10.000 Ancient Tunnels runs

A study in Diablo II magic finding

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https://github.com/oskros/MF_run_counter

Dissertation in the Holy Grail
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Contents

1 Introduction

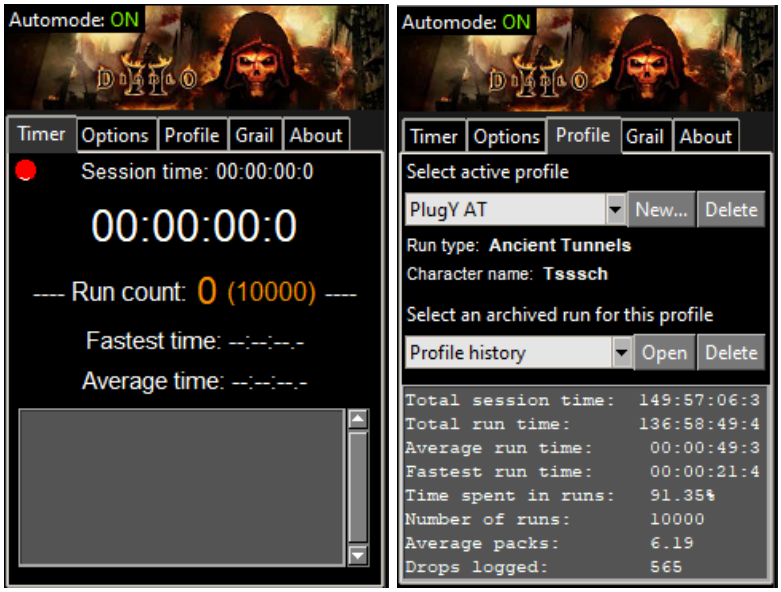
I started this project on the 7th August 2020 as a way to test updates and come up with new features for the MF Run Counter that I am developing. Initially the plan was to stop at 1000 runs, but I had a streak of good luck and quite a bit of fun, so I thought what the heck, might as well go for 10.000 runs before switching over to the next MF project.

After 132 days I finally completed the goal, playing on average approximately 1 hour a day.

Table 1: Statistics for completion time of the project

Total runs	10.000
Days to complete	132
Avg runs/day	75.8
Avg playtime/day	01h:02m

Figure 1: MF Run Counter front page and descriptive statistics after completion



2 Descriptive statistics

Table 2: Overall statistics for run progression during each month

	Run count	Avg run time	Avg level	Avg playersX	Avg MF	Avg XP/run	Avg pack kill/run	Total pack kills
⊞aug	220	107.2						
⊞sep	1080	69.8						
⊞oct	3150	51.1	96	3	527	64144	6.15	9325
⊞nov	3568	43.5	96.7	1.9	535	30251	6.21	22144
⊞dec	1982	39.1	97	1	548	14220	6.20	12286
Grand Total	10000	49.3	97	1.9	537	33031	6.19	43755

There are various takeaways from table 2. It should be noted that I only added the feature in MF Run Counter for collecting additional stats during the middle of October, which is the reason some of the data is missing prior to this.

- **Average run time:** As I will investigate in the following section, I significantly improved my run time during the project. This is a combination of rolling an optimal map, and a lot of practice
- **Level:** I started the project around level 94, and got experience quite quickly. After reaching level 96 the rate died down a bit and it took a long while to reach level 97. After the completion I am 22.5% through level 97, with approximately another 15.000 runs to go before reaching level 98 (on players 1)
- **Players X:** Initially I started the project on players 5, because I was hoping to score some extra high runes while playing and also get a bit more experience. After having no high rune luck, I decided to drop down to players 3 until reaching level 97 where I went all the way down to players 1, since experience was getting slow anyway, and I wanted to focus on kill speed to optimize tc87 finding (uniques and champions drop rate is not impacted by players X). I explore this topic in more detail in section 4.1
- **MF:** I kept the item composition very similar throughout the project, only swapping out some charms as I found better ones on the way with more MF. This is explored in more detail in section 4.2
- **Pack kills:** Packs are measured as $Pack\ kills = Unique\ kills + \frac{Champion\ kills}{2.53456}$. This conversion rate is based on the fact that uniques have a ≈ 2.53 higher chance of dropping Tyrael's Might, compared to a champion. Source: http://dropcalc.silospen.com/

Table 3: Statistics for run progression during the final month, December

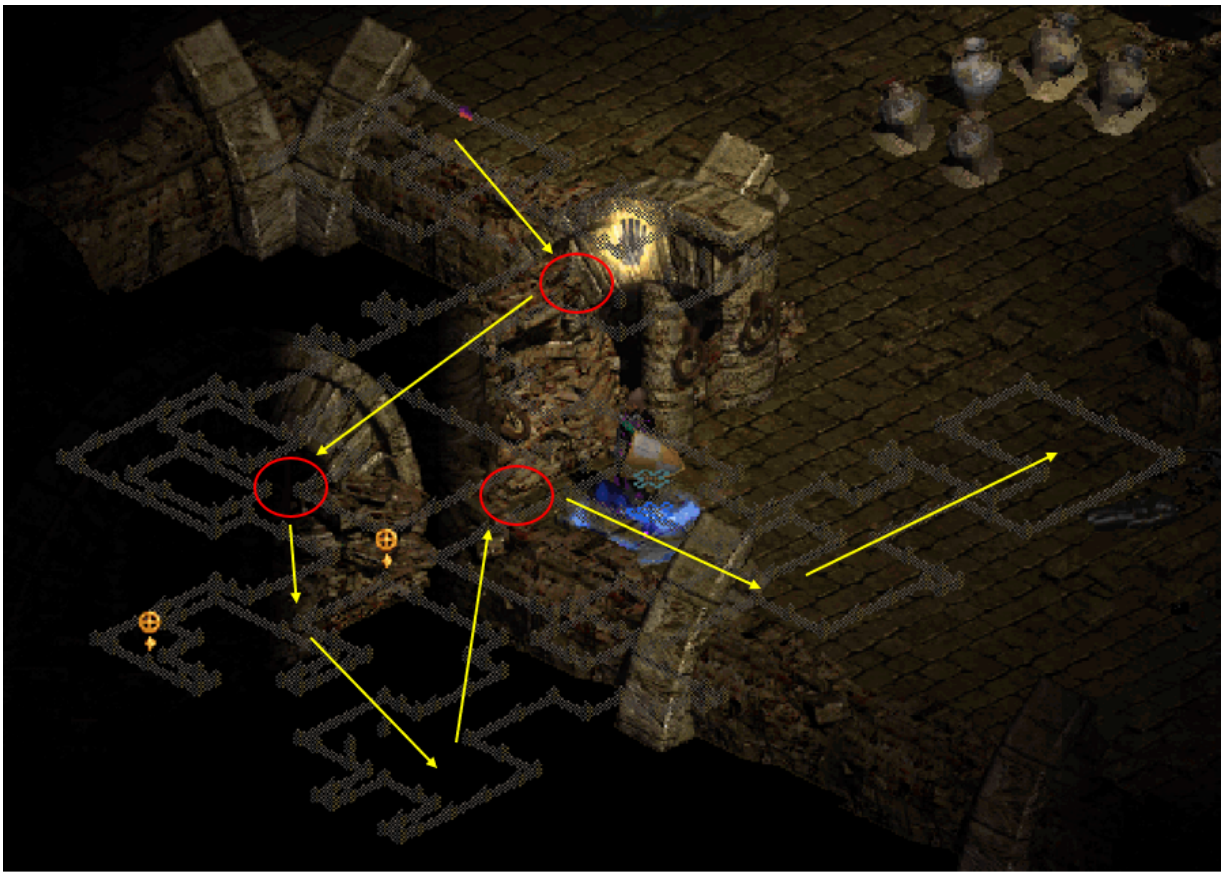
	Run count	Avg run time	Avg level	Avg playersX	Avg MF	Avg XP/run	Avg pack kill/run	Total pack kills
dec	**1982**	**39.1**	**97**	**1**	**548**	**14220**	**6.20**	**12286**
03-dec	40	37.5	97	1	547	14163	6.18	247
04-dec	147	39.5	97	1	547	14536	6.28	923
05-dec	133	38.5	97	1	547	14594	6.25	831
06-dec	262	38.7	97	1	548	14074	6.14	1610
07-dec	20	41.2	97	1	548	14502	6.16	123
08-dec	205	37.0	97	1	548	14137	6.23	1278
09-dec	225	40.8	97	1	548	14071	6.19	1394
10-dec	200	39.6	97	1	548	13749	6.08	1216
11-dec	59	35.2	97	1	548	13319	6.01	355
13-dec	31	36.7	97	1	548	14410	6.24	193
14-dec	9	39.7	97	1	548	13109	6.12	55
15-dec	496	39.3	97	1	548	14357	6.19	3069
16-dec	95	41.6	97	1	548	14301	6.32	600
17-dec	60	40.5	97	1	548	15302	6.54	392

3 Run evolution and map selection

When doing a project of this size, it can save you an enormous amount of time to spend some time on optimizing your clear speed (ultimately measured in seconds per pack kill). I would highly recommend anyone interesting in running Ancient Tunnels to read the following guide by Albatross [Guide] From rolling ancient tunnel maps to completing the grail. It all comes down to rolling a great map, figuring out where spawns are most likely to occur, and then practising your route.

During the project I was playing 3 different maps. The first one I was fairly happy with, but I accidentally re-rolled it by going to nightmare difficulty due to a miss-click. The second map I initially thought was great, but after playing it for a while I realised the average packs killed were below 6, and thus I re-rolled and got the final map that I completed the majority of my runs with

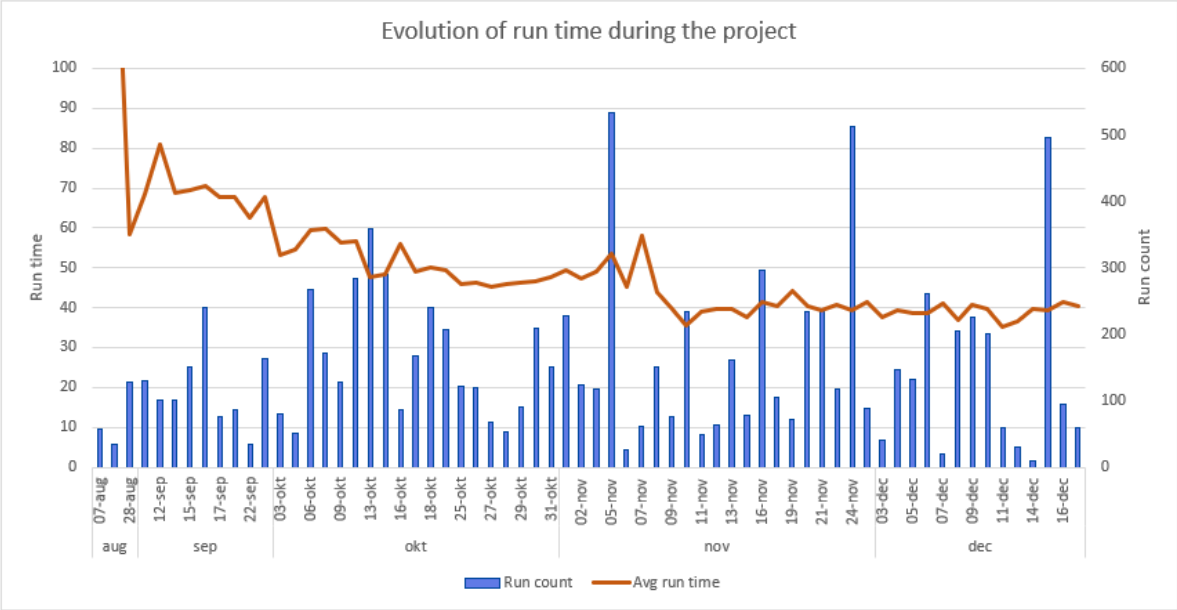
Figure 2: Map layout and route of the final map that I completed the project with. The red circles are hotspots where I encountered most of the packs



Aside of selecting a great map, it is also important to practice run speed. I am no contender for the Single Player Forum: Hall of Records, where top contenders manage an average run time of around 31 secods, but I am still pretty satisfied with my progress. During the sessions where I focused a lot, I was able to reach an average run time of around 35.7 seconds, with a clear speed of 5.84 seconds per pack (this is including time for identifying / stashing items).

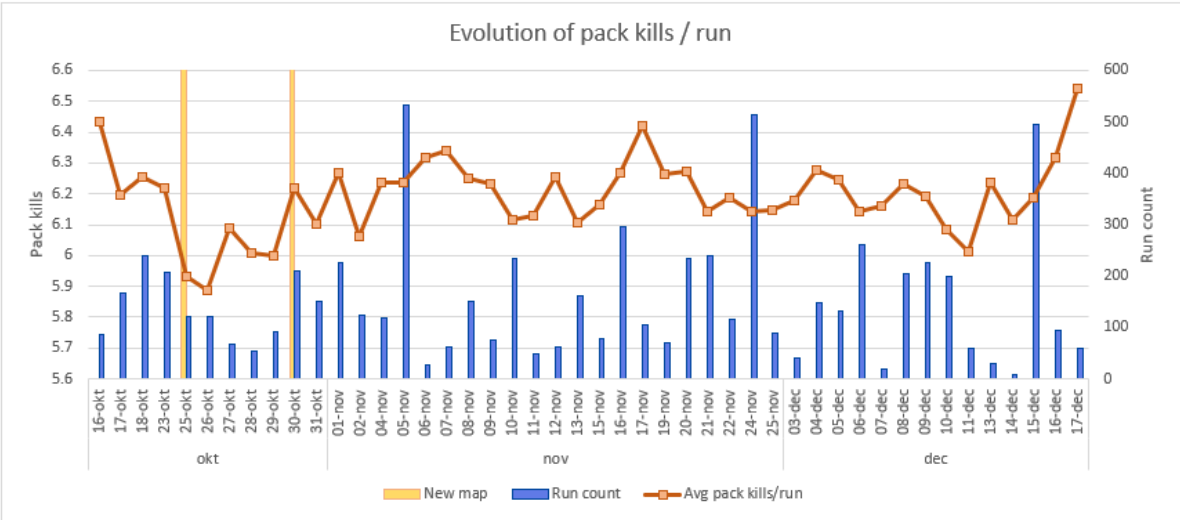
As seen in figure 3, I progressively got more efficient at running throughout the project, starting around 80 seconds per run and ending up between 35-40 seconds per run on average. There is still room for improvement, but certainly a good progression for me.

Figure 3: Run time progression throughout the project. I cut the left y-axis at 100, as the first couple of runs were VERY slow due to me initially clearing all monsters instead of just going for uniques and champions



I include figure 4 as an example of how much average pack kills can fluctuate between sessions. This I hope can be used to get an indication of how many runs are needed to properly assess whether your current map is good in terms of spawned packs.

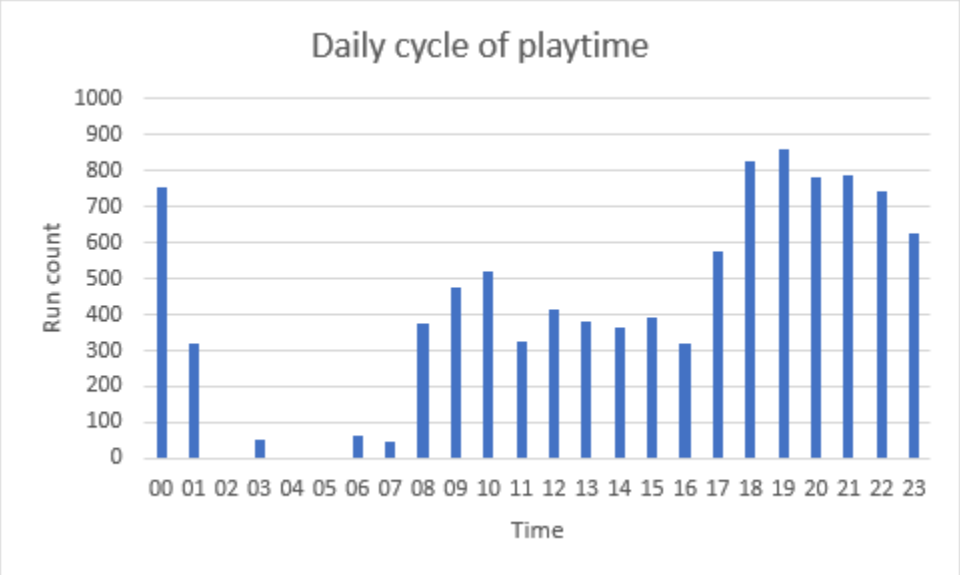
Figure 4: Average pack kills per run, marking the two occasions where I changed my map. I removed all dates prior to the update of MF Run Counter where I started logging pack kills, as they wouldn't be relevant for this plot



3.1 Daily play-time cycle

The following plot is mostly included for my own amusement, to get an idea of when during the day I am spending the most time playing Diablo II (also as a showcase of which useful stats you can get from using MF Run Counter). A conclusion would be that considering the amount of runs completed between 8 and 16, I should probably work more and play less during the working from home corona days... ☺

Figure 5: Sum of runs completed during each hour of the day



4 Setup

4.1 What players X setting to use

It is my opinion that running Ancient Tunnels is mostly interesting for the potential of dropping TC87 uniques, and that is optimized by only going for champions and uniques. As the drops from these are not affected by increasing players X, the only benefit from this is lowering the no-drop chance of minions and regular monsters, and of course the additional XP gained.
If you are also on the hunt for high runes, the players X could be increased to improve the odds for minions and regular monsters. This was my initial thinking, and the reason why I started this project on players 5. After around 2000 runs I had only found one high rune (Ohm) which dropped from a unique monster which isn't affected by players X anyway. I then decided to drop down to players 3, which I ran for another 3500 runs. In this part of the project I found quite a few high runes (Vex, Sur, Ber, Jah, Cham) but all of them actually dropped from uniques or champions, so again players X did not have an impact. Based on this, for the last 4500 runs I dropped down to players 1, and I still found quite a few runes (Vex, 2 Ohm, Lo and 3 Ber).

Based on this experience, it is my recommendation that you should run Ancient Tunnels on players 1, even if you are also interested in finding high runes.

4.2 MF and gear

As mentioned in section 2, I ran with MF between 527 and 548, getting a bit higher as I found better small charms along the way. Assuming MF of 548, this translates to the following effective MF

$$MF_{unique} = \frac{MF_{base} \cdot 250}{MF_{base} + 250} = \frac{548 \cdot 250}{548 + 250} = 171.68$$
$$MF_{set} = \frac{MF_{base} \cdot 500}{MF_{base} + 500} = \frac{548 \cdot 500}{548 + 500} = 261.45$$

This is as high as I could reach while staying at max res, 105 fcr, and 5.5k blizzard damage. I also kept a few slots in my inventory open as quality of life, so I didn't have to throw everything into the cube. I did however opt out of carrying tomes for TP and identification and instead used Cain for this, finding it resulted in practically no slowdown due to my map having a good Act 1 layout. Albatross' AT guide also touches on the subject of ensuring your rolled map has the right Act 1 layout, so have a look there for more information.

Figure 6: Gear and inventory. Rings are 30 mf nagel and a 10 fcr ring with allres. Charms are an assortment of 6-7 mf small charms and one 5 fhr charm to reach the 60 fhr breakpoint with spirit

5 Drops

Now for the exciting part that you've all (probably) been waiting for - The drops!

5.1 Runes

As seen in table 4, I found a total of 48 runes from Lem and upwards. Of those 13 were high runes (Vex or better), which I am quite satisfied about. Especially the Jah and 4 Ber runes were highly appreciated and was used for building my first Infinity and Enigma on PlugY. The Cham was given my upcoming pitzerker for his Shako to gain CBF.

Table 4: Rune spread for runes Lem or higher

Rune	Count
Lem Rune	9
Pul Rune	6
Um Rune	6
Mal Rune	8
Ist Rune	4
Gul Rune	2
Vex Rune	2
Ohm Rune	3
Lo Rune	1
Sur Rune	1
Ber Rune	4
Jah Rune	1
Cham Rune	1
Grand Total	**48**

Now an obvious question would be how does this compare to rune finding in Lower Kurast?

Table 5: Average runs needed for dropping a rune of said quality or better. For example, I found a Mal or better rune every 370 runs.

Rune	Avg runs
$\geq$ Pul	256
$\geq$ Um	303
$\geq$ Mal	370
$\geq$ Ist	526
$\geq$ Gul	667
$\geq$ Vex	769
$\geq$ Ohm	909
$\geq$ Lo	1250
$\geq$ Sur	1429
$\geq$ Ber	1667
$\geq$ Jah	5000
$\geq$ Cham	10000

As can be seen in table 5, I found a high rune (Vex or better) every 769 runs. With an average run time of 45 seconds, that means on average I spent 9.6 hours to find one high rune. Let us compare this to LK

Table 6: Rune patterns in LK superchest on players 7/8. The total number of patterns are 65536. Source is https://forums.d2jsp.org/topic.php?t=77282905&f=87

Rune	Patterns
Pul	14
Um	10
Mal	15
Ist	7
Gul	11
Vex	6
Ohm	5
Lo	2
Sur	11
Ber	3

Based on the above, we see that you are expected to find a high rune (Vex or better) every 405 runs, assuming you open 6 superchests and run on players 7/8. With a conservative estimate of an average run time of 25 seconds you are expected to find a high rune for every 2.8 hours of playtime. In terms of time invested, that is about 3.4 times better than the results I have gotten in Ancient Tunnels. It should however be kept in mind that I also found a Jah and Cham which is not possible in LK, plus the fact that I found tons of uniques as well and finally that many people find running LK extremely dull. With all these things in mind, I would personally recommend skipping LK entirely in your PlugY playthrough (save maybe for your first Vex/Ohm for HotO and CtA) and just finding your runes elsewhere, such as in Ancient Tunnels.

5.2 Jewellery

I found a good assortment of jewellery, with the most notable drops being a $-5/5$ lightning level facet, a BK 5% ring, a SoJ and 2 Maras (23 and 27).

Table 7: Tally of the different jewellery and charms that I found. Interesting drops highlighted in yellow

Amulet	**28**
Atma's Scarab	1
Crescent Moon	1
Highlord's Wrath	2
Mara's Kaleidoscope	2
Nokozan Relic	6
Saracen's Chance	2
Seraph's Hymn	2
Tal Rasha's Adjudication	1
Telling of Beads	4
The Cat's Eye	2
The Eye of Etlich	1
The Mahim-Oak Curio	1
The Rising Sun	3
Charm	**27**
Annihilus	13
Gheed's Fortune	14

Jewel	**11**
Rainbow Facet (Cold Level Up)	3
Rainbow Facet (Light Die)	3
Rainbow Facet (Light Level Up)	2
Rainbow Facet (Poison Die)	2
Rainbow Facet (Poison Level Up)	1
Ring	**39**
Bul-Kathos' Wedding Band	1
Carrion Wind	3
Dwarf Star	4
Manald Heal	15
Nagelring	9
Nature's Peace	3
Raven Frost	3
Stone of Jordan	1

5.3 TC84 and TC87

I logged all drops of TC84 and TC87 items, and found a total of 69 TC84 sets and uniques, and a total of 61 TC87 sets and uniques. This translates to the following drop frequencies

Table 8: Drop frequencies (i.e. how many runs on average does it take to find an item in this category) for TC84 and TC87 items, shown separated between sets and uniques, and also as a combined number

	TC84	TC87
Set	222.2	250.0
Unique	416.7	476.2
Combined	144.9	163.9

I honestly expected these numbers to be worse. Of course a sample of 10000 runs is not sufficient for accurately determining this number, and if you complete a similar project your results might certainly vary from these. But finding a TC87 unique every 476 runs (every 5.95 hours) is honestly a pretty good rate considering their rarity.

Table 9: Drop counts for each individual TC87 item, separated into uniques and rares

TC87 uniques	
Astreon's Iron Ward	2
Crown of Ages	1
Darkforce Spawn	-
Death Cleaver	2
Death's Fathom	-
Death's Web	3
Earth Shifter	-
Executioner's Justice	2
Gargoyle's Bite	-
Ghostflame	1
Griffon's Eye	-
Mang Song's Lesson	-
Shadow Dancer	1
Steel Pillar	3
Steelrend	-
Stormspire	-
Templar's Might	1
The Cranium Basher	-
The Grandfather	2
Tyrael's Might	-
Windforce	3

TC87 rares	
Bul-Kathos' Sacred Charge	3
Bul-Kathos' Sacred Tribal Guardian	6
Griswold's Honor	1
Griswold's Redemption	2
Griswold's Valor	13
Immortal King's Soul Cage	5
M'avina's True Sight	7
Natalya's Mark	3

I was both thrilled and saddened by these results. Finding 2 Astreons and 3 Death's Web is honestly insane considering their rarity. Even so, I was really hoping to get either a Death's Fathom or a Griffon's Eye which I found none of - This is especially taunting considering I found a total of 7 M'avina's True Sight. In my opinion one of the coolest items I found was an Eth Death Cleaver, that I will stick a Zod into as soon as I find one.

Figure 7: My Eth Death Cleaver with 271 ED. Very cool find

Table 10: Drop counts for each individual TC84 item, separated into uniques and rares

TC84 uniques

Dragonscale	-
Fleshripper	1
Frostwind	4
Giant Skull	2
Gut Siphon	2
Messerschmidt's Reaver	2
Ravenlore	3
Schaefer's Hammer	1
Spirit Ward	4
Steel Carapace	4
Stone Crusher	1

TC84 rares

Aldur's Deception	4
Sazabi's Cobalt Redeemer	13
Taebaek's Glory	4
Tal Rasha's Guardianship	12
Trang-Oul's Girth	6
Trang-Oul's Guise	6

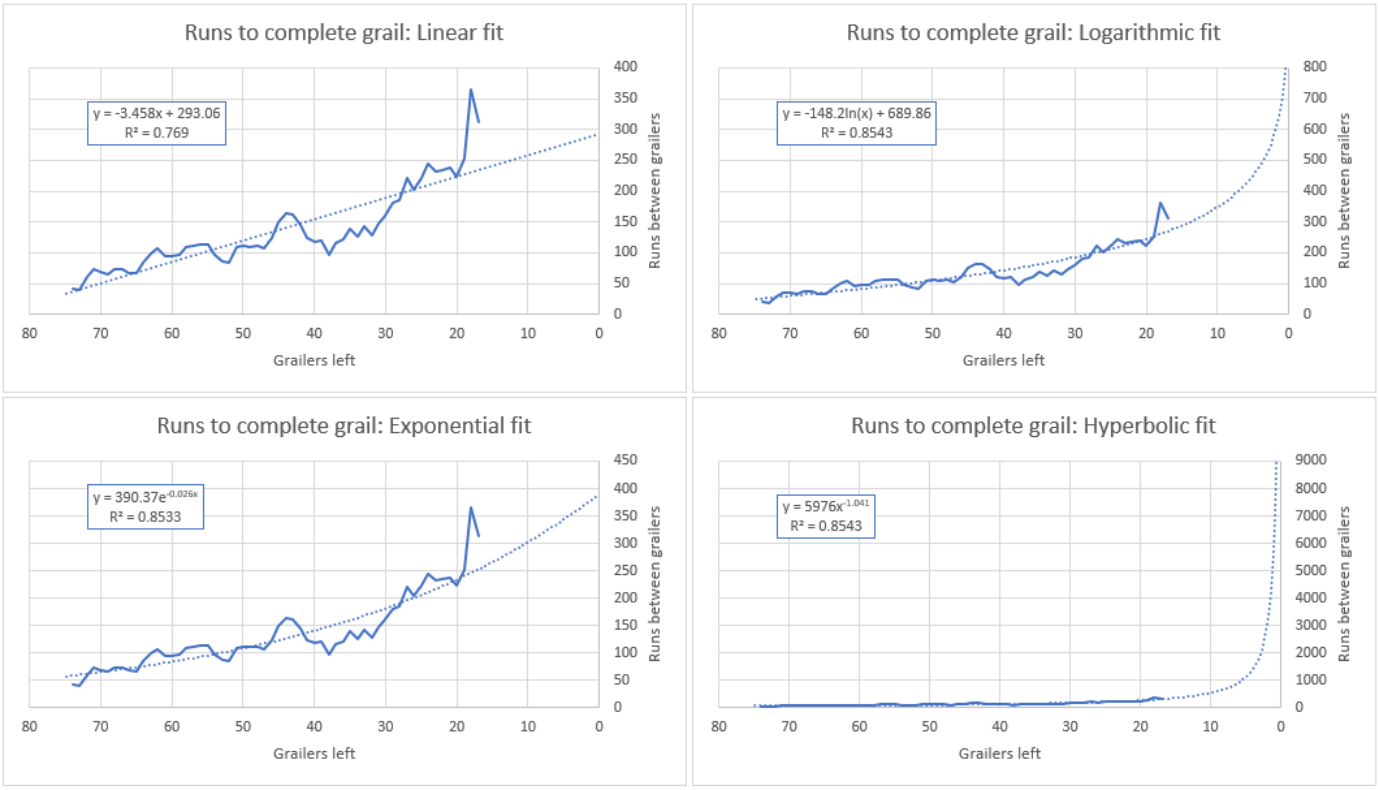
I found all TC84 items except Dragonscale, but I already found one from Pindle so all in all pretty happy about this. Aside of that I found 12 Tals armor, so to anyone hunting this item you could give Ancient Tunnels a shot!

6 Completing the grail

I started this project with 83 grailers to go, and ended up with having 17 grailers left. Considering the amount of time I spent on completing this project, and the fact that finding grailers becomes increasingly difficult the less you have left should put into perspective just how difficult and time consuming completing the grail is. But HOW difficult is it really? This is the final topic I wish to explore.

To get an idea about this question, I calculated the number of runs between finding each grail item. Then I applied a rolling average for every 10^{th} item, to smooth out the curve a bit. I did tests with other windows for the rolling average, but found that 10 was a good compromise between smoothing and still keeping some of the dynamics in the observations. I then tested out various functional fits for modelling how much the difficulty of finding the last grail items would increase, which you can see below in figure 8

Figure 8: Plots of the number of runs between finding each grail item. The underlying data is the same in each plot, the only difference is the functional form used for making the fit



To gauge how the model fits perform, let's say that Tyrael's is your last missing item. If we assume 6.2 packs per run, it takes on average 64768 runs to find Tyrael's, which is a daunting number. Of course the final item could also be something else, for example Mang Song's Lesson which on average would drop once even 18706 runs or Death's Web which drops on average once every 18755 runs. Thus a reasonable guess would be that any fit should reach somewhere between 15000 and 65000 runs when approaching 0 grailers left.
With that in mind, we can quickly disregard both the linear and exponential fit. Logarithmic and hyperbolic fits are a bit weird, since they tend to infinity when approaching zero, although the hyperbolic fit grows quicker than the logarithmic does. Even so, I would expect the logarithmic fit to be the most representative of reality.

With some knowledge of discrete probabilities and calculus, we could actually calculate this rate directly without the need of data, but this document has already grown quite large and it would take me a while to determine how to do this, so I leave it for another time.

7 Appendix

JSON profile for the MF Run Counter with all the data
https://drive.google.com/file/d/1SYotJN0q9YYeEfhVu5763dWZtIFSwn9G/view?usp=sharing

Excel spreadsheet where I made all the graphs and data analysis based on the collected data from MF Run Counter
https://drive.google.com/file/d/1pSjuRFwMkW7tQhO-pRCGE8SGdEQq9bmY/view?usp=sharing