301(h)-Modified
NPDES Permit Reissuance
Questionnaire for Small Dischargers

Attachment E: Supporting Technical Analysis
Farfield Dissolved Oxygen Demand

UTULEI WASTEWATER
TREATMENT PLANT

NPDES Permit No. AS0020001

Submitted By

AMERICAN SAMOA POWER AUTHORITY

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Dissolved Oxygen Demand in the Farfield

The procedure specified in the EPA *Amended 301(h) Technical Support Document* (EPA 301(h) TSD: EPA 842-B-94-007, September 1994) was applied using a Microsoft Excel spreadsheet application. This method typically gives conservative results in coastal waters (over-predicts DO depression) because the method used is very conservative and does not account for the replenishment of oxygen in the receiving water as a result of contact with the atmosphere (re-aeration) or photosynthesis, and does not provided for vertical diffusion while using a very conservative horizontal diffusion coefficient. The method for farfield analysis is described in the following equation:

$$DO(t) = DO_a + \frac{DO_f - DO_a}{D_s(t)} - \left[\frac{L_{fc}}{D_s(t)}(1-\exp(K_c t))\right] - \left[\frac{L_{fn}}{D_s(t)}(1-\exp(-K_n t))\right]$$

where,

$DO(t)$ =dissolved oxygen as a function of time, mg/l,

DO_a = ambient dissolved oxygen, mg/l,

DO_f = final dissolved oxygen at end of initial dilution, mg/l,

D_s = subsequent (farfield) dilution (calculated using the Brooks method as described in the EPA 301(h) TSD),

L_{fc} = ultimate carbonaceous BOD (CBOD) above ambient after initial dilution, mg/l,

L_{fn} = Nitrogenous BOD (NBOD) above ambient after initial dilution, mg/l,

K_c = CBOD decay rate constant (day^{-1}),

K_n = NBOD decay rate constant (day^{-1}), and

t = travel time (days).

The calculation of $DO(t)$ using the above relation has four main terms (on the right hand side of the above equation):

1. The first term is the DO in the ambient receiving water.
2. The second term accounts for the mixing of the effluent and the receiving water over the farfield dilution phase. This term is numerically equal to the difference between the DO at the end of initial dilution, DO_f, and the DO of the receiving water, DO_a, divided by the farfield dilution, D_s. DO_f must include the effect of IDOD effect as calculated above.
3. The third term accounts for both the dilution and decay of the carbonaceous BOD as a function of time, based on measured BOD_5 in the effluent and receiving water.

4. The fourth term accounts for both the dilution and decay of the nitrogenous BOD as a function of time, based on the TKN levels measured in the effluent.

All of the terms and coefficients used above are identical to those in the EPA 301(h) TSD.

The calculations were done for 10 days, at 6-hr intervals as required using the lowest observed value of ambient DO levels. To examine the DO impacts more closely, the calculation was also done in more detail for 1 day at 0.6-hour intervals. The results of the calculations are shown in Figures 1 and 2. Input values for the farfield calculations were as follows:

- The ambient average water column DO was taken as 5.63 mg/l. This is the lowest background value of DO observed at the diffuser monitoring station (See Attachment C).
- The final DO concentration to begin the farfield calculation (after CID) was 5.55 mg/l, as determined for the CID in III.B.1 of the 301(h) questionnaire.
- A CBOD decay rate of 0.325/day (base e) was used based on a value of 0.23/day, as specified in the EPA 301(h) TSD, adjusted for the ambient water temperature. Ambient water temperature varies seasonally. A value of 27.5°C was used to calculate the CBOD decay rate using the expression:

$$K_c = 0.23x(1.047)^{(T-20)} = 0.23\times 1.047^{7.5} = 0.325$$

- Similarly, an NBOD decay rate of 0.141/day (base e) was used based on a value of 0.1/day adjusted for the ambient water temperature, based on a similar expression:

$$K_n = 0.10\times(1.047)^{(T-20)} = 0.10\times 1.047^{7.5} = 0.141$$

- The ultimate CBOD concentration was based on an effluent BOD_5 of 157 mg/l, as the daily maximum permit limitation, increased by a factor of 1.46 for conversion to ultimate BOD as recommended in the EPA 301(h) TSD. This yields an ultimate CBOD value of 229 mg/l.
- Maximum effluent TKN concentration was taken as 67.1 mg/l (based on limited data collected during the priority pollutant scans done in 2004 and 2005)
- Ultimate NBOD was calculated by multiplying the effluent TKN concentration by 4.57, as recommended in the EPA 301(h) TSD. This yields an ultimate NBOD of 307 mg/l.
- Pursuant to the EPA guidelines, the ultimate NBOD and CBOD are to be decreased by the ambient ultimate NBOD and CBOD and divided by the CID. The ambient BOD_5 is unknown and available TKN measured values are very small. Since smaller ambient values will result in lower predicted DO (or higher DO demand) a value of 0.0 was used for the ambient values of each of these parameters in order to remain conservative (predict the lowest ambient farfield DO).
- The values of farfield dilution, D_S, as a function of travel time were calculated using methods given in the EPA 301(h) TSD for the initial condition of a maximum field width with a variable diffusion coefficient applicable to open ocean conditions. The relationship used to calculate the farfield dilution, D_S, was:

$$D_s = \left[erf \left[\frac{1.5}{\left(1 + \frac{8 \cdot e_0 \cdot t}{b^2} \right)^3 - 1} \right]^{1/2} \right]^{-1} \qquad (8\text{-}15)$$

where,

erf = the error function,

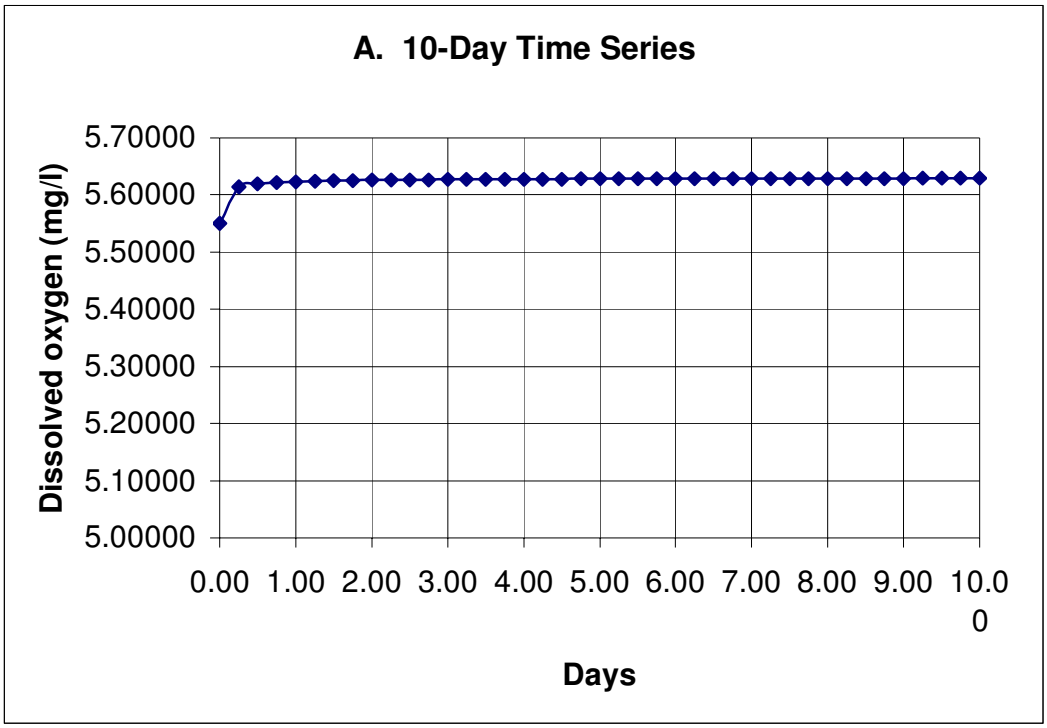
e_0 = the initial diffusion coefficient (ft^2/sec) = $0.001 \times b^{4/3}$,

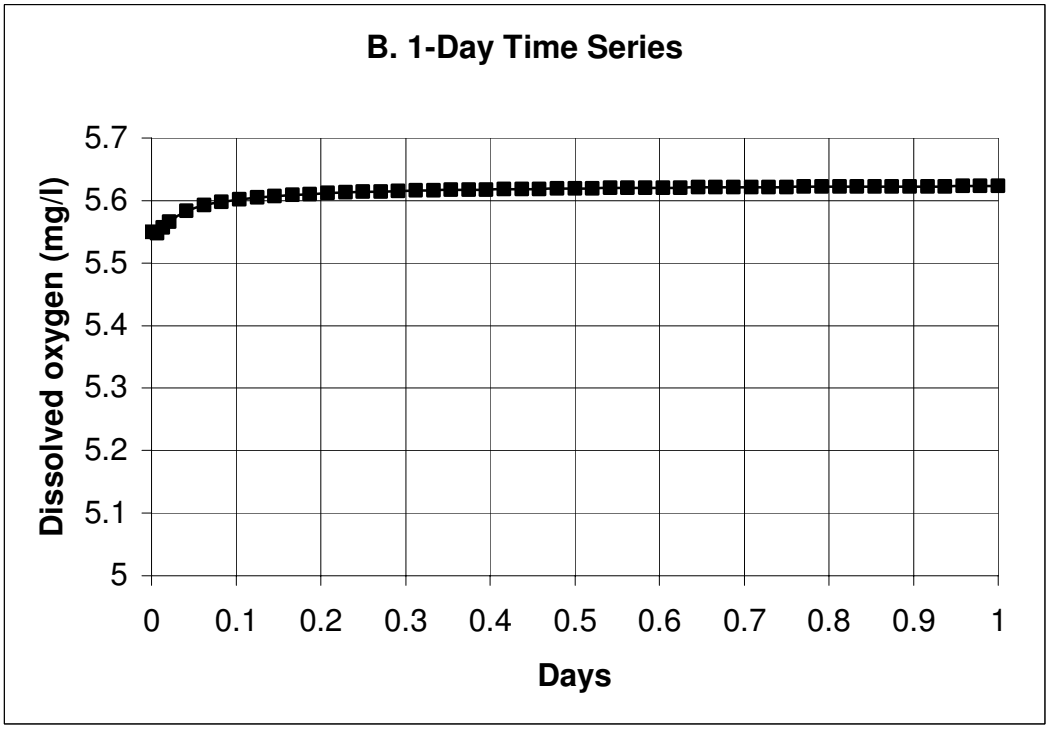
b = the effective diffuser length (ft), and

t = travel time (sec).

The effective diffuser length, b, is the initial width of the plume after initial dilution. Consideration of the equation for farfield or subsequent dilution, D_s, shows that the inverse of D_s is related to *b* by an error function. The larger the value of b, the smaller the value of D_s and, therefore, the lower the value of *DO(t)*. To be as conservative as possible, the calculations use the largest possible value of *b*. This occurs when the ambient current flows perpendicular to the axis of the diffuser. Therefore, *b* was set to be consistent with the total length of the diffuser plus the width of the plume under critical conditions (approximately 100 feet).

The calculations are summarized in the following charts and the calculation details are provided in tabular form below. The results of the farfield DO demand calculations, shown below, indicate an insignificant DO demand in the farfield (< 0.01 mg/l) following the initial dilution. The minimum DO is calculated to be greater than 5.5 mg/l. Thus, the DO criterion of the ASWQS will be achieved in both the nearfield and the farfield.





Dissolved Oxygen Sag in the Farfield

DO Model

DOa= average dissolved oxygen concentration (ambient)	5.63	BODf: final BOD5 concentration	1.80
DOe=average dissolved oxygen concentration of effluent	0.0	BODfu: ultimate BOD5 concentration at end of initial dilution	2.63
BODa: ambient BOD5 concentration (mg/l)	0	TKNe	67.1
BODe: effluent BOD5 concentration (mg/l)	229	TKNa	0
Initial Dilution, flux-averaged	127	effective diffuser length in feet	100.0
IDOD (15 min)	5.0	Reaeration Constant	0
DOf: final dissolved oxygen concentration at trapping level	5.55000	Saturated DO concentration	

FARFIELD DILUTION - 10 days at .25 day increments

Time (seconds)	Time (days)	x term	t term	erf	DS	DOa	(DOf-DOa)/Ds	CBOD decay	NBOD decay	DO(time)	Reaer.	Final DO
0	0.00									5.55000		5.55000
21600	0.25	0.04523596	0.9853975	0.05101	19.6045	5.63	-0.004080693	-0.007657404	-0.004568655	5.61369	0	5.6136932
43200	0.50	0.01741142	0.9943285	0.01964	50.9041	5.63	-0.001571584	-0.005652619	-0.003453754	5.61932	0	5.619322
64800	0.75	0.00976194	0.9968123	0.01101	90.7863	5.63	-0.00088119	-0.004559115	-0.002851253	5.62171	0	5.6217084
86400	1.00	0.00643652	0.9978959	0.00726	137.688	5.63	-0.000581022	-0.003846116	-0.002460766	5.62311	0	5.6231121
108000	1.25	0.00464765	0.9984798	0.00524	190.683	5.63	-0.000419544	-0.003333263	-0.00218067	5.62407	0	5.6240665
129600	1.50	0.00355719	0.9988361	0.00401	249.136	5.63	-0.000321109	-0.002941363	-0.001966629	5.62477	0	5.6247709
151200	1.75	0.0028352	0.9990721	0.0032	312.579	5.63	-0.000255935	-0.002629451	-0.001795866	5.62532	0	5.6253187
172800	2.00	0.00232821	0.9992379	0.00263	380.646	5.63	-0.000210169	-0.002373868	-0.001655326	5.62576	0	5.6257606
194400	2.25	0.00195616	0.9993596	0.00221	453.042	5.63	-0.000176584	-0.002159832	-0.001536915	5.62613	0	5.6261267
216000	2.50	0.00167363	0.999452	0.00189	529.522	5.63	-0.00015108	-0.00197754	-0.001435304	5.62644	0	5.6264361
237600	2.75	0.00145311	0.9995242	0.00164	609.878	5.63	-0.000131174	-0.001820184	-0.001346823	5.6267	0	5.6267018
259200	3.00	0.0012771	0.9995818	0.00144	693.932	5.63	-0.000115285	-0.001682859	-0.001268848	5.62693	0	5.626933
280800	3.25	0.00113396	0.9996287	0.00128	781.529	5.63	-0.000102364	-0.001561922	-0.001199444	5.62714	0	5.6271363
302400	3.50	0.00101569	0.9996674	0.00115	872.529	5.63	-9.16875E-05	-0.001454599	-0.001137148	5.62732	0	5.6273166
324000	3.75	0.00091664	0.9996998	0.00103	966.81	5.63	-8.27464E-05	-0.001358731	-0.001080828	5.62748	0	5.6274777
345600	4.00	0.00083271	0.9997273	0.00094	1064.26	5.63	-7.51695E-05	-0.001272609	-0.001029596	5.62762	0	5.6276226
367200	4.25	0.00076085	0.9997508	0.00086	1164.78	5.63	-6.86823E-05	-0.001194857	-0.000982739	5.62775	0	5.6277537
388800	4.50	0.00069875	0.9997711	0.00079	1268.29	5.63	-6.30773E-05	-0.001124353	-0.000939681	5.62787	0	5.6278729
410400	4.75	0.00064467	0.9997889	0.00073	1374.68	5.63	-5.81952E-05	-0.001060171	-0.000899946	5.62798	0	5.6279817
432000	5.00	0.00059722	0.9998044	0.00067	1483.9	5.63	-5.3912E-05	-0.001001539	-0.000863142	5.62808	0	5.6280814
453600	5.25	0.00055532	0.9998181	0.00063	1595.87	5.63	-5.01295E-05	-0.000947807	-0.000828936	5.62817	0	5.6281731
475200	5.50	0.0005181	0.9998303	0.00058	1710.51	5.63	-4.67695E-05	-0.000898423	-0.00079705	5.62826	0	5.6282578
496800	5.75	0.00048486	0.9998412	0.00055	1827.78	5.63	-4.37688E-05	-0.000852914	-0.000767246	5.62834	0	5.6283361
518400	6.00	0.00045503	0.999851	0.00051	1947.62	5.63	-4.10758E-05	-0.000810875	-0.000739317	5.62841	0	5.6284087
540000	6.25	0.00042813	0.9998598	0.00048	2069.96	5.63	-3.86481E-05	-0.000771953	-0.000713086	5.62848	0	5.6284763
561600	6.50	0.00040379	0.9998677	0.00046	2194.76	5.63	-3.64504E-05	-0.000735842	-0.000688399	5.62854	0	5.6285393
583200	6.75	0.00038167	0.999875	0.00043	2321.98	5.63	-3.44534E-05	-0.000702274	-0.00066512	5.6286	0	5.6285982
604800	7.00	0.00036149	0.9998816	0.00041	2451.56	5.63	-3.26323E-05	-0.000671011	-0.00064313	5.62865	0	5.6286532
626400	7.25	0.00034303	0.9998876	0.00039	2583.47	5.63	-3.09662E-05	-0.000641846	-0.000622324	5.6287	0	5.6287049
648000	7.50	0.0003261	0.9998932	0.00037	2717.66	5.63	-2.94371E-05	-0.000614595	-0.000602607	5.62875	0	5.6287534
669600	7.75	0.00031051	0.9998983	0.00035	2854.09	5.63	-2.80299E-05	-0.000589091	-0.000583897	5.6288	0	5.628799
691200	8.00	0.00029612	0.999903	0.00033	2992.74	5.63	-2.67314E-05	-0.000565189	-0.000566118	5.62884	0	5.628842
712800	8.25	0.00028282	0.9999074	0.00032	3133.56	5.63	-2.55301E-05	-0.000542757	-0.000549204	5.62888	0	5.6288825
734400	8.50	0.00027048	0.9999114	0.00031	3276.53	5.63	-2.44161E-05	-0.000521676	-0.000533093	5.62892	0	5.6289208
756000	8.75	0.00025901	0.9999152	0.00029	3421.6	5.63	-2.33809E-05	-0.000501842	-0.00051773	5.62896	0	5.628957
777600	9.00	0.00024833	0.9999187	0.00028	3568.75	5.63	-2.24168E-05	-0.000483156	-0.000503066	5.62899	0	5.6289914
799200	9.25	0.00023836	0.9999219	0.00027	3717.96	5.63	-2.15172E-05	-0.000465533	-0.000489056	5.62902	0	5.6290239
820800	9.50	0.00022904	0.999925	0.00026	3869.19	5.63	-2.06762E-05	-0.000448893	-0.000475657	5.62905	0	5.6290548
842400	9.75	0.00022032	0.9999278	0.00025	4022.41	5.63	-1.98886E-05	-0.000433166	-0.000462833	5.62908	0	5.6290841
864000	10.00	0.00021214	0.9999305	0.00024	4177.61	5.63	-1.91497E-05	-0.000418285	-0.000450548	5.62911	0	5.629112

FARFIELD DILUTION - 1 day at 0.5 hour increments												
Time (seconds)	Time (days)	x term	t term	erf	DS	DOa	(DOf-DOa)/Ds	CBOD decay	NBOD decay	DO(time)	Reaer.	Final DO
0	0									5.55		5.55
600	0.0069	1.34566021	0.6940462	0.94297	1.06048	5.63	-0.075437298	-0.004100586	-0.00238942	5.54807	0	5.5480727
1200	0.0139	0.8615336	0.7798908	0.77693	1.28713	5.63	-0.062154001	-0.006748929	-0.003935297	5.55716	0	5.5571618
1800	0.0208	0.64158871	0.8263242	0.63577	1.57288	5.63	-0.050861988	-0.00827421	-0.004827976	5.56604	0	5.5660358
3600	0.0417	0.35714221	0.8952579	0.38649	2.58736	5.63	-0.030919528	-0.010023651	-0.005860722	5.5832	0	5.5831961
5400	0.0625	0.23954938	0.9272359	0.26522	3.77046	5.63	-0.021217589	-0.010280452	-0.006023133	5.59248	0	5.5924788
7200	0.0833	0.17572792	0.9455667	0.19627	5.09514	5.63	-0.015701226	-0.010106997	-0.005933568	5.59826	0	5.5982582
9000	0.1042	0.13620355	0.9572868	0.15274	6.5469	5.63	-0.012219527	-0.009796898	-0.005763209	5.60222	0	5.6022204
10800	0.1250	0.10964255	0.9653274	0.12322	8.11527	5.63	-0.009857953	-0.009450171	-0.005570523	5.60512	0	5.6051214
12600	0.1458	0.09075254	0.9711286	0.10212	9.79212	5.63	-0.008169833	-0.009104419	-0.005377587	5.60735	0	5.6073482
14400	0.1667	0.07674188	0.9754766	0.08642	11.5708	5.63	-0.006913948	-0.008774016	-0.005192913	5.60912	0	5.6091191
16200	0.1875	0.06600663	0.9788345	0.07437	13.4458	5.63	-0.005949808	-0.008463909	-0.005019489	5.61057	0	5.6105668
18000	0.2083	0.05756431	0.9814915	0.06488	15.4124	5.63	-0.005190626	-0.008175048	-0.004857951	5.61178	0	5.6117764
19800	0.2292	0.05078218	0.9836364	0.05725	17.4665	5.63	-0.004580198	-0.007906685	-0.004707931	5.61281	0	5.6128052
21600	0.2500	0.04523596	0.9853975	0.05101	19.6045	5.63	-0.004080693	-0.007657404	-0.004568655	5.61369	0	5.6136932
23400	0.2708	0.04063146	0.9868643	0.04582	21.8233	5.63	-0.003665809	-0.00742558	-0.004439222	5.61447	0	5.6144694
25200	0.2917	0.03675888	0.9881014	0.04146	24.12	5.63	-0.003316754	-0.007209599	-0.004318728	5.61515	0	5.6151549
27000	0.3125	0.03346499	0.989156	0.03775	26.492	5.63	-0.003019779	-0.007007947	-0.004206318	5.61577	0	5.615766
28800	0.3333	0.03063547	0.9900638	0.03456	28.9371	5.63	-0.002764619	-0.006819244	-0.004101216	5.61631	0	5.6163149
30600	0.3542	0.02818353	0.9908518	0.03179	31.4531	5.63	-0.002543473	-0.006642252	-0.00400272	5.61681	0	5.6168116
32400	0.3750	0.02604218	0.991541	0.02938	34.038	5.63	-0.002350314	-0.006475867	-0.003910208	5.61726	0	5.6172636
34200	0.3958	0.02415897	0.9921479	0.02726	36.6901	5.63	-0.002180423	-0.006319113	-0.003823125	5.61768	0	5.6176773
36000	0.4167	0.02249233	0.9926856	0.02538	39.4078	5.63	-0.002030057	-0.00617112	-0.00374098	5.61806	0	5.6180578
37800	0.4375	0.02100893	0.9931647	0.0237	42.1894	5.63	-0.001896212	-0.006031121	-0.003663336	5.61841	0	5.6184093
39600	0.4583	0.01968173	0.9935937	0.02221	45.0335	5.63	-0.001776455	-0.005898431	-0.003589807	5.61874	0	5.6187353
41400	0.4792	0.01848864	0.9939797	0.02086	47.9388	5.63	-0.001668794	-0.005772444	-0.003520049	5.61904	0	5.6190387
43200	0.5000	0.01741142	0.9943285	0.01964	50.9041	5.63	-0.001571584	-0.005652619	-0.003453754	5.61932	0	5.619322
45000	0.5208	0.0164349	0.9946449	0.01854	53.9281	5.63	-0.001483458	-0.005538469	-0.003390648	5.61959	0	5.6195874
46800	0.5417	0.01554638	0.9949329	0.01754	57.0097	5.63	-0.001403271	-0.005429563	-0.003330485	5.61984	0	5.6198367
48600	0.5625	0.01473514	0.9951961	0.01663	60.1478	5.63	-0.001330057	-0.00532551	-0.003273045	5.62007	0	5.6200714
50400	0.5833	0.01399209	0.9954372	0.01579	63.3415	5.63	-0.001262995	-0.005225959	-0.003218129	5.62029	0	5.6202929
52200	0.6042	0.01330946	0.9956589	0.01502	66.5898	5.63	-0.001201384	-0.005130593	-0.003165557	5.6205	0	5.6205025
54000	0.6250	0.01268058	0.9958631	0.01431	69.8919	5.63	-0.001144625	-0.005039126	-0.003115167	5.6207	0	5.6207011
55800	0.6458	0.01209973	0.9960519	0.01365	73.2467	5.63	-0.001092199	-0.004951296	-0.003066811	5.62089	0	5.6208897
57600	0.6667	0.0115619	0.9962267	0.01305	76.6536	5.63	-0.001043656	-0.004866868	-0.003020356	5.62107	0	5.6210691
59400	0.6875	0.01106277	0.996389	0.01248	80.1118	5.63	-0.000998605	-0.004785624	-0.00297568	5.62124	0	5.6212401
61200	0.7083	0.01059855	0.99654	0.01196	83.6204	5.63	-0.000956704	-0.004707369	-0.00293267	5.6214	0	5.6214033
63000	0.7292	0.01016592	0.9966808	0.01147	87.1788	5.63	-0.000917654	-0.004631921	-0.002891226	5.62156	0	5.6215592
64800	0.7500	0.00976194	0.9968123	0.01101	90.7863	5.63	-0.00088119	-0.004559115	-0.002851253	5.62171	0	5.6217084
66600	0.7708	0.00938402	0.9969353	0.01059	94.4423	5.63	-0.000847078	-0.004488799	-0.002812666	5.62185	0	5.6218515
68400	0.7917	0.00902988	0.9970506	0.01019	98.146	5.63	-0.000815112	-0.004420832	-0.002775386	5.62199	0	5.6219887
70200	0.8125	0.00869746	0.9971589	0.00981	101.897	5.63	-0.000785107	-0.004355085	-0.002739339	5.62212	0	5.6221205
72000	0.8333	0.00838495	0.9972607	0.00946	105.694	5.63	-0.000756899	-0.004291438	-0.002704458	5.62225	0	5.6222472
73800	0.8542	0.00809072	0.9973566	0.00913	109.538	5.63	-0.00073034	-0.004229781	-0.00267068	5.62237	0	5.6223692
75600	0.8750	0.0078133	0.997447	0.00882	113.427	5.63	-0.000705299	-0.004170011	-0.002637949	5.62249	0	5.6224867
77400	0.8958	0.00755139	0.9975323	0.00852	117.361	5.63	-0.000681657	-0.004112033	-0.00260621	5.6226	0	5.6226001
79200	0.9167	0.00730378	0.9976131	0.00824	121.34	5.63	-0.000659307	-0.004055758	-0.002575413	5.62271	0	5.6227095
81000	0.9375	0.00706942	0.9976895	0.00798	125.362	5.63	-0.000638152	-0.004001103	-0.002545512	5.62282	0	5.6228152
82800	0.9583	0.00684733	0.9977619	0.00773	129.428	5.63	-0.000618105	-0.003947992	-0.002516464	5.62292	0	5.6229174
84600	0.9792	0.00663663	0.9978306	0.00749	133.537	5.63	-0.000599085	-0.003896352	-0.002488228	5.62302	0	5.6230163
86400	1.0000	0.00643652	0.9978959	0.00726	137.688	5.63	-0.000581022	-0.003846116	-0.002460766	5.62311	0	5.6231121