CENWP-EC-HD 25FEB2005
MEMORANDUM FOR THE RECORD

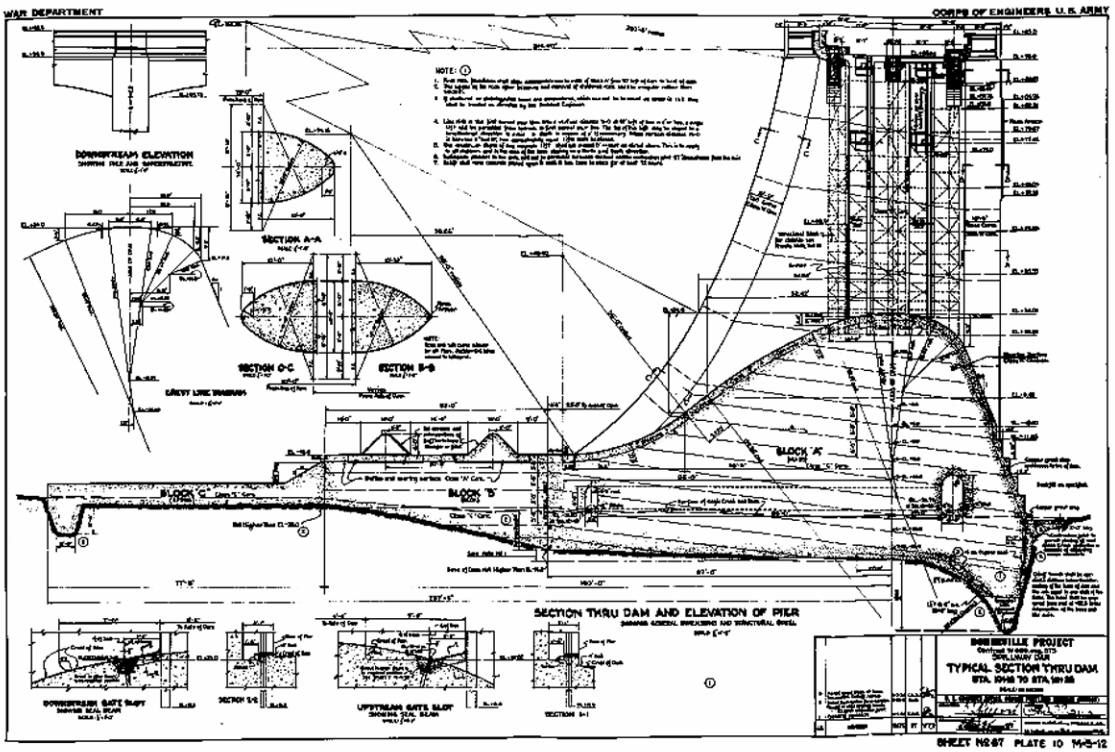
Subject:
Bonneville Lock and Dam, Revision to Fish Passage Plan Spill Patterns FEB2005

1. Introduction/Background:

Location: Bonneville Dam and Lake, Columbia River Basin

General Overview of Project

View of Spillway



Cross Section View of Spillway

Since additional flow deflectors were installed at Bonneville Dam Spillway (immediately prior to the 2002 spill season) a discrepancy between the computed inflow (The Dalles Outflow + tributary inflow) and outflow from Bonneville Dam was identified. This discrepancy occurred during times of spill. The reported spillway discharge turned out to be greater than the actual discharge (as measured downstream of the project). The magnitude of this discrepancy varied but was on the order of 20 Kcfs.

It has been determined that there are two major issues that have resulted in this flow discrepancy. One is a mis-calibration in the gate opening mechanism. The other is an out of date rating curve that gives the relationship between gate opening and flow.

During July 2004, it was discovered that the spillway gate hoist controller (GDACS) at Bonneville had been mis-calibrated and actual gate openings were up to 4 inches less than was reported. The greatest impact of this mis-calibration was on discharges at smaller gate openings. This effect was magnified by the new spill pattern developed for the new flow deflectors, which utilizes a larger number of gates at smaller openings for a given total spillway flow as compared to previous patterns.

The calibration errors would be significant primarily when the project was trying to meet a target discharge such as the 75 Kcfs daytime spill. When the project discharges to the gas cap the gas concentration downstream determines the spill volume that can be passed. The actual volume may have been misreported but the volume was set to meet the water quality requirements downstream. When the total river flows exceed the powerhouse capacity, the excess flow is also discharged through the spillway, increasing the 75 Kcfs daytime spill. In this case the spill is governed by total inflow and not increasing the forebay elevation.

During the investigation of the flow discrepancy between The Dalles (TDA) and Bonneville (BON) the spillway rating curves for both projects were scrutinized. Upon review the original TDA spillway-rating curve is consistent with current EM guidance. In addition the TDA discharge is verified by using a USGS gauging station just downstream of the TDA project. The BON spillway-rating curve is based on the orifice equation with the discharge coefficient determined from the original design physical model studies. In the 1970s the gate lip design was changed to reduce gate vibration. The lip changed from a rounded to a sharp edge design that also reduced the gate effeciency, especially at lower discharges. However, it does not appear that the rating curve was updated, and operation continued with the original rating curve. With older spill patterns, this difference was not particularly noticeable.

This memorandum will document the recommended BON spillway-rating curve and provide a relationship between actual spill in 2002 through 2004 given the reported spill in the Columbia River Operational Hydromet Management System (CROHMS) database for that same period. The relationship will not be exact but will provide a reasonable estimate of the actual spill volumes during the 2002, 2003 and 2004 spill season.

2. Rating Curve Revision:

The original Bonneville Spillway Rating Curve is based on the following orifice equation (HDC 311-1):

$$Q = C_d A\sqrt{2gH}$$

Where:

Q is the discharge in cfs

C_d is the discharge coefficient

A is the area of the opening in ft^2

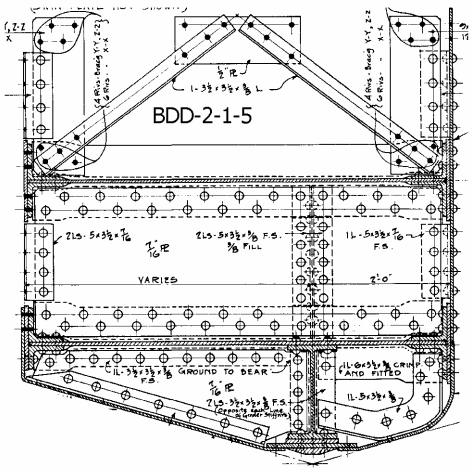
A = B*Height of opening

B is the width of the opening in ft

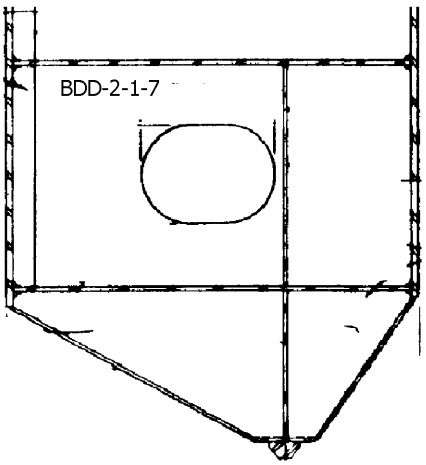
g = gravity (32.2 ft/sec^2)

H is the height of water from centerline of the opening to the surface

Physical model work conducted during the original design phase has been used to compute the discharge coefficient, C_d. The discharge coefficient from the original model work ranged from 1.1 for small gate openings to 0.7 for large gate openings (greater than 5 ft). For small gate openings the discharge coefficient appears to be unusually high. Typical discharge coefficients range from 0.65 to 0.75 for tainter gates, 0.7 to 0.85 for regulating gates and 1.0 for very efficient tube orifices. It is most likely that the original gate lip may have been extremely efficient for small gate openings where as the current gate lip may be more typical of vertical sluice gates. Another possible factor is that gate leakage in the model may have adversely affected the flow measurements.



Original Rounded Gate Lip



Current Sharp Edge Gate Lip

Comparison of original and current Bonneville Spillway gate lips

Discharge under high head vertical lift gates can be computed using the standard orifice equation (HDC 311-1) or using a relationship between gate-controlled discharge to free discharge (HDC 312). A spillway-rating curve was developed using both methods and they are presented in Figure 1. Included in Figure 1 is the original spillway-rating curve. The discharge coefficient for small gate openings is set equal to 0.80 in the rating curve called "Corrected Orifice Equation". The original rating curve falls above the other two rating curves for small gate openings. For this application a discharge coefficient of 0.80 was assumed for small gate openings. For example, for a 74.0 ft forebay, a gate opening equivalent to 1 dog, or 1.06 ft, yield a coefficient of 1.01 under the old rating curve for a flow of 3047 cfs, while the new rating curve would fix the coefficient at 0.80 for a flow of 2411 cfs. For a single bay this is a difference of 636 cfs, and across 18 bays the difference would be on the order of 11000 cfs (assuming for this example that all bays are open 1.06 ft). As the gate opening increases, the coefficients match up better, and the differences themselves become less signifigant.

Thus the recommended rating curve for the Bonneville Spillway is documented in Table 2, which details a full rating curve for a full range of forebays (70 ft NGVD to 77 ft NGVD) and gate openings in both dogs and feet up to 12 dogs, or 22.15 ft.

Note that this will allow GDACS to compute the spillway discharge given the reported gate openings. The spill patterns recommended in the Fish Passage Plan and incorporated into the GDACS system at Bonneville need to have the discharge associated with a specific set of gate openings (the pattern) updated using the revised rating curve.

RELATIONSHIP BETWEEN REPORTED AND ACTUAL SPILL

Using the spill patterns detailed in the Fish Passage Plan and incorporating the revised rating curve and the actual gate openings, the following comparison can be made for reported versus actual spill volumes. This assumes a Bonneville forebay elevation of 74.0 feet NGVD. The relationship would vary slightly for different forebay elevations and the impact of forebay elevation can be seen in Table 3. The results in Table 1 are presented in Figure 3 and a trend line has been fitted through the data points where:

$$ActualSpill = 0.001x^2 + 0.8788x - 23.45$$

Where:

x = reported spill

For example, if the reported spill from the CROHMS database showed 89 kcfs, using the *ActualSpill* formula the spill would actually be 63 kcfs.

Table 1
Comparison for spill patterns used since 2002, both ratings corrected for gate opening
Assumed correction applied to all gates to determine "Actual Gate Opening"
All values based on a Bonneville Forebay Elevation of 74.0 ft NGVD

		Gate Corrected Only			Gate and Gate Coefficient Corrected		
Nominal Spill	Reported Spill	PRE2005 Rating Curve Flow	Difference	% Difference	FEB2005 Rating Curve Flow	Difference	% Difference
kcfs	kcfs				kcfs	kcfs	%
50	49.9	33.4	16.5	33.0	23.1	26.8	53.8
75	74.6	62.8	11.8	15.9	47.6	27.0	36.2
100	100.2	91.1	9.1	9.1	74.8	25.4	25.4
125	125.2	117.1	8.1	6.5	102.4	22.8	18.2
150	150.2	142.1	8.1	5.4	131.1	19.1	12.7

For a given requested spill, the spill pattern that closest matched was selected from the Fish Passage Plan. Table 1 shows the impact of the gate opening correction and the gate opening correction in conjunction with the gate coefficient correction.

3. Recommendations:

As of this writing (FEB2005) the GDACS system has been properly calibrated (see MFR "Bonneville Spillway Recalibration Field Trip Report", 18OCT2004) by the project and reports an accurate gate opening. As of this writing the rating curve in GDACS has not been updated.

Recommended Actions:

- GDACS system used to control the spillway needs to be updated with the revised rating curves
- The Fish Passage Plan needs to be updated with the revised rating curves in the Bonneville Spill Pattern, it is recommended that the FEB2005 rating curve for a 74.0 ft NGVD forebay be used
- GDACS gate calibration should be confirmed prior to spill season and documented. Due to mechanical issues the hoists in general and the gantry operated bays in particular may loose calibration over time, and may do so to varying degrees (see MFR "Bonneville Spillway Recalibration Field Trip Report", 18OCT2004)

- Spill should be monitored during the 2005 spill season to determine if discrepancy has been corrected to an acceptable level, if not, a field test may be required to update the rating curve due to the non-standard lip design.

4. References:

"Spillway Flow Discrepancy, Executive Summary", 15 pgs, Prepared by David B. Smith, Bonneville Project, dated 27JUL2004.

"Bonneville Spillway Recalibration Field Trip Report", 18oct2004bonnswrecal-1, written by HIGA, Nathan T., dated 18OCT2004, EC-HD files.

"Hydraulic Design Criteria" (HDC), US Army Corps of Engineers Waterways Experiment Station, 1988.

Written by
HIGA, Nathan T.
Engineer, Hydraulic Design Section

Technical Review, Approval: Laurie L. Ebner, P.E.

CF: CENWP-EC-HD Files

Bonneville Spillbay 17, looking across top of gate towards right pier, the markings shown correspond to dogs. However the dogs match the old 50 ft tall gates, and not the current 60 ft tall gates. Calibrating to the dogs resulted in the gates being open approximately 0.3 ft lower than reported by the hoisting equipment.


Local gate control with front panel open during recalibration process.

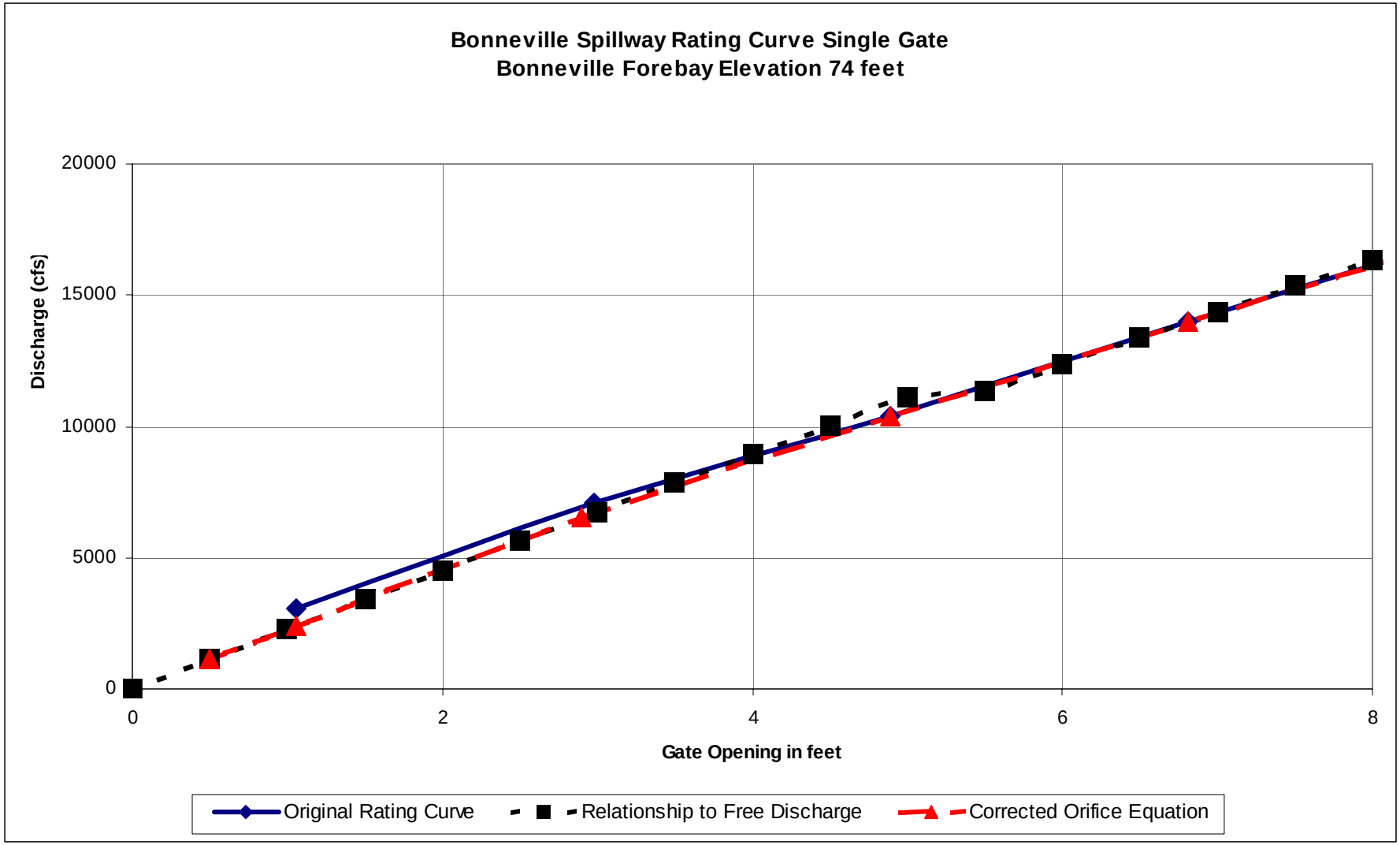


Figure 1 Bonneville Spillway Rating Curve Single Gate, Bonneville Forebay Elevation 74 ft.

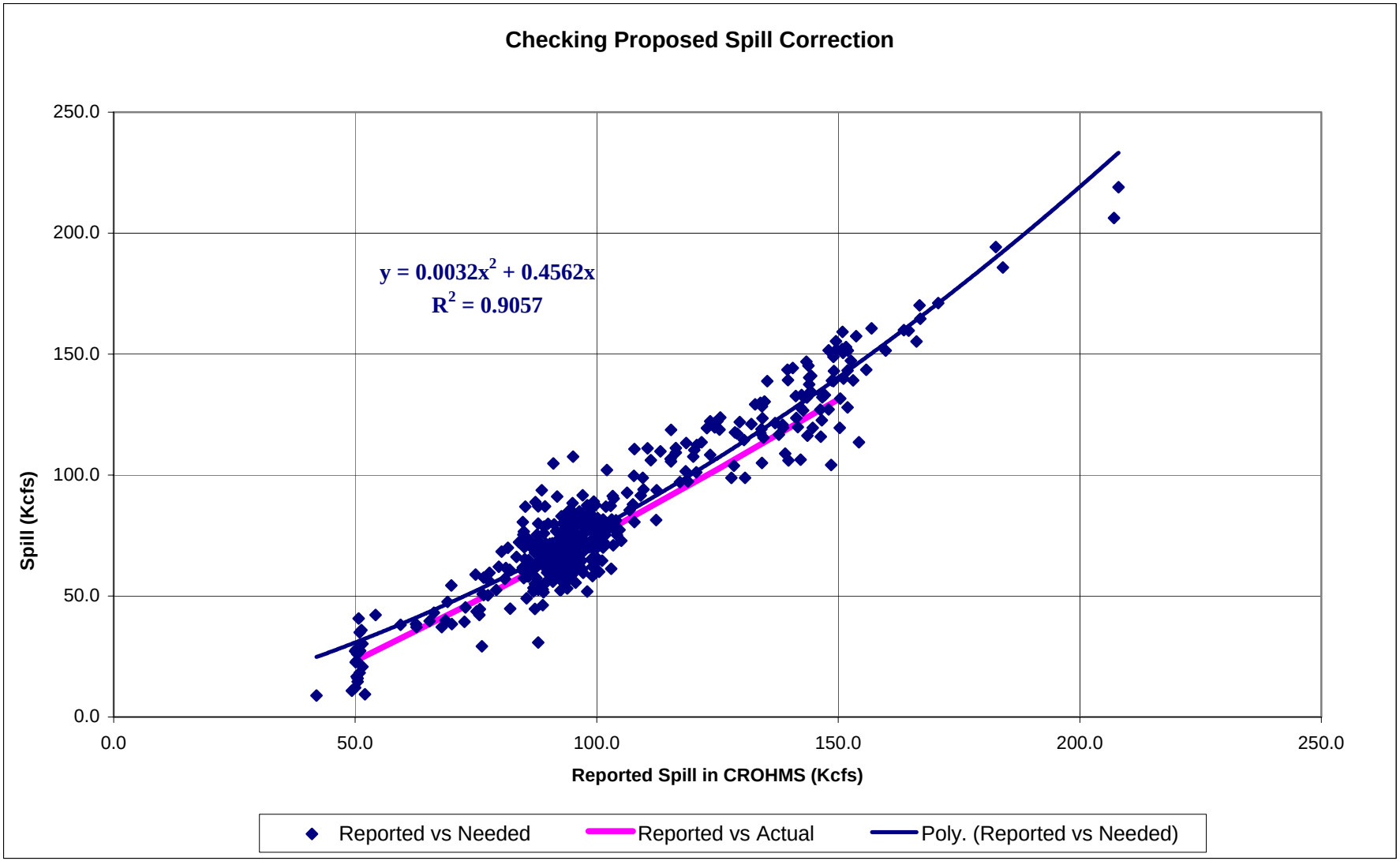


Figure 2 Checking Proposed Spill Correction

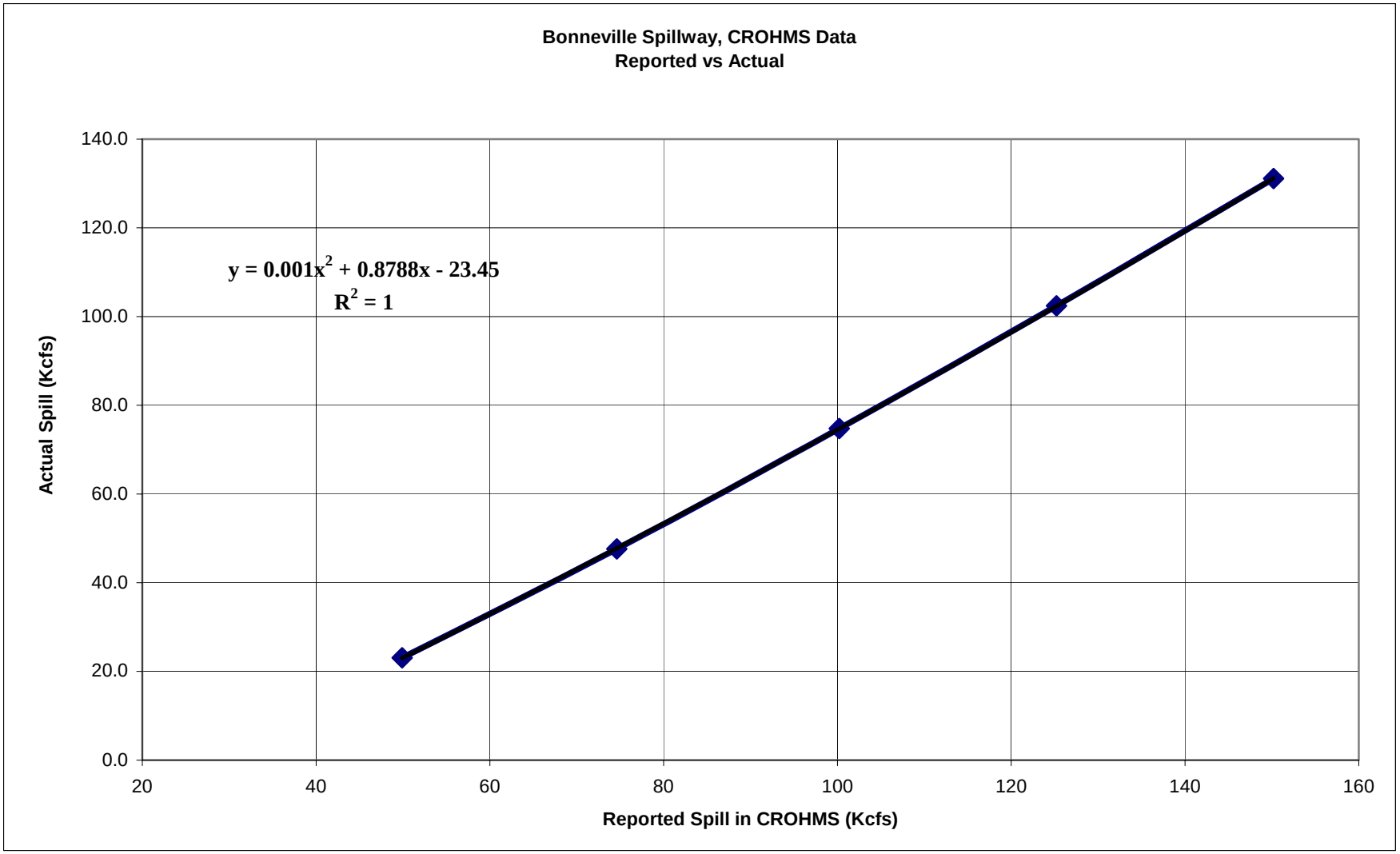


Figure 3 Bonneville Spillway, CROHMS Data, Reported vs Actual Flow

Table 2 Bonneville Spill from a single bay with respect to Opening in Dogs (& feet) and Lake Elevation, flow in CFS. 60 foot Gate

Computed by LLE on February 11, 2005

Backed checked and compared to work by NTkH on 09FEB2005

Forebay Elevation	Gate Opening																
FB	dogs	0	1					2						3			
ft	feet	0	0.5	1	1.06	1.5	2	2.5	2.9	3	3.5	4	4.5	4.89	5	5.5	6
70		0	1102	2179	2307	3233	4265	5275	6069	6265	7235	8187	9120	9837	10037	10938	11824
70.2		0	1104	2184	2312	3240	4274	5287	6082	6279	7251	8205	9141	9859	10060	10963	11851
70.4		0	1106	2188	2317	3247	4283	5298	6095	6293	7267	8223	9161	9881	10083	10988	11878
70.6		0	1109	2193	2322	3254	4293	5310	6109	6306	7283	8241	9182	9903	10105	11012	11904
70.8		0	1111	2198	2327	3261	4302	5321	6122	6320	7299	8260	9202	9925	10128	11037	11931
71		0	1113	2202	2331	3268	4311	5333	6135	6334	7315	8278	9222	9947	10150	11062	11958
71.2		0	1116	2207	2336	3275	4320	5344	6148	6347	7331	8296	9243	9969	10172	11086	11985
71.4		0	1118	2212	2341	3282	4330	5356	6162	6361	7347	8314	9263	9991	10195	11111	12011
71.6		0	1120	2216	2346	3289	4339	5367	6175	6375	7363	8332	9283	10013	10217	11135	12038
71.8		0	1123	2221	2351	3296	4348	5378	6188	6388	7378	8350	9303	10035	10239	11160	12064
72		0	1125	2226	2356	3303	4357	5390	6201	6402	7394	8368	9323	10057	10262	11184	12091
72.2		0	1127	2230	2361	3309	4366	5401	6214	6415	7410	8386	9343	10078	10284	11208	12117
72.4		0	1130	2235	2366	3316	4375	5412	6227	6429	7426	8403	9363	10100	10306	11232	12144
72.6		0	1132	2239	2371	3323	4384	5424	6240	6442	7441	8421	9383	10121	10328	11257	12170
72.8		0	1134	2244	2375	3330	4393	5435	6253	6456	7457	8439	9403	10143	10350	11281	12196
73		0	1137	2248	2380	3337	4402	5446	6266	6469	7472	8457	9423	10165	10372	11305	12222
73.2		0	1139	2253	2385	3344	4411	5457	6279	6483	7488	8474	9443	10186	10394	11329	12248
73.4		0	1141	2258	2390	3350	4420	5469	6292	6496	7504	8492	9462	10207	10416	11353	12274
73.6		0	1143	2262	2395	3357	4429	5480	6305	6509	7519	8510	9482	10229	10438	11377	12300
73.8		0	1146	2267	2400	3364	4438	5491	6318	6523	7534	8527	9502	10250	10459	11401	12326
74		0	1148	2271	2404	3371	4447	5502	6331	6536	7550	8545	9522	10271	10481	11424	12352
74.2		0	1150	2276	2409	3377	4456	5513	6344	6549	7565	8562	9541	10293	10503	11448	12378
74.4		0	1153	2280	2414	3384	4465	5524	6356	6562	7581	8580	9561	10314	10524	11472	12404
74.6		0	1155	2285	2419	3391	4474	5535	6369	6576	7596	8597	9580	10335	10546	11496	12430
74.8		0	1157	2289	2423	3398	4483	5546	6382	6589	7611	8615	9600	10356	10568	11519	12455
75		0	1159	2294	2428	3404	4492	5557	6395	6602	7627	8632	9619	10377	10589	11543	12481
75.2		0	1162	2298	2433	3411	4501	5568	6407	6615	7642	8649	9639	10398	10611	11566	12507
75.4		0	1164	2303	2438	3418	4509	5579	6420	6628	7657	8667	9658	10419	10632	11590	12532
75.6		0	1166	2307	2442	3424	4518	5590	6433	6641	7672	8684	9677	10440	10653	11613	12558
75.8		0	1168	2312	2447	3431	4527	5601	6445	6654	7687	8701	9697	10461	10675	11637	12583
76		0	1170	2316	2452	3437	4536	5612	6458	6667	7702	8718	9716	10482	10696	11660	12608
76.2		0	1173	2320	2456	3444	4545	5623	6471	6680	7718	8735	9735	10503	10717	11683	12634
76.4		0	1175	2325	2461	3451	4553	5634	6483	6693	7733	8753	9754	10524	10739	11707	12659
76.6		0	1177	2329	2466	3457	4562	5645	6496	6706	7748	8770	9773	10544	10760	11730	12684
76.8		0	1179	2334	2470	3464	4571	5656	6508	6719	7763	8787	9793	10565	10781	11753	12709
77		0	1182	2338	2475	3470	4579	5666	6521	6732	7778	8804	9812	10586	10802	11776	12734

Table 2 Bonneville Spill from a single bay with respect to Opening in Dogs (& feet) and Lake Elevation in CFS. 60 foot Gate

Computed by LLE on February 11, 2005 2/3

Backed checked and compared to work by NTkH on 09FEB2005

Forebay Elevation	Gate Opening																
FB	dogs	4						5					6				
ft	feet	6.5	6.81	7	7.5	8	8.5	8.73	9	9.5	10	10.5	10.64	11	11.5	12	12.5
70		12695	13228	13553	14398	15231	16053	16428	16865	17668	18462	19248	19467	20028	20801	21568	22331
70.2		12724	13259	13584	14431	15267	16091	16467	16905	17710	18506	19295	19514	20076	20851	21621	22386
70.4		12753	13289	13615	14465	15302	16129	16505	16945	17752	18550	19341	19561	20125	20902	21674	22441
70.6		12782	13319	13646	14498	15338	16166	16544	16985	17794	18594	19387	19608	20173	20952	21726	22495
70.8		12811	13350	13677	14531	15373	16204	16582	17024	17836	18638	19433	19654	20221	21003	21779	22550
71		12840	13380	13708	14564	15408	16241	16621	17064	17877	18682	19479	19701	20269	21053	21831	22605
71.2		12869	13410	13739	14597	15443	16278	16659	17103	17919	18726	19525	19747	20317	21103	21883	22659
71.4		12898	13440	13770	14630	15478	16316	16697	17143	17960	18769	19570	19793	20365	21153	21935	22713
71.6		12926	13470	13801	14663	15513	16353	16735	17182	18001	18813	19616	19840	20412	21203	21987	22767
71.8		12955	13500	13832	14696	15548	16390	16773	17221	18043	18856	19661	19886	20460	21252	22039	22821
72		12983	13530	13862	14729	15583	16427	16811	17260	18084	18899	19707	19932	20507	21302	22091	22875
72.2		13012	13560	13893	14761	15618	16464	16849	17299	18125	18942	19752	19977	20555	21351	22143	22929
72.4		13040	13589	13924	14794	15653	16500	16887	17338	18166	18985	19797	20023	20602	21401	22194	22983
72.6		13069	13619	13954	14827	15687	16537	16924	17377	18207	19028	19842	20069	20649	21450	22245	23036
72.8		13097	13649	13984	14859	15722	16574	16962	17415	18247	19071	19887	20114	20696	21499	22297	23090
73		13125	13678	14015	14891	15756	16610	16999	17454	18288	19114	19932	20160	20743	21548	22348	23143
73.2		13153	13708	14045	14924	15791	16647	17037	17492	18329	19157	19977	20205	20790	21597	22399	23196
73.4		13182	13737	14075	14956	15825	16683	17074	17531	18369	19199	20021	20250	20837	21646	22450	23249
73.6		13210	13767	14105	14988	15859	16719	17111	17569	18410	19242	20066	20295	20883	21695	22501	23302
73.8		13238	13796	14135	15020	15894	16756	17149	17607	18450	19284	20110	20340	20930	21743	22551	23355
74		13266	13825	14165	15052	15928	16792	17186	17646	18490	19326	20155	20385	20976	21792	22602	23407
74.2		13294	13854	14195	15084	15962	16828	17223	17684	18530	19369	20199	20430	21023	21840	22652	23460
74.4		13321	13883	14225	15116	15996	16864	17260	17722	18570	19411	20243	20475	21069	21888	22703	23512
74.6		13349	13912	14255	15148	16030	16900	17297	17760	18610	19453	20287	20520	21115	21936	22753	23565
74.8		13377	13941	14285	15180	16063	16936	17333	17798	18650	19495	20331	20564	21161	21984	22803	23617
75		13405	13970	14315	15212	16097	16971	17370	17835	18690	19536	20375	20609	21207	22032	22853	23669
75.2		13432	13999	14344	15243	16131	17007	17407	17873	18730	19578	20419	20653	21253	22080	22903	23721
75.4		13460	14028	14374	15275	16164	17043	17443	17911	18770	19620	20462	20697	21298	22128	22953	23773
75.6		13487	14057	14403	15307	16198	17078	17480	17948	18809	19661	20506	20741	21344	22176	23002	23824
75.8		13515	14085	14433	15338	16231	17114	17516	17986	18849	19703	20550	20785	21389	22223	23052	23876
76		13542	14114	14462	15369	16265	17149	17552	18023	18888	19744	20593	20829	21435	22271	23101	23928
76.2		13569	14143	14491	15401	16298	17184	17589	18060	18927	19786	20636	20873	21480	22318	23151	23979
76.4		13597	14171	14521	15432	16331	17220	17625	18098	18966	19827	20679	20917	21525	22365	23200	24030
76.6		13624	14200	14550	15463	16365	17255	17661	18135	19006	19868	20723	20961	21570	22412	23249	24081
76.8		13651	14228	14579	15494	16398	17290	17697	18172	19045	19909	20766	21004	21615	22459	23298	24133
77		13678	14256	14608	15525	16431	17325	17733	18209	19084	19950	20809	21048	21660	22506	23347	24184

Table 2 Bonneville Spill from a single bay with respect to Opening in Dogs (& feet) and Lake Elevation, flow in CFS. 60 foot Gate

Computed by LLE on February 11, 2005 3/3

Backed checked and compared to work by NTkH on 09FEB2005

Forebay Elevation	Gate Opening																
FB	dogs	7				8					9					10	
ft	feet	12.56	13	13.5	14	14.48	14.5	15	15.5	16	16.4	16.5	17	17.5	18	18.31	18.5
70		22422	23089	23844	24597	25318	25348	26097	26846	27595	28195	28345	29096	29850	30606	31076	31365
70.2		22477	23146	23904	24659	25382	25412	26164	26915	27666	28268	28419	29172	29928	30687	31159	31449
70.4		22532	23204	23963	24720	25446	25476	26230	26983	27737	28341	28492	29248	30006	30768	31241	31532
70.6		22587	23261	24023	24782	25509	25539	26296	27052	27808	28413	28565	29324	30084	30848	31323	31615
70.8		22642	23317	24082	24843	25573	25603	26362	27120	27879	28486	28638	29399	30162	30928	31405	31698
71		22697	23374	24141	24904	25636	25667	26427	27188	27949	28558	28711	29474	30240	31009	31487	31781
71.2		22752	23431	24199	24965	25699	25730	26493	27256	28019	28630	28783	29549	30317	31088	31568	31863
71.4		22806	23487	24258	25026	25762	25793	26558	27324	28089	28702	28856	29624	30395	31168	31650	31945
71.6		22861	23544	24317	25087	25825	25856	26624	27391	28159	28774	28928	29699	30472	31248	31731	32027
71.8		22915	23600	24375	25148	25888	25919	26689	27459	28229	28846	29000	29773	30548	31327	31812	32109
72		22969	23656	24433	25208	25951	25981	26754	27526	28298	28917	29072	29847	30625	31406	31892	32191
72.2		23023	23712	24491	25268	26013	26044	26819	27593	28368	28988	29144	29921	30702	31485	31973	32272
72.4		23077	23768	24549	25329	26075	26106	26883	27660	28437	29059	29215	29995	30778	31564	32053	32353
72.6		23131	23823	24607	25389	26137	26169	26948	27726	28506	29130	29286	30069	30854	31642	32133	32434
72.8		23184	23879	24665	25449	26199	26231	27012	27793	28575	29201	29358	30142	30930	31721	32213	32515
73		23238	23934	24722	25508	26261	26293	27076	27859	28643	29271	29429	30216	31006	31799	32292	32596
73.2		23291	23989	24780	25568	26323	26354	27140	27926	28712	29342	29499	30289	31081	31877	32372	32676
73.4		23345	24045	24837	25627	26385	26416	27204	27992	28780	29412	29570	30362	31156	31954	32451	32756
73.6		23398	24100	24894	25687	26446	26478	27268	28058	28849	29482	29641	30435	31232	32032	32530	32836
73.8		23451	24154	24951	25746	26507	26539	27331	28124	28917	29552	29711	30507	31307	32109	32609	32916
74		23504	24209	25008	25805	26568	26600	27395	28189	28984	29622	29781	30580	31381	32187	32688	32996
74.2		23557	24264	25065	25864	26629	26661	27458	28255	29052	29691	29851	30652	31456	32264	32766	33075
74.4		23609	24318	25122	25923	26690	26722	27521	28320	29120	29761	29921	30724	31531	32340	32844	33154
74.6		23662	24373	25178	25981	26751	26783	27584	28385	29187	29830	29991	30796	31605	32417	32923	33233
74.8		23714	24427	25235	26040	26811	26844	27647	28450	29254	29899	30060	30868	31679	32493	33001	33312
75		23767	24481	25291	26098	26872	26904	27710	28515	29321	29968	30129	30940	31753	32570	33078	33391
75.2		23819	24535	25347	26156	26932	26965	27772	28580	29388	30036	30199	31011	31827	32646	33156	33469
75.4		23871	24589	25403	26215	26992	27025	27835	28644	29455	30105	30268	31082	31900	32722	33233	33548
75.6		23923	24643	25459	26273	27052	27085	27897	28709	29522	30173	30336	31154	31974	32797	33310	33626
75.8		23975	24697	25515	26330	27112	27145	27959	28773	29588	30242	30405	31224	32047	32873	33387	33704
76		24027	24750	25570	26388	27172	27205	28021	28837	29655	30310	30474	31295	32120	32948	33464	33781
76.2		24078	24804	25626	26446	27232	27265	28083	28901	29721	30378	30542	31366	32193	33024	33541	33859
76.4		24130	24857	25681	26503	27291	27324	28144	28965	29787	30446	30610	31436	32266	33099	33618	33936
76.6		24181	24910	25736	26561	27351	27384	28206	29029	29853	30513	30679	31507	32338	33174	33694	34014
76.8		24232	24963	25792	26618	27410	27443	28268	29093	29919	30581	30746	31577	32411	33248	33770	34091
77		24284	25016	25847	26675	27469	27502	28329	29156	29984	30648	30814	31647	32483	33323	33846	34168