

Table 3 - Water Carriers

by Rudolf Volz

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| Up No. | The Up Number represents the specific level of the total pyramid counted from the bottom to the top (1 - 210). |
| Down No. | The Down Number represents specific the level of the step pyramid counted backwards from the bottom to the top (209 - 1). Up_No. = 210 – Down_No. |
| Delivery lanes | The blocks were transported on the delivery lanes up to the corresponding level. This quantity is the key factor that determines the production capacity of the entire project. The capacity is limited by the total number of lanes and the number of workers. Since the way back was a separate lane, the following condition must hold: $\text{Delivery_lanes} \leq \text{Total_lanes} - 1$ |
| Max. rate | The maximal rate represents the number of produced and installed blocks per day for 3 months during the Nile flood. Each lane can deliver 15 blocks per hour, or 180 blocks per day. $\text{Maximal_rate} = \text{Delivery_lanes} * 180$ Then the numbers <code>Delivery_lanes</code> and <code>Maximal_rate</code> have to be reduced so that the corresponding number <code>Workers_maximum</code> does not exceed 20,000. |



The water carriers move on a separate path, which is marked by the two blue lines. The towing team with sliding sledges consists of 18 workers, what is the same number as using wooden rollers. Compare the image at the end of this document. The two workers with the clay jars receive 5 liters of water from the water carriers every 4 minutes. They have to lubricate the wooden beams at the position of the sledges to reduce friction. The two workers with the wooden bars are responsible for braking and direction control, not for levering.

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| Workers tow | <p>Number of workers during the Nile flood who towed the blocks on the ramps up to the corresponding level. This is calculated as follows:</p> $W_1 = 2 * \text{Delivery_lanes} * (3 + 0.5 * \text{Up_No.} + \text{Down_No.}/44) * 1.2 * 18$ <p>The factor 2 stands for the two shifts in one day.</p> <p>On each lane, the tow teams were spaced 11 block lengths apart what is indicated by the orange lines. This corresponds to 2 levels and therefore, the number of tow teams can be expressed by $0.5 * \text{Up_No.}$</p> <p>At the bottom of the pyramid, 3 towing teams were waiting to be deployed.</p> <p>Statistically, on the top level of the pyramid there were $\text{Down_No.}/44$ teams to transport their block to the designated location.</p> <p>The factor 1.2 expresses the additional proportion of workers on the way back what corresponds to $20/120 \triangleq 17\%$.</p> <p>Each tow team consisted of 18 workers.</p> |
| Workers quarries | <p>Workers which worked in the quarries during the Nile flood. They had to produce, smooth, store and install blocks. Also, they had to transport the blocks next to but not onto the pyramid.</p> <p>Each block required 6 days of work.</p> $W_2 = 6 * \text{Maximal_rate}$ <p>Due to the large number of blocks, the number of stored blocks had to be kept small and therefore, the production had to be just-in-time.</p> |
| Water carriers | <p>Number of workers during the Nile flood who carried water to all the tow teams.</p> $N = 3 + 0.5 * \text{Up_No.} + \text{Down_No.}/44$ <p>N represents the number of tow teams on a single lane. All teams had to be permanently supplied with water.</p> <p>The number of water carriers can be expressed as follows:</p> $W_3 = 2 * \text{Delivery_lanes} * 1.8 * 1.1 * 0.13 * (1 + 2 + 3 + \dots + N)$ $= 2 * \text{Delivery_lanes} * 1.8 * 1.1 * 0.13 * N * (N + 1) / 2$ <p>The factor 2 stands for the two shifts in one day.</p> <p>The factor 1.8 indicates that an additional proportion of water carriers were on the way back. This corresponds to $80/180 \triangleq 44\%$.</p> <p>The factor 1.1 expresses an additional proportion of water carriers needed to bring the water next to the pyramid. This corresponds to $10/110 \triangleq 9\%$.</p> <p>The factor 0.13 expresses that the water carriers moved at about eight times the speed of the tow teams.</p> <p>They carried 20 liters of water.</p> <p>The basic idea of this term is that the tow team at position k permanently must be supplied with water.</p> <p>Each team received 20 liters of water in 4 minutes during which the team moved by 12 m.</p> <p>Therefore $0.13 * k$ or $k/8$ water carriers had to be equally distributed on the lane in order to supply the team at position k.</p> |

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| Workers others | <p>Workers which neither towed blocks, nor worked in the quarries, nor did carry water during the Nile flood.</p> $W_4 = 1.2 * 1.2 * 0.42 * (W_1 + W_2)$ $= 0.565 * (W_1 + W_2)$ <p>This term represents the additional workers to build ramps. The factor 0.42 expresses the additional number of workers for building ramps when using wooden rollers without water carriers. The water carriers moved at different speed towards the tow teams. Therefore, each lane of the ramp had to be wider by 20 % or 66 cm. This is expressed by the factor 1.2. The term $1.2 * 1.2 = 1.44$ states that the volume of the ramp grows quadratically with its width and therefore, the number of workers must grow in the same proportion.</p> $W_5 = 0.15 * (W_1 + W_2 + W_3 + W_4)$ <p>This term refers to the extra workers who prepared food and organized things. The factor 0.15 corresponds to $15/115 \approx 13\%$ of all employees.</p> |
| Workers maximum | <p>Total number of workers during the Nile flood.</p> $W_6 = W_1 + W_2 + W_3 + W_4 + W_5$ $= (W_1 + W_2 + W_3 + W_4) + 0.15 * (W_1 + W_2 + W_3 + W_4)$ $= 1.15 * (W_1 + W_2 + W_3 + W_4)$ $= 1.15 * (W_1 + W_2) + 1.15 * W_3 + 1.15 * 0.565 * (W_1 + W_2)$ $= 1.15 * 1.565 * (W_1 + W_2) + 1.15 * W_3$ $= \mathbf{1.8 * (W_1 + W_2) + 1.15 * W_3}$ |
| Constr. years | <p>The construction years represent the time required to construct the corresponding level. Each year consisted of 300 working days. The rest were Saint days.</p> |
| Work years | <p>The working years represent the total working time required to build the corresponding level.</p> |

| Up No. | Down No. | Delivery lanes | Max. rate | Workers tow | Workers quarries | Water carriers | Workers others | Workers maximum | Constr. years | Work years |
|--------|----------|----------------|-----------|-------------|------------------|----------------|----------------|-----------------|---------------|------------|
| 1 | 209 | 7.45 | 1,341 | 2,655 | 8,046 | 146 | 9,070 | 19,918 | 0.174 | 2,163 |
| 2 | 208 | 7.35 | 1,323 | 2,771 | 7,938 | 161 | 9,079 | 19,949 | 0.174 | 2,174 |
| 3 | 207 | 7.25 | 1,305 | 2,883 | 7,830 | 175 | 9,084 | 19,972 | 0.175 | 2,186 |
| 4 | 206 | 7.10 | 1,278 | 2,970 | 7,668 | 189 | 9,023 | 19,849 | 0.177 | 2,197 |
| 5 | 205 | 6.93 | 1,247 | 3,041 | 7,484 | 202 | 8,930 | 19,658 | 0.180 | 2,208 |
| 6 | 204 | 6.93 | 1,247 | 3,184 | 7,484 | 221 | 9,054 | 19,943 | 0.178 | 2,218 |
| 7 | 203 | 6.80 | 1,224 | 3,265 | 7,344 | 236 | 9,005 | 19,850 | 0.180 | 2,228 |
| 8 | 202 | 6.70 | 1,206 | 3,355 | 7,236 | 252 | 8,993 | 19,835 | 0.180 | 2,237 |
| 9 | 201 | 6.60 | 1,188 | 3,441 | 7,128 | 268 | 8,976 | 19,813 | 0.181 | 2,246 |
| 10 | 200 | 6.50 | 1,170 | 3,523 | 7,020 | 284 | 8,957 | 19,784 | 0.182 | 2,255 |

Table 3 - Water Carriers / 4

| Up No. | Down No. | Delivery lanes | Max. rate | Workers tow | Workers quarries | Water carriers | Workers others | Workers maximum | Constr. years | Work years |
|--------|----------|----------------|-----------|-------------|------------------|----------------|----------------|-----------------|---------------|------------|
| 11 | 199 | 6.40 | 1,152 | 3,601 | 6,912 | 301 | 8,934 | 19,747 | 0.183 | 2,263 |
| 12 | 198 | 6.30 | 1,134 | 3,674 | 6,804 | 317 | 8,907 | 19,703 | 0.184 | 2,271 |
| 13 | 197 | 6.25 | 1,125 | 3,774 | 6,750 | 337 | 8,949 | 19,809 | 0.184 | 2,278 |
| 14 | 196 | 6.20 | 1,116 | 3,872 | 6,696 | 357 | 8,989 | 19,913 | 0.184 | 2,285 |
| 15 | 195 | 6.12 | 1,102 | 3,948 | 6,610 | 375 | 8,983 | 19,915 | 0.184 | 2,291 |
| 16 | 194 | 6.05 | 1,089 | 4,027 | 6,534 | 394 | 8,989 | 19,944 | 0.184 | 2,298 |
| 17 | 193 | 5.95 | 1,071 | 4,083 | 6,426 | 411 | 8,948 | 19,868 | 0.185 | 2,303 |
| 18 | 192 | 5.90 | 1,062 | 4,171 | 6,372 | 432 | 8,979 | 19,953 | 0.185 | 2,309 |
| 19 | 191 | 5.80 | 1,044 | 4,220 | 6,264 | 449 | 8,931 | 19,864 | 0.186 | 2,314 |
| 20 | 190 | 5.75 | 1,035 | 4,302 | 6,210 | 470 | 8,958 | 19,940 | 0.186 | 2,318 |
| 21 | 189 | 5.67 | 1,021 | 4,359 | 6,124 | 488 | 8,936 | 19,907 | 0.187 | 2,322 |
| 22 | 188 | 5.62 | 1,012 | 4,436 | 6,070 | 509 | 8,959 | 19,975 | 0.186 | 2,326 |
| 23 | 187 | 5.54 | 997 | 4,487 | 5,983 | 528 | 8,932 | 19,931 | 0.187 | 2,330 |
| 24 | 186 | 5.42 | 976 | 4,502 | 5,854 | 543 | 8,837 | 19,735 | 0.189 | 2,333 |
| 25 | 185 | 5.42 | 976 | 4,614 | 5,854 | 569 | 8,936 | 19,972 | 0.187 | 2,335 |
| 26 | 184 | 5.30 | 954 | 4,621 | 5,724 | 583 | 8,834 | 19,762 | 0.189 | 2,338 |
| 27 | 183 | 5.25 | 945 | 4,685 | 5,670 | 605 | 8,846 | 19,807 | 0.189 | 2,340 |
| 28 | 182 | 5.20 | 936 | 4,748 | 5,616 | 626 | 8,857 | 19,847 | 0.189 | 2,341 |
| 29 | 181 | 5.15 | 927 | 4,809 | 5,562 | 648 | 8,866 | 19,884 | 0.188 | 2,342 |
| 30 | 180 | 5.07 | 913 | 4,838 | 5,476 | 666 | 8,821 | 19,800 | 0.189 | 2,343 |
| 31 | 179 | 5.02 | 904 | 4,894 | 5,422 | 687 | 8,825 | 19,828 | 0.189 | 2,344 |
| 32 | 178 | 4.95 | 891 | 4,928 | 5,346 | 706 | 8,793 | 19,773 | 0.190 | 2,344 |
| 33 | 177 | 4.91 | 884 | 4,989 | 5,303 | 729 | 8,812 | 19,833 | 0.189 | 2,343 |
| 34 | 176 | 4.85 | 873 | 5,028 | 5,238 | 749 | 8,793 | 19,808 | 0.189 | 2,343 |
| 35 | 175 | 4.80 | 864 | 5,076 | 5,184 | 770 | 8,790 | 19,820 | 0.189 | 2,342 |
| 36 | 174 | 4.72 | 850 | 5,088 | 5,098 | 787 | 8,730 | 19,703 | 0.190 | 2,340 |
| 37 | 173 | 4.68 | 842 | 5,142 | 5,054 | 810 | 8,742 | 19,748 | 0.189 | 2,339 |
| 38 | 172 | 4.67 | 841 | 5,227 | 5,044 | 838 | 8,810 | 19,918 | 0.188 | 2,337 |
| 39 | 171 | 4.62 | 832 | 5,266 | 4,990 | 859 | 8,800 | 19,916 | 0.188 | 2,334 |
| 40 | 170 | 4.58 | 824 | 5,315 | 4,946 | 882 | 8,809 | 19,953 | 0.187 | 2,332 |
| 41 | 169 | 4.53 | 815 | 5,351 | 4,892 | 904 | 8,796 | 19,943 | 0.187 | 2,328 |
| 42 | 168 | 4.48 | 806 | 5,384 | 4,838 | 924 | 8,782 | 19,928 | 0.187 | 2,325 |
| 43 | (50%) | 4.44 | 799 | 5,427 | 4,795 | 947 | 8,785 | 19,955 | 0.186 | 2,321 |
| 44 | 166 | 4.39 | 790 | 5,457 | 4,741 | 968 | 8,768 | 19,934 | 0.186 | 2,317 |
| 45 | 165 | 4.32 | 778 | 5,459 | 4,666 | 984 | 8,708 | 19,816 | 0.187 | 2,313 |
| 46 | 164 | 4.30 | 774 | 5,522 | 4,644 | 1,011 | 8,747 | 19,924 | 0.185 | 2,308 |
| 47 | 163 | 4.25 | 765 | 5,546 | 4,590 | 1,031 | 8,724 | 19,891 | 0.185 | 2,303 |
| 48 | 162 | 4.23 | 761 | 5,607 | 4,568 | 1,058 | 8,762 | 19,995 | 0.184 | 2,297 |
| 49 | 161 | 4.17 | 751 | 5,613 | 4,504 | 1,076 | 8,715 | 19,908 | 0.184 | 2,292 |
| 50 | 160 | 4.14 | 745 | 5,658 | 4,471 | 1,100 | 8,730 | 19,959 | 0.183 | 2,286 |
| 51 | 159 | 4.10 | 738 | 5,688 | 4,428 | 1,122 | 8,722 | 19,960 | 0.183 | 2,279 |
| 52 | 158 | 4.05 | 729 | 5,702 | 4,374 | 1,141 | 8,691 | 19,908 | 0.183 | 2,272 |
| 53 | 157 | 4.01 | 722 | 5,728 | 4,331 | 1,163 | 8,680 | 19,902 | 0.182 | 2,265 |
| 54 | 156 | 3.98 | 716 | 5,768 | 4,298 | 1,187 | 8,689 | 19,942 | 0.181 | 2,258 |
| 55 | 155 | 3.95 | 711 | 5,806 | 4,266 | 1,212 | 8,697 | 19,981 | 0.180 | 2,251 |
| 56 | 154 | 3.91 | 704 | 5,827 | 4,223 | 1,233 | 8,683 | 19,965 | 0.180 | 2,243 |
| 57 | 153 | 3.88 | 698 | 5,863 | 4,190 | 1,257 | 8,689 | 19,999 | 0.179 | 2,234 |
| 58 | 152 | 3.84 | 691 | 5,881 | 4,147 | 1,278 | 8,671 | 19,977 | 0.178 | 2,226 |
| 59 | 151 | 3.80 | 684 | 5,899 | 4,104 | 1,298 | 8,652 | 19,953 | 0.178 | 2,217 |
| 60 | 150 | 3.72 | 670 | 5,851 | 4,018 | 1,304 | 8,540 | 19,713 | 0.179 | 2,208 |

Table 3 - Water Carriers / 5

| Up No. | Down No. | Delivery lanes | Max. rate | Workers tow | Workers quarries | Water carriers | Workers others | Workers maximum | Constr. years | Work years |
|--------|----------|----------------|-----------|-------------|------------------|----------------|----------------|-----------------|---------------|------------|
| 61 | 149 | 3.72 | 670 | 5,928 | 4,018 | 1,338 | 8,610 | 19,893 | 0.177 | 2,199 |
| 62 | 148 | 3.70 | 666 | 5,972 | 3,996 | 1,365 | 8,633 | 19,966 | 0.175 | 2,189 |
| 63 | 147 | 3.64 | 655 | 5,950 | 3,931 | 1,377 | 8,562 | 19,820 | 0.176 | 2,179 |
| 64 | 146 | 3.61 | 650 | 5,976 | 3,899 | 1,400 | 8,559 | 19,834 | 0.175 | 2,169 |
| 65 | 145 | 3.58 | 644 | 6,000 | 3,866 | 1,423 | 8,556 | 19,845 | 0.174 | 2,158 |
| 66 | 144 | 3.56 | 641 | 6,040 | 3,845 | 1,449 | 8,575 | 19,909 | 0.173 | 2,147 |
| 67 | 143 | 3.54 | 637 | 6,079 | 3,823 | 1,476 | 8,594 | 19,972 | 0.171 | 2,136 |
| 68 | 142 | 3.46 | 623 | 6,013 | 3,737 | 1,477 | 8,465 | 19,692 | 0.173 | 2,125 |
| 69 | 141 | 3.42 | 616 | 6,014 | 3,694 | 1,494 | 8,432 | 19,634 | 0.172 | 2,114 |
| 70 | 140 | 3.40 | 612 | 6,049 | 3,672 | 1,520 | 8,447 | 19,688 | 0.171 | 2,102 |
| 71 | 139 | 3.36 | 605 | 6,047 | 3,629 | 1,537 | 8,412 | 19,624 | 0.170 | 2,090 |
| 72 | 138 | 3.35 | 603 | 6,098 | 3,618 | 1,567 | 8,450 | 19,733 | 0.168 | 2,077 |
| 73 | 137 | 3.32 | 598 | 6,112 | 3,586 | 1,588 | 8,438 | 19,723 | 0.168 | 2,065 |
| 74 | 136 | 3.29 | 592 | 6,124 | 3,553 | 1,609 | 8,424 | 19,711 | 0.167 | 2,052 |
| 75 | 135 | 3.26 | 587 | 6,136 | 3,521 | 1,629 | 8,409 | 19,695 | 0.166 | 2,039 |
| 76 | 134 | 3.23 | 581 | 6,146 | 3,488 | 1,650 | 8,393 | 19,677 | 0.165 | 2,026 |
| 77 | 133 | 3.20 | 576 | 6,155 | 3,456 | 1,669 | 8,377 | 19,657 | 0.164 | 2,012 |
| 78 | 132 | 3.19 | 574 | 6,201 | 3,445 | 1,700 | 8,411 | 19,758 | 0.162 | 1,998 |
| 79 | 131 | 3.19 | 574 | 6,267 | 3,445 | 1,736 | 8,472 | 19,920 | 0.159 | 1,985 |
| 80 | 130 | 3.15 | 567 | 6,253 | 3,402 | 1,750 | 8,426 | 19,831 | 0.159 | 1,970 |
| 81 | 129 | 3.12 | 562 | 6,258 | 3,370 | 1,769 | 8,406 | 19,802 | 0.158 | 1,956 |
| 82 | 128 | 3.10 | 558 | 6,282 | 3,348 | 1,793 | 8,411 | 19,835 | 0.157 | 1,941 |
| 83 | 127 | 3.08 | 554 | 6,305 | 3,326 | 1,818 | 8,416 | 19,865 | 0.155 | 1,926 |
| 84 | 126 | 3.05 | 549 | 6,307 | 3,294 | 1,836 | 8,393 | 19,829 | 0.154 | 1,911 |
| 85 | 125 | 3.03 | 545 | 6,328 | 3,272 | 1,860 | 8,396 | 19,856 | 0.153 | 1,896 |
| 86 | 124 | 3.00 | 540 | 6,327 | 3,240 | 1,878 | 8,371 | 19,816 | 0.152 | 1,881 |
| 87 | 123 | 2.99 | 538 | 6,367 | 3,229 | 1,908 | 8,400 | 19,905 | 0.150 | 1,865 |
| 88 | 122 | 2.98 | 536 | 6,408 | 3,218 | 1,938 | 8,430 | 19,994 | 0.148 | 1,849 |
| 89 | 121 | 2.90 | 522 | 6,295 | 3,132 | 1,922 | 8,259 | 19,609 | 0.150 | 1,833 |
| 90 | 120 | 2.88 | 518 | 6,311 | 3,110 | 1,945 | 8,258 | 19,625 | 0.148 | 1,817 |
| 91 | 119 | 2.86 | 515 | 6,326 | 3,089 | 1,968 | 8,256 | 19,639 | 0.147 | 1,801 |
| 92 | 118 | 2.84 | 511 | 6,341 | 3,067 | 1,990 | 8,253 | 19,651 | 0.145 | 1,784 |
| 93 | 117 | 2.82 | 508 | 6,354 | 3,046 | 2,013 | 8,250 | 19,662 | 0.144 | 1,767 |
| 94 | 116 | 2.80 | 504 | 6,367 | 3,024 | 2,035 | 8,245 | 19,671 | 0.142 | 1,751 |
| 95 | 115 | 2.79 | 502 | 6,402 | 3,013 | 2,064 | 8,270 | 19,749 | 0.140 | 1,734 |
| 96 | 114 | 2.78 | 500 | 6,436 | 3,002 | 2,093 | 8,294 | 19,826 | 0.139 | 1,716 |
| 97 | 113 | 2.78 | 500 | 6,493 | 3,002 | 2,131 | 8,348 | 19,975 | 0.136 | 1,699 |
| 98 | 112 | 2.75 | 495 | 6,480 | 2,970 | 2,145 | 8,312 | 19,906 | 0.135 | 1,682 |
| 99 | 111 | 2.70 | 486 | 6,418 | 2,916 | 2,142 | 8,213 | 19,689 | 0.135 | 1,664 |
| 100 | 110 | 2.68 | 482 | 6,426 | 2,894 | 2,163 | 8,205 | 19,688 | 0.134 | 1,646 |
| 101 | 109 | 2.67 | 481 | 6,457 | 2,884 | 2,192 | 8,226 | 19,758 | 0.132 | 1,628 |
| 102 | 108 | 2.65 | 477 | 6,463 | 2,862 | 2,212 | 8,216 | 19,754 | 0.130 | 1,610 |
| 103 | 107 | 2.63 | 473 | 6,468 | 2,840 | 2,233 | 8,206 | 19,747 | 0.129 | 1,592 |
| 104 | 106 | 2.60 | 468 | 6,448 | 2,808 | 2,244 | 8,163 | 19,663 | 0.128 | 1,574 |
| 105 | (Median) | 2.58 | 464 | 6,452 | 2,786 | 2,264 | 8,151 | 19,653 | 0.127 | 1,555 |
| 106 | 104 | 2.56 | 461 | 6,455 | 2,765 | 2,283 | 8,138 | 19,640 | 0.125 | 1,537 |
| 107 | 103 | 2.55 | 459 | 6,482 | 2,754 | 2,311 | 8,156 | 19,703 | 0.123 | 1,518 |
| 108 | 102 | 2.55 | 459 | 6,534 | 2,754 | 2,348 | 8,206 | 19,843 | 0.121 | 1,499 |
| 109 | 101 | 2.53 | 455 | 6,535 | 2,732 | 2,367 | 8,191 | 19,826 | 0.119 | 1,480 |
| 110 | 100 | 2.52 | 454 | 6,562 | 2,722 | 2,396 | 8,208 | 19,887 | 0.118 | 1,461 |

Table 3 - Water Carriers /6

| Up No. | Down No. | Delivery lanes | Max. rate | Workers tow | Workers quarries | Water carriers | Workers others | Workers maximum | Constr. years | Work years |
|--------|----------|----------------|-----------|-------------|------------------|----------------|----------------|-----------------|---------------|------------|
| 111 | 99 | 2.50 | 450 | 6,561 | 2,700 | 2,414 | 8,192 | 19,867 | 0.116 | 1,442 |
| 112 | (90%) | 2.49 | 448 | 6,586 | 2,689 | 2,442 | 8,209 | 19,926 | 0.114 | 1,423 |
| 113 | 97 | 2.47 | 445 | 6,584 | 2,668 | 2,460 | 8,192 | 19,903 | 0.113 | 1,404 |
| 114 | 96 | 2.46 | 443 | 6,608 | 2,657 | 2,488 | 8,207 | 19,960 | 0.111 | 1,385 |
| 115 | 95 | 2.43 | 437 | 6,578 | 2,624 | 2,495 | 8,155 | 19,852 | 0.110 | 1,365 |
| 116 | 94 | 2.42 | 436 | 6,601 | 2,614 | 2,522 | 8,169 | 19,906 | 0.108 | 1,346 |
| 117 | 93 | 2.41 | 434 | 6,623 | 2,603 | 2,550 | 8,183 | 19,959 | 0.106 | 1,326 |
| 118 | 92 | 2.35 | 423 | 6,507 | 2,538 | 2,523 | 8,026 | 19,594 | 0.107 | 1,307 |
| 119 | 91 | 2.34 | 421 | 6,527 | 2,527 | 2,550 | 8,038 | 19,642 | 0.105 | 1,287 |
| 120 | 90 | 2.33 | 419 | 6,547 | 2,516 | 2,576 | 8,050 | 19,690 | 0.103 | 1,268 |
| 121 | 89 | 2.31 | 416 | 6,539 | 2,495 | 2,592 | 8,027 | 19,652 | 0.102 | 1,248 |
| 122 | 88 | 2.30 | 414 | 6,558 | 2,484 | 2,618 | 8,038 | 19,697 | 0.100 | 1,228 |
| 123 | 87 | 2.29 | 412 | 6,576 | 2,473 | 2,644 | 8,048 | 19,742 | 0.098 | 1,208 |
| 124 | 86 | 2.28 | 410 | 6,595 | 2,462 | 2,670 | 8,059 | 19,786 | 0.096 | 1,189 |
| 125 | 85 | 2.26 | 407 | 6,584 | 2,441 | 2,684 | 8,033 | 19,742 | 0.095 | 1,169 |
| 126 | 84 | 2.25 | 405 | 6,601 | 2,430 | 2,710 | 8,042 | 19,783 | 0.093 | 1,149 |
| 127 | 83 | 2.23 | 401 | 6,588 | 2,408 | 2,724 | 8,015 | 19,735 | 0.092 | 1,129 |
| 128 | 82 | 2.22 | 400 | 6,604 | 2,398 | 2,749 | 8,024 | 19,775 | 0.090 | 1,109 |
| 129 | 81 | 2.21 | 398 | 6,620 | 2,387 | 2,775 | 8,032 | 19,813 | 0.088 | 1,089 |
| 130 | 80 | 2.20 | 396 | 6,636 | 2,376 | 2,800 | 8,039 | 19,851 | 0.086 | 1,069 |
| 131 | 79 | 2.19 | 394 | 6,651 | 2,365 | 2,825 | 8,047 | 19,888 | 0.084 | 1,050 |
| 132 | 78 | 2.18 | 392 | 6,665 | 2,354 | 2,850 | 8,054 | 19,923 | 0.083 | 1,030 |
| 133 | 77 | 2.16 | 389 | 6,648 | 2,333 | 2,862 | 8,023 | 19,867 | 0.081 | 1,010 |
| 134 | 76 | 2.15 | 387 | 6,662 | 2,322 | 2,887 | 8,029 | 19,900 | 0.080 | 990 |
| 135 | 75 | 2.13 | 383 | 6,644 | 2,300 | 2,898 | 7,997 | 19,840 | 0.078 | 970 |
| 136 | 74 | 2.11 | 380 | 6,625 | 2,279 | 2,909 | 7,965 | 19,777 | 0.077 | 950 |
| 137 | 73 | 2.10 | 378 | 6,637 | 2,268 | 2,933 | 7,969 | 19,807 | 0.075 | 931 |
| 138 | 72 | 2.09 | 376 | 6,648 | 2,257 | 2,957 | 7,973 | 19,836 | 0.073 | 911 |
| 139 | 71 | 2.08 | 374 | 6,660 | 2,246 | 2,980 | 7,977 | 19,864 | 0.072 | 891 |
| 140 | 70 | 2.07 | 373 | 6,670 | 2,236 | 3,004 | 7,981 | 19,891 | 0.070 | 872 |
| 141 | 69 | 2.06 | 371 | 6,680 | 2,225 | 3,028 | 7,984 | 19,917 | 0.068 | 852 |
| 142 | 68 | 2.05 | 369 | 6,690 | 2,214 | 3,051 | 7,986 | 19,942 | 0.067 | 833 |
| 143 | 67 | 2.04 | 367 | 6,700 | 2,203 | 3,075 | 7,989 | 19,966 | 0.065 | 814 |
| 144 | 66 | 2.03 | 365 | 6,709 | 2,192 | 3,098 | 7,991 | 19,990 | 0.064 | 794 |
| 145 | 65 | 2.00 | 360 | 6,651 | 2,160 | 3,090 | 7,913 | 19,814 | 0.063 | 775 |
| 146 | 64 | 2.00 | 360 | 6,692 | 2,160 | 3,128 | 7,954 | 19,934 | 0.061 | 756 |
| 147 | 63 | 1.99 | 358 | 6,700 | 2,149 | 3,151 | 7,955 | 19,954 | 0.059 | 737 |
| 148 | 62 | 1.97 | 355 | 6,673 | 2,128 | 3,157 | 7,915 | 19,872 | 0.058 | 718 |
| 149 | 61 | 1.95 | 351 | 6,645 | 2,106 | 3,163 | 7,874 | 19,788 | 0.057 | 699 |
| 150 | 60 | 1.94 | 349 | 6,651 | 2,095 | 3,185 | 7,873 | 19,804 | 0.055 | 681 |
| 151 | 59 | 1.93 | 347 | 6,657 | 2,084 | 3,206 | 7,872 | 19,819 | 0.053 | 662 |
| 152 | 58 | 1.93 | 347 | 6,697 | 2,084 | 3,245 | 7,911 | 19,937 | 0.052 | 644 |
| 153 | 57 | 1.83 | 329 | 6,387 | 1,976 | 3,113 | 7,539 | 19,015 | 0.053 | 625 |
| 154 | 56 | 1.82 | 328 | 6,390 | 1,966 | 3,132 | 7,535 | 19,023 | 0.051 | 607 |
| 155 | 55 | 1.81 | 326 | 6,392 | 1,955 | 3,152 | 7,530 | 19,029 | 0.050 | 589 |
| 156 | 54 | 1.80 | 324 | 6,394 | 1,944 | 3,171 | 7,526 | 19,034 | 0.048 | 571 |
| 157 | 53 | 1.78 | 320 | 6,360 | 1,922 | 3,172 | 7,478 | 18,932 | 0.047 | 553 |
| 158 | 52 | 1.78 | 320 | 6,396 | 1,922 | 3,208 | 7,515 | 19,042 | 0.045 | 536 |
| 159 | 51 | 1.78 | 320 | 6,433 | 1,922 | 3,245 | 7,551 | 19,152 | 0.043 | 518 |
| 160 | 50 | 1.78 | 320 | 6,470 | 1,922 | 3,282 | 7,588 | 19,262 | 0.042 | 501 |

Table 3 - Water Carriers / 7

| Up No. | Down No. | Delivery lanes | Max. rate | Workers tow | Workers quarries | Water carriers | Workers others | Workers maximum | Constr. years | Work years |
|------------|----------|----------------|-----------|-------------|------------------|----------------|----------------|-----------------|---------------|----------------|
| 161 | 49 | 1.76 | 317 | 6,433 | 1,901 | 3,282 | 7,539 | 19,155 | 0.040 | 484 |
| 162 | 48 | 1.75 | 315 | 6,433 | 1,890 | 3,300 | 7,532 | 19,155 | 0.039 | 467 |
| 163 | 47 | 1.74 | 313 | 6,432 | 1,879 | 3,318 | 7,525 | 19,154 | 0.038 | 450 |
| 164 | (99%) | 1.73 | 311 | 6,431 | 1,868 | 3,335 | 7,517 | 19,152 | 0.036 | 434 |
| 165 | 45 | 1.72 | 310 | 6,429 | 1,858 | 3,353 | 7,509 | 19,149 | 0.035 | 417 |
| 166 | 44 | 1.71 | 308 | 6,427 | 1,847 | 3,370 | 7,501 | 19,145 | 0.034 | 401 |
| 167 | 43 | 1.69 | 304 | 6,387 | 1,825 | 3,367 | 7,448 | 19,027 | 0.032 | 385 |
| 168 | 42 | 1.69 | 304 | 6,421 | 1,825 | 3,403 | 7,483 | 19,133 | 0.031 | 370 |
| 169 | 41 | 1.69 | 304 | 6,456 | 1,825 | 3,440 | 7,518 | 19,240 | 0.029 | 354 |
| 170 | 40 | 1.68 | 302 | 6,453 | 1,814 | 3,457 | 7,508 | 19,232 | 0.028 | 339 |
| 171 | 39 | 1.67 | 301 | 6,449 | 1,804 | 3,473 | 7,498 | 19,224 | 0.027 | 324 |
| 172 | 38 | 1.67 | 301 | 6,483 | 1,804 | 3,510 | 7,533 | 19,330 | 0.026 | 310 |
| 173 | 37 | 1.66 | 299 | 6,479 | 1,793 | 3,526 | 7,522 | 19,320 | 0.024 | 295 |
| 174 | 36 | 1.65 | 297 | 6,474 | 1,782 | 3,542 | 7,511 | 19,309 | 0.023 | 281 |
| 175 | 35 | 1.65 | 297 | 6,508 | 1,782 | 3,579 | 7,546 | 19,414 | 0.022 | 267 |
| 176 | 34 | 1.65 | 297 | 6,542 | 1,782 | 3,616 | 7,580 | 19,520 | 0.021 | 253 |
| 177 | 33 | 1.65 | 297 | 6,576 | 1,782 | 3,653 | 7,615 | 19,626 | 0.020 | 240 |
| 178 | 32 | 1.65 | 297 | 6,610 | 1,782 | 3,691 | 7,649 | 19,732 | 0.018 | 227 |
| 179 | 31 | 1.65 | 297 | 6,644 | 1,782 | 3,729 | 7,683 | 19,838 | 0.017 | 214 |
| 180 | 30 | 1.64 | 295 | 6,637 | 1,771 | 3,744 | 7,671 | 19,824 | 0.016 | 201 |
| 181 | 29 | 1.62 | 292 | 6,590 | 1,750 | 3,736 | 7,611 | 19,687 | 0.015 | 189 |
| 182 | 28 | 1.61 | 290 | 6,582 | 1,739 | 3,751 | 7,598 | 19,670 | 0.014 | 177 |
| 183 | 27 | 1.60 | 288 | 6,574 | 1,728 | 3,765 | 7,584 | 19,652 | 0.014 | 166 |
| 184 | 26 | 1.60 | 288 | 6,607 | 1,728 | 3,803 | 7,618 | 19,756 | 0.013 | 155 |
| 185 | 25 | 1.60 | 288 | 6,640 | 1,728 | 3,840 | 7,652 | 19,860 | 0.012 | 144 |
| 186 | 24 | 1.60 | 288 | 6,673 | 1,728 | 3,879 | 7,685 | 19,965 | 0.011 | 133 |
| 187 | 23 | 1.55 | 279 | 6,497 | 1,674 | 3,794 | 7,478 | 19,443 | 0.011 | 123 |
| 188 | (99,9%) | 1.55 | 279 | 6,529 | 1,674 | 3,832 | 7,510 | 19,544 | 0.010 | 113 |
| 189 | 21 | 1 | 180 | 4,233 | 1,080 | 2,496 | 4,866 | 12,675 | 0.012 | 104 |
| 190 | 20 | 1 | 180 | 4,253 | 1,080 | 2,520 | 4,887 | 12,741 | 0.010 | 94 |
| 191 | 19 | 1 | 120 | 2,849 | 720 | 1,697 | 3,272 | 8,538 | 0.011 | 86 |
| 192 | 18 | 1 | 100 | 2,386 | 600 | 1,427 | 2,739 | 7,152 | 0.011 | 77 |
| 193 | 17 | 1 | 90 | 2,158 | 540 | 1,297 | 2,475 | 6,470 | 0.011 | 69 |
| 194 | 16 | 1 | 80 | 1,927 | 480 | 1,164 | 2,210 | 5,781 | 0.012 | 62 |
| 195 | 15 | 1 | 80 | 1,936 | 480 | 1,175 | 2,219 | 5,810 | 0.011 | 54 |
| 196 | 14 | 1 | 60 | 1,459 | 360 | 889 | 1,671 | 4,380 | 0.012 | 48 |
| 197 | 13 | 1 | 50 | 1,222 | 300 | 748 | 1,399 | 3,668 | 0.013 | 41 |
| 198 | 12 | 1 | 40 | 982 | 240 | 604 | 1,124 | 2,950 | 0.015 | 35 |
| 199 | 11 | 1 | 35 | 863 | 210 | 534 | 987 | 2,594 | 0.015 | 30 |
| 200 | 10 | 1 | 30 | 743 | 180 | 462 | 850 | 2,235 | 0.014 | 25 |
| 201 | 9 | 1 | 25 | 622 | 150 | 388 | 711 | 1,872 | 0.013 | 20 |
| 202 | 8 | 1 | 20 | 500 | 120 | 313 | 571 | 1,505 | 0.012 | 16 |
| 203 | 7 | 1 | 16 | 402 | 96 | 253 | 459 | 1,210 | 0.011 | 12 |
| 204 | 6 | 1 | 12 | 303 | 72 | 191 | 346 | 912 | 0.010 | 9 |
| 205 | 5 | 1 | 10 | 253 | 60 | 161 | 289 | 764 | 0.008 | 6 |
| 206 | 4 | 1 | 12 | 306 | 72 | 195 | 348 | 921 | 0.005 | 4 |
| 207 | 3 | 1 | 10 | 256 | 60 | 164 | 292 | 771 | 0.002 | 1 |
| 208 | 2 | 1 | | | | | | | | |
| 209 | 1 | 1 | | | | | | | | |
| 210 | 0 | | | | | | | | | |
| Sum | | | | | | | | | 23.38 | 287,659 |

Comprehensive Comparison of the Two Transportation Techniques

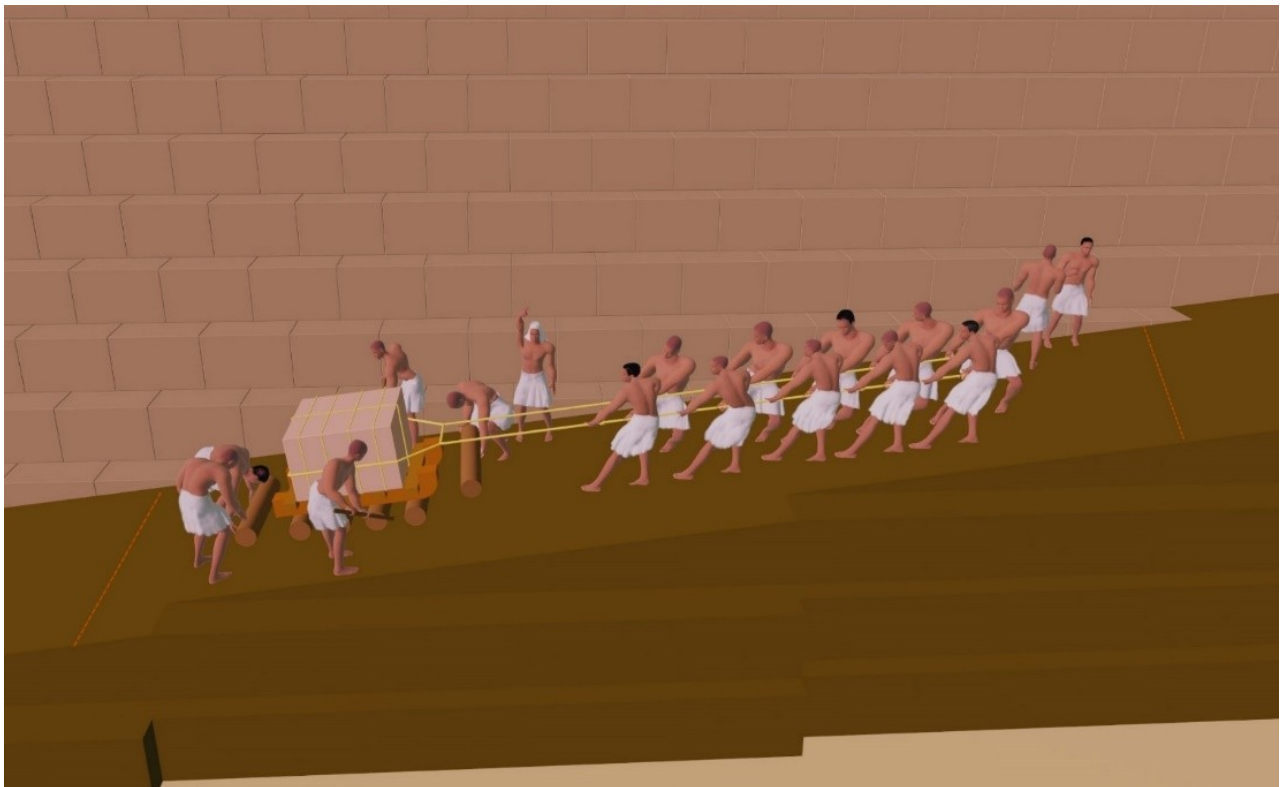
The transportation technique with sliding sledges on lubricated wooden beams would have required many water carriers, particularly in the upper half of the pyramid.

Also, the ramps would have been wider by 20 % what increased the ramp volume by 44 %. This required additional workers for building ramps, particularly in the lower half of the pyramid. Because fewer workers were available for towing and in the quarries, the production rate (installed blocks per day) was lower.

Construction time for the inner step pyramid: **23.4 years**

Total amount of the labor time of all workers: **288 thousand years**

Let's compare this with the transportation technique using wooden rollers.



Construction time for the inner step pyramid: **19.1 years**

Total amount of the labor time of all workers: **232 thousand years**

In summary, if the sliding technology had been used instead of the wooden rollers, the entire construction process would have lasted 4.3 years longer and required 24 % more work.

The following table gives a comprehensive comparison of the two transport techniques, using sliding sledges with Nile mud or sledges with rollers.

The columns “Deviation” show how the two techniques differ with the height of the individual levels. The “Accumulated construction years” of the inner step pyramid are displayed in a diagram.

| Up No. | Down No. | Length delivery lane (m) | Water carriers | Accum. work years sliding | Accum. work years rollers | Dev. % | Accum. constr. years sliding | Accum. constr. years rollers | Dev. |
|--------|----------|--------------------------|----------------|---------------------------|---------------------------|--------|------------------------------|------------------------------|------|
| 1 | 209 | 6 | 146 | 2,163 | 1,897 | 14.0 | 0.17 | 0.15 | 0.02 |
| 10 | 200 | 61 | 284 | 22,111 | 19,322 | 14.4 | 1.78 | 1.56 | 0.22 |
| 20 | 190 | 121 | 470 | 45,040 | 39,159 | 15.0 | 3.63 | 3.16 | 0.47 |
| 30 | 180 | 182 | 666 | 68,391 | 59,131 | 15.7 | 5.51 | 4.78 | 0.73 |
| 40 | 170 | 279 | 882 | 91,788 | 78,896 | 16.3 | 7.40 | 6.37 | 1.03 |
| 50 | 160 | 340 | 1,100 | 114,877 | 98,147 | 17.0 | 9.25 | 7.92 | 1.33 |
| 60 | 150 | 428 | 1,304 | 137,331 | 116,618 | 17.8 | 11.05 | 9.40 | 1.65 |
| 70 | 140 | 488 | 1,520 | 158,849 | 134,077 | 18.5 | 12.79 | 10.81 | 1.98 |
| 80 | 130 | 549 | 1,750 | 179,163 | 150,332 | 19.2 | 14.44 | 12.12 | 2.32 |
| 90 | 120 | 634 | 1,945 | 198,040 | 165,227 | 19.9 | 15.96 | 13.32 | 2.64 |
| 100 | 110 | 694 | 2,163 | 215,284 | 178,643 | 20.5 | 17.36 | 14.40 | 2.96 |
| 105 | 105 | 749 | 2,264 | 223,243 | 184,770 | 20.8 | 18.01 | 14.89 | 3.12 |
| 110 | 100 | 779 | 2,396 | 230,738 | 190,500 | 21.1 | 18.61 | 15.35 | 3.26 |
| 120 | 90 | 861 | 2,576 | 244,292 | 200,754 | 21.7 | 19.71 | 16.18 | 3.53 |
| 130 | 80 | 940 | 2,800 | 255,880 | 209,400 | 22.2 | 19.81 | 16.91 | 2.90 |
| 140 | 70 | 1,030 | 3,004 | 265,485 | 216,468 | 22.6 | 20.64 | 17.54 | 3.10 |
| 150 | 60 | 1,125 | 3,185 | 273,144 | 222,028 | 23.0 | 22.03 | 18.05 | 3.98 |
| 160 | 50 | 1,210 | 3,282 | 278,950 | 226,185 | 23.3 | 22.52 | 18.42 | 4.10 |
| 170 | 40 | 1,316 | 3,457 | 283,053 | 229,084 | 23.6 | 22.86 | 18.69 | 4.17 |
| 180 | 30 | 1,427 | 3,744 | 285,665 | 230,905 | 23.7 | 23.07 | 18.85 | 4.22 |
| 190 | 20 | 1,543 | 2,520 | 287,062 | 231,867 | 23.8 | 23.19 | 18.95 | 4.24 |
| 200 | 10 | 1,678 | 462 | 287,590 | 232,225 | 23.8 | 23.32 | 19.02 | 4.30 |
| 210 | 0 | 1,835 | 164 | 287,659 | 232,272 | 23.8 | 23.38 | 19.06 | 4.32 |

Construction Years

