/or structural members to provide lateral stability according to the standard shipbuilding practices of that time.

According to Hoerner,<sup>6</sup> the prow as shown in Fig. 2 reduces the drag coefficient from 1.0 to 0.4. Further drag reductions down to 0.3 are possible by means of additional contouring, but the value 0.4 will be used. Note (from the formulas in the Appendix) that the total fluid dynamic drag scales as the square of the ark's velocity relative to the water flow. It is interesting to note that the Genesis-specified, length-to-width ratio of 6/1 for the ark affords the maximum stability, which is confirmed by the modern dynamics approach of Hoerner. Other factors needed to establish the validity of drag forces have been considered (including the Reynold's number, Froude number, etc.), but are deemed too detailed to warrant being included here in the text.



Figure 2. Configuration of Noah's Ark and Its Draft upon the Water.

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A draft of 5 ft, where 40 ft remains above the water line, will be shown to readily allow the ark [weighing less than 10.5 million pounds] to be blown upstream. A discussion relating to the mass of the ark, and correspondingly its buoyancy, must be included since this determines the ark's draft (the depth to which a vessel is immersed when bearing a given load, Fig. 2). In turn, the effects of wind blowing the ark upstream versus water drag tending to push it downstream, depends markedly on the buoyancy factor and correspondingly the draft.

A draft of 5 ft, where 40 ft remains above the water line, will be shown to readily allow the ark to be blown upstream. This condition may seem unrealistic at first glance; however, a brief consideration of the ark and the ark's cargo proves otherwise. The ark, if forced to become totally submerged, would displace a volume of water of about 1,520,000 ft<sup>3</sup>, weighing 94.8 million pounds, wherein an assumed 5-ft draft would displace a water volume weighing 10.5 million pounds. That is, the fully loaded ark would have to weigh more than 10.5 million pounds to cause the draft to exceed 5 feet.

So, let us now "ballpark" a lower probable weight for the ark, according to the estimates shown in Table 1 below. One could argue that some of these estimates are low. For example, more drinking water could be required if no fresh water were collected from the rain, more food could be needed, and the total weight of animals may have been underestimated. But let us use this beginning scenario as a baseline upon which curves to be generated remain self-consistent. At the end of this discussion, the outcomes for heavier "arks" will be tabulated.

# Computational Results for Floodwater Dynamics

The mathematical treatise for this paper is entirely relegated to the Appendix, in sympathy for a general readership. The results and the assumptions on which they are based will follow in these final two sections.

I have evaluated many rainfall distribution scenarios, but for simplicity sake, only a single "benchmark" one (with several variations) will be presented. For this scenario, a rainfall and spring water distribution has been adjusted to develop the characteristics specifically described in Genesis 6-8. Essentially, the water depth immediately rises to 40 ft (not including the central 600-ft-wide assumed river channel of an additional depth of 20-30 ft) and floods the entire Mesopotamian plain, including the ziggurats there. The foothills of the mountains of Ararat are also flooded by rain, snow melt, and spring waters pouring off the surrounding mountain highs.

The rainfall distribution over time for the benchmark scenario is shown in Fig. 3A. As Gen. 7:12 states, the hard rainfall is limited to a 40-day period, whereas weaker rain fell thereafter until day 150, and then both the rain and spring flow stopped completely after 150 days (Gen. 8:2). Interestingly, a peak rainfall of only 2.75 inches per hour, tapering off to just one inch per hour in 40 days produces the requisite conditions. Such rainfall rates are not unreasonable for large hurricanes. Here, the conduit flow has been stretched to cover a 40-mile width (defined

Table 1. Estimated Minimum Weight of Loaded Ark			
Super structure: 6" thick cedar wood, all 6 sides 65,000 $ft^3$ ; density of cedar = 0.5g/cm <sup>3</sup>	2.00 million pounds		
Braces	2.00 million pounds		
Cages, food bins, etc	1.00 million pounds		
Collected animals: 2 ea x 2500 species x 250 lbs average weight	1.25 million pounds		
Food for animals	2.50 million pounds		
Fresh water for animals and people (assuming the ark was kept shut up until Day 263)	1.00 million pounds		
Humans + 50 slaughtered ("clean") animals (250 lbs average weight)	0.15 million pounds		
Human accommodation	0.10 million pounds		
Total:	10.00 million pounds		

by  $2\theta_1$  in Fig. 1) at the confluence with the Persian Gulf. If the main channel width were to be further constricted to ~25 miles, the requisite peak rainfall value gets reduced to only 0.7 inches per hour (graph not shown).

Conditions somewhat modified from those of Fig. 3A develop a peak depth of 30 ft located at the assumed ark landing site. Again, the pre-existing river channel may have added another 20 ft at the point of maximum depth. These conditions will be shown to require a peak wind flow velocity of 72 mph (maintained for six days) in order to push the ark up the 80-mile long ascent into the foothills of the mountains of Ararat. Therefore, a second variation of the condition for the water supply rate onto the foothills region has alternatively been investigated. For this second scenario, the maximum depth at the landing site of the ark is reduced to 20 ft (plus the river channel depth) in order to reduce the peak wind-flow requirement. Hence, the required peak wind velocity gets reduced down to 62 mph. This alternative rainfall and spring water distribution falling onto the foothills of the mountains of Ararat is shown in Fig. 3B.



**Figure 3. Water Influx Versus Time**: (A) onto the Mesopotamian alluvial plain. Benchmark case: produces a 40-ft mean water depth, whereas an adjusted input data set (not shown) produces a 30-ft peak depth at the ark landing site; (B) onto the slope of the mountains of Ararat for the further reduced flow case as displayed (as B) which produces a 20-ft peak depth at the landing site.

Having specified a set of input conditions, let us now explore the outcome. The *rate* of water falling onto the total area (i.e., the "reservoir") is shown in Fig. 4 in terms of cubic feet per day over time. The total *accumulated* water retained in the reservoir is also plotted over time. By comparing these two functions, we can get a feeling for how rapidly the floodwaters accumulated versus how rapidly the waters flowed into the Persian Gulf. Fig. 4A applies this comparison for our benchmark case.

Fig. 4B shows what would happen if the flood channels were taken to be only 10 miles wide instead of 40 miles wide, thereby further constricting the water escape route into the Persian Gulf. As expected, relatively more water backs up. Hence, the waters reach their maximum depth at different points in time than in the benchmark case; that is, they reach an 85-ft depth in 25 days, wherein for the 40-mile-wide channel, a 40-ft depth is reached in five days. Also, the peak channel flow velocity rises from 6 mph up to 8 mph.

Despite the fact that both depth and velocity increase, the reservoir retention still doubles over the value achieved in the benchmark case. Also, the retained water curve loses its similarity to the flow-rate curve as the channel narrows, which is to be expected. Nevertheless, it is interesting to note that the water still drains away on a time scale of ~360 days in either case.



**Figure 4. Water Influx Rate and Reservoir Retention**: (A) for the benchmark study case, channel width = 40 miles; (B) like A, except channel width is narrowed to 10 miles.



The choice of channel width ... remains arbitrary.

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This fact indicates that slight adjustments could be made to accommodate a wide selection of values for channel width and yet we could find reasonable, self-consistent solutions. This is encouraging in that the choice of channel width, while reasonable, remains arbitrary.

Figure 5 displays the water depth for the benchmark scenario at two locations: the assumed ark launch and landing sites, respectively. Once again, the inclusion of an additional 20 to 40-ft depth over a potentially pre-existing riverbed is assumed, which does not cause a perceptible change to the hydrological dynamics.

The third region being analyzed is the marshland where the floodwaters flow into



Figure 5. Water Depth at the Ark Launch Point. Benchmark case: 40 mile-wide channel at confluence with Persian Gulf.



Figure 6. Mean Flow Velocity at the Confluence of the Flood Channel with the Persian Gulf. Benchmark case: 40-mile wide main conduit channel.

the Persian Gulf. This curve is omitted from Fig. 5 since it closely resembles the two curves shown. The maximum mean depth at this point, however, is increased to reach 45 ft owing to the extra drag of the water flow caused by the marsh vegetation in this region.

Next, Fig. 6 displays the mean water flow velocity within the 40-mile wide channel at its confluence with the Persian Gulf, which peaks on day 15 and which has fully receded by day 300. These depth and flow velocity parameters at the confluence are particularly important since they control the time-changing rate of water drainage, and this quantity taken in balance with the time-dependent water influx determines the water retention dynamics, i.e., how long it takes for the flood waters to recede.

Figures 5 and 6 both indicate that the floodwaters receded by approximately day 300, a time conformable with Gen. 8:12-13. In fact, note the sudden downturn to zero of the velocity in Fig. 6 at day 300. This zero effect is caused by the inclusion of an evaporation term in the model. Evaporation rates on the order of 0.3 to 1.0 cm/day are known to be characteristic of desert regions like Iraq,7 whereas I have determined empirically that the incorporation of the rate 0.15 cm/day (or 0.0022 inches per hour) causes the downturn specifically at about day 300, or perhaps at day 310, which is consistent with Gen. 8:13 where the ground was drying, but not yet completely dry.8 It took an additional 50 days after day 314 to dry up the earth completely, bringing the day of disembarkment from the ark at day 364, or day 365 (one solar year) if both the first and last days are included (Gen. 8:14). A slightly cloudier sky condition could have produced the exact number I empirically derived. These evaporation rates may appear to be too small to matter. However, evaporation provides an absolutely critical mechanism for getting rid of the last of the water, since at shallow depths, viscous drag forces impede the ability for water to flow. Also, evaporation was needed to dry up the mud sediments, which would have extended to many feet in depth.

As inferred earlier, I am taking a somewhat empirical approach that uses certain controlling formulas to produce realistic

answers. In doing so, certain physical constants must be derived from physical data. Then the calculations may be judged as to how well they predict (or conform to) natural occurrences. Normally the Manning formula is used to relate water flow velocity to the hydrological gradient, and the drag due to boundary effects along the "wetted perimeter" (the surface along which the flow stream touches). In addition to considering effects caused by boundary conditions, the "wetted perimeter" is assigned to a "constant" called the Manning roughness factor, nr. In textbooks, Nr is "called out" (for the case of very wide channels) according to the nature of the channel surface. In turn, this calibrates the effect that drag forces create at the flow boundaries. For example, the numerical value corresponding to the desert sand for our case is  $n_r = 0.035$ .<sup>9</sup> The existence of marshes can be accounted for by increasing the value for n<sub>r</sub>; in fact, the need to increase n<sub>r</sub> by a factor of 2 or 3 is not uncommon and the highest values used to fit a known physical situation reach the value of 0.4.<sup>10</sup>

As it turns out, the value of n<sub>r</sub> can be adjusted to more generally include all of the "head-loss" factors, including eddy losses due to turbulence as well as surface drag.<sup>11</sup> This method is now sometimes used by geomorphologists in lieu of incorporating a loss term in an energy equation, such as Bernoulli's equation. This technique is well suited to a situation where detailed data is lacking along the flow path. Based on known situations (such as flood data for particular positions), a new value for nr may be established for that region of space. Sometimes nr is continuously varied along the flow channel, or it may be assigned specific values characteristic of known regions. This latter scheme serves the purpose of this presentation quite well. For example, recent flood data taken in the Baghdad, Iraq region fixed the high water mark depth for the Tigris River at 23 feet when the corresponding flow velocity reached  $\sim$ 3.5 to 4 mph.<sup>12</sup> This measured data can be used to back out a value of  $n_r = 0.059$  for flood conditions. Interestingly, I had empirically backed out the number  $n_r = 0.06$  for the marshland region, which ideally conformed to the purpose of reconciling all of the conditions specified in Genesis. Actually, I used the number  $n_r = 0.05$  at Baghdad and  $n_r = 0.06$  in the marshland area, having increased it to account for the additional friction of the marshland vegetation. My choice of lowering nr slightly for both regions falls within reason, given that the floodwaters were much deeper in the case of Noah's Flood.

In any case, I find it quite remarkable that the  $n_r$  value generated from actual flood data for the Tigris River matches my value generated empirically, on the basis that it leads to physical conditions for the Flood as specified by Scripture.

### Noah's Uphill Journey

Having developed a hydrological framework, we are now positioned to explore plausible, but not unique nor specifically correct, wind conditions that could have moved Noah's ark from launch to final resting point, in conformance with the literal Genesis account. In review: (1) the waters quickly (within a few days) reach depths on the order of 40 ft at the launch point; (2) it rained heavily for 40 days and 40 nights, then tapered off, but continued to rain for 150 days, at which point the rain and springs ceased; (3) the waters had fully receded by day 314, and it required another 50 days for the mud to harden enough for Noah and his family to disembark.

Genesis does not indicate at what point the ark reached the region of its final destination, only that it came "to rest" in the mountains of Ararat on day 150. In any case, the dynamics allow for the ark to have reached its assumed landing area near Cizre within 40 days from launch. While the trek could have taken much longer, it is much more energy efficient to move the ark rapidly. This is because most of the "wind work" is needed simply to hold the ark in place; that is, stationary against a 6 to 8 mph water current. So in order to move the ark 380 miles in 40 days, we need add only a net 0.86 mph forward velocity to the ark, i.e., we must increase the velocity of the ark relative to the current by only ~10% as opposed to simply holding the ark stationary against the current, and in doing so the ark arrives (as computationally shown) in 36-40 days. The flow dynamics of this situation is shown in Fig. 2, which illustrates the ark, its draft upon the water, and the forces which act on it and which are needed to move it from launch to landing.

The solid line of Fig. 7 traces the water flow conditions along the actual path taken by the ark. The lower portion covers the 300 miles traveled along the alluvial plain against a hydrologic gradient of 0.00072. The curve jumps from its lower position to its upper position at the point where the ark begins its final 80-mile ascent against a gradient of 0.0017. The water flows faster along the steeper



Figure 7. Water Velocity as Observed from the Ark



The ark could have been blown upstream, given a least-favorable set of assumptions.

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slope, reaching almost 8.5 mph as shown. This calculation applies to our benchmark assumption where the maximum water depth is 40 ft in the alluvial plain and 30 ft deep along the steeper ascent to the foothills of the mountains of Ararat.

Figure 8 tracks the minimum wind velocity needed to move the ark upstream at a constant velocity of 0.86 mph, wherein it arrives in the mountains of Ararat in 36 days. In essence, the required wind rises to ~52 mph and must be maintained near this level for 28 days. Then the ark arrives at the point of ascent, which requires that wind conditions near 70 mph be sustained for another six days in order to negotiate the steeper slope. Possibly the tail end of the cyclonic storm moved by in order to provide the needed additional push.

The lower, final hump of the wind velocity curve presents a trade-off scenario, whereas only a 62-mph wind lasting six days is needed instead of a 70-mph wind; how-





ever, these conditions reduce the maximum depth from 30 ft to 20 ft within the landing site region. The ultimate water influx distribution in the steep slope region is needed to produce this relatively shallow trade-off condition, as shown in Fig. 5, lower graph.

Winds really blow in gusts so the needed velocity over time displayed in Fig. 8 actually corresponds to the "root mean square" of the gust velocities. Figure 8 is intended to prove feasibility for my hypothesis – that is, that the ark could have been blown upstream, given a least-favorable set of assumptions.

Finally, let us compare the ease of moving an ark upstream given differing assumptions for its weight, and the choice of definition for the length of a cubit. Although more formidable winds are required to move a 20-million-pound ark (with a correspondingly smaller draft) upstream, even these winds fall well within the range of a great hurricane.

It is interesting to note that, if a Mesopotamian cubit of about a half a meter is used (1 cubit = 21.6 inches), then the winds required to move even a 20-million-pound ark become markedly reduced (Table 2). And, it is probably likely that the Mesopotamian cubit was referred to in Gen. 6:15 because that was the value used in the time frame of Noah (~2500 BC).<sup>13</sup>

A question remains: If the ark did reach the region of its final destination in only 36–40 days, what then held it from slipping back downstream during the remaining 110 days until Gen. 8:4 tells us that "the ark rested on the seventh month, seventeenth day on the mountains of Ararat" (day 150)? Perhaps the ark floated around the backwaters of the Cizre basin outside the steep-

Table 2.			
Scenario	Weight, Draft	Maximum wind Shallow gradient	Maximum wind Steep gradient
Case A (18" cubit)	Weight = 10 million lbs Draft = 5 feet	54 mph	70 mph
Case B (18" cubit)	Weight = 15 million lbs Draft = 7.5 feet	68 mph	90 mph
Case C (18" cubit)	Weight = 20 million lbs Draft = 10 feet	86 mph	118 mph
Case D (21.6" cubit)	Weight = 20 million lbs Draft = 6.6 feet	59 mph	85 mph

gradient current flow, similar to when water has stayed backed up for months in the Mississippi hydrologic basin. $^{14}$ 

### Conclusions

In conclusion, I have presented one of any number of possible formulations of conditions, backed up by plausible calculations that verify that a local flood could have occurred within the framework of known physical parameters in the Mesopotamian region. That is, these events can potentially be viewed as "nature miracles" in light of a literal reading of Genesis.

I have also modeled one of any number of possible scenarios that can feasibly account for how Noah's ark could have been blown upstream into the foothills of the mountains of Ararat against the floodwater current. This possibility refutes the standard Young Earth Creationist argument that a universal flood is inevitable because the ark would have been floated down to the Persian Gulf by the flood current. Had a more complete model, which included wave action and wind shear effects, been included in the analysis, the rainfall and wind velocity requirements could have been shown to be even less stringent than the values shown here.

#### Acknowledgments

I thank Larry Hill of Los Alamos National Labs for insightful technical discussions, Carol Hill for reviewing the manuscript and for developing an enormous base of information on which this paper stands; also Robert Cushman and Phil Metzger for helpful corrections to this article.

### Appendix

An abbreviated outline of the mathematical model used to generate the data contained in this paper will be given here. Formula derivations are omitted because such a level of detail is inappropriate for this journal. It is hoped, however, that a certain level of credibility is established for the more technically minded reader.<sup>15</sup>

First, several general functions have been composed that input the time varying rates of rainfall and spring output uniformly over each of three differing regions on the flood plain. These regions pertain to: (1) the marshland region at the confluence of the Tigris River with the Persian Gulf, (2) the alluvial plain, and (3) the steeper gradient region leading into the foothills of the mountains of Ararat. See Fig. 1 for a geometrical diagram of all three areas.

The equations controlling the rates of rainwater and spring water, respectively, are:

$$f_{1}(t) = n_{rain} \left( \left( \left( 1 - e^{-\frac{t}{\tau_{1}}} \right) e^{-\frac{t}{\tau_{2}}} (0.25)(1 - Tanh[t - 41]) + 1.20 \right) \times (1 - Tanh[t - 150]) \right) e^{-\frac{t}{\tau_{3}}}$$
[1]  
$$f_{2}(t) = 0.5 (1 + Tanh[t]) \left( n_{spring} e^{-\frac{1}{t_{4}}} (1 - Tanh[t - 149]) \right)$$
[2]

Figure 3 (p. 135) plots particular solutions to equations [1] and [2]. Equations [1] and [2] may be adjusted to develop any desired distribution by modifying the time constants  $\tau_1$ ,  $\tau_2$ ,  $\tau_3$ , and  $\tau_4$  and by selecting appropriate peak value levels. The hyperbolic tangent function is liberally used throughout the various derivations to round off instantaneous changes of slope, which otherwise cause singularities that plague convergence of the differential equations involved.

Next, the rate of total water volume falling upon the reservoir (or a specific region therein) is simply:

$$Vol_{tot}(t) / day = [(f_1[t] + f_2[t]) \times 0.5 \times (r_5^2 - r_1^2) \times 5280^2]$$
[3]

In preparation for solving the master continuity equation, a hydrodynamic slope function must be specified:

$$slope(r) = slope1 - (slope1 - slope2)Tanh[r - r_2]$$
[4]

which automatically switches the gradient where the boundary separating the alluvial plain from the foothills is crossed.

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Next, equations [5] through [7] further specify boundary conditions that geometrically constrain the solutions. The initial conditions volume Vol = 0 at time  $\tau$  = 0, and depth z = 0 at  $\tau$  = 0, are also imposed.

$$w_{(r5)} = 2 \times r5 \times Tan[\theta_2] \times 5280$$
<sup>[5]</sup>

$$SurfAreaChan = \frac{1}{2} \times Tan[\theta_1] \times (r_5^2 - r_1^2) \times 5280^2$$
[6]

$$volCh = z_{ch} \times surfAreaChan$$
[7]

Constraints and input conditions expressed in equations [1] through [7] are incorporated into the master continuity equation [8]:

$$\frac{\partial Vol(\tau)}{\partial \tau} = \frac{1}{2} \times \left( f_1(t) + f_2(t) \right) \times 2\theta_1 \times \left( r_5^2 - r_1^2 \right) \times 5280^2 - w(r) \times \eta \times (24 \times 3600) \times \left( if \ Vol(t) \ge volCh, \ then \ z(t) = z_{ch} + \frac{Vol(t) - volCh}{SurfAreaRegion}, \ else \ z(t) = \frac{Vol(t)}{SurfAreaChan} \right)^{\frac{5}{3}}$$
[8]

Then, the continuity equation [8] is solved simultaneously with the depth equation [9], the Manning equations [10] and [11] and the rate of volume change versus volume, equation [12], which are:

$$z(t) = \left(\frac{\left(2 \times f_{1}(t) + f_{2}(t) - evap\right) \times \frac{1}{2} \times \theta_{1} \times (r_{5}^{2} - r_{1}^{2}) \times 5280^{2} - \frac{\partial Vol(t)}{\partial t}}{w(t) \times \eta \times (24 \times 3600)}\right)^{\frac{3}{5}}$$
[9]

$$vel(t) = \eta \times (z(t))^{\frac{2}{3}}$$
 [10]

$$\eta = \frac{1.49}{\eta_r} \times \sqrt{slope(r)}$$
[11]

$$\frac{\partial V_{(t)}}{\partial t} = -2\eta^{\left(\frac{4}{3}\right)} \frac{\sqrt{\mathbf{v}_{water(t)}}}{3 \times 32}$$
[12]

The continuity equation [8] is a highly nonlinear first-order differential equation that contains both independent and dependent variables as its driving functions. Fortunately, the powerful Mathematica Code yields a numerical time-dependent solutions to these equations. Note also in [8] that Mathematica can process logical operations built right into equations as they are being solved.

The equations [10] and [11] are the primary drivers that contain the total "head losses," due both to turbulence and surface drag phenomenon. Careful adjustment of the Manning Roughness Factor, inserted into equation [11], is incorporated to simulate the head-loss effect, and has been extracted from (wherever possible) physical data known for the Mesopotamian region. Note the functional dependence and that the water velocity v scales as the depth  $z^{(2/3)}$  from equation [10].

The travel time from the launch point to the foothills and then from the foothills to the arrival point is given by equations [13] and [14], respectively, and typically amounts to 26 days plus 8 days, respectively, if the ark is specified to move at a constant velocity  $v_{ship} = 0.86$  mph.

Travel to Foothills = 
$$\frac{r_5 - r_3}{v_{ship} \times 0.678 \times 24}$$
[13]

Travel Foothills to End = 
$$\frac{r_2 - r_1}{v_{ship} \times 0.678 \times 24}$$
 [14]

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Finally, the four equations [15], [16], [17], and [18] controlling the motion of the ark are:

windwork 
$$2(t) = \frac{1}{2} \times \rho_{air} \times f_w \times \left[ wv(t) - v_{ship} \right]^2 \times S_1$$
 [15]

$$viscuswork 2(t) = \frac{1}{2} \times c_d \times \rho_{vater} \times \left(v_{ship} - (-vel[t])\right)^2 \times v_{ship} \times S_2$$
[16]

$$liftwork 2(t) = mg \times v_{ship} slope$$
<sup>[17]</sup>

$$windwork 2(t) = viscuswork 2(t) + liftwork 2(t)$$
[18]

Equation [18] simply balances all of the horizontal forces on the ark, where wv(t) is the wind velocity,  $v_{ship}$  is the ship velocity,  $c_d$  is the drag coefficient (0.04),  $\rho_{air}$  = the air density,  $\rho_{water}$  = the water density,  $S_1$  and  $S_2$  are the frontal ark submerged area and rear areas above the water line, respectively.

Finally, a factor *f* is designated to adjust the value of air density for its water content. It can be shown that:

$$f = \frac{\rho_{net}}{\rho_{air}} = 1 + 0.222 \times \frac{n_{in}}{v_{water Vert}}$$
[19]

where  $n_{in}$  is the rainfall in inches/hour, and  $v_{waterVert}$  is the rainfall vertical velocity component in inches/second.

The rainfall velocity depends on droplet size, and the bottom line is that this calculation depends on unknown factors. It does appear that *f* must be very near unity, as will be assumed in the data presented here. Its presence remains as a flag for future work.

Finally, the computer is asked to solve equations [15], [16], [17], and [18] simultaneously for the time dependant value of wind velocity. Its solution is plotted in Fig. 8 for two cases of interest.

The output of this solution for the final result was generated by Mathematica software. Since the complex formulation would be of no use to the reader, it is omitted here. Note also that the formulas presented in this Appendix have been stripped of computer syntax for simplicity of understanding, and cannot be directly inputted into Mathematica as shown.

#### Notes

<sup>1</sup>C. A. Hill, "The Noahian Flood: Universal or Local?" *Perspectives on Science and Christian Faith* 54, no. 3 (2002): 170–83.

- <sup>2</sup>C. A. Hill, "Quantitative Hydrology of Noah's Flood," *Perspectives* on Science and Christian Faith 58, no. 2 (2006): 120–9.
- <sup>3</sup>P. Johnstone, *The Sea Craft of Prehistory* (Cambridge: Harvard University Press, 1980); M. C. DeGraeve, *The Ships of the Ancient Near East* (c. 2000–500 BC) (Lewen: Department Orientalistich, 1981); L. Casson, *Ships and Seafaring in Ancient Times* (Austin: University of Texas Press, 1994); G. F. Bass, "Sea and River Craft in the Ancient Near East," in *Civilization of the Ancient Near East* 3, ed. J. M. Sasson (New York: Charles Scribner's, 1995), 1421–31.
- <sup>4</sup>L. D. Landau and E. M. Lifshitz, *Fluid Mechanics, Course of Theoretical Physics* 6 (Oxford: Pergamon Press, 1959); C. E. Fröberg, *Introduction to Numerical Analysis* (Reading MS: Addison-Wesley, 1969); S. Humphries, Field Solutions on Computers (New York: CRC Press, 1998).
- <sup>5</sup>The Mesopotamian cubit was somewhat larger than the 18 inch cubit mentioned in the King James Version of the Bible. Circa 2500 BC, the Babylonian cubit was about 20 inches and the Egyptian cubit was about 25 inches; J. C. Warren, *The Early Weights and Measures of Mankind* (London: Committee of the Palestine Exploration Fund, 1913), 10–11.
- <sup>6</sup>S. F. Hoerner, *Fluid-Dynamic Drag* (Midland Park, NJ: published by the author, 1965) inconseq. pages.
- 7A. P. Schick, "Hydrologic Aspects of Floods in Extreme Arid Environments," in *Flood Geomorphology*, eds. V. R. Baker, R. C. Kochel, and P. C. Patton (New York: John Wiley, 1988), 193.

<sup>8</sup>C. A. Hill, "The Noahian Flood," 171, table 1.

- <sup>9</sup>V. L. Streeter, *Fluid Mechanics* (New York: McGraw-Hill, 1958), 176.
   <sup>10</sup>G. P. Williams, "Paleofluvial Estimates from Dimensions of Former Channels and Meanders," in *Flood Geomorphology*, 326–7.
- <sup>11</sup>V. T. Chow, *Open-Channel Hydraulics* (New York: McGraw-Hill, 1959), 217; J. E. O'Connor and R. H. Webb, "Hydraulic Modeling for Paleoflow Analysis," in *Flood Geomorphology*, 394.
- <sup>12</sup>H. F. Vos, *Beginnings in Bible Geography* (Chicago: Moody Press, 1973), 13.
- <sup>13</sup>J. Friberg, "Numbers and Measures in the Earliest Written Records," *Scientific American* 250, no. 2 (1984): 110–8.
- <sup>14</sup>K. K. Hirschboeck, "Catastrophic Flooding and Atmospheric Circulation Anomolies," ed. R. Mayer and D. Nash, *Catastrophic Floods* (Boston: Allen and Unwin, 1987), 46.
- <sup>15</sup>Basic references used for the hydrodynamic equations in the Appendix are: P. D. Patel and T. G. Theofanous, "Hydrodynamic Fragmentation of Drops," *Journal of Fluid Mechanics* 103 (1981): 207–23; A. A. Ranger and J. A. Nicholls, "Aerodynamic Shattering of Liquid Drops," *AIAA Journal* 7 (1969): 285–90; E. Y. Harper, G. W. Grube and I. D. Chang, "On the Breakup of Accelerating Liquid Drops," *Journal of Fluid Mechanics* 52 (1972): 565–91; Advisory Council on Scientific Research and Technical Development, "The Shape and Acceleration of a Drop in a High-Speed Air Stream," *Publication of ACSRTD*, no. 50 (1949): 457–64.